ACROSS THE HORIZON

CAA Auckland Tāmaki Makaurau 8 - 12 April 2024

51st Computer Applications and Quantitative Methods in Archaeology International Conference

8-12 April 2024

Auckland Tāmaki Makaurau
Aotearoa New Zealand

Program

CAA Australasia

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S22: The Ethics of Open Data (259)

S23: Advances in Computational Archaeology (276)

Sponsors

Platinum Tier

intrasis
intrasite information system

Intrasis is a program for documenting, visualizing, interpreting, and analysing archaeological information. It is one of the industry's most powerful tools for creating and mapping information in a GIS environment. Intrasis is a combination of a normalised database and geographical tool where you can record and relate different types of geographical and object information. With Intrasis' 3D functionality you can view your data together with 3D models.

Intrasis will fulfil nearly all your documentation needs! It is the perfect tool to store all digital documentation from your excavation. You can create a unique database for every project and can change the metadata to fit the site's specific needs. Intrasis is outstanding when it comes to storing interdisciplinary data.

If you want your data to be reusable, CIDOC CRM and CRMarchaeo can be used on Intrasis templates, making it possible for other researchers to see if your data is fit for their purpose.

Gold Tier

EAGLE TECHNOLOGY

Australasian Institute for Maritime Archaeology

Bronze Tier

The New Zealand Archaeology Assoication and The Polynesian Society will both be selling their publications in the main exhibition hall during the conference.

Supporters

Welcome to Tāmaki Makaurau

Nau mai, haere mai!

Nau mai, haere mai! The Australasia chapter of CAA is excited to welcome you to the 51 st conference of CAA. CAA2024 conference is hosted by the University of Auckland Tāmaki Paenga Hira (UoA). This is the second time that the CAA conference has been hosted in the southern hemisphere and the first time in the Pacific region. CAA Australasia was founded in 2013 with the CAA conference in Perth, and has since grown to one of the largest chapters of the CAA family. Many founding members of the Australasian chapter have a long association to the CAA.

We look forward to sharing some of the work being done in Australasia with the wider community. We also hope that during the week you will have an opportunity to explore our wonderful city and country, and leave with fond memories of your time here.

Whether you have traveled from across the world or down the road, we look forward to hosting you during the conference and anticipate a fruitful exchange of ideas.

The organizing committee:
Joshua Emmitt
Rebecca Phillipps
Simon Wyatt-Spratt
Patricia Pillay
The CAA Australasia Committee

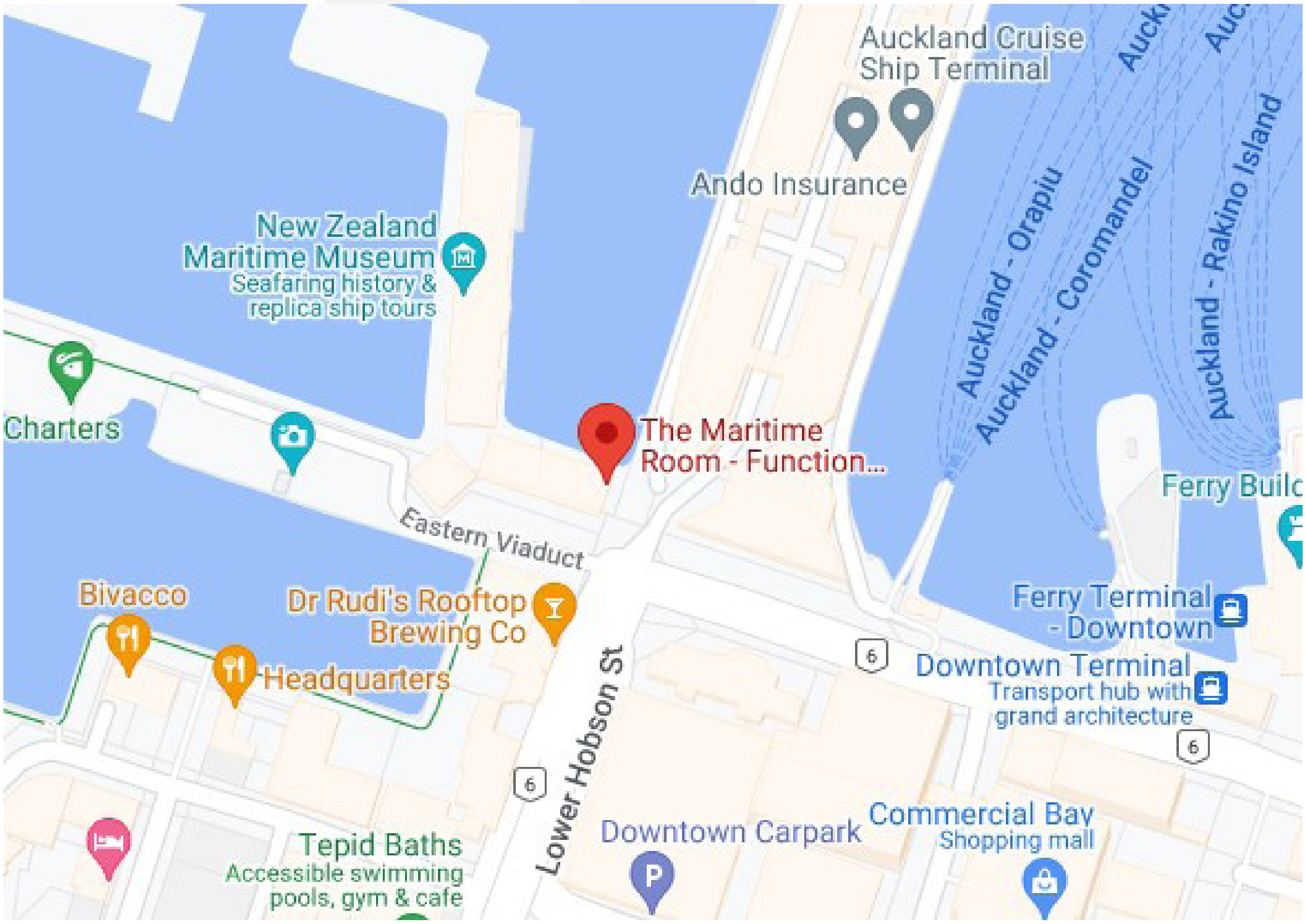
Map of the Venue

Eagle Technology Icebreaker Reception

The Eagle Technology Icebreaker function will be held in the newly completed B201 building on Monday the 8th from 17:30-19:00. Attendance is included with your registration, and a guest can be added for $30

Conference Dinner at the Maritime Room

The conference dinner will be held at the Maritime Room by the Auckland waterfront on Wednesday 10th from 19:00-22:00. Tickets can be bought with registration. There may be an option to buy a ticket during the event if there is space, so please ask the local team if interested.



Tuesday Evening Visit to the Auckland War Memorial Museum

The Auckland War Memorial Musuem is offering all attendees to the conference complimentary general admission from 8th April - 14th April 2024. Please show your name badge at the ticket desk to receive your entry ticket. Please note this is only for general admission to the main galleries and does not include any special exhibitions or other paid activities.

On Tuesday 9th April Auckland Museum will be open until 8.30pm. While there is no structured event we encourage you to head up to the museum with us to walk around the galleries.

Excursion to Tiritiri Matangi

This excursion is undertaken with the support of the Manu Whenua of Tiriitri Matangi, Ngāti Manuhiri.

The excursion will be on Friday 12th April and will be to Tiritiri Matangi Island in the Hauraki Gulf. Please register by March 28th. While at the conference if you would like to come along there may be spots available so please touch base with the local team.

The ferry will leave from the Explore Booking Kiosk at the Auckland Viaduct at 9 am. The ferry is 80 minutes and will arrive at the island at 10.20 am. Departure from the island will be at 2.40pm and will arrive back in Auckland at 4 pm. There is only one ferry per day, so if you miss departure you will not be able to go on the excursion and you will not be able to be refunded.

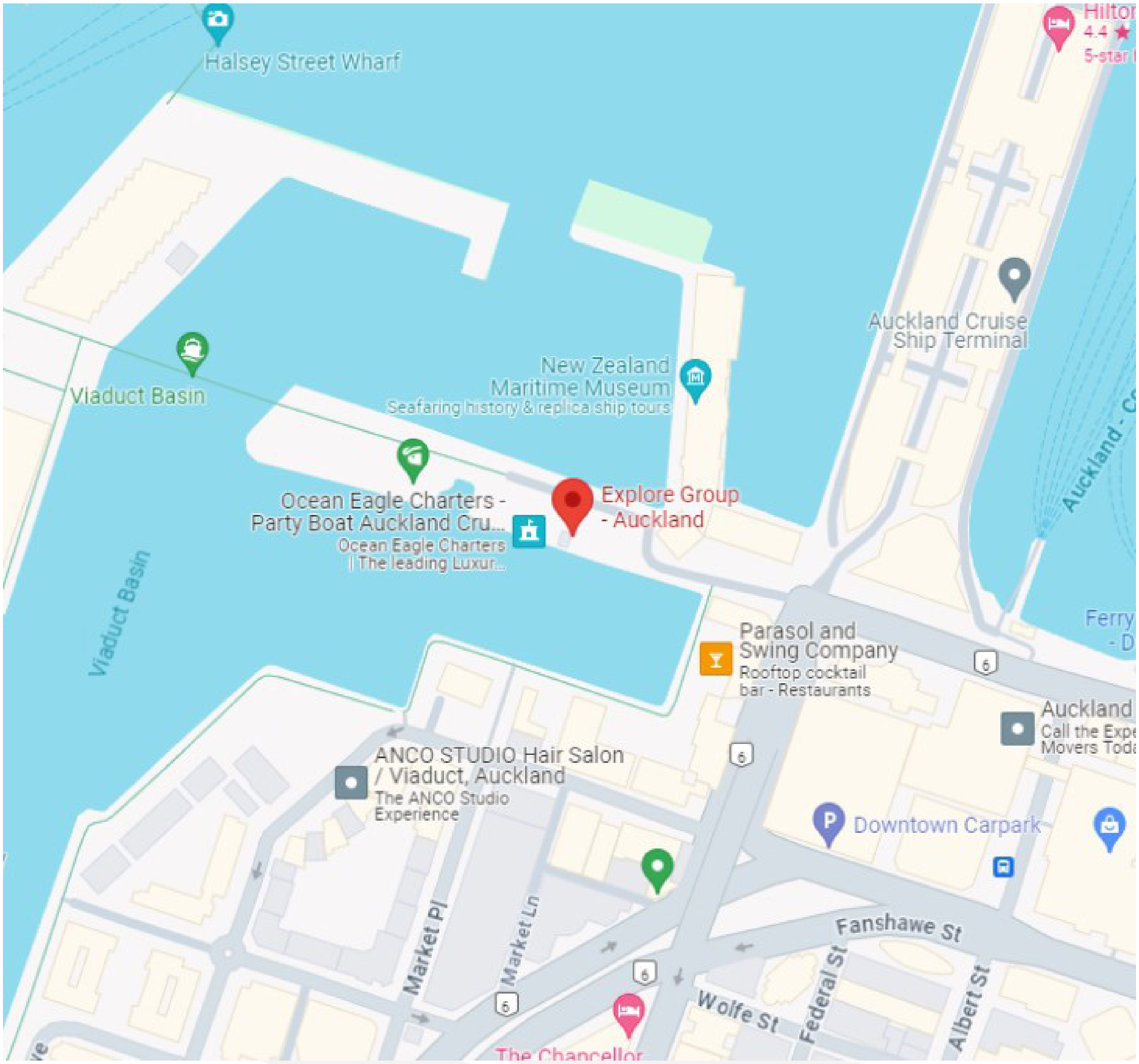
Tiritiri Matangi Island is a 22 hectare island which has been transformed from farmland to a predator-free scientific and nature reserve. It is home to a number of native birds, including some that are threatened or endangered and are there as part of breeding efforts.

There are also a number of archaeological sites on the island and we will have two guides, Robert Brassey and Brendan Kneebone with us to talk about the work they have done on the island

Tiritiri is a protected island and has limited amenities. You will need to bring lunch, which we can provide for an additional fee ($19, must be ordered at the time of registration) and have for you at the ferry, or you are free to bring your own. Please bring your own water bottle. Walking shoes and a raincoat are a must, as there is no shelter on the tracks, and the terrain is steep in places.

Being a predator-free island, the Department of Conservation requires that your gear is clean and secured before you depart. Please see the guide below for more information.

The ferry will arrive at Tiritiri Wharf. You are free to explore the island, but please be back for the departing ferry by no later than 2.20pm to ensure an on-time departure. There will be archaeologists who have worked on the island giving talks around Tiritiri Matangi Pa and Hobbs Beach throughout the trip, but you are welcome to explore the island at your leisure. There are a number of walking tracks on the island, but please note some of these are longer than the time available for this trip.


Halsey Street Wharf
Viaduct Basin
New Zealand Maritime Museum
Seafaring history & replica ship tours
Auckland Cruise Ship Terminal
Ocean Eagle Charters - Party Boat Auckland Cru...
Ocean Eagle Charters | The leading Luxur...
Explore Group - Auckland
Viaduct Basin
Parasol and Swing Company
Rooftop cocktail bar - Restaurants
ANCO STUDIO Hair Salon / Viaduct, Auckland
The ANCO Studio Experience
Downtown Carpark
Fanshawe St
Market Pl
Market Ln
Wolfe St
Federal St
Albert St
The Chancellor

Keynote: Time Machines, Visualisation, and Archaeological Settlement Patterns in Aotearoa New Zealand

Tuesday 9th April, 09:00–10:40, Owen G Glenn Building room 098

Professor Simon Holdaway.

Simon Holdaway is professor of archaeology and Associate Deputy Vice-Chancellor Research at Waipapa Taumata Rau, the University of Auckland. He was educated at the University of Otago and the University of Pennsylvania where he completed his PhD in 1991 under the supervision of Harold Dibble. He held a post-doctoral fellowship at La Trobe University, Melbourne in 1993 and subsequently lectured at La Trobe from 1994-1998, returning to the University of Auckland in 1999, where he became professor in 2009. From 2016-2021 he was Head of School Social Sciences, in the Faculty of Arts before taking up his current role.

His research interests span material culture in multiple forms with a focus on stone artefacts and the landscape archaeology of arid regions. He has conducted field work in several regions of the world including southwest France, semi-arid and tropical regions of Australia, the north of Egypt, and Aotearoa | New Zealand. He is a corresponding fellow of the Australian Academy of the Humanities and a Fellow of the Royal Society of New Zealand Te Apārangi.

Abstract

Time is the most used noun in the English language, with this usage partly reflecting a desire to time travel as part of experience culture, seen for example in historical role play, reenactments, movies, themed environments, and of course virtual realities and computer games. Archaeologists engage in experience culture through the construction of visualisations, with for example, Jean-Claude Golvin's artwork in Assassin's Creed: Origins based on archaeological excavation results. But archaeologists also deal with palimpsests, with the material they study accumulating in ways that often make individual depositional episodes indistinguishable. This has led to criticisms of the types of synchronic reconstructions involved in visualisation, with authors like Bailey, Lucas, Murray, Perreault, and Wandsnider questioning whether behavioural interpretations based on synchronic social theory are useful for interpreting archaeological data. Many years ago, Wilfred Shawcross wrote about the archaeology of Aotearoa New Zealand as one characterised by a short, isolated timescale. Here I ask whether the scope, sampling interval, and resolution of Aotearoa archaeology (to use Perreault's terms) might be more amenable to synchronic interpretation and therefore visualisation. I use settlement pattern studies, a topic with a long history of investigation in Aotearoa, to explore this question. I focus on the results from a recent fieldwork program on Ahuahu Great Mercury Island where my colleagues and I have used a landscape approach to investigate multiple archaeological deposits. Despite a short, high-resolution chronology, the field evidence from Ahuahu shows a palimpsest of features and objects with evidence of reuse. I consider what this means for settlement pattern reconstructions in Aotearoa and what archaeologists might seek to visualise when investigating the archaeological record.

Schedule

Monday 8-4-2024	Workshops				
Room	260-055 Case Room 3	260-040B	260-073 OGGB4	260-317	260-321
08:00 - 12:00	W6: CRMarchaeo Workshop: a stepping stone to FAIR practice		W2: GigaMesh – 3D Artifact Documentation with the GigaMesh Software Framework	W7: Photogrammetry methods	W8: Chronological modelling with ChronoLog: theory and practice
9:00 - 12:00		W4: Information Session on Arches Cultural Heritage Data Management Platform			
13:00 - 17:00			W3: ADAF – a user-friendly tool for Automatic Detection of Archaeological Features		
13:00-16:00		W5: Data Modeling and Controlled Vocabulary Management using Arches			
17.30-19.00	Eagle Technology Icebreaker - School of Social Sciences Building Atrium (B201)				

Tuesday 9-4-24	Sessions				
Room	OGGB-098	260-057 Case Room 2	260-055 Case Room 3	260-092 OGGB3	260-073 OGGB4
09:00 - 10:40	Welcome and Keynote				
10:40 - 11:00	Morning Tea		New members catch-up	Morning Tea	
11:00-11:20	Poster Session in main exhibition hall				
11:20 - 12:00				11. 3D modelling in perspective	21. Fair Reuse of Archive Data
12:00 - 13:00	Lunch				
13:00 - 15:00	17. Conversations across the (digital) ditch	06. Data Sources and Data Integration for Macroscale Archaeology		11. 3D modelling in perspective	22. The Ethics of Open Data
15:00-15:20	Afternoon Tea				
15:20- 17:00	17. Conversations across the (digital) ditch			11. 3D modelling in perspective	22. The Ethics of Open Data *Discussion until 17:40*

Wednesday 10-4-24	Sessions				
Room	OGGB-098		260-055 Case Room 3	260-092 OGGB3	260-073 OGGB4
9:00 - 10:00	20. The legacy of Harold Dibble in stone artefact archaeology in Australasia and beyond		R1: Towards a future research agenda of archaeological practices in the digital era		
10:00 - 10:20	Morning Tea				
10:20 - 12:00	20. The legacy of Harold Dibble in stone artefact archaeology in Australasia and beyond		13. Computational Approaches to Archaeological Mega-Projects	11. 3D modelling in perspective	02. Bringing the Past to Life: Immersive Approaches to Education and Cultural Heritage
12:00 - 13:00	Lunch				
13:00 – 15:00	20. The legacy of Harold Dibble in stone artefact archaeology in Australasia and beyond		19. Archaeological Heritage in Conflict Zones: from data gathering to virtual environments	11. 3D modelling in perspective	10. CAA in the real world: making computational archaeology commonplace
15:00 - 15:20	Afternoon Tea				
15:20 - 17:00	01. Beyond Binary: Exploring Maritime and Coastal Archaeology across the Water's Edge through Digital Methods		14. Modelling Monumental Landscapes in 4D: A Novel Approach to Understanding Architectural Settlement Patterns and Temporal Dynamics	11. 3D modelling in perspective	
17:10 - 18:40	CAA Interntional AGM				
19:00-22:00	Conference dinner at the Maritime Room (Paid add-on)				

Thursday 11-4-24	Sessions				
Room	OGGB-098	260-057 Case Room 2	260-055 Case Room 3	260-092 OGGB3	260-073 OGGB4
09:00-10:00	07. From trials and errors to triumphs: Machine Learning applications in archaeology		15. Keep it simple, just not too simple — Challenges and (Best?) Practices in Managing and Integrating Archaeological Data	03. Point Process Models in Archaeology and Heritage: State of the Field and New Directions	
10:00 - 10:20	Morning Tea				
10:20 - 12:00	07. From trials and errors to triumphs: Machine Learning applications in archaeology	R3: Exploring the Nexus of Robotics and Archaeology: Unveiling the Potential and Ethical Dimensions	15. Keep it simple, just not too simple — Challenges and (Best?) Practices in Managing and Integrating Archaeological Data	03. Point Process Models in Archaeology and Heritage: State of the Field and New Directions	23. Advances in Computational Archaeology
12:00 - 13:00	Lunch				
13:00 - 15:00	07. From trials and errors to triumphs: Machine Learning applications in archaeology	R4: Unveiling the Past, Safeguarding the Future: Pioneering Technologies in the Battle Against Illicit Archaeological Looting and Trafficking		18. Digital Landscape Archaeology: New Possibilities and Old Problems	23. Advances in computational archaeology S9: Between the Nile and the Brahmaputra: Computational methods to study ancient societies, landscapes and riverine systems straddling Asia and Africa
15:00 - 15:20	Afternoon Tea				
15:20 – 17:00	07. From trials and errors to triumphs: Machine Learning applications in archaeology			18. Digital Landscape Archaeology: New Possibilities and Old Problems	08. Maritime Horizons: Modeling Movement and Navigation

Workshops

W2: GigaMesh – 3D Artifact Documentation with the GigaMesh Software Framework

Half day workshop - Morning: Monday 8th April, 08:00–12:00, 260-073 OGGB4

Florian Linsel, Martin-Luther-University of Halle-Wittenberg, Institute of Computer Science, AG eHumanities & FCGLab

The widespread adoption of 3D-acquisition devices, especially those using Structured-Light-Scanning (SLS) and photogrammetry, has revolutionized the digitization of archaeological artifacts, greatly benefiting excavations and archives. This workshop offers a comprehensive program to demonstrate working with the resulting 3D meshes.

The workshop focuses on the analysis and documentation of 3D datasets using the GigaMesh Software Framework. Developed by the Forensic-Computational-Geometry-Laboratory (FCGL) at Martin Luther University of Halle, GigaMesh offers tools for processing 3D data, primarily in the Stanford-Polygon (PLY) format. Practical applications include rapid calculation of profile lines for ceramic sherds as vector drawings in XML-based Scalable-Vector-Graphics (SVG) format, rollouts of decorated vessels, and visualization of small features. The workshop will also cover data inspection and cleaning to ensure high-quality open data publications. Participants will also be introduced to the latest developed GigaMesh tools (Release 2023-06-22) and features, such as automatic orientation of lithic artifacts.

After completion, archaeologists will be well-equipped to establish or improve their 3D-acquisition-based documentation pipelines similar to our own research (Linsel et al. 2023) and our long-term users like the Honduras excavation of the Commission for Archaeology of Non-European Cultures (KAAK) at the DAI Bonn (Fecher et al. 2020). This workshop will enable archaeologists to use advanced 3D technologies to document, analyze, and publish artifacts in their research.

Information for participants

Participants can bring their own archaeological data to develop research questions firsthand, but all data must be sent in advance to ensure accuracy and to evaluate the scope of the research question.

Requirements

To ensure successful participation, attendees are strongly encouraged to bring their own laptops running Linux or Windows, as GigaMesh is primarily developed for Linux (e.g. a recent version of Ubuntu) and Windows.

W3: ADAF – A User-friendly Tool for Automatic Detection of Archaeological Features

Half day workshop - Afternoon: Monday 8th April, 13:00–17:00, 260-073 OGGB4

Žiga Kokalj and Nejc Čož, Research Centre of the Slovenian Academy of Sciences and Arts (ZRC SAZU), and Nejc Čož

The rapid development of image analysis techniques and the increasing availability of high-quality airborne laser scanning data (ALS, lidar) are encouraging the use of machine learning in archaeology. The ADAF tool consists of two Jupyter notebooks, one for training (creating specific machine learning models) and one for automatic recognition of archaeological features. While the training part is time-consuming and requires suitable hardware, the recognition part can be done on any modern laptop. This workshop aims to provide participants with hands-on experience with the software and enable them to use it independently for their own projects. We will cover the basics of deep learning in archaeology, the installation, explain all components of the training part and run the detection process. The currently implemented model is optimised to detect three classes of Irish archaeology (barrows, enclosures, ringforts), but you can also input your own model. The software requires minimal interaction and no prior knowledge of machine learning techniques, which greatly increases its accessibility to the archaeological community.

Requirements

Participants should bring their laptop and have an internet connection to download all the requirements and data. We will provide a link to download everything before the workshop starts. You can bring your own (ALS) data. The software is tested to run on Windows.

W4: Information Session on Arches Cultural Heritage Data Management Platform

Half day workshop – Morning: Monday 8th April, 09:00–12:00, 260-0408

Annabel Lee Enriquez, Getty Conservation Institute
Rachel Ford, Heritage Unit Auckland Council
Mei Nee Lee, Heritage Unit Auckland Council

Arches (www.archesproject.org) is an open-source data management platform freely available for organizations worldwide to install, configure, and extend in accordance with their individual needs and without restrictions on its use. Arches was originally developed for the cultural heritage field by the Getty Conservation Institute and World Monuments Fund. Due to the complex and varied nature of cultural heritage data, and to promote interoperability and sustainable data practices, Arches has been developed as a standards-based, comprehensive and flexible platform that supports a wide array of uses. The Arches Project has an established international community of developers, service providers, heritage organizations and specialists that collaborates, shares ideas and resources, explores solutions, and provides guidance and support.

This session will cover the following topics

- An overview of management of heritage data in Arches, including international data standards, data modeling, controlled vocabularies, creating and editing data, and integration with external web services and GIS applications
- System design and capabilities, geospatial layers and integration with ArcGIS Pro, enhanced searching functionality, and reporting
- Arches deployment considerations including platform installation and legacy data import, configuration and localization tools, and customization of the platform through the integrated Arches Designer
- The forthcoming Arches for Science to manage heritage science data
- The Arches open-source community, including how to participate
- How Arches is being implemented by a range of heritage organizations and projects around the world, including Auckland Council, Historic England for archaeological impact assessment in Greater London, numerous Arcadia-funded projects recording endangered archaeology across the Global South, and the Swedish Institutes in Rome, Athens, and Istanbul recording excavation activities over many decades.

W5: Data Modeling and Controlled Vocabulary Management using Arches

Half day workshop – Afternoon: Monday 8th April, 13:00–16:00, 260-0408

Annabel Lee Enriquez, Getty Conservation Institute

For those who have attended the Arches Information Session or have previous experience with the Arches Cultural Heritage Data Management Platform, this workshop highlights how Arches can accommodate an organization's or project's use case through data modeling and controlled vocabulary management with no coding via interface tools within Arches.

Learning objectives of the workshop include:

- Learn how to model data within Arches using the Arches Designer, including how to incorporate semantic metadata and controlled vocabularies
- Examine examples of data models (or resource models) from existing Arches implementations
- Learn how to manage and organize controlled vocabularies within Arches using the Arches Reference Data Manager
- Learn how to use Arches Modeling Resources, including the Package/Project Library, to find and leverage the modeling work of others in the Arches community to create your own models
- Understand the role of the Arches Resource Modeling Working Group and how you can be involved in the Arches community as it relates to data modeling
- Learn about the latest developments regarding the new Arches Reference Data Manager, which will include many enhancements and new features for the management of controlled vocabularies.

W6: CRMarchaeo Workshop: A Stepping Stone to FAIR Practice

Full day workshop: Monday 8th April, 08:00–16:00, 260-055 Case Room 3

Stephen Stead, Paveprime Ltd and Open University
Jane Jansen, National Historical Museums in Sweden and Intrasis

In this workshop, we will explore how to use CRMarchaeo, an extension of the CIDOC Conceptual Reference Model (CRM), for the purpose of linking a wide range of existing documentation from archaeological excavations.

When working with archaeological data deposited in archives in different eras and by different organisations using ever-evolving recording methodologies, a recurrent problem is being able to systematically access elements of the record without immersing oneself in the recording milieu of each of the original deposits. This high intellectual cost must be paid by each scholar wishing to work on the records of a particular archaeological investigation and so effectively creates a barrier to extensive reuse of archived data. The FAIR data principles require “that all research objects should be Findable, Accessible, Interoperable and Reusable (FAIR) both for machines and for people” (Wilkinson et al. 2016). One approach to making data FAIRly accessible while reducing the effort to a single “intellectual act” is to map to a “lingua franca”, such as CRMarchaeo.

The CRMarchaeo extension has been meticulously designed to promote a shared understanding of how to formalise the knowledge extracted from the observations made by archaeologists. It provides a set of concepts and properties that allow clear explanation (and separation) of the observations and interpretations made, whether in the field or during post-excavation phases.

The participants of the workshop will work through a series of case studies that reflect different excavation documentation practices: from 1950s style day books through to context recording sheets and extend to database and computer-aided design (CAD) combinations and advanced integrated, object-oriented database/geographic information systems (GIS) like Intrasis.

The aim is to explore archetypical solutions and provide attendees with hands-on experience of mapping actual documentation practice to CRMarchaeo. This can then be applied to their own or archive documentation, both current and historical, in their own institutions or archives and lead to integrated reusable composites being available for both internal and external use. We will also demonstrate how to use the CRMinf extension to document the background to alternative interpretations and reinterpretations.

W7: Photogrammetry Methods

Full day workshop: Monday 8th April, 08:00–16:00, 260-317

Michael Rampe, Rampe Realistic Imaging Pty Ltd, Pedestal 3D Pty Ltd, Macquarie University

This workshop will consist of two parts. The morning session will be demonstration-based and work through a range of modern photogrammetry approaches for a range of subjects from the micro and objects up to fieldwork, buildings and boats. This will include theoretical underpinning, photography and imaging methods and a lot of custom know-how on how to approach a scan.

In the afternoon, participants will have the opportunity to get out into the field and apply some of the lessons to the digitisation of whatever we can find. During the conference, the presenter will then process and curate the participant's data and share the results with the convocation on Pedestal 3D®.

The presenter has years of experience delivering professional photogrammetry services through Rampe Realistic Imaging Pty Ltd, developed the Pedestal 3D® platform for web publishing and analysis of 3D data and runs a successful internship training program at Macquarie University in Sydney Australia. Examples from all of these ventures will be discussed and analysed.

Requirements

Bring a good camera if you can. Bring your phone as a minimum.

W8: Chronological Modelling with ChronoLog – Theory and Practice

Full day workshop: Monday 8th April, 08:00–16:00, 260-321

Eythan Levy, University of Bern

This workshop will present the foundations of ChronoLog, a free tool for building chronological models, testing their consistency, and computing tight, checkable, chronological estimates. These models consist of a network of entities (e.g. archaeological strata, ceramic periods, historical reigns) connected by a set of synchronisms. The tool allows users to modify the data in the model and assess on-the-fly the impact of these updates on the overall chronology. ChronoLog also allows users to add radiocarbon determinations to their models, and to convert the model automatically to an OxCal Bayesian radiocarbon model. This feature allows archaeologists with no knowledge of the OxCal specification language to build complex Bayesian models on their own, with just a few clicks of the mouse. ChronoLog is freely available for download at https://chrono.ulb.be. For more details on ChronoLog, a user manual is available on the ChronoLog website. For additional details, see the bibliography below, especially Levy et al. 2021 (Journal of Archaeological Science), and Levy et al., in press (Proceedings of CAA 2021).

The workshop will start with a general introduction to ChronoLog, its basic principles, and its main functionalities. The second part of the session will be devoted to practical modelling exercises, which users will do on their own laptops. In these exercises, users will first learn how to build chronological models by themselves, based on a wide set of archaeological and historical data. They will then explore how ChronoLog can serve as a useful tool for archaeological cross-dating. This part will also present the use ChronoLog as a front-end to OxCal for building Bayesian radiocarbon models. In the final part of the workshop, participants will be invited to present their own data sets, and will be assisted in the modelling of these datasets using ChronoLog.

Requirements

Participants should bring their laptop, and have an internet connection to download the ChronoLog app at https://chrono.ulb.be or, alternatively, download the app before the start of the workshop. Participants are also encouraged, if they have not already done so, to create an OxCal account at https://c14.arch.ox.ac.uk/oxcal/.

Roundtables

R1: Towards a Future Research Agenda of Archaeological Practices in the Digital Era

Wednesday 10th April, 09:00–10:00, 260-055 Case Room 3

Isto Huvila Uppsala University
Anne Hunnell Chen, Bard College
Stephen Stead, Paveprime Ltd

The recent years have seen a growing interest in conducting empirical, theoretical and reflective research on contemporary and past archaeological practices. Such research has created new knowledge on the practicalities and underpinnings of archaeological work in the past and at the present, update of digital technologies and their impact on archaeological knowledge production, and much more. At the same time, as it has enhanced our understanding of archaeological practices, it has informed development of new tools and infrastructures, and creation, organisation, management and dissemination of archaeological knowledge. Beyond the domain of archaeology, the research on archaeological practices has resulted in insights that have transferred to other domains.

The aim of this roundtable is to invite researchers of archaeological practices and archaeological practitioners to discuss what next steps the studies of contemporary archaeological practices should take to advance the understanding of present, past and future archaeological work, use and development of existing and new digital tools and infrastructures and practices. Each participant is asked to propose and give a brief lightning talk highlighting one specific aspect of archaeological practices that needs to be studied in more detail in the future, a particular knowledge gap, a potentially useful method or theory in advancing the understanding of archaeological practices, or a issue or problem that could be addressed or solved by inquiring deeper into how archaeological or archaeology-related paid or voluntary, professional or non-professional practices are enacted, what are their underpinning factors, or implications. The invitation is especially extended to both senior and junior scholars and practitioners representing all genders and backgrounds, disciplines, and perspectives to studying or engaging with archaeological practices. After the lightning talks, the roundtable continues with a discussion on a future research agenda of archaeological practices in the digital era with the panellists and the audience, and closes with an invitation to continued work on developing the agenda.

The roundtable is organised in collaboration with the research projects CAPTURE (http://www.uu.se/en/research/capture) and IDEA (duraeuroposarchive.org) and the CAASIG ARKWORK on archaeological practices and knowledge work in the digital environment.

R3: Exploring the Nexus of Robotics and Archaeology: Unveiling the Potential and Ethical Dimensions

Thursday 11th April, 10:20–12:00, 260-057 Case Room 2

João Marreiros, Leiza
Arianna Traviglia, Istituto Italiano di Tecnologia

In the tapestry of modern society, robots have woven their threads across diverse domains, functioning as integral components. Spanning healthcare, manufacturing, agriculture, and industries, robots are the linchpin that sustains and advances numerous systems. Notably, the field of archaeology has also embraced these mechanical collaborators, testing ways to employ them on archaeological sites, within laboratories, and even in public exhibitions. These robotic allies range from automated machine performing cultural heritage manipulation and scanning to unmanned aerial vehicles (UAVs) that probe depths and spaces beyond human reach, elevating the efficiency and reliability of archaeological and conservation practice endeavors. Recently, the use of robots in archaeological research has been extended to the field of experimental archaeology, in which controlled setups are used to test the properties of resources used on past human technologies. However, amidst these accomplishments, a pivotal question arises: Can we catapult robots to new heights within archaeology and the field of Cultural heritage at large, perhaps merging them with Artificial Intelligence, to craft an "Artificial Archaeologist"?

This dynamic roundtable delves into the current landscape of robotics within archaeology and Cultural Heritage domain, pushing the boundaries of possibility into the foreseeable future. We invite thought-provoking proposals encompassing a spectrum of insights, spanning both concrete case studies and theoretical reflections. Our exploration encompasses multiple dimensions:

- The Role of Robots in Archaeological Practice: Archaeologists have harnessed robotic technology across various scenarios. This session seeks to unveil the nuances of these interactions. What are the contexts in which robots prove indispensable, and what challenges do they alleviate? How do these mechanical aids impact archaeological processes, amplifying the precision of data collection, analysis, and preservation? Contributions on practical applications, from data collection during fieldwork to laboratory analysis, are invited to enrich the discourse.

- Robots and the Act of Excavation: An intriguing discourse revolves around the notion of robots as 'fieldwork companions'. Could robots assume the role of human archaeologists in the excavation process? We aim to deliberate on the potential benefits and implications of this prospect, spanning efficiency gains, preservation of archaeological sites, and even the reshaping of archaeological narratives

- -Robots as Architects of Archaeological Knowledge: Another compelling avenue to explore is the fusion of robotics with knowledge-building endeavors. How might robots serve as tools for processing voluminous data, and constructing comprehensive archaeological narratives? We welcome explorations of how robotic technologies can augment the archaeological discipline, aiding in generating insights and perspectives previously unattainable.

- Ethical Considerations in Robotic Archaeology: The surge of robotic engagement in archaeological practice mandates a critical examination of ethical dimensions. What concerns arise when technology interweaves with cultural heritage preservation? This round table aspires to stimulate conversations on ethical implications such as data ownership, the potential displacement of human expertise, and the preservation of archaeological integrity. As we venture into the nexus of robotics and archaeology, this round table seeks to map the contours of this evolving collaboration, unraveling its current standing and paving a path toward its future potential. It serves as an invaluable platform for showcasing ongoing work, fostering dialogue, and receiving constructive feedback. In embracing diversity and nurturing fresh perspectives, this session promises to be a fertile ground for the exchange of novel ideas.

R4: Unveiling the Past, Safeguarding the Future: Pioneering Technologies in the Battle Against Illicit Archaeological Looting and Trafficking

Thursday 11th April, 13:00–15:00, 260-057 Case Room 2

Arianna Traviglia, Istituto Italiano di Tecnologia
Michela De Bernardin
Riccardo Giovanelli

The pressing global concern surrounding the decimation of archaeological sites due to illegal excavations and cultural heritage vandalism has sparked fervent initiatives from governments, cultural institutions, and concerned citizens alike. In the wake of pivotal contemporary events such as the 2004 Iraqi war, the 2011 ‘Arab Spring’, the rise of ISIS in the Middle East and North Africa, the disruptive impact of the COVID pandemic, and the tumultuous 2022 Ukraine conflict, the international antiquities market has been inundated with a distressing influx of looted items. In response to this escalating crisis, the past decade has witnessed an unprecedented surge in computer-aided technologies geared towards the surveillance of looting activities and the intricate web of art markets. These technological innovations have emerged as essential tools for detecting and deterring unlawful behaviors.

Remote sensing technologies, synergized with multispectral imagery (Tapete and Cigna, 2021), alongside manual and automated recognition of looting patterns (Casana and Panahipour, 2014; Contreras, 2010; Stone, 2008; Lasaponara and Masini, 2021), harness the power to unmask illicit excavations. Moreover, the integration of synthetic aperture radar (SAR) data (Tapete, Cigna, and Donoghue, 2016; El Haji, 2021) and multi-temporal analysis (Agapiou, 2020) elevates the sophistication of detection methodologies. A remarkable breakthrough has been the utilization of very high-resolution (VHR) imagery time-series through platforms like Google Earth, revolutionizing the identification and tracking of looted sites on a global scale (Contreras and Brodie, 2011; Parcak et al., 2016; Zerbini and Fradley, 2018), thereby paving new avenues for innovative recognition mechanisms. Harnessing the power of cutting-edge computer vision and machine learning, researchers are delving into their potential for analyzing web-scraped content (Huffer and Graham, 2018; Huffer, Wood, and Graham, 2019; Graham et al., 2020) to trace illicit online transactions. Leveraging network science methodologies, researchers have unveiled criminal networks within the antiquities trade (Tsiriogiannis and Tsiriogiannis, 2016) and actors entrenched in the ‘grey market’ of antiquities (Bowman, 2008; Mackenzie, 2019; Mackenzie and Yates, 2016). Intriguingly, artificial intelligence models are under development to identify looted archaeological items surfacing in the market (Winterbottom, Leone, and Al Moubayed, 2022).

In a remarkable turn, vigilant monitoring of social media platforms, online forums, marketplaces, and even the elusive deep web is yielding vital intelligence about the shadowy realm of the illicit market, employing both quantitative and qualitative content analysis (Al-Azm and Paul, 2019;

Hardy, 2014, 2015, 2017, 2018; Paul, 2018; Giovanelli, 2018; Altaweel and Hadjitofi, 2020; De Bernardin, 2021). Forward-looking enforcement units like Italy's Comando Tutela Patrimonio Culturale and INTERPOL have formulated databases of stolen objects and initiated due diligence protocols (Arma dei Carabinieri, 2016). The integration of 3D imagery-powered blockchain technologies (Gandolfi and Cox, 2018) holds great promise for fortifying future interventions.

As the loss of archaeological contexts and cultural heritage items continues to accelerate, the pace of research quickens. While these technologies exhibit increasing specialization, they often lack the sophistication necessary for robustly combating illicit trafficking. This conference session invites original research contributions in the aforementioned realms—remote sensing, network sciences, computer vision, machine learning, data mining, blockchain, and social media data analysis. Beyond showcasing advances, the session aims to fuel a critical dialogue on the effectiveness, advantages, and limitations of established and emerging technologies. By identifying effective approaches, this Round Table endeavors to lay the groundwork for constructing resilient systems that effectively thwart and prevent the looting and illicit trade of cultural heritage objects.

The call for submissions extends to pioneering methodologies and applications that remain untapped within the realm of countering cultural property trafficking, particularly in the unexplored intersection of Network Sciences and Graph Theory. The Round Table caters primarily to researchers immersed in the expansive field of antiquities crimes, encompassing both traditional and computational methodologies. Simultaneously, professionals engaged in the described technologies and methods—such as remote sensing and machine learning—are invited to contribute within the broader context. A pre-conference position paper will be published by the organisers of the session approximately 3 months ahead of the conference, and perspective participants to the Round Table will be invited to submit a written response in advance or to participate in a structures, open-forum discussion during the conference.

The session is seamlessly integrated into the HORIZON EU RITHMS (Research, Intelligence, and Technology for Heritage and Market Security) project framework. The initiative endeavors to craft an innovative, interoperable, and multifunctional Social Network Analysis (SNA) digital platform, tailored to pinpointing criminal networks engaged in cultural property trafficking. Within the framework of this collaborative endeavor, stakeholders engaged in the battle against looting and cultural heritage trafficking will gain access to invaluable recommendations. These insights will amplify ongoing efforts to prevent future criminal activities, ultimately fortifying the protection of cultural heritage.

References

Al-Azm, A and Paul, K A 2019 Facebook's Black Market in Antiquities. Trafficking, terrorism, and war crimes. (June). Agapiou A 2020 Detecting Looting Activity through Earth Observation Multi-Temporal Analysis over the Archaeological Site of Apamea (Syria) during 2011-2012, Journal of Computer Applications in Archaeology, 3(1): 219-237. DOI: https://doi.org/10.5334/jcaa.56/

Altaweel, M and Hadjitofi, T A 2020 The sale of heritage on eBay: Market trends and cultural value, Big Data & Society, 7(2). DOI: https://doi.org/10.1177/2053951720968865.

Arma dei Carabinieri 2016 PSYCHE : THE PROTECTION SYSTEM FOR CULTURAL HERITAGE HOME/2011/ISEC/AG/PRUM/4000002157. 2016. Available at http://tpcweb.carabinieri.it/SitoPubblico/psyche/generic.

Bowman, B A 2008 Transnational Crimes Against culture: Looting at Archaeological Sites and the 'Grey'

Market in Antiquities, Journal of Contemporary Criminal Justice, 24(3): 225–242. DOI: https://doi.org/10.1177/1043986208318210.

Casana, J and Panahipour, M 2014 Satellite-Based Monitoring of Looting and Damage to Archaeological Sites in Syria, Journal of Eastern Mediterranean Archaeology and Heritage Studies, 2(2): 128–151.

Contreras, D A 2010 Huaqueros and remote sensing imagery: assessing looting damage in the Viru Valley. Peru., Antiquity, 84(324): 544– 545.

Contreras, D A and Brodie, N 2011 The Utility of Publicly-Available Satellite Imagery for Investigating Looting of Archaeological Sites in Jordan, Journal of Field Archaeology, 35(1): 101–114. DOI: https://doi.org/10.1179/009346910×12707320296838.

De Bernardin, M 2021 Palmyrene Funerary Portraits: a 'Conflict Antiquities' Case. In: Traviglia, A, Milano, L, Tonghini, C and Giovanelli, R (eds.) Stolen Heritage. Multidisciplinary Perspectives on Illicit Trafficking of Cultural Heritage in the EU and the MENA Region. Venice: Edizioni Ca' Foscari, pp. 79-95. DOI: http://doi.org/10.30687/978-88-6969-517-9/004

El Hajj, H 2021 Interferometric SAR and Machine Learning Using Opens Source Data to Detect Archaeological Looting and Destruction, Journal of Computer Applications in Archaeology, 4(1): 47-62. DOI: https://doi.org/10.5334/jcaa.70/

Gandolfi, E and Cox, G 2018 New approaches to Open Data in Archaeology: the blockchain revolution. Paper presented to 2018 Computer Applications and Quantitative Methods in Archaeology (CAA) international conference, Tübingen, 19- 23 March, 2018. Available at https://2018.caaconference.org/wp-content/uploads/sites/22/2018/03/AbstractBook.pdf [Last accessed 17 June 2019].

Graham, S, Lane, A, Huffer, D and Angourakis, A 2020 Towards a Method for Discerning Sources of Supply within the Human Remains Trade via Patterns of Visual Dissimilarity and Computer Vision, Journal of Computer Applications in Archaeology, 3(1): 253-268. DOI: https://doi.org/10.5334/jcaa.59/

Giovanelli, R 2018 Provenance non verificabili nel mercato di antichità romane: case study sui 300 oggetti di più alto valore in vendita in eBay US, Archeomafie, X: 115-135. Available at: http://hdl.handle.net/10278/3740198.

Hardy, S A 2014 Using Open-Source Data to Identify Participation in the Illicit Antiquities Trade: A Case Study on the Cypriot Civil War, European Journal on Criminal Policy and Research, 20(4): 459–474. DOI: https://doi.org/10.1007/s10610-014-9250-x.

Hardy, S A 2015 Is looting-to-order "just a myth"? Open-source analysis of theft-toorder of cultural property, Cogent Social Sciences, 1(1): 1–22. DOI: https://doi.org/10.1080/23311886.2015.1087110.

Hardy, S A 2017 Quantitative analysis of open-source data on metal detecting for cultural property: Estimation of the scale and intensity of metal detecting and the quantity of metal-detected cultural goods, Tong, S. (ed.) Cogent Social Sciences, 3(1): 1–49. DOI: https://doi.org/10.1080/23311886.2017.1298397.

Hardy, S A 2018 Metal-Detecting for Cultural Objects until 'There Is Nothing Left': The Potential and Limits of Digital Data, Netnographic Data and Market Data for Open- Source Analysis, Arts, 7(3): 40. DOI: https://doi.org/10.3390/arts7030040.

Huffer, D and Graham, S 2018 Fleshing Out the Bones : Studying the Human Remains Trade with Tensorflow and Inception, Journal of Computer Applications in Archaeology, 1(1): 55–63. DOI: https://doi.org/doi.org/10.5334/jcaa.8.

Huffer, D, Wood, C and Graham, S 2019 What the Machine Saw: some questions on the ethics of computer vision and machine learning to investigate human remains trafficking, Internet Archaeology, DOI: https://doi.org/10.11141/ia.52.5.

Lasaponara, R and Masini, N 2021 Remote and Close Range Sensing for the Automatic Identification and Characterization of Archaeological Looting. The Case of Peru, Journal of Computer Applications in Archaeology, 4(1): 126-144. DOI: https://doi.org/10.5334/jcaa.73/

Mackenzie, S 2019 White-Collar Crime, Organised Crime and the Challenges of Doing Research on Art Crime. In: Hufnagel, S. and Chappel, D. (eds.) The Palgrave Handbook on Art Crime. London: Palgrave Macmillan UK. pp. 839–853. DOI: https://doi.org/10.1057/978-1-137-54405-6_37.

Mackenzie, S and Yates, D 2016 Collectors on illicit collecting: Higher loyalties and other techniques of neutralization in the unlawful collecting of rare and precious orchids and antiquities, Theoretical Criminology, 20(3): 340–357. DOI: https://doi.org/10.1177/1362480615607625.

Parcak, S, Gathings, D, Childs, C, Mumford, G and Cline, E 2016 Satellite evidence of archaeological site looting in Egypt: 2002 – 2013, Antiquity, 90(349): 188–205. DOI: https://doi.org/10.15184/aqy.2016.1.

Paul, K 2018 Ancient Artifacts vs. Digital Artifacts: New Tools for Unmasking the Sale of Illicit Antiquities on the Dark Web, Arts, 7(2): 12. DOI: https://doi.org/10.3390/arts7020012.

Stone, E C 2008 Patterns of looting in southern Iraq, Antiquity, 82(315): 125–138. DOI: https://doi.org/10.1017/s0003598x00096496.

Tapete, D, Cigna, F and Donoghue, D N M 2016 ' Looting marks ' in space-borne SAR imagery: Measuring rates of archaeological looting in Apamea (Syria) with TerraSAR-X Staring Spotlight, Remote Sensing of Environment, 178(April): 42–58. DOI: https://doi.org/10.1016/j.rse.2016.02.055.

Tapete, D and Cigna, F 2021 Satellite Technologies for Monitoring Archaeological Sites. In: Traviglia, A, Milano, L, Tonghini, C and Giovanelli, R (eds.) Stolen Heritage. Multidisciplinary Perspectives on Illicit Trafficking of Cultural Heritage in the EU and the MENA Region. Venice: Edizioni Ca' Foscari, pp. 155-167. DOI: http://doi.org/10.30687/978-88-6969-517-9/007.

Tsiriogiannis, C and Tsiriogiannis, C 2016 Uncovering the Hidden Routes: Algorithms for Identifying Paths and Missing Links in Trade Networks. In: Brughmans, T., Collar, A., and Coward, F. (eds.) The Connected Past Challenges to Network Studies in Archaeology and history. Oxford: Oxford University Press. pp. 103–122.

Winterbottom, T, Leone, A, Al Moubayed, N 2022 A deep learning approach to fight illicit trafficking of antiquities using artefact instance classification, Scientific Reports, 12, 13468. DOI: https://doi.org/10.1038/s41598-022-15965-2.

Zerbini, A and Fradley, M 2018 Higher Resolution Satellite Imagery of Israel and Palestine: Reassessing the Kyl-Bingaman Amendment, Space Policy, 44–45: 14–28. DOI: https://doi.org/10.1016/j.spacepol.2018.03.002.

Poster Session

Main foyer, Owen G Glenn Building

79. Fail and Try Again: Return on Topic Modelling Apply to Archaeological Scientific Literature (Poster)

Mathias Bellat (University of Tübingen); Ruhollah Taghizadeh-Mehrjardi (University of Tübingen); Thomas*

Background

Scoping large amounts of data for literature review is a time-consuming task, and automated solutions emerged as promising tools to sorting and analysing the vast array of results. These classification methods can take the form of query systems akin to research portals, employing criteria like publication date, authorship, and keywords, or automated classification models (Padarian et al. 2020). Latent Dirichlet allocation (LDA), a Bayesian Network unsupervised model, has found widespread application across various domains for this purpose (Jelodar et al. 2019). LDA, noted for its user-friendly nature and the ability to categorize information into predefined topics, has therefore been used in our study to automatically detect different topics among our corpus and classify them by coherence. The recent development of machine learning techniques into archaeology has led to various practice in different subfield of archelogy (i.e. G.I.G., paleogenetic, artefact classification). This development of new methods into different subfield of archaeology had never been explored before, and a topic modeling approach seams to be an efficient way to analysis relationship between different topics. Our question was: what relation is there between the collected articles, and how relevant it is to classify them into different categories with topic modelling?

Subject

To gather our dataset, we systematically scoured five different online databases using a series of 12-word combinations. This process yielded a total of 532 articles, which were subsequently subjected to automated filtering to eliminate irrelevant content. After this first filter 377 articles were analyzed via LDA model under R. Parameters were optimized according to different metrics such as in Ponweiser (2012), LDA was performed on both the full texts and abstracts of the articles. However, the results did not yield a clear-cut classification (Fig. 1). Many of the identified topics exhibited overlap, with one category significantly overrepresented.

The reason of such a failure is difficult to input to only one factor. The diversity of topics represented and the low capacity of LDA to treat complex data set are probably the main reasons of the failure of this attempt. Nevertheless, the LDA analysis did reveal certain linguistic patterns within the articles, such as “technophile” language bias.

Discussion

Our research serves as a candid account of an unsuccessful experiment, we aim share the parameters employed to standardize future approaches in this domain. We will discuss the reasons behind this lack of success and compare the LDA model with BERTopic, another popular topic modelling approach. These two models have been widely used and were successful in past research, therefore, we think important to compare both of them and there results. Additionally, we will discuss emerging developments in machine learning field, such as large language model, which hold promise as reliable solutions for complex and extensive data sets.

Reference:

Padarian, José, Budiman Minasny, and Alex B. McBratney. 2020. 'Machine Learning and Soil Sciences: A Review Aided by Machine Learning Tools'. SOIL 6 (1): 35–52. https://doi.org/10.5194/soil-6-35-2020.

Jelodar, Hamed, Yongli Wang, Chi Yuan, Xia Feng, Xiahui Jiang, Yanchao Li, and Liang Zhao. 2019. 'Latent Dirichlet Allocation (LDA) and Topic Modeling: Models, Applications, a Survey'. Multimedia Tools and Applications 78 (11): 15169–211. https://doi.org/10.1007/s11042-018-6894-4.

Ponweiser, Martin. 2012. Latent Dirichlet Allocation in R. WU Vienna University of Economics and Business. Theses / Institute for Statistics and Mathematics No. 2

129. Evaluating Initial Upper Paleolithic Dispersal in Central/East Asia using Least Cost Path Modelling (Poster)

Andrew L Jenkins (University of Wollongong); Sam C Lin (University of Wollongong); Fei Peng (Minzu University of China); Lydia Mackenzie (University of Tasmania)*

Clarifying the timing and pathways of modern human dispersal out of Africa is of great importance to archaeology and palaeoanthropology. In Central and East Asia, the arrival of our species is commonly thought to be associated with the appearance of the Initial Upper Paleolithic industry, or IUP, approximately 50 to 40 thousand years ago. The IUP is defined by its distinct combination of the Levallois method and Upper Paleolithic volumetric techniques for blade production, and it is also often associated with bone tools and symbolic ornaments such as beads and pendants (Zwyns, 2021). Based on the geographic distribution of the earliest IUP sites, researchers have suggested that the IUP toolmakers appeared in the west by at least 45 thousand years ago, at sites such as Shugnou in Tajikistan and Obi Rakhmat in Uzbekistan, and spread east through the Altai mountains, the Transbaikal, Mongolia, and eventually to North China by approximately 41 thousand years ago.

However, to date, only a few studies have employed formal spatial modelling approaches to verify the proposed IUP dispersal routes. One of the limited examples is the study by Li et al. (2019), who conducted Least Cost Path (LCP) analyses to evaluate potential dispersal pathways under different environmental settings. Using slope as the primary factor for computing travel cost, Li et al. (2019) showed that the presence of paleolakes in regions such as the Tarim Basin and the Tian Shan corridor during Marine Isotope Stage 3 (MIS 3) could have facilitated IUP dispersal through these modern arid areas. However, the Li et al's (2019) study has several shortcomings. First, their analysis required all LCPs to end at the site of Shuidonggou in China. While this assumption is logistically necessary and reasonable for their modelling approach, it remains unclear to what extent are the identified pathways dictated by this assumption. Second, Li et al. (2019) employed the Last Glacial Maximum climatic reconstruction to simulate the drier environmental setting of the region during MIS 3. However, it is evident that the region's climate was considerably warmer and wetter during MIS 3 than during the Last Glacial Maximum. Therefore, it remains to be verified whether the simulation outcome will change if more appropriate MIS 3 climatic data are incorporated into the LCP analysis.

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To address these questions, we replicated the LCP analysis by Li et al. (2019) and made a number of changes to the model design. First, we relaxed the assumption about the origin and destination of the LCPs by employing a modified version of the 'From-everywhere-to-everywhere' method (White, 2015), where LCPs were modelled from equal-spaced points placed along the perimeter of the study area. Second, we incorporated hindcasted MIS 3 precipitation data to more accurately reflect the paleoclimatic condition of the region during IUP dispersal, especially the spatial distribution of deserts that could have impeded human dispersal. Third, we introduced travel cost relief to desert areas near water bodies such as lakes and rivers to facilitate movement across arid zones.

Our results support the possible IUP dispersal pathways through the Tarim Basin and the Tian Shan corridor, as suggested by Li et al. (2019). However, contrasting to the commonly held view that the IUP toolmakers in Mongolia spread southward to North China, the model outputs indicate that such a dispersal scenario is unlikely owing to the presence of large deserts in the area during that time. Instead, it is possible that the IUP sites in the Transbaikal/Mongolia and North China represent separate IUP dispersal events. Our study has important implications for the understanding of modern human dispersal into Central and East Asia during the Late Pleistocene. The LCPs not only provide an objective means to evaluate the feasibility of hypothesised routes but also offer a potential guide to help future field reconnaissance to identify IUP sites in the region. This research showcases the potential of formal spatial modelling as a hypothesis-building tool to enhance our understanding of ancient human dispersal across the globe.

References

Li, F., Vanwezer, N., Boivin, N., Gao, X., Ott, F., Petraglia, M., & Roberts, P. (2019). Heading north: Late Pleistocene environments and human dispersals in central and eastern Asia. PLOS ONE, 14(5), e0216433. https://doi.org/10.1371/journal.pone.0216433

White, D. A. (2015). The Basics of Least Cost Analysis for Archaeological Applications. Advances in archaeological practice : a journal of the Society of American archeaology, 3(4), 407-414. https://doi.org/10.7183/2326-3768.3.4.407

Zwyns, N. (2021). The Initial Upper Paleolithic in Central and East Asia: Blade Technology, Cultural Transmission, and Implications for Human Dispersals. Journal of Paleolithic Archaeology, 4(3), 19. https://doi.org/10.1007/s41982-021-00085-6

120. The Challenges in Creating Databases for Pacific Ceramics (Poster)

Kristine Hardy (ANU); Mathieu Leclerc*

Petrographic fabrics, the mixtures of different mineral and rock inclusions in clay pastes of pottery sherds, provide geological signatures that can help identify the site of production, and can indicate the degree of variability within a pottery community or changes in techniques over time. In petrographic analysis, thin sections of pottery, mounted on microscope slides, are viewed under different filters to identify the minerals and rocks and characterise the fabrics.

The results of ceramic petrographic analysis can be challenging to present, interpret and compare and this has been exacerbated by past limitations on publishing colour images. Variable ontologies and methods of quantifying or describing the inclusions, also add to the difficulties in understanding petrographic reports. Unfortunately, often thin sections are also not archived, or if kept, are difficult to access.

The geologist, William Dickinson extensively characterised the fabrics of archaeological pottery found throughout the Pacific (Dickinson 2006). His collection of 2291 thin-sections, is held by the Bishop Museum of Hawai'i and digital copies of his associated reports are archived at several places, including the Australian National University Archives. We aimed to use his reports and thin-sections to seed databases for petrographic images and the quantitative mineral/rock abundances of the fabrics of Pacific pottery.

Using the reports we created a relational database (kuden) with 'fabrics', 'sites', 'slides/sherds' and 'reports' tables. The fields for the fabrics table include quantitative measures for the different minerals, and the presence or absence of different rock types. We have created a Django web interface for the database, to allow users to search for fabrics that match certain mineral/rock abundances, and/or are found at certain locations. The kuden database also includes links to example images of the fabric. To facilitate the viewing of images at different magnifications, and with the different filters, we used the Open Microscopy Environment Remote Objects (OMERO) opensource software system. OMERO was designed for archiving and managing biological slide images (Burel et al. 2015).

Slide scanners such as the Axioscan7 have made it easier to obtained high resolution images of whole slides, under multiple filters. OMERO is able to serve these files in a tiled, memory efficient manner, resulting in a 'virtual microscope'. Using whole slide scans and more simple TIF image stacks we have imaged approximately half of the fabrics of Pacific pottery in an OMERO implementation, VIMIPO and found that OMERO software is an effective way of presenting ceramic petrographic data.

We are investigating converting the kuden relational database to a CIDOC-CRM graph-based database, with the future possibility of using linked data to address questions such as how pottery technology changes related to other temporal changes in the Pacific.

References

Burel, Jean-Marie, Sebastien Besson, Colin Blackburn, Mark Carroll, Richard K. Ferguson, Helen Flynn, Kenneth Gillen, et al. 2015 "Publishing and sharing multi-dimensional image data with OMERO." Mammalian Genome 26:441–447. https://doi.org/10.1007/s00335-015-9587-6

Dickinson, William. 2006. "Temper Sands in Prehistoric Oceanian Pottery: Geotectonics, Sedimentology, Petrography, Provenance." Geological Society of America Special Paper 406:1–164. https://doi.org/10.1130/SPE406.

197. Digital Archaeology of New Zealand's Historical Landscapes

James Robinson and Simon H. Bickler

This poster showcases how digital archaeology is reshaping our understanding of New Zealand's historical heritage. In Aotearoa New Zealand, researchers are integrating GIS mapping, archaeological surveys, excavation, databases, and virtual reconstructions with archival and oral history to unearth intricate narratives of diverse historical sites.

Case studies presented include Tawhiti Rahi (Poor Knights Islands), where seemingly conflicting databases of history, science, and archaeology have been carefully analysed, leading to integration and reconciliation. This process enhances the interpretation of the chronology and changing nature of Māori history.

A second multidisciplinary study that employs historical and traditional knowledge records, coupled with precise mapping from surveys, aerial photos, and lidar illustrates the evolution of traditional pā (hill forts) into gunfighter pā during the early historic period. The goal was to identify distinctive structural elements differentiating modified traditional sites and purpose-built pā for musket warfare. The findings reveal that these pā originated from early interactions between Māori and European explorers in the late 18th century. The study highlights the parallel evolution of offensive and defensive musketry during the musket wars between 1818-1837.

The final study analyses digitised newspaper records and archaeological records of pā and colonial redoubts, tracking the trajectories of the New Zealand Wars during the 1860s-1880s.

This research is redefining our understanding of the transformative impact of coloniser settlements within a long-standing Māori landscape. The projects not only contribute to academic debate but also serve as a catalyst for public outreach, enriching the narrative of New Zealand's past. The poster is sponsored by the Australasian Society for Historical Archaeology.

45. Exploring Early Holocene Sahara Cultural Adaptations and Networks through Socio-ecological Inferential Modelling (Poster)

*Rocco Rotunno (McDonald Institute for Archaeological Research, University of Cambridge)**

Early Holocene hunter-gatherer-fisher communities in North Africa and the Sahara, dating back around 10.5 thousand years, exhibit material and socio-economic patterns across vast regions with a certain degree of similarity. Although attributed to rapid demographic expansion, the exact dynamics of dissemination, cultural transmission processes, contacts, and networks sustaining this consistency remain poorly understood. This biennial research project, EHSCAN, aims to determine if this long-term persistence resulted from slow cultural change or extensive inter-group connections, potentially facilitated by a large-scale interaction network. To address these questions, EHSCAN proposes a statistical and spatial approach integrating generative inference and geostatistical analyses. It will assess differences and similarities between North African archaeological cultures and study micro-scale processes governing cultural transmission. By combining diverse datasets and approximate Bayesian computation, EHSCAN will analyse material culture assemblages across the Sahara, examining the diffusion of specific cultural traits. Focusing on pottery and radiocarbon dates, it will identify factors influencing these processes and establish new models for Early Holocene settlement history in North Africa and possibly broaden the conceptual and interpretative frameworks for Saharan prehistory.

S1: Beyond Binary: Exploring Maritime and Coastal Archaeology across the Water's Edge through Digital Methods

Wednesday 10th April, 15:20 –17:00, OGGB-098

John McCarthy, Flinders University
Benjamin D Jones, University of Auckland/Waipapa Taumata Rau
Isaac McIvor, University of Otago/Te Whare Wānanga o Otāgo

The subdiscipline of maritime archaeology has always had a strong emphasis on technology. However, since the turn of the century, there has been a transformative shift with the increasingly ubiquitous integration of digital methods and advanced remote sensing methods, including high-resolution bathymetry, multibeam sonar, and airborne laser scanning (McCarthy et al., 2020). Improvements in digital technologies and remote sensing methods have blurred the binary distinctions between land and sea. This has led to an increasing focus on research that spans the sub-tidal, intertidal, coastal, and terrestrial realms. As a result, maritime and coastal themes now encompass nautical archaeology and ancient seafaring, submerged ancient landscapes, and the archaeology of the coast and its hinterlands (Jones et al. 2023). This session will explore how these technologies have been integrated into research and enhanced our understanding of the interaction between human societies and the sea.

The digital nature of the session will be centred around two themes:

- Documentation and imaging technology: This theme will explore the latest advances in digital technologies for documenting and imaging maritime and coastal heritage. Topics will include the use of GIS, 3D modelling, photogrammetry, and virtual reality. Attendees will gain insights into the enhanced ability to analyse and interpret maritime and coastal archaeological sites and make informed management decisions based on comprehensive spatial data. Digital documentation and imaging techniques will take centre stage in the session. Researchers will present the latest advances in GIS, 3D modelling, photogrammetry, and virtual reality applications, showcasing their potential for preserving and communicating maritime and coastal archaeological sites. We also welcome speakers researching the use of artificial intelligence and machine learning for coastal and maritime archaeology.

- Stewardship and accessibility: This theme will discuss the challenges and opportunities of using digital technologies to steward and make maritime and coastal heritage more accessible to the public. Topics will include the ethical use of digital technologies, the role of indigenous communities in stewardship, and the use of digital technologies for education and outreach. Maritime and coastal heritage can be uniquely difficult to access for the public, Traditional Owners, and Tangata Whenua, who hold deep connections to the coast and sea and who have led and continue to lead our stewardship of Sea Country; of whenua me moana tupuna. The session will also delve into how these technologies can support and communicate this connection through tools such as immersive experiences. With these tools, heritage professionals, stakeholders and indigenous communities can explore virtual replicas of submerged archaeological sites, enhancing public engagement and education on maritime and coastal heritage. Attendees will explore the transformative potential of digital technologies in revealing untold stories of coastal and maritime cultures, preserving underwater cultural heritage, and fostering a deeper appreciation for our maritime past.

Overall, the session will provide attendees with the opportunity to learn about the latest advances in digital technologies for maritime and coastal heritage, and to discuss the challenges and opportunities of using these technologies to achieve these goals.

References

Bennett, K., McIvor, I. H., & Paul, L. (2018). Report on the rescue and preservation of Daring, a mid-19th-century schooner built in Aotearoa/New Zealand. Australasian Journal of Maritime Archaeology, 42, 75-80.

Jones, B.D., Dickson, M.E., Ford, M., Hikuroa, D. and Ryan, E.J., 2023. Aotearoa New Zealand's coastal archaeological heritage: A geostatistical overview of threatened sites. The Journal of Island and Coastal Archaeology, pp.1-21. https://doi.org/10.1080/15564894.2023.2207493

McCarthy, J., Benjamin, J., Winton, T. and Van Duivenvoorde, W., 2019. The rise of 3D in maritime archaeology. In McCarthy, J., Benjamin, J., Winton, T. and Van Duivenvoorde, W. (Eds.) 3D Recording and Interpretation for Maritime Archaeology. Cham: Springer, pp.1-10. https://link.springer.com/book/10.1007/978-3-030-03635-5

S1: Beyond Binary: Exploring Maritime and Coastal	
15:20-15:40	*104. Submerged Archaeological Landscape Prospection, Analysis and Dissemination in Australia and Beyond* *John McCarthy (Flinders University)**
15:40-16:00	*30. Regional Implementation of Coastal Erosion Hazard Zones for Archaeological Applications* *Benjamin D Jones, Ben Collings, Mark E Dickson, Murray Ford, Daniel Hikuroa, Simon Bickler, and Emma Ryan*
16:00-16:20	*127. Continuous or Abandoned: Horizontal Stratigraphy and Past Cultural Coastal Landscapes from the Coromandel Peninsula, Aotearoa New Zealand* *Ben D Jones (University of Auckland)*; Simon H. Bickler (Bickler Consultants Ltd)*
16:20-16:40	*48. Underwater Drones: A Low-cost, yet Powerful Tool for Underwater Archaeological Mapping* *Eleni Diamanti (NTNU)*; Oyvind Odegard (NTNU); Vasilis Mentogiannis (KORSEAI)*
16:40-17:00	*98. 3D Reconstruction Methods using Machine Learning for Submerged Wreck Documentation* *Kartik Jalal (University of Melbourne); Brian J Armstrong (University of Melbourne)*; Matt Carter (Major Projects Foundation); Martin Tomko (University of Melbourne)*

104. Submerged archaeological landscape prospection, analysis and dissemination in Australia and beyond

*John McCarthy (Flinders University)**

We present an exploration of research into submerged landscapes in Australia. This presentation describes innovative technological approaches for the identification and quantification of ancient underwater sites dotting the Australian coastline. With environmental changes, growing developmental pressures, and natural processes at play, the need to comprehensively characterize this archaeological treasure trove has never been more pressing. This research includes surveys on sub-tidal sites of Northwest Australia, initially initiated under the Deep History of Sea Country project. These endeavours led to the remarkable discovery of the first submerged Aboriginal archaeological sites surrounding the Australian continent. Building upon these groundbreaking discoveries, our subsequent investigations have grown into new regions and with new technologies.

An important part of this work is to increase both public awareness and developer engagement with this archaeologically significant yet fragile landscape in Australia. While the knowledge of submerged landscapes has been passed down through Aboriginal oral traditions, it remains largely obscure to the general public. To bridge this gap, we have embarked on a journey of creating digital resources, creating outputs for use in immersive VR experiences, interactive games, animations, and documentary films.

30. Regional implementation of coastal erosion hazard zones for archaeological applications

Benjamin D Jones[a], Ben Collings[a], Mark E Dickson[a], Murray Ford[a], Daniel Hikuroa[b], Simon Bickler, and Emma Ryan[a]

a: School of Environment, University of Auckland
b: Te Wānanga o Waipapa, University of Auckland
c: Faculty of Arts and Social Sciences, University of Waikato

The significant potential impact of sea-level rise (SLR) on vulnerable archaeological sites worldwide has spurred numerous investigations utilizing Geographic Information Systems (GIS) to study coastal hazards and their associated consequences. Several studies (e.g., Andreou et al. 2017; Cantasano et al. 2021; Ezcurra and Rivera-Collazo 2018; Kamal et al. 2021; Narra et al. 2017; Pourkerman et al. 2018; Reeder Myers 2015; Rivera-Collazo 2020; Sánchez et al. 2020; Westley and McNeary 2014; Westley 2019) have contributed to this growing body of research. However, most existing coastal archaeological risk assessments have thus far inadequately addressed the dynamic nature of SLR along coastlines, with only a limited number of approaches considering SLR projections spanning the next century.

In the context of Aotearoa New Zealand, the preservation of coastal archaeological heritage is closely intertwined with the cultural significance of ancestral communities (mana whenua). Unfortunately, our understanding of the spatiotemporal variability in coastal erosion risk for cultural heritage remains quite limited. Coastal erosion hazard zones (CEHZs) have typically been designed to mitigate erosion risks to modern infrastructure. This paper argues that the methodology employed can also be highly valuable in the context of preserving coastal archaeological heritage.

This study introduces a novel application of a methodology for determining CEHZs for archaeological sites, incorporating various SLR scenarios and parameters related to wave patterns, dune stability, historical erosion rates, short-term coastal responses to storms, and long-term coastal reactions to rising sea levels (Figure 1).

The study specifically focuses on calculating Coastal Erosion Hazard Zones within a region of Aotearoa / New Zealand, namely Te Tai Tokerau/ Northland. The results of our analysis suggest that approximately 19% of the coastal archaeological sites in the region may be vulnerable to erosion with a 20 cm rise in sea levels. The scenarios presented in this research should assist a wide range of stakeholders in assessing the risks to heritage and offer coastal managers an opportunity to incorporate heritage preservation into their adaptive planning strategies.

127. Continuous or Abandoned: Horizontal Stratigraphy and Past Cultural Coastal Landscapes from the Coromandel Peninsula, Aotearoa New Zealand

Ben D Jones (University of Auckland), Simon H. Bickler (Bickler Consultants Ltd)*

The exploration of Māori coastal sites along New Zealand's Coromandel Peninsula during the period from 1500 CE to 1700 CE presents a compelling narrative of historical significance. At the heart of this narrative lies a central debate regarding the continuity or abandonment of the Cooks Beach area. Maxwell et al. (2017) have asserted that the Cooks Beach settlement underwent a series of phases marked by occupation and subsequent abandonment. The initial phase of abandonment is attributed to the intermittent nature of habitation, primarily oriented towards resource extraction, including the procurement of obsidian and chert. Large-scale settlement evidence is conspicuously lacking. Subsequently, a period of abandonment around the 15th century AD is followed by a resurgence of smaller-scale occupation, focusing on cultivation. Radiocarbon dates presented by Maxwell et al. (2017) suggest a potential decline in use or outright abandonment by 1650 AD. This abandonment has been ascribed to multiple factors, encompassing a decline in soil productivity and an increase in regional conflict.

However, this paper introduces new Bayesian analysis of dates that overlap with late dates from Hoffman's previous projects (Figure 1). These later dates span a more extensive time range and potentially encompass the post-abandonment period discussed by Maxwell et al. (2017). Cumulatively, these findings cast uncertainty on the concept of complete abandonment of the Cooks Beach area. Instead, they suggest a dynamic pattern of settlement relocation to alternative locales, such as the prominent hill within the landscape, distinct from the earlier dunes.

This paper emphasizes the critical role of Bayesian analysis in shedding light on the complex historical narrative of Māori coastal occupation. It integrates archaeological discoveries within the broader context of geomorphological and environmental histories, enriching our comprehension of the past. Employing a multidisciplinary approach, this study leverages cutting-edge technologies, including LiDAR, GPS, and GIS, to craft three-dimensional reconstructions of past coastal landscapes through the utilization of Unreal Engine (Figure 2). These reconstructions not only provide a visual representation of the past but also serve as a platform for collaborative knowledge-sharing between researchers and mana whenua, fostering a more nuanced understanding of the cultural and environmental dynamics of the region.

References

Maxwell, J.J., McCoy, M.D., Tromp, M., Hoffmann, A. and Barber, I.G., 2018. The difficult place of deserted coasts in archaeology: New archaeological research on Cooks Beach (Pukaki), Coromandel Peninsula, New Zealand. The Journal of Island and Coastal Archaeology, 13(1), pp.1-20.

48. Underwater drones: a low-cost, yet powerful tool for underwater archaeological mapping

Eleni Diamanti (NTNU); Oyvind Odegard (NTNU); Vasilis Mentogiannis (KORSEAI)*

Underwater photogrammetry has been massively applied as a remote sensing solution for mapping underwater archaeological and historical sites the last decades. Together with the technological advances in underwater photography and photogrammetric software – especially since the release of user-friendly Structure from Motion software – a few hundreds of underwater cultural heritage sites have been 3D modelled and published up to today. Although the majority of these 3D modelling works has been conducted through human diving at the wide depth range from zero to 120 meters, the use of unmanned underwater vehicles (UUVs) into marine archaeological mapping is not something new [Drap et al, 2015; Johnson-Roberson et al, 2017; Pacheco-Ruiz et al, 2019; Mogstad et al, 2020; Diamanti et al, 2021]. In light of the remarkable advancements in UUVs technology, characterized by increasing capabilities and substantial cost reduction [Stein, 2023], this study aims to investigate the transformative impact of micro-class Remote Operated Vehicles (ROVs), commonly referred to as underwater drones, on underwater archaeological mapping. With the expanding accessibility of user friendly and compact underwater drones that require no specialized technical expertise, our research seeks to explore the evolving dynamic wherein this affordable technology facilitate a democratization of underwater archaeological documentation while reducing human diving significantly. The research question centralizes on assessing the growing ratio of capabilities to cost in underwater archaeology, akin to the paradigm shift observed the last decade in aerial drone photogrammetry and cultural heritage [Pepe et al, 2022].

The paper consists of two parts. The first part discusses the advantages of underwater drones in marine archaeology, highlighting high payload capacity, portability, maneuverability, user-friendliness and affordability to name a few, as well as the potentials in performing semi-autonomous mapping missions, with full site coverage, obstacle avoidance and real-time data quality assessment. The discussion extends beyond the inherent safety advantages of using ROVs over human diving and the apparent associated constraints such as depth and diving time. The combination of navigational and optical sensors offers capabilities for real-time computations, thus assisting the maritime archaeologist to take on-site decisions, evaluate the mapping process, and avert the need for revisiting the site because of low data quality.

The second part presents a case study involving a methodological approach for the photogrammetric mapping of an ancient wreck site in Greece, through the use of a multi-sensor setup mounted on an underwater drone. The case study's vehicle is rated to 300 meters, with an internal forward looking HD camera, an Inertial Measurement Unit (IMU), a depth sensor, a Doppler Velocity Logger (DVL) and LED lights. To empower this payload for photogrammetric purposes, we added a stereo-rig of two downward-looking GoPro cameras and a pair of external LED lights. Finally, a transponder of a USBL (Ultra-Short BaseLine) positioning system is attached on the drone, which provides georeferencing and real-time tracking of the vehicle. All three cameras of the system are pre-calibrated for the estimation of their intrinsic parameters. The DVL sensor provides measurements that keep the ROV's diving altitude h – or flying height in aerial drone mapping terms – constant, so that the ROV follows the terrain of the site and the pixel size in images is being kept standard. The combination of the DVL and IMU measurements provides the vehicle's trajectory, which are then integrated into the photogrammetric software as initialization values for the camera poses.

The ROV photogrammetric setup was tested at an ancient shipwreck site in Fournoi, Greece, that dates to the 3rd-4th ct. CE, consists of a cargo of intact amphorae, covers an area of 25 by 15 meters, lies in a steep sandy seabed 40 to 50 meters deep, and since 2021 is under excavation [Campbell, 2021]. The wreck was selected as an ideal object for sea trials because of the good prevailing underwater conditions, its lowstructural complexity as a 3D object (low operational risks, e.g. tether entanglement), the opportunity for multiple operations during this year's excavation season and finally, because of available and geometrically reliable ground truth derived by a former photogrammetric mission. During the field experiments, a 30-minutes recording mission was enough for a successful data acquisition and a full 3D reconstruction of the site. The final resolution for both the orthophotomosaic and the 3D textured model is sub-millimeter, while the final RMS in XYZ, after extracting a control points network from the ground truth, was up to 2.5 cm.

Besides the configuration of the underwater drone's setup for photogrammetry and its implementation in a real-world scenario, our work summarizes an entire photogrammetric pipeline, including the sensors configuration and synchronization, the data collection and real-time quality assessment approaches, the data post-processing and the final visualization and assessment of the results in terms of geometrical accuracy, site coverage, color consistency and computational efficiency of the process. Future work focuses on optimizations on ROV photogrammetric data acquisition and underwater missions with a higher level of autonomy and user-friendliness similar to contemporary aerial drone mapping. Finally, our impression is that the growing availability of these affordable, compact, and robust underwater platforms will lead to an anticipated rise in 3D archaeological recording results via robotic means in the literature in the near future.

References

[1] Drap, P., Seinturier, J., Hijazi, B., Merad, D., Boi, J.M., Chemisky, B., Seguin, E. and Long, L., 2015. The ROV 3D Project: Deep-sea underwater survey using photogrammetry: Applications for underwater archaeology. Journal on Computing and Cultural Heritage (JOCCH), 8(4), pp.1-24.

[2] Johnson‐Roberson, M., Bryson, M., Friedman, A., Pizarro, O., Troni, G., Ozog, P. and Henderson, J.C., 2017. High‐resolution underwater robotic vision‐based mapping and three‐dimensional reconstruction for archaeology. Journal of Field Robotics, 34(4), pp.625-643.

[3] Pacheco-Ruiz, R., Adams, J., Pedrotti, F., Grant, M., Holmlund, J. and Bailey, C., 2019. Deep sea archaeological survey in the Black Sea–Robotic documentation of 2,500 years of human seafaring. Deep Sea Research Part I: Oceanographic Research Papers, 152, p.103087.

[4] Mogstad, A.A., Ødegård, Ø., Nornes, S.M., Ludvigsen, M., Johnsen, G., Sørensen, A.J. and Berge, J., 2020. Mapping the historical shipwreck figaro in the high arctic using underwater sensor-carrying robots. Remote Sensing, 12(6), p.997.

[5] Diamanti, E., Løvås, H.S., Larsen, M.K. and Ødegård, Ø., 2021. A multi-camera system for the integrated documentation of Underwater Cultural Heritage of high structural complexity; The case study of M/S Helma wreck. IFAC-PapersOnLine, 54(16), pp.422-429.

[6] Stein, M., 2023. How the Micro ROV Class Will Change the Maritime Sector: An Introductory Analysis on ROV, Big Data and AI. In Autonomous Vehicles-Applications and Perspectives. IntechOpen.

[7] Pepe, M., Alfio, V.S. and Costantino, D., 2022. UAV platforms and the SfM-MVS approach in the 3D surveys and modelling: A review in the cultural heritage field. Applied Sciences, 12(24), p.12886.

[8] Campbell, P. and Koutsouflakis, G., 2021. Aegean Navigation and the Shipwrecks of

Fournoi: the archipelago in Context. Under the Mediterranean I. Studies in Maritime Archaeology, Leiden: Sidestone Press, pp.279-298

98. 3D reconstruction methods using Machine Learning for submerged wreck documentation.

Kartik Jalal (University of Melbourne); Brian J Armstrong (University of Melbourne); Matt Carter (Major Projects Foundation); Martin Tomko (University of Melbourne)*

Underwater environments contain a wealth of cultural heritage that is inaccessible to most scholars and public due to difficult access conditions. The harsh marine environment accelerates decay and cultural heritage digital preservation helps maintains the link with our material history. Digital preservation in underwater contexts is hard – light attenuation due to refraction and reflection of the dense water environment prevent faithful portrayal of underwater objects and is constrained by depth. Photogrammetric 3D model reconstruction of underwater artefacts from 2D images by traditional techniques leads to suboptimal results sometimes due to variable turbidity of the water rich in particles and plankton.

Here, we investigate how to reconstruct faithful photogrammetric models of underwater heritage from images suffering multiple degradations (poor visibility, lack of contrast and colour shift), made possible thanks to recent advances in computer vision. We present a workflow combining state of the art techniques for constructing photorealistic 3D models of colour-corrected underwater artefacts.

We present a workflow starting with a pre-processing step for the colour correction of images, followed by the reconstruction of the dense point cloud of the scene. A 3D rasterisation based on gaussian splatting then leads to realistic visual rendering of submerged wrecks. The modular separation of the pre-processing step provides flexibility with respect to the target environments enhancing the information entropy of the obtained images to produce high-quality dense point cloud reconstructions of historical wrecks (WWII era planes) submerged at different depths and in waters of vastly diverse turbidity in the Pacific.

S2: Bringing the Past to Life: Immersive Approaches to Education and Cultural Heritage

Wednesday 10th April, 10:20 –11:40, 260-073 OGGB4

Robert Stephan, University of Arizona
Caleb Simmons, University of Arizona
Aviva Doery, University of Arizona

In recent years, the fields of archaeology and technology have converged in unprecedented ways, revolutionizing our understanding of the past and how we engage with antiquity. This proposed conference session delves into the dynamic intersection of archaeology, education, and cutting-edge virtual reality (VR) and augmented reality (AR) technologies. By bringing together archaeologists, technologists, and educators, this session will explore the multifaceted applications, challenges, and transformative potential of VR and AR in archaeological research, preservation, education, and public engagement. Recent research has highlighted the variety of ways in which these technologies have been utilized within the field of archaeology (Champion 2023). Studies have shown, for example, how VR and AR can be used in archaeological research, helping researchers better understand the sites they investigate (Morgan 2009). These technologies have also been employed to digitally preserve and reconstruct archaeological sites and artifacts, mitigating physical deterioration while providing an interactive platform for study and analysis (Haydar et al. 2011). Within the field of education, VR and AR have been used to create immersive and experiential learning environments, enabling students to explore historical contexts and artifacts in unprecedented ways (Gartski et al. 2019). Similarly, those involved in public outreach have relied upon VR and AR to enable broader audiences to virtually experience archaeological discoveries and cultural heritage, transcending geographical and cultural barriers (Boboc et al. 2022). This session focuses on the applications of VR and AR within the realm of archaeological and cultural heritage education. In doing so, it takes a case study approach, inviting scholars to describe their own attempts to integrate these technologies as teaching tools, whether in the classroom, in the museum, or at archaeological sites. By showcasing the variety of contexts in which these tools have been used, along with specific decisions about software, hardware, content-design, and logistics, attendees will gain a better understand of the wide range of ways VR and AR might be incorporated for the benefit of students and the public at large. Results – both successes and challenges – from these attempts will help guide future educators in their own endeavors. A sample, but by no means comprehensive, set of relevant topics includes the following:

- Highlighting how VR and AR technologies can create immersive and experiential learning environments, allowing students to virtually step into historical contexts, explore archaeological sites, and engage with artifacts in unprecedented ways.
- Discussing the use of VR to digitally reconstruct ancient sites and artifacts, enabling educators and the public to virtually explore and interact with cultural heritage that may be physically inaccessible.
- Demonstrating how AR can be employed to overlay digital information on physical

artifacts and historical sites, enhancing visitor experiences and enabling real-time historical context while preserving the authenticity of the artifacts.

- Exploring the use of VR and AR to enable users to virtually travel to distant historical locations.
- Addressing ethical considerations, cultural sensitivity, and inclusivity when using VR and AR technologies in archaeological education and cultural heritage preservation.

This session is particularly important as education opens to increasingly diverse populations. Over the past decade, and especially since the pandemic, online and hybrid learning have created educational opportunities for students who may not fall within the traditional 18 to 22-year-old, middle- to upper-class college demographic. Yet outside constraints often these prevent students from taking full advantage of these opportunities. According to the 2022 Education Dynamics Online College Students report, for example, the top three (59% of responses) pain points for those enrolling in online programs are related to finances and family and work obligations (Aslanian et al. 2022). The integration of VR and AR, then, gives a far greater range of archaeology students the ability to virtually participate in opportunities like study abroad trips, archaeological fieldwork, museum curation, and experiential learning more broadly. In short, this session gives presenters and attendees an opportunity to learn from each other about the promise and pitfalls of these exciting new technologies. Participants will gain insights into the transformative role of VR and AR in archaeology, fostering interdisciplinary collaborations and sparking new ideas for integrating these technologies into their own research, educational, and outreach endeavors. The proposed session promises to be a thought-provoking and forward-looking exploration of the symbiotic relationship between technology and archaeology, ultimately enhancing our ability to unearth, interpret, and share our findings about the ancient world.

References

Aslanian, C.B., Fischer, S, and Kitchell, R. Online College Students, 2022.

Boboc, Răzvan Gabriel, Elena Băutu, Florin Gîrbacia, Norina Popovici, and Dorin-Mircea Popovici. “Augmented Reality in Cultural Heritage: An Overview of the Last Decade of Applications.” Applied Sciences 12.19 (2022): 9859.

Champion, Erik. Playing with the Past. Cham: Springer International AG, 2023.

Garstki, K, Larkee, C, and LaDisa, J. “A role for immersive visualization Experiences in teaching archaeology.” Studies in Digital Heritage 3.1 (2019): 46-59.

Haydar, Mahmoud, David Roussel, Madjid Maïdi, Samir Otmane, and Malik Mallem. “Virtual and Augmented Reality for Cultural Computing and Heritage: A Case Study of Virtual Exploration of Underwater Archaeological Sites.” Virtual Reality : The Journal of the Virtual Reality Society 15.4 (2011): 311-27.

Morgan, Colleen L. “(Re)Building Çatalhöyük: Changing Virtual Reality in Archaeology.” Archaeologies 5.3 (2009): 468-87.

S2: Bringing the Past to Life: Immersive Approaches to Education and Cultural Heritage	
10:20-10:40	*17. Immersive Approaches to Archaeology in Higher Education: Theory and Practice* *Robert Stephan (University of Arizona)*; Caleb Simmons (University of Arizona); Aviva Doery (University of Arizona)*
10:40-11:00	*52. "Re-living the Past" – Bridging Archaeology, Local History, and Gamified Digital Realities for Public Engagement* *Cinzia Bettineschi (University of Augsburg)*; Armando De Guio (University of Padova); Amy Rodighiero (Indipendet); Riccardo Mantoan (Nea Archeologia); Martino Gottardo (Nea Archeologia); Luigi Magnini (Ca' Foscari University of Venice)*
11:00-11:20	*18. The Cinis Vulcani VR Project: Virtual Reality and the Marzuolo Archaeological Project* *Thomas J Keep (The University of Melbourne)**
11:20-11:40	*158. Archaeological Maps, VR Dioramas & 3D Cartophony* *Mike Yeates (Monash University); Thomas Chandler (Monash University)*; Patrick Kersalé (Independant Scholar)*
11:40-12:00	*185. Standing stones and swarming robots: Differential human engagement with virtual and physical realities* *Elena M Vella (The University of Melbourne)*; Aleksandra Michalewicz (University of Melbourne)*

17. Immersive Approaches to Archaeology in Higher Education: Theory and Practice

Robert Stephan (University of Arizona); Caleb Simmons (University of Arizona); Aviva Doery (University of Arizona)*

In recent years, virtual reality (VR) has emerged as a powerful technology with the potential to impact higher education (Liu et al., eds. 2017). This paper examines the use of VR as a teaching tool in college classrooms, with a specific focus on its ability to provide previously inaccessible archaeological experiences to students. By immersing students in virtual environments, educators can potentially overcome geographical, financial, and logistical constraints, allowing students to explore the world and its diverse cultures without leaving their home learning environment.

The paper will begin with a broad overview of the challenges and opportunities afforded by using immersive technologies in the college classroom, discussing both the theoretical foundations supporting the incorporation of VR as an educational tool and the current constraints of university-level online education programs (Boboc et al. 2022). The goal will be to frame the topic within the current landscape of higher education, with a specific focus on the problems and possibilities of integrating VR within archaeology courses within the limited budgets of many large public universities.

The paper will then delve into practical examples of recording VR content to bring travel experiences to online students. Presenters will share a case study on their new "Seven Wonders of Ancient Greece" course that has been filmed in 360 VR over the past year. It stresses the environmental challenges of outdoor filming, including camera stabilization, wind noise, and the presence of visitors to the site. It also provides useful strategies for working with local site guards and permitting agencies to ensure a smooth recording process. This presentation will include best practices for on-site video and audio recording, as well as post-processing and editing.

In conclusion, this paper contributes to, and provides a framework for, the ongoing discourse on leveraging VR technology to provide a more inclusive educational experience for students of archaeology (Garstki, Larkee, and LaDisa 2019). It offers insights and recommendations to educators, administrators, and policymakers on how to navigate the operational and budgetary considerations while embracing the transformative potential of VR in fostering equitable access to archaeological education worldwide.

References

Boboc, R, Băutu, E, Gîrbacia, F, Popovici, N, and Popovici, D 2022 Augmented Reality in Cultural Heritage: An Overview of the Last Decade of Applications. Applied Sciences 12(19): 9589. DOI: 10.3390/ app12199859

Garstki, K, Larkee, C, and LaDisa, J 2019 A role for immersive visualization Experiences in teaching archaeology. Studies in Digital Heritage 3(1): 46-59. DOI: 10.14434/ sdh.v3i1.25145

Liu, D, Bhagat, K, Gao, Y, Chang, T-W, and Huang R 2017 The potentials and trends of virtual reality in education: A bibliometric analysis on top research studies in the last two decades. In: Liu, D et al. (eds.) Virtual, augmented, and mixed realities in education. Smart computing and intelligence. Singapore: Springer Singapore Pte. Limited. pp. 105-130.

52. “Re-living the Past”: Bridging Archaeology, Local History, and Gamified Digital Realities for Public Engagement

Cinzia Bettineschi (University of Augsburg); Armando De Guio (University of Padova); Amy Rodighiero (Indipendet); Riccardo Mantoan (Nea Archeologia); Martino Gottardo (Nea Archeologia); Luigi Magnini (Ca’ Foscari University of Venice)*

Context

Up to approximately six years ago, the archaeological park of Bostel and its Museum (municipality of Rotzo, Vicenza, Italy) constituted a local reality, poorly known beyond academic circles. The site is located on a pre-Alpine promontory controlling the Assa and the Astico Valleys and during the mid to late 1st millennium BCE it hosted a prosperous mountain village with relevant contacts with the Po plain and the Alpine world (Magnini et al. 2019). Today, immediately after two POR-FESR regional projects based on EU-fundings, Bostel constitutes the first archaeological site in Italy – and one of the few in Europe – where AR and VR coexist with an immersive 270° cinema experience, a gamified app to explore the Museum, and on-site digital orienteering activities which take place among the archaeo-experimental reconstructions of the house units, the excavated buildings, and the active excavation trenches.

Main Arguments

Rather than delving into the technical details related to the creation of the digital reality experiences themselves, we intend to tackle the challenges and compromises in maintaining the highest scientific and philological standards in the virtual reconstructions, all while navigating constraints imposed by the archaeological record and the varied expectations and prior knowledge of the visitors, who are mainly constituted by local students of all levels. By blending historical accuracy with interactive play, the project “Re-living the Past” aimed not only to cater the curiosity of young learners but also to offer an inclusive and engaging platform for adults and professionals to deepen their understanding of the archaeological site and its surroundings.

Furthermore, this study explores the efforts posed by managing and promoting archaeological sites located in peripheral mountainous regions, far from mainstream tourist routes. The site’s attractiveness, in this context, becomes a central concern. By employing immersive technologies, we aimed to transform Bostel into a compelling destination, drawing in enthusiasts and scholars alike. In this sense AR and VR are on one hand touristic attractors able to boost the cultural offer of the area, and on the other powerful tools to enhance accessibility for individuals with disabilities, who are now able to experience the digital contents on an equal ground with their peers, fostering a sense of empowerment and inclusion.

The presentation will showcase a selection of the AR and VR experiences created during the project as a starting point for a reflection on immersive technologies, education via gamified digital experiences, but also on the ethics of digital “authenticity” (sensu Di Giuseppantonio Di Franco, Galeazzi, and Vassallo 2018).

At its core, the “Re-living the Past” project contends that immersive AR and VR technologies possess transformative potential in the realms of archaeology and cultural heritage education. However, we argue that this capability can be fully accomplished only by weaving together historical faithfulness with interactive play and inclusive engagement.

Applications and implications

In today's dynamic educational environment, cultivating an appreciation for history and cultural heritage among young learners has emerged as an essential pursuit to inspire conscious citizenship in the future. Students, and even more so elementary school children, often grapple with the issue of connecting with antiquity on a profound level, primarily due to the abstract nature of historical narratives and archaeological interpretations. "Re-living the Past" constitutes our tentative way to bridge this cognitive gap by offering immersive VR and AR experiences that enable visitors to virtually step into the shoes of important historical figures from the local history, or to witness firsthand the everyday life of the Iron Age village and interact with its inhabitants. Through audio-visual storytelling, people are transported back in time, allowing them to assist to the discovery of site as well as to its destruction. Additionally, they can virtually manipulate the ancient artifacts preserved in the Museum and engage with the past in a manner that not only sparks their curiosity but also fosters a genuine learning experience.

Guided tours to the Museum are always assisted by professional archaeologists, who integrate the immersive cinema experience and the gamified activities, including mini-games and recap quizzes, and a final collaborative VR experience into the visit. Recognizing the pedagogical importance of play in the learning process, the project integrates gamification elements to enhance engagement, happiness, and visitor loyalty (Khan et al. 2022). By employing a reward-based approach, children and adults are encouraged to explore the Museum actively and to interact with the archaeologists for additional clues. While advanced AR and VR applications stay at the center of our approach, we fully acknowledge the relevance of Museum operators as essential trait-d'union between the visitors, the ancient objects, the exhibition, and the institution itself. With their experience and skills, they represent invaluable resources to adjust the visit to the educational needs of each group, while at the same time collecting relevant feedback for improvement.

The presentation intends to offer an explicatory overview of our approach and of the results obtained, contributing to showcase how the convergence of technology and innovative educational approaches can open up a realm of possibilities for engaging diverse audiences, thereby ensuring that the local archaeological heritage remains relevant for generations to come.

References

Giuseppantonio Di Franco, P. Di, F. Galeazzi, and V. Vassallo, eds. 2018. Authenticity and Cultural Heritage in the Age of 3D Digital Reproductions. Cambridge: McDonald Institute for Archaeological Research. https://doi.org/https://doi.org/10.17863/CAM.27029.

Khan, Imran, Ana Melro, Ana Carla Amaro, and Lídia Oliveira. 2022. "Role of Gamification in Cultural Heritage Dissemination: A Systematic Review." In Proceedings of Sixth International Congress on Information and Communication Technology, 393–400. https://doi.org/10.1007/978-981-16-2377-6_37.

Magnini, Luigi, Cinzia Bettineschi, Armando De Guio, Laura Burigana, Giacomo Colombatti, Carlo Bettanini, and Alessio Aboudan. 2019. "Multisensor-Multiscale Approach in Studying the Proto-Historic Settlement of Bostel in Northern Italy." Archeologia e Calcolatori 30: 347–65. https://doi.org/10.19282/ac.30.2019.20.

18. The Cinis Vulcani VR Project: Virtual Reality and the Marzuolo Archaeological Project

*Thomas J Keep (The University of Melbourne)**

The use of computer-based visualisations of archaeological sites are today thoroughly established as a means of conveying the findings of archaeological research and excavation to the public. Visualisations offer a means for researchers to engagingly inform the general public, students, and other researchers on interpretations of archaeological materials, presenting a comprehensible and sensorially appealing means of conveying complex data. Virtual reality (VR) as a medium for presenting visualisations is likewise growing as an avenue for conveying research as the availability and public awareness of VR technology has significantly grown in the past decade. However, many reconstruction visualisations of archaeological sites remain focused on grand, significant, monumental urban sites which are more likely to receive funding for preservation and public tours. Instead, this paper contends that VR reconstructions of archaeological sites are better suited to those sites unlikely to be preserved or which do not already form part of the urban-centric narrative of the past conveyed through preserved monumental sites. As a case study, the 'Cinis Vulcani VR Project' explores the use of VR reconstruction for a significant rural archaeological site in Tuscany, the site of Podere Marzuolo excavated through the Marzuolo Archaeological Project.

Podere Marzuolo is a late Republican to early Imperial multi-craft production site and minor centre with evidence of terra sigillata distribution, blacksmithing, woodworking, and agricultural production within an opus reticulatum masonry complex. The site was identified and initially excavated as part of the Roman Peasant Project between 2012 and 2013, and has been intensively excavated through the Marzuolo Archaeological Project since 2016. As the project nears completion, the Cinis Vulcani VR Project is exploring how VR reconstruction can be used to preserve the project findings and make them available to the local community as part of an ongoing community outreach programme. The Cinis Vulcani VR Project uses a combination of structure-from-motion photogrammetric modelling and 3D modelling within Blender to produce an interactive VR reconstruction of the blacksmith's workshop uncovered in the 2017, 2018 and 2019 excavation seasons (Van Oyen et al. 2022). Panoramic renders generated through Blender are displayed in the virtual tour software package 3D Vista, with interactive 'hotspots' allowing participants to inspect elements of the immersive environment in more detail, launching narrated video animations displaying photogrammetry models of key uncovered finds alongside reconstructions of the objects in their original condition.

The display is aimed at both secondary school students and general audiences, and is to be displayed at a local secondary school in July 2024. The project seeks to investigate how learning outcomes and engagement are influenced by VR displays, and whether VR displays of minor rural archaeological sites present a viable educational and engagement resource. The project builds on from existing research into educational VR heritage displays which have found improvements in learning retention and interest compared to traditional teaching media (Chong et al. 2022), but have generally focussed on more monumental archaeological sites that are more grand and visually engaging. Additionally, the project engages with developing literature on archaeology reconstruction paradata, adopting the 'Five Step Method using the Extended Matrix' developed by Demetrescu and Ferdani (2021) to make the decision making process behind reconstructions comprehensible and open to outside evaluation.

References

Chong, Hwei Teeng, Chen Kim Lim, Abdul Rafi, Kian Lam Tan, and Mazlin Mokhtar. 2022. 'Comprehensive Systematic Review on Virtual Reality for Cultural Heritage Practices: Coherent Taxonomy and Motivations'. Multimedia Systems 28 (3): 711–26. https://doi.org/10.1007/s00530-021-00869-4.

Demetrescu, Emanuel, and Daniele Ferdani. 2021. 'From Field Archaeology to Virtual Reconstruction: A Five Steps Method Using the Extended Matrix'. Applied Sciences 11 (11): 5206. https://doi.

org/10.3390/app11115206.

Van Oyen, Astrid, Gijs Tol, Rhodora G. Vennarucci, Alexander Agostini, Vincent Serneels, Anna Maria Mercuri, Eleonora Rattigheri, and Alessandra Benatti. 2022. 'Forging the Roman Rural Economy: A Blacksmithing Workshop and Its Tool Set at Marzuolo'. American Journal of Archaeology 126 (1): 53–77. https://doi.org/10.1086/718180.

Figure

5. Digital Preservation of Archaeological Cultural Heritage in Sri Lanka

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Introduction

Digital archaeologists emphasize that their methods serve as a significant tool for mediating conflicts, highlighting that the shift towards digital approaches in archaeology requires engaging with current political issues. This declaration can be examined by studying a replica of the Syrian Arch of Triumph, as the original was destroyed in 2015. A year later, a duplicate was accurately crafted from Egyptian marble, with the aid of digital documentation, enabling archaeologists to create a precise 3D model. While this replica found its way to various Western locations, it never made its way back to Syria. The hybrid nature of this artifact, along with its cultural and political significance, as well as its 'Grand Tour,' invite us to contemplate various interpretive dimensions of this object within the realm of ideological discourse, including ontological, epistemological, and ethical facets (Stobiecka, 2020).

Archaeologists have become notably active and vocal participants in discussions concerning endangered heritage, driven largely by the rapid advancements in technology for heritage preservation. This transition from analog to digital approaches within archaeology represents a noticeable shift in focus, moving away from the traditional, destructive methods often associated with academic archaeology, as noted by Schnapp in 1996. Instead, there is a growing emphasis on non-invasive digital and cyber interventions, as evident in the works of many scholars in the world. This shift has given rise to a new form of archaeology known as digital and cyber rescue archaeology.

Methods and Materials

Qualitative method was used to collect secondary data by way analysing desktop document of related journal articles, and institutional websites etc.

Results

Digital and cyber archaeologists are generating vast amounts of data related to endangered heritage (Lercari et al, 2016), creating databases and innovative digital heritage forms, proposing new operational approaches for safeguarding archaeological monuments and sites. These archaeologists are harnessing complex technological tools and expanding their computer-based skill sets within newly established institutional frameworks. Notably, many Western universities and archaeological departments are now launching specialized digital and cyber labs, with a particular focus on endangered heritage. Western scholars are also founding nonprofit organizations dedicated to protecting heritage threatened by destruction, such as CyArk, based in Oakland, and the Center for Cyber-Archaeology and Sustainability at the University of San

Diego. In this context, uncountable efforts are carried out on a daily, monthly, and yearly basis to safeguard and conserve heritage for the benefit of future generations.

Discussion

The status of digital technologies in the context of heritage preservation is vague. Technology can simultaneously be a double-edged sword, offering both harmful and beneficial aspects. Recognizing an integral conflict within the application of digital technologies for heritage protection, archaeologists and heritage experts should maintain a sharp awareness and openness to theoretical observation and deep assessment. Regrettably, this level of diligence is not consistently observed in every instance. Some digital archaeologists themselves acknowledge that digital and cyber-archaeology lacks comprehensive theoretical underpinnings, and many researchers in this field may not possess a deeper understanding of their roles and responsibilities. Digital archaeology has been accused of being overly focused on technology, lacking of political engagement, and unconcerned with social and cultural issues, often displaying a disconnect with contemporary archaeological theoretical perspectives (Dallas, 2015).

However, preservation of archaeological heritage has become a crucial aspect of modern life. This legacy provides valuable insights into our ancestors' lifestyles, production methods, and historical knowledge. With the rapid advancement of 3D technology, we can now recreate archaeological cultural heritage with remarkable accuracy. This technology enables us to document, recover, and showcase various aspects of our rich archaeological cultural heritage for future generations. It's not limited to physical structures like buildings or monuments; it also encompasses intangible cultural heritage (ICH), such as traditions, crafts, and oral storytelling, which are passed down through generations. Unfortunately, due to the fast-paced nature of modern society and widespread migration, ICH often faces the risk of being forgotten. Therefore, safeguarding and preserving ICH as well as tangible cultural heritage (TCH) have become essential in today's world. Though there are ups and downs of the technological process, digital preservation is needed to protect archaeological cultural heritage for usage of present and future generations.

References

Dallas, C. 2015. "Curating Archaeological Knowledge in the Digital Continuum: From Practice to Infrastructure." Open Archaeology 1 (1): 176–207.

Lercari, Nicola, Jan Shulze, Willeke Wendrich, Benjamin Porter, Michael Burton, and Thomas E. Levy. 2016. "3-D Digital Preservation of At-Risk Global Cultural Heritage." In Eurographics Workshop on Graphics and Cultural Heritage, 4 pages.

Stobiecka, Monika. 2020. "Archaeological heritage in the age of digital colonialism." Archaeological Dialogues 27: 113–125.

158. Archaeological Maps, VR Dioramas & 3D Cartophony

Mike Yeates (Monash University); Thomas Chandler (Monash University); Patrick Kersalé (Independent Scholar)*

This paper describes the sonic exploration of a medieval landscape in virtual reality. The site is the city of Angkor in Cambodia, circa 1300 C.E. Our digital application incorporates two collections of digital assets. The first is a library of evidence-based historical 3D models that recreate the urban core of medieval Angkor. The second is an assortment of audio field recordings from Cambodia, including the sounds of reconstructed musical instruments, many of which were hitherto lost to history. In this paper, we will describe how these 3D model and sound collections can be merged together in a virtual reality experience: a 'sonic map' of medieval Angkor.

The VR experience outlined in this paper is a meeting between two long term projects, one in historical visualisation, and the other in ethnomusicology. Both projects deal with Cambodia and the Angkorian civilisation, and both concern 'models' crafted from historical and anthropological evidence.

The Virtual Angkor project (www.virtualangkor.com) involves the creation of digital models and animated forms. At the heart of this venture is the consolidation of a diverse set of evidence-based 3D models. These 3D models range from small and distinct artefacts, such as ceramic vessels and textiles, through to the large-scale architectural assemblies of temple complexes and the cultural landscapes around them. Animated human and animal characters compliment this collection and enable the visualisation of a "living", operational city. The virtual reconstruction of Angkor is guided by primary sources, such as detailed bas-reliefs, the corpus of Khmer inscriptions, archaeological mapping, and eye-witness accounts of Angkor from 1296 C.E. The reconstructed 3D scenes are also informed by supplementary sources, including architectural plans, botanical and palynological studies, textile studies, and archival photography. These 3D models form the visual grammar of the reconstructed city, and can be deployed for visualisations of different scales, from fixed perspective views of daily life at ground level to cityscapes of several thousand square kilometres, navigated with an aerial camera.

The Sounds of Angkor project (https://www.soundsofangkor.org/), concerns the physical recreation of long-lost South East Asian musical instruments, and the sounds that these instruments generate. Although there has been research into the musical instruments of Angkor as they appear in graphical descriptions, the Sounds of Angkor project attempts to recover the sounds of the Angkorian period by starting from the sources (iconography, epigraphy, archaeological objects). Following the reconstruction of all known musical instruments and sound tools, the project applied experimental archaeological approaches with Cambodian musicians to understand the problems linked to each instrument and to the coherence of the instrumental ensembles. Although the true nature of Angkorian music remains elusive, the sound obtained through these reconstructions offer tantalising hints of its richness. In addition to reconstructing musical instruments, the Sounds of Angkor project also collected field recordings of villages, daily work, means of transport, and ecological recordings of forests and rice fields

While the VR experience overviewed in this paper can be termed as a digital diorama with a dynamic soundscape, the size of the area that the user experiences is vast enough that it also qualifies as a kind of map. Perhaps a sonic map, including 3D modelled elements. Cartographers have been interested in sound for decades, and a wide range of topics have been explored in audiovisual maps by cartographers and mapmakers who used sound to transmit both quantitative and qualitative data. Though still relatively obscure, the combination of cartographic and sonic activities, termed by Thulin as 'cartophony' stands to make an important contribution to emerging ways of thinking and practicing mapping.

This prototype suggests novel ways of visualising digital heritage, where 3D models, cartographic layers and culturally specific sound recordings can be melded into a singular VR experience. By miniaturising scale in the tradition of a modelled diorama, we have been able to bring a 58km-wide area into the space of a single room. The map is arbitrarily scaled so that 1 metre in the real-world accords with 2km of the virtual map. The resulting 'sonic map' is not dissimilar to a walkable sound map that one can follow in a real, physical city. The difference is entirely down to relative scale – every step the user takes strides over a kilometre of the digital city

We did not set out to divide our sound recordings into biological, geophysical and anthropogenic categories, but because we attached sounds to different map layers, these distinctions emerged regardless.

In line with Schafer, our sonic map included keynote sounds, sound signals and sound marks, though most of these were concentrated around the temples, which, as the bas reliefs at Angkor attest, were likely strongly sonic locations. The temple layer, which mapped the hundreds of ruins of local shrines together with state sponsored temple complexes, was the location of choice for the sounds of reconstructed instruments, together with recordings of markets, denoting commerce, and industry, including stone sculpture workshops.

Our sound collection was broadly divided into geophonic (wind, rain, thunder) biophonic (crickets, frogs, wild birds) and anthrophonic sets. The anthrophonic set was by far the most extensive, not only because of the collection of sounds from reconstructed medieval instruments, but also because it included many field recordings from villages, where the predominant sounds were the people of the villages and the domesticated animals around them.

We perceive a number of extensions and elaborations for this prototype, including matching the soundscapes with recent archaeological research. For example, we found that we could pair the distribution of sounds in our library with Klassen's density map of Angkor, so that the density of anthropological sounds matched the density of population around the year 1300.

Fundamentally, this is a prototype for a VR exhibition about sound, space and history, where simulating rich sonic environments delivers an immersive virtual experience for cultural heritage transmission and communication.

185. Standing Stones and Swarming Robots: Differential Human Engagement with Virtual and Physical Realities

Elena M Vella (The University of Melbourne); Aleksandra Michalewicz (University of Melbourne)*

The recent public performance installation, 'Sacrifice', is a collaboration between archaeologists, roboticists and theatre specialists. Inspired by culturally significant standing stones from around the world, Sacrifice brought together members of the public to encounter and interact with a slow-moving swarm – a collective of robotic agents – of life-size, synthetic stone-robots. Upon entering the Science Gallery Melbourne, visitors were greeted and asked to fill out a brief pre-entry survey on their associations of stones, their expected movement and their familiarity and trust in technology. They then proceeded into a dimly lit theatre where they were offered a stone to hold and wireless headphones that played voices discussing ancient stones, over droning background music. In the theatre, visitors initially faced darkness, gradually with increasing brightness a spotlight revealed moving silhouetted stones of varying sizes. As visitors approached the centre of the spotlight, the stone-robots responded to their movements slowly entering the illuminated space, the visitor explored and played with the stone-robots until the space lighted dimmed the stone robots begin to light up with star constellations as they went back to their original positions. Visitors left the space, returned the stoney they had been carrying and headphones. They were then invited to complete a post-experience survey. The experience can be watched here: https://drive.google.com/file/d/1TpSW2jUqnHSBPqxMHa6dDNzE4ngz0k4l/view?usp=sharing.

This experience is both performance and

experiment, melding time-honored practices with cutting-edge technologies. Through their movements, the stone-robots reward visitors who commit to the embodied experience of sacrificing time and trust to slower-than-human agents. We hypothesised that slowing to 'stone-time' would increase trust in robotic swarm behaviours, raise awareness of an individual's agency in effecting change in their environment, and inspire empathy for the non-human world. Quantitative data was collected on the movement of the user and how they interacted and became part of the stone-robot swarm. Central to this process were a series of consultations with a network of archaeologists and cultural heritage specialists from Morocco, The Gambia, Costa Rica and Mongolia who shared with us access to standing stones under their custodianship. We were interested not only in the archaeological knowledge of the past but likewise the cultural understandings and interactions in the present day.

The installation was achieved through the collection of images of the standing stones (physical) from our international partners, creation of photogrammetric models (digital) and then two developmental stages: the first in virtual reality (VR) and the second in physical reality (PR). Here, the research addresses a gap surrounding human interactions and engagement with swarm behaviours at the human scale and provides new insights into embodied knowledge through educating and engaging with the general public. The VR environment was developed by the team in Unity, including the swarming behaviours, human dynamics and monolith dynamics (Vella, 2022). The VR environment was used for a pilot study to analyse how users behave, interact with respect to the digital world, pushing the user to question the philosophical fundamentals such as is it real and how do we know if it is real (Chalmers, 2022)? To understand the control primitives of the robotic swarm behaviour we turned to machine learning techniques to understand the role of stillness and trust in human experiences, in this case applied to cultural heritage. The project in VR and PR generated data by tracking human movement and behaviour during their interactions in VR and PR as well as qualitative data following audience experience interviews. We were interested in how standing stones and swarming robots can be reimagined and recreated and what that might mean in terms of the reconstruction of archaeological sites as loci of human production and technological engagement. We also explored understandings of temporality and creativity and their communal creation, meaning and performance. In the PR, the tactile nature of the stones needed to match or exceed the expectations projected by their appearance. Calcium carbonate, a key component of paper-mâché clay, brought our making process full circle as our rock carapaces were literally made of limestone. This allowed us to engage the audience's instinctive reaction to the visual appearance of stone by recreating the aesthetic characteristics of a 'rocklike' appearance. We reflected on the interplay of the physical stones, the creation of digital models, and both virtual and theatrical fabrication resulting in stone imitations. Comparing interactions with physical stones (be they originals or replicas) and their synthetic counterparts (either physical or digital) leads us to question how (stone) mimeses can affect subjective experience. Yet digital immersion creates a virtual barrier where key senses like touch and smell are absent, impacting user experiences and interpretations. Further, the VR experience can feature a lack of translation and understanding of cultural respect of PR archaeological sites.

Two stark observations from the virtual prototype compared to the physical prototype were the behaviour of users in the virtual world: kicking the monoliths, disrespecting their space and 'playing cheekily' with the stones. In the physical engagement, users were curious yet cautious; to further explore user behaviour we removed the proxemic constraints so that the monoliths could move into the personal space of the user and so that users could touch the stones. Through engaging with both the VR and PR standing stones the question of responsibility and custodianship emerges. Instances of users recklessly interacting with digital reconstructions highlight the importance of promoting cultural respect and understanding of ethical considerations when developing and integrating technology for educative purposes in archaeology. While technology can enhance research, visualisation, and education, it cannot fully replicate the tangible, sensory experience of being in a physical archaeological site. The next iteration of the Sacrifice installation takes place at the Victorian College of the Arts in early 2024.

Vella, Elena M., Daniel A. Williams, Aleks Michalewicz, Airlie Chapman, and Robert Ellis Walton. “Did That Stone Move? Staging stone swarms in galleries and virtual reality.” Proceedings of EVA London 2022 (2022): 229-233. Chalmers, David J. Reality+: Virtual worlds and the problems of philosophy. Penguin UK, 2022.

S3: Point Process Models in Archaeology and Heritage: State of the Field and New Directions

Thursday 11th April, 09:00–12:00, 260-092 OGGB3

Giacomo Fontana, Institute of Archaeology, University College London
Marco Nebbia, Institute of Archaeology, University College London
Eduardo Herrera Malatesta, Centre for Urban Network Evolutions, Aarhus University

The application of point process models (PPM) in archaeology and heritage has shown varying degrees of success. Despite the promising potential for these models to serve as effective tools in characterizing the generative processes behind observed spatio-temporal distributions of events (Baddeley, Rubak and Turner, 2016; Bevan, 2020), their utilization has been hindered by the steep learning curve required to master them. PPM addresses two classes of point patterns behaviors that are traditionally difficult to untangle in archaeological research: site location preferences and the structural types of spatial distributions (i.e., clusters, dispersion, regularity). By leveraging an understanding of the pattern's structure and its associations with other cultural and/or environmental variables, both first and second-order characteristics of the pattern can be explored. Moreover, PPM enable the analysis of what are known as 'marked point patterns'. These patterns represent real-world phenomena reduced into points with associated marks, which can signify site size, chronology, presence/absence, and more. The exploration of marked point patterns holds significant promise in archaeology, as it can provide deeper insights into the spatial structure and interactions between various distributions of sites, materials, etc. Furthermore, one of the primary strengths of adopting a PPM approach to investigate these matters is its robustness and applicability across diverse research scenarios, facilitated in part by the sharing of data and code.

Despite this potential, PPM have witnessed limited utilization in archaeology and heritage, likely due to the steep learning curve necessary to comprehend their theoretical underpinnings, their implementation in software such as R, and the complexity involved in interpreting the results. The untapped potential of PPM becomes more apparent when considering recent trends towards the generation of extensive point-based datasets. The rapid advancement of AI-driven tools for large-scale regional and interregional detection of archaeological sites, coupled with substantial recording projects like those funded by Arcadia (e.g., CAAL, EAMENA), has yielded an immense collection of archaeological data often represented as spatial points. However, the analysis of these new and vast datasets has somewhat fallen behind, resulting in a significant portion of the data remaining unexplored. From this perspective, the promise of PPM shines through, as they facilitate robust analysis of this fresh data, serving both archaeological research and heritage management practices. Likewise, the growing availability of accurately georeferenced survey data presents exciting prospects for advancing PPM at the intra-site level. Incorporating variables such as erosion modeling and high-resolution visibility maps into PPM offers new avenues for accounting for post-depositional processes, thereby enhancing the accuracy of reconstruction of the original distribution of materials. Similarly, akin to the application of PPM for landscape analysis, these possibilities remain largely unexplored.

References:

Baddeley, A., Rubak, E. and Turner, R. (2016) Spatial Point Patterns: Methodology and Applications with R. Boca Raton: CRC Press. doi: 10.1201/b19708.

Bevan, A. (2020) ‘Spatial Point Patterns and Processes’, in Gillings, M., Hacıgüzeller, P., and Lock, G. (eds) Archaeological Spatial Analysis: A Methodological Guide. Routledge, pp. 60–76.

S3: Point Process Models in Archaeology and Heritage: State of the Field and New Directions	
9:00-9:20	*21. Uncertainties and Robustness in Archaeological Spatial Analysis* *Eduardo Herrera Malatesta (Urbnet, Aarhus University)*; Sébastien De Valeriola (QuaDiHum Lab, Université libre de Bruxelles)*
9:20-9:40	*107. Predictive Modelling of Settlement Patterns in the Córdoba Province (Argentina, South America)* *Andrés D. Izeta (IDACOR. CONICET & Universidad Nacional de Córdoba)*; Giacomo Bilotti (University of Kiel, CRC 1266); Roxana Cattáneo (IDACOR. CONICET & Universidad Nacional de Córdoba)*
9:40-10:00	*136. Spatial Analysis of Monumental Neolithic Ritual Landscape of North-western Saudi Arabia* *Amy G Hatton (Max Planck Institute for Geoanthropology)**
Morning Tea	
10:20-10:40	*65. Pointing out the Pattern: Modelling Human-environmental Dynamics in Etruria during the 1st Millennium BCE* *Camilla Zeviani (Kiel University, CRC 1266)*; Giacomo Bilotti (University of Kiel, CRC 1266); Simon Stoddart (University of Cambridge)*
10:40-11:00	*36. How much data is enough? Modelling the earliest occupations of Western Europe* *Carolina Cucart-Mora (Museum National d'Histoire Naturelle,)*; Harry Hall (CNRS UMR 7194 HNHP, National Museum of Natural History, Institut de Paleontologie Humaine); Jan-Olaf Reschke (CNRS UMR 7194 HNHP, National Museum of Natural History, Institut de Paleontologie Humaine); Kamilla Lomborg (CNRS UMR 5602 GEODE Géographie de l'Environnement, Maison de la Recherche, Université Toulouse 2 Jean Jaurès); Matt Grove (Department of Archaeology, Classics and Egyptology, University of Liverpool,); Christine Hertler (ROCEEH Senckenberg, Senckenberg Research Institute); Mehdi Saqalli (CNRS UMR 5602 GEODE Géographie de l'Environnement, Maison de la Recherche, Université Toulouse 2 Jean Jaurès); Marie-Hélène Moncel (CNRS UMR 7194 HNHP, National Museum of Natural History, Institut de Paleontologie Humaine)*

S3: Point Process Models in Archaeology and Heritage: State of the Field and New Directions	
11:00-11:20	*71. Spatial Risk Assessment and the Protection of Cultural Heritage in Southern Tajikistan* *Marco Nebbia (University College London)**
11:20-11:40	*91. A delicate balance: using Point Process Models to explore the intersection of heritage and infrastructure in South Africa* *Rachel King (University College London); Giacomo Fontana (University College London)**

21. Uncertainties and Robustness in Archaeological Spatial Analysis

Eduardo Herrera Malatesta (Urbnet, Aarhus University); Sébastien De Valeriola (QuaDiHum Lab, Université libre de Bruxelles)*

Landscape research in archaeology has greatly benefited from the increasing application of computational methods over the last decades. Spatial statistical methods such as point patterns have been particularly revolutionary (Bevan, 2020; Hodder & Orton, 1976). Archaeologists have used point pattern analysis to explore spatial arrangements and relations between 'points' (e.g., the locations of artifacts or archaeological sites). However, the results obtained from these techniques can be greatly affected by the uncertainty coming from the fragmentary nature of archaeological data, their irregular distribution in the landscape, and the working methods used to study them. The quantification of uncertainty in spatial data coming from non-systematic surveys has never been fully addressed, and neither have the challenges of applying spatial statistical methods to study databases with partial evidence. To overcome this challenge, archaeologists have increasingly relied on applying advanced methods from statistics, data science and geography. This comes with the implicit idea that advanced methods from formal sciences will provide robustness to past models. As with uncertainty, robustness must be assessed in relation to the case study, the regional context, and the methods used. These issues are of great importance when the models from advanced methods are directly used to create narratives about past landscapes. While there is a growing trend of researchers working on the improvement of data and computational models (see e.g., Bevan & Crema, 2021; Brughmans et al., 2019; Castiello, 2022; Davies & Romanowska, 2018; Romanowska, 2015), archaeology is still largely a reactive discipline. This means, that while analyzing the evidence we collect to answer research questions is a good approach, considering how uncertain archaeological data is, we should focus on creating experiments to test the hypothesis we propose and assess the uncertainty in our data and computational models. Archaeologists must start asking questions such as: What would my conclusions be if my data and/or model had been slightly different, for example, because they were collected/calibrated under different circumstances? Knowing that my data is inevitably incomplete and affected by my working methods, which models should I use to obtain the most solid conclusions? In this paper, we used a series of point pattern analysis methods to assess and quantify the uncertainties in an archaeological database from the northwestern Dominican Republic and to establish strategies to create a robust framework to better understand spatial point processes and subsequent narratives. We will contribute to archaeology, and digital humanities more broadly, by making advances in these methodological gaps.

References

Bevan, A. (2020). Spatial Point Patterns and Processes. In M. Gillings, P. Hacigüzeller, & G. Lock (Eds.), Archaeological Spatial Analysis: A Methodological Guide (pp. 60-76). Routledge.

Bevan, A., & Crema, E. R. (2021). Modifiable reporting unit problems and time series of long-term human activity. Phil. Trans. R. Soc. B, 376, 20190726. https://doi.org/http://dx.doi.org/10.1098/rstb.2019.0726

Brughmans, T., Hanson, J., Mandich, M., Romanowska, I., Rubio-Campillo, X., Carrignon, S., Collins-Elliott, S., Crawford, K., Daems, D., Fulminante, F., de Haas, T., Kelly, P., Moreno Escobar, M., Paliou, E., Prignano, L., & Ritondale, M. (2019). Formal Modelling Approaches to Complexity Science in Roman Studies: A Manifesto. Theoretical Roman Archaeology Journal, 2(1), 4. https://doi.org/https://doi.org/10.16995/traj.367

Castiello, M. E. (2022). Computational and Machine Learning Tools for Archaeological Site

Modeling. Springer Cham. https://doi.org/https://doi.org/10.1007/978-3-030-88567-0

Davies, B., & Romanowska, I. (2018). An Emergent Community? Agent-based Modelers in Archaeology. The SAA Archaeological Record, 18(2), 27-32.

Hodder, I., & Orton, C. (1976). Spatial Analysis in Archaeology. Cambridge University Press.

Romanowska, I. (2015). So You Think You Can Model? A Guide to Building and Evaluating Archaeological Simulation Models of Dispersals. Human Biology, 87(3), 169-192. https://doi.org/10.13110/humanbiology.87.3.0169

107. Predictive Modelling of Settlement Patterns in the Córdoba Province (Argentina, South America)

Andrés D. Izeta (IDACOR. CONICET & Universidad Nacional de Córdoba); Giacomo Bilotti (University of Kiel, CRC 1266); Roxana Cattáneo (IDACOR. CONICET & Universidad Nacional de Córdoba)*

Predictive modelling is an open-box that includes all type of statistical analyses that can be used to "predict" an outcome. Although in very simple forms these models have always been used in archaeology, their formalisation dates back to the processual revolution. Today, understanding human-environmental relationship holds a central role in academic research, especially in environmental sciences, and archaeology has a central role in it. However, bridging the gap between often-inaccessible data and global research interests remains a challenge.

In recent years, researchers at the Universidad Nacional de Córdoba and the CONICET compiled an extensive, standardised and up-to-date database of the archaeological sites throughout the Province of Córdoba (Argentina). The database contains 2390 sites, classified by chronology and typology. This is the first time that in this region a freely accessible and well-maintained database is available, paving the way for many types of spatial analyses and modelling. Furthermore, the availability of geomorphological and environmental variables and satellite imagery increase the possibilities of more accurate modelling.

Our presentation aims to present the results of the first ever-carried predictive modelling in this region. Specifically, we focus on site location patterns and site-environmental relationship in order to understand past population's behaviours in terms of settlement choice and its variation through time. Additionally, a more formal understanding of these dynamics will allow more precise modelling of archaeological potential, with positive outcomes in terms of heritage management and selection of suitable areas for surveys.

We approach the predictive modelling by considering archaeological sites as point processes and carrying out Point Pattern Analyses (PPA), studying the underlying first and second-order effects generating the observed processes. We are interested in site intensity as a function of spatially continuous covariates, such as environmental and geomorphological variables. These variables are then used as predictors in the fitting of a Point Process Models to our data. Furthermore, our model incorporates the interactions between sites, in order to explore the relationship, stability, and changes in settlement patterns using a hybrid approach. We recognize the inherent challenge in fully disentangling first and second-order effects and addressing research biases. Therefore, we integrate these components in a more holistic and sustainable model.

Notably, all analyses presented herein are conducted using free and open-source software, complemented by open data sources. This approach not only enhances the transparency and reproducibility of our research but also extends its educational impact to our respective institutions. By making these resources accessible, we aim to allow an increasing number of students and researchers to engage in quantitative analyses in archaeology in Argentina and South America.

136. Spatial Analysis of Monumental Neolithic Ritual Landscape of North-western Saudi Arabia

*Amy G Hatton (Max Planck Institute for Geoanthropology)**

The archaeological record of the Arabian Peninsula is rich, stretching back to at least the late Middle Pleistocene. Multiple dispersals of hominins occurred during periods of increased humidity. Numerous stone structures, built over the last 10 thousand years, cover the landscape of Arabia. An emerging feature of this archaeological record are the monumental mustatil stone structures. These were built during the Holocene in north-western Arabia, and so far, date to 5000 BC. The Holocene Humid Period (HHP) is a period of increased precipitation in Arabia, that broadly dates to between 8000 and 4000 BC. Recent work from Tayma, an oasis in north-western Saudi Arabia, has shown that the HHP in this region was much shorter, lasting from 6800-5900 BC, and with some data suggesting a more abrupt termination (Neugebauer et al. 2022). Based on this new palaeoenvironmental data, mustatils were built in a climate that was becoming more arid. People likely used high mobility as a strategy to deal with the lack of resources (Kennedy et al. 2023). Given that people were likely very mobile, mustatils have been hypothesized to be territorial markers on the landscape. Through the use of point process models (PPM), I aimed to address what influenced the locations of mustatils. Specifically I asked questions such as, what is their relationship to underlying geology, is mustatil location affected by proximity to water sources, are mustatils built in areas that have good visibility across the landscape and finally, what their spatial patterning is and how this can add to the hypothesis of them as territorial markers on the landscape.

These structures have not yet been studied using rigorous spatial analysis to understand their patterning and what their landscape context tells us about their role in Neolithic society. To evaluate their connection to the local landscape, I: (1) systematically surveyed ca. 44,100 km2 satellite imagery to increase the total number of identified mustatils along the southern and western margins of the Nefud desert to 169; (2) conducted viewshed analysis to better understand if mustatils are located in areas of the landscape that have good visibility; (3) conducted a point process model (PPM) to understand how diverse environmental and landscape variables affect mustatil locations; (4) Used the mark correlation function to assess spatial patterning of mustatils based on their size.

I assessed the significance of 17 variables on mustatil spatial patterning using univariate regression models, and identified 11 variables that were useful. These 11 variables, elevation, eastness, TPI 90m, TPI 150m, TRI 150m, TRI 450m, distance to palaeorivers, distance to sandstone geology, distance to non-quaternary geology, viewshed and distance to recent water accumulation were included in a PPM. The Pair Correlation Function (PCF) for the null hypothesis of CSR showed significant clustering of mustatils in the first 4km. The first-order model using the 11 variables accounted for more of the variation, but showed statistically significant dispersion of mustatils from 0-1.8km, and clustering from 2-3km. I included an Area Interaction model term for the second-order model, with a defined circular neighbourhood of based on the results of the first order model.

Mustatil locations are affected most by their proximity to palaeorivers and recent (1984-2021) surface water occurrence being on east facing slopes, in close proximity to sandstone geology and non-quaternary geology, located at elevations between 880-950 masl, and being located on or near ridges (positive topographic position index). The viewshed analysis showed that mustatils are preferentially located in areas that have viewshed between 0.0 to 0.6 (where 0 is no viewshed and 1 is the cell with the best viewshed in the entire study area) indicating complex landscape positioning that balances different factors.

Mustatils, within the study area, range in length from 20 to 616m and mustatils of different lengths are often clustered together. In order to better understand the spatial patterning of mustatils in relation to their length, I applied the mark correlation function. It showed that mustatil length is significantly autocorrelated for mustatils spaced 25-35km apart. Based on this distance I applied DBSCAN to the mustatils to identify 15 meaningful clusters ranging in number of 3 to 29 mustatils. To assess whether mustatils within each group are arranged hierarchically based on size I applied a rank permutation method (Carrero-Pazos, Bevan, and Lake 2019). From this, I determined that mustatils within the clusters are not arranged hierarchically in terms of length.

I have used PPM's to better understand the regional patterning of mustatils. People were building mustatils as territorial markers thereby creating ritual landscapes, yet they were probably also places where rituals were performed and it was perhaps the combination of these two aspects that influenced where people chose to build mustatils. Furthermore, I was able to identify meaningful clusters of mustatils which may hint at mobility and transhumance patterns of Neolithic peoples in north-western Saudi Arabia.

65. Pointing out the Pattern: Modelling Human-environmental Dynamics in Etruria during the 1st Millennium BCE

Camilla Zeviani (Kiel University, CRC 1266); Giacomo Bilotti (University of Kiel, CRC 1266); Simon Stoddart (University of Cambridge)*

This paper studies settlement data recovered from several archaeological survey projects conducted in Central Italy in the last 70 years. We will focus, in particular, on those dated to the first half of the first millennium BCE and we analyse them using Point Pattern Analysis (PPA). These are crucial centuries for the development of what will be Etruscan urban, social and economic structures. Seeds of these developments were planted at the end of the Late Bronze Age and in particular during the Early Iron Age, the 'Villanovan' (900—730 BCE) in Etruscan chronological terms. A radical restructuring of the landscape, with the abandonment of most Bronze Age settlements in favour of fewer, larger ones, found on defensive natural positions gave origin to the great Etruscan metropoles and central places. Lineage groups, integrated in Mediterranean exchange networks, fully emerged, sponsoring communal activities at these centres and beyond: various classes of settlements, in fact, appeared in the countryside (from secondary settlements to isolated farmsteads). This process reached a peak between the end of the 7th and the 6th centuries BCE; appropriation and exploitation of land and metal resources to feed urban and rural populations and to produce surplus to be then exported and exchanged, as well as the control of communication routes, were prime motivators behind this process. The urban, social and political structures were fully consolidated by the 5th century. However, the period also saw a

contraction of sites, explained in the literature as a decline of maritime supremacy of South Etruria due to historical events. Attention was redirected towards domestic affairs, marking the beginning of the decline of the southern compartment of the region. Moreover, this decline has to be attributed to Rome's increasing dominion. On the other hand, we assist to the emergence of the northern sector (North Etruria), thanks to a different response, more collaborative, to Rome's aggressive policy.

In recent years, Point Pattern Analyses (PPA) have seen increased use in archaeological research, thanks to the growing accessibility of computational resources. However, many of these applications either prove overly complex and dismissed by non-specialists or lack a clear research focus and a solid theoretical foundation.

Nevertheless, concepts such as first and second-order effects, patterns of attraction, repulsion, or correlations with environmental variables are progressively making their way into archaeological discussions. Yet, the application of these techniques remains uneven and continues to occupy a niche within the field of Archaeological Sciences, potentially exacerbating the gap between "traditional" and computational archaeology. This discrepancy is partly attributed to differences in the lack of statistical and theoretical backgrounds among many archaeologists.

Etruria emerges as one of the first regions in Italy where quantitative methods were applied during the New Archaeology movement; in more recent years, quantitative approaches to Etruscan settlement data have been subjected to a revival (Palmisano et al. 2018; Stoddart 2020; Stoddart et al. 2020). However, there is need for a substantial follow-up. Etruscology has indeed reached great heights in the accumulation of enormous amounts of cultural data, through excavations but, more relevantly for this work, archaeological surveys. This data represents an invaluable resource, since continuous advances in computational capabilities and methodology now enable more robust and up-to-date results.

This paper employs PPA methods to examine site location patterns, notably site-environmental covariate relationships, land suitability, clustering patterns around central places, interactions between sites of different classes and across different periods. Additionally, we study the variation of these patterns over time. Specifically, we study the intensity of sites (the point process) as a function of a spatial covariate and then fitting a Poisson Process Model to different subsets of data to assess their predictive power. Furthermore, established analyses such as the Ripley's K function and related methods, as well as empty space and nearest neighbour functions, are employed to investigate the structure and temporal variations in our point processes. All analyses are conducted in a fully documented approach, relying exclusively on Free and Open-Source Software (FOSS).

The research potential of pre-Roman Etruria has been used in limited ways following the usual frameworks within the "Great Tradition" of Classical studies, often based on "external" written sources (Greek and Roman) and art historical approaches. In the last few years, however, archaeologists specialising in this region have been more and more open to the employment of techniques and methods that are often routine in other branches of archaeology. In particular, great efforts have been invested in the study of aDNA, mobility, archaeobotanical studies, archaeozoology, isotope analyses and so on. The general degradation caused by soil erosion has damaged or severely contained the potentials of archaeological surveys in Central Italy: luckily, there is sufficient data to be further explored with methods that have largely been underexploited in these areas. It is our intention to contribute to this new season of Etruscan studies, one defined by interdisciplinarity and collaborative approaches.

References

Palmisano, Alessio, Andrew Bevan, and Stephen Shennan. 2018. “Regional demographic trends and settlement patterns in central Italy: archaeological sites and radiocarbon dates.” Journal of Open Archaeology Data 6(2). DOI: 10.5334/joad.43

Stoddart, Simon. 2020. Power and Place in Etruria. The Spatial Dynamics of a Mediterranean Civilization, 1200-500 BC. Cambridge: Cambridge University Press.

Stoddart, Simon, Alessio Palmisano, David Redhouse, Graeme Barker, Giorgia di Paola, Laura Motta, Tom Rasmussen, Troy Samuels, and Robert Witcher. 2020. “Patterns of Etruscan Urbanism.” Frontiers of Digital Humanities. Digital Archaeology 7. DOI: 10.3389/fdigh.2020.00001

36. How much data is enough? Modelling the earliest occupations of Western Europe

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The spatio-temporal patterning of the first dispersal into Western Europe is a fitting archaeological problem to be approached using computational models. The archaeological record suggests that during the first Out of Africa dispersal, Western Europe stayed at the limit of the human “Oikoumene” for almost 1 million years. The earliest evidence of hominin dispersal out of Africa is dated to 2.1. million years in Eurasia (Levant and China). Hominins reached the gateway of Europe, specifically the southern Caucasus, around 1.8 million years ago, but the first human occupations of Western Europe are not observed until 1.2-1-4 million years ago. Within our project (ERC Lateurope), we developed a simulation-based approach to formalize and test different hypotheses while integrating available archaeological and climatic data.

Before starting with the construction of the models the first challenge we faced was related to the amount and the quality of the archaeological data. The available data has a direct impact on the process of parametrization and validation of the models. Our collection included archaeological data on sites in Eurasia dated between 2.1 and 500 ka years ago, a record which is known to be sparse, fragmented and with a very low temporal resolution. Some of these issues are related to the age of the remains and the different taphonomical agents that have acted on them which is an unavoidable issue in archaeology. Other issues are related to biases in archaeological research, different publication standards or data accessibility.

We circumnavigated these issues with a good data management strategy. In order to establish a baseline knowledge of the period we first engaged in an extensive literature review and through it identified the basic fields of our database. For each site we collected their coordinates, technological modes, palaeoanthropological remains, relative and absolute dates and environmental information. Data was retrieved from an array of sources, like the ROAD database and scientific papers. This endeavour required information from many different fields, some of which outside of our own specialization. In these instances, we relied on the expertise of international researchers involved in the project. Simultaneously, we compiled a metadata document describing each site included in the table. This document synthesises the process of data collection, making explicit all the decisions made and critically evaluates the quality of the data.

We will present our data collection protocol, the challenges we faced as well as the strategies we implemented to minimize and/or overcome them. We collected information on around 70 archaeological sites, with around 20% having such sparse available information that they could not be used in any further analysis. For most of the other site's information allows us to locate them in time and space and ascribed them to a technological tradition. Chronological information is variable, e.g., of all sites only 55% have been radiometrically dated. Simultaneously, within the project a database on hominin technological behaviour is being developed. It will include a thorough description of the lithic assemblages of some of the most important sites of western Europe. Through this endeavour, we have established our own protocols, and adopted some developed by other researchers. Altogether we expect that it will help us make the most of the available data.

71. Spatial Risk Assessment and the Protection of Cultural Heritage in Southern Tajikistan

*Marco Nebbia (University College London)**

Introduction

Growing digital documentation of cultural heritage resources yielded from an increasing number of international projects, calls for the development of formal computational approaches to assess the risks that this invaluable material heritage is exposed to. This paper proposes a nuanced case-control approach to the risk assessment developed by the Central Asian Archaeological Landscape (CAAL) project for an area of southern Tajikistan. A number of statistical methods including point process modelling and relative risk surface are applied for the spatial assessment of the risk to the cultural heritage across the study area and for the evaluation of the local scenarios of potential archaeological features already affected by natural and human threats. The value of this formal approach is in its flexible applicability to diverse regional and national settings, as well as in its capability of being updated and repeated within the same territory. This provides local stakeholders, heritage professionals, and local authorities, with a useful tool to develop a risk management plan that includes quantitative as well as qualitative spatial assessments (Nebbia et al. 2021).

Method and materials

The main focus of this paper is on the potential use of remotely sensed data and related computational methods, to develop a better understanding of on-going threats in a specific area of Tajikistan, South Khatlon. Major disturbances endangering and destroying the archaeological landscape of the region are discussed, and a nuanced case-control approach, borrowed from disciplines such as epidemiology and ecology, is proposed in order to understand the regional distribution of risk levels arising from a variety of natural and human threats. A bespoke database has been set-up within GIS in order to map potential archaeological features – including monuments, sites, and landscapes – and record a preliminary assessment of the threats that each feature currently faces. Mapping of potential archaeological features is being carried out on very-high resolution (VHR) imagery available via Google Earth and Bing Imagery, streamed within the GIS platform. Basic information regarding the nature of the mapped features is recorded in a bespoke PostgreSQL database with PostGIS spatial extension.

Point pattern analysis (PPA) and point process modelling (PPM) are useful tools to explore how the distribution of archaeological sites or features is dependent on a set of independent variables, thus providing a first explanation of different recovery rates in different environs across the territory under study. Moreover, PPM can also help to disentangle the behaviours of internal attraction or repulsion of site locations, thus giving a second possible explanation of why features are clustered (or not) in a specific area (Bevan 2020). In this study, we employ computational approaches usually applied to researching past human locational strategies, to the cultural heritage management domain. Specifically, looking at the first order characteristics of a point pattern representing potential archaeological features mapped from the satellite imagery, in relation to spatial covariates representing potential threats to the cultural resource. This is carried out via a non-parametric estimation/function of the relationship between the density (=intensity) of archaeological features and four covariates representing different sources of threats to the cultural heritage in the region. Once the behaviour of the whole point pattern of archaeological features is explored, we then propose a way of identifying areas of higher risk to the archaeology, on the basis of the condition assessment recorded during the initial mapping, via a case-control logistic regression model. Finally, by modelling relative risk surfaces (Bithell 1991), including the mapping of the statistical significance of the risk across the study region, allows to locate the areas that are most endangered by the threats considered in the research.

Results

Generally, first order effects suggest that potential archaeological features are located in relatively 'safe' areas, even though the overall absence of features in the valley bottom can most likely be attributed to the resulting severe destruction of the cultural heritage over the last century. A binary multivariate logistic regression based on a randomised non-site samples confirmed that the four covariates where good predictors for the location in relatively 'safe' areas of the overall population of mapped features. However, in order to understand whether or not the features mapped as already affected by any of the threats are located in 'riskier' areas compared to the non-affected ones, we adopt a case-control approach, widely used in disciplines like ecology and epidemiology. This shows how those features already endangered by natural threats generally follow similar locational settings to the rest of the population, thus indicating that they sit in nor 'riskier' nor 'safer' areas. Conversely, the second model shows how three of the four predictors are influencing the location of features endangered by human activities in a statistically different way compared to the rest of the population, thus meaning that they might be located in 'riskier' areas. The relative risk surfaces map out the areas of high and low risks including a level of statistical tolerance of peaks and troughs.

Discussion

The potential of these formal methods of regional assessment lies in the fact that all of the input factors considered here can change over time. Thus, if more features are mapped, or ground-truth shows some sites to be of no historical interest, or if the number of modern settlements and cultivated lands increases, the final result of the model could be remarkably different. Moreover, if new threats develop, they could easily be added to the model, again producing different outputs in terms of risk prediction maps. Therefore, the advantage of the proposed approach stands in it being customizable to different circumstances (e.g. new or updated input factors) and to diverse regions that present distinct priorities. The efforts of this study to formally quantify the risk to the cultural heritage in a specific region should be considered one aspect of a more complete approach to risk management, which should involve an equal qualitative participation of local stakeholder and heritage authorities.

References

Bevan, Andrew. 2020. 'Spatial Point Patterns and Processes'. In Archaeological Spatial Analysis, edited by Mark Gillings, Piraye Hacıgüzeller, and Gary Lock, 1st ed., 60–76. Routledge. https://doi.org/10.4324/9781351243858-4.

Bithell, J.F. 1991. "Estimation of Relative Risk Functions." Statistics in Medicine 10 (11): 1745–51. https://doi.org/10.1002/sim.4780101112.

Nebbia, Marco, Federica Cilio, and Bobomullo Bobomulloev. 2021. 'Spatial Risk Assessment and the Protection of Cultural Heritage in Southern Tajikistan'. Journal of Cultural Heritage 49 (March): 183–96. https://doi.org/10.1016/j.culher.2021.01.012.

91. A Delicate Balance: Using Point Process Models to Explore the Intersection of Heritage and Infrastructure in South Africa

*Rachel King (University College London); Giacomo Fontana (University College London)**

Despite decades of significant infrastructure development across African countries, conducting a comprehensive assessment of its archaeological impact remains an ongoing challenge. This challenge largely stems from disparities in data coverage and accessibility. Only a handful of countries, South Africa being one of them, actively maintain open-access repositories of national heritage management decisions. These repositories hold immense potential for addressing crucial questions regarding how various industries have influenced the archaeological record, but these possibilities have largely remained unexplored.

In this paper, we introduce a recently launched research program that seeks to harness the potential of SAHRIS, the South African heritage repository, to delve into critical questions concerning development and heritage. To do this, we employ a range of quantitative and qualitative tools, including point process models. Within this framework, point process models offer a promising approach to untangle the intricate relationship between different types of infrastructural development and the emergence of heritage cases over the past three decades. These developments can include roads, railways, settlements, mining operations, powerlines, and power plants, among others. Each of these can be transformed into a series of covariates and seamlessly integrated into point process models. Additionally, the wealth of information available in the SAHRIS dataset, such as the creation dates of heritage cases, can be incorporated through point marks to illuminate the diachronic and typological links between various industries' developments and the appearance of heritage sites.

Throughout our presentation, we will address two primary challenges encountered in this endeavour. Firstly, we'll delve into the spatial reduction challenge, wherein we'll discuss the process of transforming a database comprised of various geometry types into the point data required for the development of point process models. Secondly, we'll explore the intricacies of handling and analysing such large datasets. This includes the entire expanse of South Africa, spanning 1.2 million square kilometres, and encompasses over 20,000 heritage cases catalogued in the SAHRIS dataset. The sheer size of the areas under investigation and the vastness of the heritage dataset pose unique challenges within the field of archaeology. These challenges may portend issues in data analysis via point process models and similar tools that have not been encountered in traditional, smaller archaeological datasets. It's worth noting that these challenges extend beyond the South African context and offer a glimpse into what we may soon encounter as large-scale interregional datasets become more prevalent with the advent of AI-driven remote sensing for archaeological research.

In summary, this paper will present our preliminary findings and detail the challenges we've encountered in developing the first large-scale analysis of the delicate balance between heritage preservation and development in an African context. By doing so, we aim to contribute to the broader discourse surrounding the utilization of point process models in archaeological and heritage research, especially within the context of emerging, large-scale interregional datasets.

S6: Data Sources and Data Integration for Macroscale Archaeology

Tuesday 9th April, 13:00 –15:00, 260-057 Case Room 2

Christine Hertler Research Center ROCEEH, Senckenberg Research Institute
Christian Sommer, Research Project ROCEEH, University of Tübingen
Volker Hochschild, Dept. of Geosciences, University of Tübingen
Jan-Olaf Reschke, LATEUROPE, Muséum National d'Histoire Naturelle, Paris

Macroscale archaeology is a highly interdisciplinary approach that examines the relationships between humans, their environments, and cultural developments over large geographic regions and extended timespans, offering a broader perspective on the past. In recent years, related disciplines such as paleogenetics (e.g. Ragsdale et al. 2023), paleoanthropology and paleoclimatology (e.g. Timmermann et al. 2022) have shown that large-scale and computationally intensive methods provide fundamental new insights. For a holistic view of prehistory, it is essential to explore cultural aspects of human development at broader scales by valorizing the archaeological record. In the first place, this requires an extensive collection of data, for example from curated databases (Kandel et al 2023), but also a community-wide commitment to sharing and linking data, including the development of accepted standards to ensure interoperability (Kansa & Kansa 2022, Pilar Birch & Szpak 2022). Furthermore, the archaeological record is extremely difficult to interpret due to its scope, sampling interval and resolution, but also the bias resulting from cultural deposition, sedimentation and scientific research (Perreault 2019). Therefore, it requires dedicated analytical methods that account for the characteristics of cultural data, from classical statistics to exploratory analysis driven by machine learning. In addition, simulation-based approaches, such as Agent-Based Modeling (Timm et al. 2016) or ecological Modeling (Roebroeks et al. 2021), can help to complete missing information or validate existing hypotheses. Properly applied, macroscale archaeology not only has the potential to capture the broad of past human behavior, but at its best can also provide a perspective on current and future social and environmental challenges (Rick & Sandweiss 2020). We welcome contributions that address one or more of the following aspects at inter-regional, continental, or greater scales with large datasets and a large time-frame.

- Curated or crowd-sourced archaeological databases
- Platforms for data collection and visualization
- Statistical analyses addressing culture directly or in combination with paleoenvironment, paleoanthropology, etc.
- Simulation-based approaches, e.g. Agent-Based Modeling, Ecological Modeling

References

Kandel, A. W., Sommer, C., Kanaeva, Z., Bolus, M., Bruch, A. A., Groth, C., Haidle, M. N., Hertler, C., Heß, J., Malina, M., Märker, M., Hochschild, V., Mosbrugger, V., Schrenk, F., & Conard, N. J. (2023). The ROCEEH Out of Africa Database (ROAD): A large-scale research database serves as an indispensable tool for human evolutionary studies. PLOS ONE, 18(8), e0289513. https://doi.org/10.1371/journal.pone.0289513

Kansa, E. C., & Kansa, S. W. (2022). Promoting data quality and reuse in archaeology through collaborative identifier practices. Proceedings of the National Academy of Sciences, 119(43), e2109313118. https://doi.org/10.1073/pnas.2109313118

Perreault, C. (2019). The Quality of the Archaeological Record. University of Chicago Press.

Pilaar Birch, S. E., & Szpak, P. (2022). Current developments and future directions in archaeological science. Proceedings of the National Academy of Sciences, 119(43), e2212490119. https://doi.org/10.1073/pnas.2212490119

Ragsdale, A.P., Weaver, T.D., Atkinson, E.G., Hoal, E.G., Möller, M., Henn, B.M. & Gravel, S. (2023). A weakly structured stem for human origins in Africa. Nature 617, 755-763. https://doi.org/10.1038/241586-023-06055-y

Rick, T. C., & Sandweiss, D. H. (2020). Archaeology, climate, and global change in the Age of Humans. Proceedings of the National Academy of Sciences, 117(15), 8250–8253. https://doi.org/10.1073/pnas.2003612117

Roebroeks, W., MacDonald, K., Scherjon, F., Bakkels, C., Kindler, L., Nikulina, A., Pop, E. & Gaudzinski-Windhäuser, S. (2021): Landscape modification by Last Interglacial Neanderthals. Science Advances 7, 51: eabj5567. https://doi.org/10.1126/sciadv.abj5567.

Timm, I.J., Lorig, F., Hölzchen, E., & Hertler, C. (2016). Multi-Scale Agent-Based Simulation of Long-Term Dispersal Processes: Challenges in Modeling Hominin Biogeography and Expansion. In: Barceló, J.A., Del Castillo., F. (eds.): Simulating Prehistoric and Ancient Worlds. Springer, Cham. 141-158. Timmermann, A., Yun, KS., Raia, P. et al. Climate effects on archaic human habitats and species successions. Nature604, 495–501 (2022). https://doi.org/10.1038/s41586-022-04600-9

S6: Data Sources and Data Integration for Macroscale Archaeology	
13:00-13:20	*140. XRONOS: Empowering Macroscale Archaeology Through Comprehensive Chronometric Data Management* *Martin Hinz (Institute of Archaeological Sciences, University of Bern)*; Joe Roe (Institute of Archaeological Sciences, University of Bern)*
13:20-13:40	*163. The Prehistoric ROCEEH Out of Africa Database (ROAD) Enables a Comprehensive View on Human Cultural Development* *Volker Hochschild (Uni Tübingen)*; Christian Sommer (Heidelberg Academy of Sciences and Humanities); Zara Kanaeva (Heidelberg Academay of Sciences and Humanities); Andrew Kandel (DE); MIriam Haidle (Heidelberg Academy of Sciences and Humanities); Christine Hertler (ROCEEH Senckenberg, Senckenberg Research Institute); Angela Bruch (ROCEEH Senckenberg, Senckenberg Research Institute)*
13:40-14:00	*132. Agent Based Modelling Experiment to Assess the Comparative Interpretation of Artefacts - Harappan (Indus) Seals and Sealings* *Pallavee Gokhale (IISER Pune)*; Marta Ameri (Colby College)*

140. XRONOS: Empowering Macroscale Archaeology Through Comprehensive Chronometric Data Management

Martin Hinz (Institute of Archaeological Sciences, University of Bern); Joe Roe (Institute of Archaeological Sciences,*

In recent years, there has been a resurgence of interest in macroarchaeology, leading to a renewed focus on the profound questions surrounding the long duree of the complex interplay between people, their environment and cultural developments. This endeavour is inevitably data-driven, and in order to explore large temporal and geographical scales, concerted action to collect and share data on a large scale is essential. Computational archaeology has benefited significantly from the increasing adoption of open data and open science principles, influenced by developments in neighbouring disciplines, particularly the palaeosciences with their large-scale research frameworks. A key area where these principles have proved very effective is in the field of chronometric data.

In macroarchaeology, chronology remains central to understanding the dynamics of prehistoric developments within coupled socio-ecological systems. In recent years, creative and innovative approaches have emerged to use data beyond their conventional role as temporal markers, with radiometric data becoming a cornerstone for the intensification and implementation of macroarchaeology.

While comprehensive compilations of radiocarbon data have become accessible to different parts of the world over the past decade, several initiatives, including the c14bazAAR retrieval tool (Schmid et al. 2019), the IntChron exchange format (Bronk Ramsey et al. 2019) and the p3kc14 synthetic database (Bird et al. 2022), aim to bring these data together on a global scale. However, these efforts are far from complete. For a holistic understanding of prehistory, it is essential to explore the cultural dimensions of human evolution on a broader scale and to increase the significance of the archaeological record. Radiocarbon records remain extremely sparse in many regions of the world, and even in regions with extensive coverage, data quality shows considerable variation and lacks adequate documentation. A central repository to ensure the long-term sustainability and completeness of these datasets does not exist. Furthermore, the potential of incorporating other sources of chronometric information, such as dendrochronology and typological dating, into an open data framework remains largely untapped.

In response to these challenges and in synergy with existing initiatives, we are pleased to introduce XRONOS (https://xronos.ch). XRONOS is a dynamic, web-based platform for managing chronometric data from archaeological contexts worldwide. It combines an open data archive with advanced tools for importing, curating and analysing data from a wide range of sources. Beyond data aggregation, XRONOS strives to become a hub for community-wide data sharing and linking, while actively participating in the development of recognised standards to ensure interoperability.

XRONOS is guided by the following main objectives.

- Unifying Diverse Data Sources: The platform's primary mission is to consolidate all available sources of radiocarbon and other chronometric data into a single, cohesive database.

- Data Quality Enhancement: XRONOS is committed to developing robust tools for the continuous ingestion and refinement of this data.

• FAIR Data Dissemination: The platform aspires to disseminate this data within an open and FAIR framework, seamlessly embedding it within the broader universe of Linked Open Data, extending far beyond archaeology.

This presentation provides a detailed insight into the conceptual and technical infrastructure that will be developed under XRONOS for the period 2019-2023. This infrastructure includes the following:

• Versatile Data Model: Tailored to accommodate site and radiocarbon information, with the flexibility to extend to other forms of chronometric data.

• Data Ingestion Pipeline: Utilizing R and Ruby, XRONOS has established a robust pipeline for the ongoing ingestion of data from a variety of sources.

• Data Quality Improvement Protocols: Implementation of continuous, semi-automated data cleaning procedures to elevate data quality.

• User-Friendly Interface and API: XRONOS features a user-friendly Ruby-on-Rails application, providing a web-based frontend for data access, accompanied by a REST API for programmatic data retrieval.

• R Package Integration: An R package has been developed to facilitate seamless interfacing with the API.

The XRONOS framework represents a significant advance, providing a more accessible, reliable and comprehensive way to access chronometric data compared to previous resources. It provides a solid foundation for the continued growth and improvement of macroarchaeology. As an open science and open source initiative, we invite all colleagues to actively participate in shaping the future course of XRONOS. We envision XRONOS acting as a catalyst for the application of quantitative and computational methods, not only in deciphering archaeological chronologies, but also in broader applications, making it a central data hub for the sustainable integration of chronometric data into ongoing efforts in macroarchaeology. The creation of a community-driven chronometric database will be instrumental in democratising these records for macro-level archaeology and ensuring their ability to shed light on the grand trajectories of the past.

References

Bird, Darcy, Lux Miranda, Marc Vander Linden, Erick Robinson, R. Kyle Bocinsky, Chris Nicholson, José M. Capriles, et al. 2022. “p3k14c, a Synthetic Global Database of Archaeological Radiocarbon Dates.” Scientific Data 9 (1): 27. https://doi.org/10.1038/s41597-022-01118-7.

Bronk Ramsey, Christopher, Maarten Blaauw, Rebecca Kearney, and Richard A Staff. 2019. “The Importance of Open Access to Chronological Information: The IntChron Initiative.” Radiocarbon 61 (5): 1121–31. https://doi.org/10. 1017/RDC.2019.21.

Schmid, Clemens, Dirk Seidensticker, and Martin Hinz. 2019. “c14bazAAR: An R Package for Downloading and Preparing C14 Dates from Different Source Databases.” Journal of Open Source Software 4 (43): 1914. https: //doi.

132. Agent Based Modelling Experiment to Assess the Comparative Interpretation of Artefacts - Harappan (Indus) Seals and Sealings

Pallavee Gokhale (IISER Pune); Marta*

Harappan material culture is a prominent phenomenon in the archaeological past of South Asia. Amongst millions of artefacts excavated from hundreds of sites, the most remarkable, popular, and analysed are the ones which bear signs. Within this set of artefacts, the characteristic artefacts are known as ‘seals’ and ‘sealings’. These are at the centre of a significant portion of archaeological discourse in Harappan archaeology. The majority of this scholarship revolves around three conjectures: (i) the signs or sign sequences which appear on these objects indicate linguistic components and are part of a script with fixed set of signs, (ii) the 'seals' ought to be used as amulets or as objects of economic or administrative activities, and (iii) the primary use of seals is for creating the impressions which form `sealings'.

The interpretations about the relationship between seals and their impressions, their perceived function, and their quantities are highly interconnected. Though it is based on evidence of impressions on shaped clay and ceramic pots (or other utilitarian forms), it is also heavily influenced by our understanding of Mesopotamian material culture. It is worth pointing out here that in the very first excavation report of Mohenjo-daro, excavators raised concern about classifying these objects as seals because no true sealing - that is impression on clay attached to a jar or object of merchandise - had been found. The majority of impressions on baked clay or faience were thus identified as amulets.

The seal-sealing hypothesis needs to be evaluated in light of the evolving picture presented by continued excavations. It is obvious that sealings for every seal may never be recovered. However, the quantities of seals viz. ~2253 and impressions ~255 make it difficult to hypothesise that every seal was used to produce an impression. Ten identical tags with elephant motif and sign sequence were found at Lothal. With a hypothetical assumption that these could be around 20% of the total impressions by the same seal, and each seal was used to create at least 50 impressions if not more, there would have been at least 1,12,650 sealings in the past for the present day number of recovered seals. With a total ~255 impressions on hand, those are 0.226% of the hypothetical total impressions. Twenty percent could be an optimistic number because it is generally believed that it's only a fraction that gets excavated of what might have existed in the past. Thus, if each seal was used more than 50 times for the impression, this proportion would be even lesser. Other parameters such as proportion of excavated areas, their spatial functions, and past climate conditions add different dimensions for hypothesising the number of expected artefacts.

Major possible causes which have been hypothesised for a smaller number of sealings are: (i) material difference - seals were made of steatite stone and got baked during the manufacturing process; hence those became sturdy and more reliable than the impressions made on clay which might not have been routinely baked, and (ii) usage pattern - seals were expected to last longer for repeated use for impressions but clay objects were to be broken to open traded goods or locked doors, were discarded at the end of the transaction, or even reused in some cases.

In the light of close contact with Mesopotamian culture, the identification of Meluhha (a region often mentioned in Mesopotamian texts) with Harappan region, and based on the evidence of similar artefacts, direct parallels have been drawn between the artefact typologies and their interpretation in these two material cultures. It is worth noting that in the Akkadian region of influence, the administrative role of seals becomes a strong hypothesis only due to sheer number of sealings of the contemporary period which have been impressed with those seals (Rakic, 2018). A volume dedicated to excavations at Arslantepe has several mentions about the quantity of sealings and their usage. Though the material pre-dates Harappan artefacts, it is important to understand how usage patterns continued over the period of time. Thousands of discarded sealing fragments with a variety of impressions have been recovered. These indicate the disposal of a possible archive of administrative records. (Pittman, 2019) However, when Frenez compares the quantity of sealings from Lothal to those in Iran and Mesopotamia, those in Lothal are equivalent to a collection in a house (Frenez, 2005).

This paper proposes to use agent based modelling to model the quantities of seals and their impressions in Harappan culture. It is believed that these artefact typologies were widely in use between 2600 BCE to 1900 BCE. The modeling assumes the present day understanding that all the seals were used to create impressions. It then incorporates the parameters such as starting number of seals, number of times each seal is impressed in the past, possible average lifespan of seals and sealings, their breakage possibilities, loss due to other reasons, number of people using these, number of sealings getting damaged or remaining intact, and their probability of showing up in the archaeological record. The objective is to see if and how any of the models result into the current quantities of seals and sealings that are available as archaeological evidence. If none of the model output quantities is equivalent to the presently excavated material, does it mean that the data needs a different interpretation. On the other hand, in order to reach the presently available quantities from the excavations, which parameters could have contributed the most? Does it again indicate a need for reappraisal or re-interpretation of this data and the systems they manifest?

References

Frenez, Dennys, and Marizio Tosi. "Lothal Sealings: Records from an Indus Civilization town at the eastern end of the maritime trade networks across the Arabian Sea." In Studi in Onore di Enrica Fiandra. Contributi di archeologiaegea e vicinorientale, Naples, edited by M. Perna, 87–211. 2005.

Pittman, Holly. "Glyptic art from Arslantepe: interregional styles, imported seals and local seals." In Arslantepe. Proceedings of the I. International Archaeology Symposium, 4-6 October 2018 Malatya, edited by Neslihan Durak and Marcella Frangipane, 131–142. İnönü University / Roma La Sapienza University, 2019.

Rakic, Yelena Z. "Sealing Practices in the Akkadian Period." In Seals and Sealing in the Ancient World: Case Studies from the Near East, Egypt, the Aegean, and South Asia, edited by Marta Ameri, Sarah Kielt Costello, Gregg Jamison, and Sarah Jarmer Scott, 81–94. Cambridge University Press, 2018. https://doi.org/10.1017/9781108160186.008.

163. The Prehistoric ROCEEH Out of Africa Database (ROAD) Enables a Comprehensive View on Human Cultural Development

Volker Hochschild (Uni Tübingen); Christian Sommer (Heidelberg Academy of Sciences and Humanities); Zara Kanaeva (Heidelberg Academay of Sciences and Humanities); Andrew Kandel (DE); MIriam Haidle (Heidelberg Academy of Sciences and Humanities); Christine Hertler (ROCEEH Senckenberg, Senckenberg Research Institute); Angela Bruch (ROCEEH Senckenberg,*

Long term and large-scale databases are a prerequisite for successful scientific work, especially in prehistoric archaeology, where stand alone projects often work on small areas with a limited investigated time period. The long-term project ROCEEH ("the Role of Culture in the Early Expansions of Humans"), whose aim is to study the origins of culture in human habitats and their expansions from Africa over Eurasia over the last three million years, has developed a web-based spatial tool called ROAD ("ROCEEH Out of Africa Database") to integrate geographical as well as archaeological, paleoanthropological, paleontological and palaeobotanical data. Major advantage of the tool is the dynamical linkage of spatial and temporal issues, enabling the development of new theories of the role of culture in prehistoric areas and timespans through database queries. The provided data is usable in Geographic Information Systems for further quantitative geostatistical analysis or modelling approaches using machine learning algorithms and even artificial intelligence. Since ROAD enables the reuse of existing data, it is an indispensable tool for all, who work in the field of human evolution and paleogeography. It makes old data acquired before the digital revolution accessible and it integrates interdisciplinary cultural, anthropological, paleoenvironmental and geographical data into a single framework.

ROAD is following the FAIR principles (Findable, Accessible, Interoperable, Reusable). It therefore preserves information from inevitably destructive research practices, facilitating sustainable open access to prehistoric research information, with comprehensiveness and longevity, often required and seldomly implemented in so called Data Management Plans. The platform ARIADNEplus enables the access to the ROAD database through a unified metadata interface.

ROAD has the form of a relational database, open to be extended by new tables and attributes. It contains published data from the literature as well as own acquired and evaluated archaeological data. Based on the Structured Query Language (SQL) the user interaction includes entering, updating and querying data. In total ROAD consists of more than 50 tables covering seven general subjects: 1) localities, 2) geological layers and profiles, 3) archaeological layers and profiles, 4) Dating results, 5) assemblage descriptions and derived data, 6) bibliographic information and 7) linking tables.

ROAD uses PostgreSQL as backend database management system and has a web-based frontend graphical user interface written in PHP, JavaScript and HTML. The user groups are divided into four levels of access: 1) the general public retrieving basic archaeological information without logging in; 2) associated scientists involved in the analysis and visualization of ROAD data; 3) associated ROCEEH members involved in data exchange and 4) ROCEEH team members with full access to ROAD including development, programming and quality control of the data entered. Anyone interested may access ROAD without a password either through the ROAD website (www.roceeh.uni-tuebingen.de/roadweb) or through the Map Module of ROADWeb (www.roceeh.uni-tuebingen.de/roadweb/map_modul) and search for a region, an assemblage type or an age. The search results are then plotted on a map showing the spatial distribution of the localities that meet the specified search conditions.

ROAD therefore may act as a valuable research tool for the prehistoric scientific community as used in a study of how the use of ochre changed over time in Africa (Dapschauskas et al. 2022) and a study about the population density in Western Europe between 560.000 and 360.000 before present (Rodriguez et al. 2022). Both examples will be shown as well as the use of prehistoric 'big data' to map early human cultural networks (Sommer et al. 2022). The presentation will also show some statistics on the spatial and chronological coverage of assemblages, on dating methods contained within the project timeframe, a holisitc and interdisciplinary perspective on archaeological data, cultural periods and the development of the ROAD database over time.

References

Dapschauskas, R., Göden, M., Sommer, C. & Kandel, A.W. 2022: The emergence of habitual ochre use in Africa and its significance for the development of ritual behavior during the Stone Age. – Journal of World Prehistory 35: 233 – 319. https://doi.org/10.1007/s10963-022-09170-2.

Rodríguez, J., Willmes, C., Sommer, C., & Mateos, A. 2022: Sustainable human population density in Western Europe between 560.000 and 360.000 years ago. - Scientific Reports, 12(1), Article 1. https://doi.org/10.1038/s41598-022-10642-w.

Sommer, C., Kandel, A.W. & Hochschild, V. 2022: The use of prehistoric 'big data' for mapping early human cultural networks. – Journal of Maps, https://doi.org/10.1080/17445647.2022.2118628.

S7: From Trials and Errors to Triumphs: Machine Learning Applications in Archaeology

Thursday 11th April, 09:00–17:00, OGGB-098

Mathias Bellat, CRC 1070, University Tübingen, Germany
Anastasia Eleftheriadou: ICArEHB, University of Algarve, Portugal
Mirijam Zickel: Institute of Geography, University of Cologne, Germany
Alex Brandsen, Faculteit Archeologie, University of Leiden, Netherlands
Alfie Talks, Department of Archaeology, York University

Over the past decade, a growing number of publications have explored the use of Machine Learning (ML) in archaeology (Argyrou and Agapiou 2022; Jamil et al. 2022). Applications are plenty in different sub-fields of archaeology (Bickler 2021; Mantovan and Nanni 2020) and mainly aiming for object detection and image classification to study of: bone surface cutting marks classification, ceramics classification palaeography, architectural reconstruction/ classification. The exponential increase of papers related to ML since 2018-2019 and the different background of researchers working on this topic have led to heterogeneous practices. During CAA 2023 a previous session, "Machine and deep learning methods in archaeological research – creating an integrated community of practitioners" concluded with a "lack of standardised approaches". Despite Machine Learning's tremendous potential, the neglect of its limitations and the inconsistency in data and/or code reproducibility practices complicate its sustainable implementation and the development of such standards.

Toward this goal, we will share successful and failed applications to synthetize a set of guidelines for future research. Various tracks have to be explored: 1) Look "across the horizon" and take examples of successful experience in other fields (e.g. geosciences, paleo-climatology, literature, medicine); 2) Share data, workflows, and accuracy parameters in a standardized manner to maximize reproducibility; 3) Share in the same way unsuccessful results and analyses the reasons of failure.

The aim of this session is to provide a reflection on the great advantages of ML techniques for archaeological daily tasks and ways to standardise the use of it . Give examples of what to do and what to avoid in ML practices in archaeology. Examples may be drawn from a single study or from a review of several studies. Authors are encouraged to outline the necessity for robust reproducibility and the methods to achieve it.

We invite authors to submit papers related to the following topics (or any related subjects):

- Epistemology, historiography or future trend prediction of ML application in archaeology.
- Standardisation and reproduction problems of ML techniques between different data sets (data type, data size…).
- Borrowing ML methods from other disciplines into archaeology.
- Tuning and using hyperparameters in ML.
- Legislative and social issues related to the standardisation and FAIRness (see Wilkinson

et al 2016) of ML approaches in archaeology (e.g., data sharing policies, access and ownership of information, Huggett 1995).

- Successful case-studies of ML application in archaeology.
- Unsuccessful case-studies of ML application in archaeology.

For practical approaches we would encourage a critical dialogue to identify individual and shared problems, opportunities, and solutions. We invite authors to provide a thorough explanation and evaluation on their methods. In the spirit of reproducibility, we ask authors to share code and data wherever possible or explain why this can't be shared. To be able to compare methods, we also highly recommend using standard accuracy metrics, such as precision, recall, F1, MAP and/or ROC, depending on your task.

In this this session we focus on dialogue, exchange of ideas, and constructive feedback. Consequently, we will pay attention to have enough time available for this purpose.

References

Argyrou, A., Agapiou, A., 2022. A Review of Artificial Intelligence and Remote Sensing for Archaeological Research. Remote Sensing 14, 6000. https://doi.org/10.3390/rs14236000

Bickler, S.H., 2021. Machine Learning Arrives in Archaeology. Adv. Archaeol. Pract. 9, 186–191. https://doi.org/10.1017/aap.2021.6

Huggett, J. 1995. Democracy, Data and Archaeological Knowledge, in: Huggett, J. and N. Ryan (eds.), CAA94. Computer Applications and Quantitative Methods in Archaeology 1994 (BAR International Series 600). Tempus Reparatum, Oxford, pp. 23-26.

Jamil, A.H., Yakub, F., Azizan, A., Roslan, S.A., Zaki, S.A., Ahmad, S.A., 2022. A Review on Deep Learning Application for Detection of Archaeological Structures. Journal of Advanced Research in Applied Sciences and Engineering Technology 26, 7–14. https://doi.org/10.37934/araset.26.1.714

Mantovan, L., Nanni, L., 2020. The Computerization of Archaeology: Survey on Artificial Intelligence Techniques. SN COMPUT. SCI. 1, 267. https://doi.org/10.1007/s42979-020-00286-w

Wilkinson, M., Dumontier, M., Aalbersberg, I. et al., 2016. The FAIR Guiding Principles for scientific data management and stewardship. Sci Data 3, 160018. https://doi.org/10.1038/sdata.2016.18

Yaworsky, P.M., Vernon, K.B., Spangler, J.D., Brewer, S.C., Codding, B.F., 2020. Advancing predictive modeling in archaeology: An evaluation of regression and machine learning methods on the Grand Staircase-Escalante National Monument. PLoS One 15, e0239424. https://doi.org/10.1371/journal.pone.0239424

S7: From Trials and Errors to Triumphs: Machine Learning Applications in Archaeology	
9:00-9:10	*Introduction*
9:10-9:30	*81. Standardisation in the Area of Big Data: Example of Automated Features Detection in Archaeology Mathias Bellat (University of Tübingen)*; Thomas Scholten (University of Tübingen)*
9:30-9:50	*124. Federated Learning, GIS, and Interpretations of Landscape Andrew A Prentice (Griffith University)**
9:50-10:00	*79. Fail and Try Again: Return on Topic Modelling Apply to Archaeological Scientific Literature Mathias Bellat (University of Tübingen)*; Ruhollah Taghizadeh-Mehrjardi (University of Tübingen); Thomas Scholten (University of Tübingen)*
Morning Tea	
10:20-10:40	*58. An Engine for Impact Assessment in Archaeology: Modeling in the State of Alagoas, Brazil Grégoire van Havre (UFPI)*; Kleython Monteiro (UFAL); Rute Barbosa (IPHAN)*
10:40-11:00	*72. Archaeological Predictive Models, Machine Learning Algorithms and Unbalanced Datasets: A Case Study in the Rock Art Sites of the Pajeú Watershed, Pernambuco/Brazil Lucas B Souza (UFPE)*; Demétrio Mutzenberg (UFPE); Eduardo Krempser (FIOCRUZ); Philip Verhagen (Vrije Universiteit Amsterdam)*
11:00-11:20	*27. Performance Evaluation of Deep Learning Methods for Archaeological Object Detection in Airborne LiDAR Data Øivind Due Trier (Norwegian Computing Center)**
11:20-11:40	*78. Their Final Resting Place: A Random Forest Approach to the Location of Early Iron Age Burial Mounds in Western Switzerland Timo Geitlinger (University of Oxford)**
11:40-12:00	*"116. Deep learning using sidescan sonar for detection of underwater aircraft wrecks from U.S. conflicts Leila Character (University of Delaware); Hannah P Fleming (HJF)*; Alba Mazza (HJF); Matthew Breece (University of Delaware); Dan Davis (Luther College); Mark Moline (University of Delaware)"*

Lunch	
13:00-13:20	*94. Past Landscapes and Future Technologies – Multimodal AI for the Analysis of Historical Maps* *Karsten Lambers (Leiden University)*; Alex Brandsen (Leiden University); Wouter B Verschoof-van der Vaart (Leiden University); Sietze van As (Leiden University); Leila Darabi (Leiden University)*
13:20-13:40	*53. Issues and Solutions for Classification Models using Deep Learning for 3D Data of Archaeological Materials* *Ryo Yamamoto (Tokyo National Museum)*; Haruhiro Fujita (Niigata University of International and Information Studies); Kazuyoshi Kawahara (Niigata University of International and Information Studies); Kenta Ichikawa (BSN Inet); Ayaka Nagumo (BSN Inet)*
13:40-14:00	*172. A Framework for Integrating Domain Knowledge and Deep Learning for 3D Shape Analysis of Lithic Fragments* *Steven Mills (University of Otago)*; Nirmal Das (Institute of Engineering and Management); Gerard O'Regan (Tūhura Otago Museum); Lana Arun (Tūhura Otago Museum); Tapabrata Dr. Chakraborty (University of Oxford); Richard Walter (University of Otago)*
14:00-14:20	*80. Utilising Deep Neural Network Models to Aid in the Decipherment of Linear A* *Emily Tour (University of Melbourne)**
14:20-14:40	*154. Places and Time: Benefits of Geographical Textual Analysis Applied to Heritage-Landscapes* *Haley A Schwartz (Universitat de Barcelona)**
14:40-15:00	*190. Machine Learning and Generative AI for Archaeological Application* *Kayeleigh Sharp (Northern Arizona University)**
Afternoon Tea	

15:20-15:40	*64. Statistical Image Processing (Decorrelation Stretch) and Deep Learning (CycleGANs) to Restore Images of Faded Artworks* *Kazutaka Kawano (Tokyo National Museu)*; Masatoshi Itagaki (Masatoshi Itagaki consultant office); Haruhiro Fujita (Niigata University of International and Information Studies); Ryo Yamamoto (Tokyo National Museum); Toshiki Takeuchi (Kyushu National Museum); Haruhiko Ochiai (Kyushu National Museum)*
15:40-16:00	*43. Image Restorations of Sundial-shaped stones of Oyu Stone Circle Site by CycleGANs* *Haruhiro Fujita (Niigata University of International and Information Studies)*; Kazutaka Kawano (Tokyo National Museum); Primitiva Ramirez (Universidad de Alcala de Henares); Masatoshi Itagaki (Itagaki Small Business Office); Toru Miyao (Niigata Prefectual Historical Museum); Ryo Yamamoto (Tokyo National Museum); Yoshito Hanami (Oyu Stone Circle Center); Tomomi Akasaka (Oyu Stone Circle Center); Ryo Kinouchi (Oyu Stone Circle Center)*
16:00-16:05	*38. Developing an Airborne Laser Scanning and Deep Learning toolkit for federal cultural resource management: A case study detecting historic agricultural terraces in the Piedmont National Wildlife Refuge, Georgia, USA.* *Claudine Gravel-Miguel (New Mexico Consortium)*; Katherine Peck (New Mexico Consortium); Jayde Hirniak (Institute of Human Origins); Grant Snitker (New Mexico Consortium)*

124. Federated Learning, GIS, and Interpretations of Landscape

*Andrew A Prentice (Griffith University)**

I will present a QGIS plugin designed using Reinforcement Learning (RL) concepts to train local models, and Federated Learning (FL) to aggregate those models; these forms of Machine Learning (ML) create models based on multiple interpretations of various landscapes. My research builds on archaeological predictive modelling, implementing the MaxEnt algorithm (Boemke et al. 2022) using Python; the plugin I will present enables researchers to train a local model using their interpretations and gives this option to upload local models to a central server, aggregating the learning. The objective of this research is to understand how archaeologists view Federated Learning, and the plugin was a way to gauge opinions and track real-world behaviour. The plugin is functional and been tested using open-access, geospatial data, but researchers may not trust it immediately; therefore, a case-study will be presented, along with data on the plugin's use at the time of presentation.

The benefit of a QGIS plugin is that it can be downloaded free by anyone, rather than being preinstalled, and can exchange data with a cloud server; therefore, including a trainable local model with the plugin and code on a cloud server to aggregate those models, means the basic architecture is in place. However, downloadability is a feature with great benefits and significant drawbacks. Importantly, indigenous knowledge holders can share, but every pseudo-archaeologist with time on their hands could 'game the system'; as with all technological advances, there is the potential for misuse. Therefore, after a survey and/or excavation, researchers can give feedback on the predictive value of the interpretations; this mechanism may create local models that trend towards interpretations with a higher predictive value, while the influence of sub-standard predictions is minimised (Wang et al. 2022). The local models are aggregated, using CRS as a label so regions can be differentiated. There are large repositories of open-access archaeological data such as CANMORE in Scotland and ARIADNE-PLUS in the EU, so case studies will be drawn from Europe; three plugins will be used, each in a different country. The local model from each plugin will be uploaded to the central server, then the aggregated model used to update local models in three plugins and as the basic model for a fourth. A predictive model created for an area in a fourth country is presented in this session.

The plugin was designed to facilitate Federated Learning in jurisdictions where archaeological data is sensitive (Graser, Heistracher, Pruckovskaja 2022, Wang et al. 2022); however, the number of researchers using it depends on confidence in data security and ability of FL to provide interpretations that have predictive value. This study measures number of uploads from unique plugins and feedback on all predictive models created, as proxies for confidence and predictive ability of ML, respectively. One important issue of concern to researchers is transparency, so justifying an interpretation based on FL and defining it as reproduceable science are difficult and important considerations; while aggregating geospatial data that is not independent and identically distributed (Graser, Heistracher, Pruckovskaja 2022, Wang et al. 2022) is a hurdle to overcome. This research begins to explore some issues; however, more research will be possible if or when FL becomes prevalent among archaeologists. ML is susceptible to sampling bias, but this can be reduced by learning from more archaeologists' interpretations and diversifying the pool of raw data; therefore, Federated Learning is suited to this task. But are archaeologists suited to Federated Learning?

References:

Boemke, Bruno, Thomas Einwögerer, Marc Händel, & Frank Lehmkuhl. 2022. "Upper Palaeolithic site probability in Lower Austria – a geoarchaeological multi-factor approach." Journal of Maps, 18:4: 610-618, http://doi.org/10.1080/17445647.2021.2009926

Graser, Anita, Clemens Heistracher, & Viktorija Pruckovskaja. 2022. "On the Role of Spatial Data Science for Federated Learning." UC Santa Barbara: Center for Spatial Studies. http://dx.doi.org/10.25436/E24K5T Retrieved from https://escholarship.org/uc/item/7mg5655h

Wang, Xumeng, Wei Chen, Jiazhi Xia, Zhen Wen, Rongchen Zhu and Tobias Schreck. 2022. "HetVis: A Visual Analysis Approach for Identifying Data Heterogeneity in Horizontal Federated Learning." IEEE Transactions on Visualization and Computer Graphics 29: 310-319. https://doi.org/10.48550/arXiv.2208.07491 Retrieved from institution

38. Developing an Airborne Laser Scanning and Deep Learning Toolkit for Federal Cultural Resource Management: A Case Study Detecting Historic Agricultural Terraces in the Piedmont National Wildlife Refuge, Georgia, USA.

Claudine Gravel-Miguel (New Mexico Consortium); Katherine Peck (New Mexico Consortium); Jayde Hirniak (Institute of Human Origins); Grant Snitker (New Mexico Consortium)*

Cultural resources are the tangible and intangible elements connected to the physical presence, practices, cultural identity, and/or spirituality of past and present societies. In the United States, they are managed and protected under multiple local, state, tribal, and federal laws/agreements. However, the logistics, costs, and capacity to complete extensive surveys to document and manage cultural resources present challenges to land managers. While the increasing availability of high-resolution airborne laser scanning (ALS) datasets, referred to as aerial LiDAR, is revolutionizing data collection and analysis across multiple fields, including cultural resource management (CRM), many cultural resource managers lack the dedicated time or computing resources to process these data, let alone leverage them for analytical or management applications. To address these issues, the Cultural Resource Sciences program at the New Mexico Consortium, in collaboration with our federal partners, is currently developing an ALS and Deep Learning toolkit specifically designed for agency CRM. Here, we discuss an applied case study focused on detecting historic agricultural terraces in the Piedmont National Wildlife Refuge, Georgia, USA.

The Piedmont National Wildlife Refuge is located in the Piedmont region of Georgia in the southeastern United States. This region is characterized by hilly terrain and was intensively cultivated for cotton by formerly enslaved communities, sharecroppers, and other small holders during the 19th and early 20th centuries. However, land degradation and the early 20th century boll weevil infestation led to the collapse of the cotton industry in this region by the 1930s. In an effort to mitigate economic hardship, the US government created a program to relocate farming communities to areas with greater economic opportunities and create public lands in areas formerly used for cotton cultivation. Today, the Piedmont Wildlife Refuge is located within a former cotton production region and managed by the US Fish and Wildlife Service (USFWS). Secondary-growth pine forests now cover most of the area, leaving the former agricultural landscape obscured both on the ground and via remote sensing. The dense canopy and understory present within the refuge makes it difficult for USFWS archaeologists – who are responsible for managing all archaeological and historical resources within the refuge – to efficiently identify, inventory, and monitor new and known heritage sites.

In our case study, we focused on identifying relict cotton terraces present within the Piedmont National Wildlife Refuge. First, we transformed the leaf-off ALS ground-filtered points provided by the USFWS into Digital Elevation Models (DEM), slope, and Simple Local Relief Models (SLRMs), which we visually inspected to determine their viability to identify agricultural terraces. Agricultural terraces were readily visible in SLRM and slope maps due to their distinct morphology and were, fortunately, present in large numbers. The size and shape of Piedmont terraces in turn informed the type of CNN we used; the sinuous and large footprint of terraces made them excellent candidates for U-Net semantic segmentation, which performs better on large and heterogeneously-shaped objects than the popular Mask R-CNN's instance segmentation, which performs better with small and homogeneously-shaped objects. The U-Net structure also proved to be the most straightforward structure to code and adapt to our ALS-derived imagery. To create the training dataset, we defined a standardized annotation workflow to ensure that each terrace was annotated systematically and in a replicable manner. We then created buffers around each terrace to provide contextual information to the training model. Given the lack of standardization for hyperparameter tuning of models trained on archaeological data, we performed extensive parameter exploration to obtain the best trained model (e.g., trying different composition of visualization layers, buffer sizes, batch sizes, learning rate, backbones, loss functions, and epochs). For each model, we recorded standard metrics such as recall, precision, and F1 computed on a validation and a testing datasets, which were not used for model training. Our best model reached recall values >0.66 on both validation and test datasets when computed pixel by pixel. However, transforming the predicted masks into vector polygons and calculating the metrics on those provided even better results with recall values as high as 0.90.

In addition to presenting the results of our best model in this symposium, we will discuss the challenges we encountered while designing our workflow, including 1) choosing between Deep Learning platforms (e.g., PyTorch, Tensorflow, ArcPro), 2) defining the best visualizations for our inputs, 3) augmenting our data without degrading its visual signature, and 4) finding code tutorials online that can be adapted to the uniqueness of archaeological data. Finally, we will also discuss our plans to expand our model structures to detect other archaeological and historic features (e.g., homestead sites, historic cemeteries, road networks and logging grades), as well as integrate our toolkit into existing federal CRM programs.

80. Utilising deep neural network models to aid in the decipherment of Linear A

*Emily Tour (University of Melbourne)**

In this paper we will present the preliminary results of our project, which aims to harness the emerging capabilities of deep neural network models to aid with the decipherment and understanding of the Linear A script and the unidentified language that it represents.

Over the past decade—with advances in deep learning and increased computational power from Graphics Processing Units (GPUs)—we have seen a substantial increase in the use of machine learning to explore and ask new questions about ancient texts and languages. Through harnessing these technological advancements, archaeologists and computer scientists alike have been able to tackle issues such as automated translation, text reconstruction and attribution in new and innovative ways.

One particularly promising area has been machine-aided decipherment, which recently saw the successful automated decipherment of both Linear B and Ugaritic, using existing machine translation techniques, coupled with information regarding their respective progenitor languages, ancient Greek and Hebrew (Luo et al. 2019). As suggested in a 2019 MIT Technology Review article, off the back of Luo et al.'s successes, machine learning may also hold the key to understanding other texts that have never been successfully deciphered, including those using the Minoan Bronze Age script, Linear A. Our project seeks to take on this challenge, exploring how deep learning techniques can help us move closer to solving this linguistic puzzle that has eluded linguists and archaeologists for over a century.

Linear A was a script employed in the Bronze Age Aegean region by the Minoan civilisation from ca.1800–1450 BCE. The main portion of the Linear A corpus comprises of clay accounting tablets, in addition to other administrative devices including sealings, dockets and labels. Less common are inscriptions on non-administrative items, often of a religious nature (e.g. stone libation tables). The Linear B script emerged slightly later in the Aegean region (ca. 1400–1190 BCE), in association with Mycenaean culture. Its use appears to have been limited to administration, again appearing on clay tablets and occasionally sealings, as well as a number of painted inscriptions on transport stirrup jars.

Both Linear A and Linear B are logosyllabic, utilising a combination of syllabograms and logograms to represent language, as well as a number of other supplementary signs, including numerals and measurements. The two scripts are clearly related, and share around 80% of the syllabary at current counts. However, the languages underlying each are seemingly unrelated. Linear B was translated in 1952 by Michael Ventris, and shown to represent an early form of ancient Greek. Efforts to similarly map Linear A to ancient Greek have not proven successful, and over the years, a rather startling range of suggestions (mostly using the discredited etymological method) have been made to affiliate the language with not only West Semitic and Anatolian Indo-European languages, but also Hurrian, Etruscan, Indo-Iranian, and more recently, Old Hungarian (the latter relying predominantly on visual similarity of the scripts).

There are some significant challenges with the Linear A corpus, particularly its paucity, which many have suggested makes decipherment near impossible. And as noted above, thus far, a clear consensus candidate for a related or progenitor language has not yet emerged. It is hoped that through using deep neural network models, a number of different languages (including those proposed above) can be tested against Linear A for cognancy. If a suitable candidate is identified, it could then possibly be used for machine translation and decipherment efforts, similar to the work carried out by Luo et al. for Linear B and Ugaritic.

In the initial stages of our project, we are training language models of Linear A, requiring the neural network to predict the next character or word given the sequence so far. This unsupervised approach is necessary, given the undeciphered status of Linear A, which does not allow for us to provide annotations in the training process. The digitisation of the entire Linear A administrative corpus on the SigLA website will make the required data easy to access, and we are in the process of developing our Python language library for Aegean scripts to help transform the data into an appropriate format for language modelling. It is hoped that the character or word embeddings produced from such a model will help to provide some high-level insights into the nature of the language represented.

We will look to pre-train individual models on a number of different cognate candidates, then fine-tune these models on Linear A, in order to assess the level of cognancy between the two languages. We anticipate that pre-training on a cognate language will improve the perplexity score on Linear A more than pre-training on unrelated languages. As a proof-of-concept for this approach, we will begin by pretraining a model on ancient Greek texts, and then applying that model to Linear B texts, as the languages are known to be closely related. The results of this POC will help validate the efficacy of this method in measuring cognancy. Pending its success, we will then look to apply this to Linear A and a range of potentially related languages, providing a systematic way to test out the various hypotheses that have been presented for the identity of Linear A over the years. The identification of potential or likely cognates will be instrumental in any future machine decipherment and translation efforts; alternatively, if no related languages can be identified, this may further support the case for the Minoan tongue being a language isolate.

Whilst there have been some preliminary attempts to investigate Linear A using n-grams and word2vec (Karajgikar, Al-Khulaidy, and Berea 2021), to the best of our knowledge no other project has undertaken the approach outlined above to aid in the decipherment of Linear A. Thus, we are excited to present the results of this promising new research avenue.

References

Emerging Technology from the arXiv. “Machine Learning Has Been Used to Automatically Translate Long-Lost Languages.” MIT Technology Review, July 1, 2019. https://www.technologyreview.com/2019/07/01/65601/machine-learning-has-been-used-to-automatically-translate-long-lost-languages/.

Karajgikar, Jajwalya R., Amira Al-Khulaidy, and Anamaria Berea. 2021. “Computational Pattern Recognition in Linear A.” https://hal.science/hal-03207615.

Luo, Jiaming, Yuan Cao, and Regina Barzilay. 2019. “Neural Decipherment via Minimum-Cost Flow: From Ugaritic to Linear B.” In Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics, 3146–55. Florence, Italy: Association for Computational Linguistics. https://doi.org/10.18653/v1/P19-13

58. An Engine for Impact Assessment in Archaeology: Modelling in the State of Alagoas, Brazil

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In this study, we present an early development stage engine for archaeological impact assessment. Small scale projects generally allow archaeologists to manually select their input variables, and fit them into the context they are researching. For large regions with various chronologies, such an engine means approaching the matter from a different perspective.

Predictive modeling in archaeology is generally referred to as a series of methods aimed at identifying the location of unknown sites in a specific region. In broad terms, two main approaches are defined as top-down and bottom-up. Brazilian archaeology shows a slowly growing interest in these methods, both in published articles and in the CRM gray literature. Most of these projects fall into the first approach and are based on map algebra [1, 2].

Developing an engine for impact assessment means we move the focus from site detection to risk probabilities. The model, then, is not directly aimed at predicting where unknown sites are located but at what areas are known to offer a context similar to already known sites. In the Brazilian legal framework, under environmental assessment studies, such an engine gives diverse actors, both public and private, the opportunity to introduce archaeology in their project design. Among the few examples of such large scale projects around the world, MnModel, in the US state of Minnesota, is probably the most well-known [3].

Alagoas is the second smallest state in Brazil, with an area of approximately 28.000 km². To the present day, a total of 455 archaeological sites are registered, making the state one of the most densely characterized. The area is also located both on the major river in the North-East Brazilian region (Rio São Francisco) and in the region first invaded by colonial powers. Along with its different physiographic subregions, Alagoas also shows a deep history of human occupations starting in the early to middle Holocene. This plurality of archaeological contexts lead us to considering the development of an engine, rather than a single model.

The present version of the engine is written in R and built on a set of environmental variables extracted from both DEM and geographical morphostructural ordering. The archaeological database is split into chronological categories in order to avoid conflation between Portuguese or Dutch and Indigenous logics. Clustering algorithms (Hierarchical Clustering on Principal Component and Fuzzy K-Means) are then produced over a number of randomly selected locations in the region, in the way a Monte Carlo simulation would. The probabilities of site occurrence in each cluster are calculated for each random location, based on the actual database, and reprojected on the area where possible impacts are to be assessed, through Random Forest, and weighted by the overall distance inside each cluster. Impact maps are finally drawn from all these partial simulations.

Our initial results show that, through machine learning, the engine is able to handle different contexts and produce a set of distinct maps where probabilities are shown. These maps do not point directly to archaeological sites: their aim is to assess impact and allow better planning. They can also serve as a possible attractor to future archaeological research.

References:

[1] VAN HAVRE, G.; BARBOSA, R.; MONTEIRO, K. 2021. Modelos Preditivos Espaciais. Arqueologia e Geografia em Perspectiva. In: AZEVEDO NETTO, C. X. & VAN HAVRE G. (Orgs.). De Ingá à Arqueologia Inclusiva. Novas Linguagens, vol. 3. NDIHR, UFPB, João Pessoa. 46-73.

[2] BONALD, L.; MUTZENBERG, D.; KREMPSER, E. 2022. Prevendo o Passado: Um Panorama sobre as Análises Espaciais, os Dados Digitais e a Modelagem Preditiva na Arqueologia. In: Cadernos do LEPAARQ, 19 (38). DOI: https://doi.org/10.15210/lepaarq.v19i38.4628.

[3] HOBBS, E. 2019. MnModel Phase 4. Project Summary and Statewide Results. Minnesota Department of Transportation. https://www.dot.state.mn.us/mnmodel/phase4/phase4.html

154. Places and Time: Benefits of Geographical Textual Analysis Applied to Heritage-Landscapes

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The use of textual analysis is not a novel computational approach, with applications in various fields, yet sources are becoming increasingly diverse allowing novel applications to interdisciplinary projects. In the context of the fields of archaeology and cultural heritage studies, there is continued development of both the spatial and digital humanities and various text mining tools and software. Specifically, there is a growing trend in the textual analysis within archaeology and heritage in extracting geospatial data, language patterns, and narratives which exist within heritage discourses. The analysis of archaeological and heritage discourses also provides insight into archaeological heritage management, modern relationships with heritage landscapes, and shifting perceptions.

These heritage discourses give insight into shifting perceptions the academic authors maintain regarding archaeological heritage and its values (ICOMOS New Zealand, 2010), the narrative in which heritage is discussed, and the context in which heritage is placed – which impacts the perception and relationship subsequent readers have with heritage (Waterton et al, 2006). Regarding geospatial data, placenames, and keywords are extracted and available for use in GIS software and for additional comparative analysis of the materiality (Tilley and Cameron, 2017) and the spatial-temporal relationships language has on impacting modern relationships with surviving relics of the past (Solli et al., 2011). Considering approaches from studies in Landscape Archaeology and a variety of texts discussing a Sense of Place (ICOMOS Australia, 2013), and studies on shifting narratives surrounding surviving heritage – textual analysis is a heuristic tool relative to each individual and provides insight into otherwise unknown geospatial and heritage data (Lafrenz-Samuels, 2016).

This paper aims to advocate for the continued application of geographic textual analysis to textual sources within the fields of archaeology and cultural heritage studies. Specifically, advocating for open-source data and software coinciding with reproducible workflows and methodologies. This paper will both highlight the theoretical debates between researchers utilizing manual or automated textual analysis methods and software, while providing a methodological framework for future use. Two approaches of text mining are: Semantic Annotation and Latent-Dirichlet Allocation. A case study will highlight the differences in both types of text mining, as well as two open-source software's for conducting text mining: Recogito and RStudio. Resulting in reproducible workflows for manual text mining using Semantic Annotation with Recogito and automated text mining using Latent-Dirichlet Allocation (a type of topic modelling) in RStudio. To further highlight how visualizing perceptions, narratives, and contexts that exist within heritage discourses illustrates how language can indicate shifting relationships with the materiality of archaeological heritage landscapes.

Computational applications and quantitative methods and reasoning are important approaches within the fields of archaeology and cultural heritage studies making it increasingly important to analyze the methods themselves and how they may be used. It is the belief of this author that textual analysis should be an integral toolkit within archaeology and cultural heritage studies. This will allow for the development of current software to be applied to additional textual sources, development of better reproducible methodologies and workflows, and access to otherwise untapped and unresearched geospatial and heritage data.

References:

ICOMOS Australia. (2013). The Burra Charter and Archaeological Practice. https://australia.icomos.org/wp-content/uploads/Practice-Note_The-Burra-Charter-and-Archaeological-Practice.pdf

ICOMOS New Zealand. (2010). ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value. https://www.icomos.org/images/DOCUMENTS/Charters/ICOMOS_NZ_Charter_2010_FINAL_11_Oct_2010.pdf

Lafrenz Samuels, K. (2016). Transnational turns for archaeological heritage: From conservation to development, governments to governance. Journal of Field Archaeology, 41(3), 355–367. https://doi.org/10.1080/00934690.2016.1174031

Solli, B., Burström, M., Domanska, E., Edgeworth, M., González-Ruibal, A., Holtorf, C., Lucas, G., Oestigaard, T., Smith, L., & Witmore, C. (2011). Some Reflections on Heritage and Archaeology in the Anthropocene. Norwegian Archaeological Review, 44(1), 40–88. https://doi.org/10.1080/00293652.2011.572677

Tilley, C., & Cameron-Daum, K. (2017). The Anthropology of Landscape: Materiality, Embodiment, Contestation and Emotion. Introduction. In C. Tilley & K. Cameron-Daum (Eds.), Anthropology of Landscape: The Extraordinary in the Ordinary (pp. 1–22). UCL Press. http://www.jstor.org/stable/j.ctt1mtz542.7

Waterton, E., Smith, L., & Campbell, G. (2006). The Utility of Discourse Analysis to Heritage Studies: The Burra Charter and Social Inclusion. International Journal of Heritage Studies, 12(4), 339–355. https://doi.org/10.1080/13527250600727000

94. Past Landscapes and Future Technologies – Multimodal AI for the Analysis of Historical Maps

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Historical maps are an important link between past, present, and future. In Europe and beyond, in the 19th century large-scale, top-down efforts led for the first time to a comprehensive and accurate, yet often politically charged cartographic coverage of the landscape. Using standardised graphical and textual elements, these maps depict pre-industrial landscapes that contain many archaeological/historical elements of land-use, water/resource management, production, etc. not available from other sources. The use of these maps for archaeological/historical research and heritage management is often limited to small case studies since efficient methods for the systematic large-scale analysis of map contents are still lacking despite promising recent efforts to extract either graphical elements (Garcia-Molsosa et al. 2021) or text (Can and Kabadayi 2021) from historical maps.

In this pilot project, we are developing automated multimodal (i.e., text and image) methods for the semantic analysis of historical maps, which can lead to a variety of applications. As a first step, we have generated a labelled dataset of map content large enough to train a Deep Learning algorithm and to evaluate its performance.

The dataset consists of two map sheets from the Topografische Militaire Kaart (TMK; Topographic-Military map) from 1850. The map sheets used are called the Nettekeningen and were made in a scale of 1:50.000. There are 62 sheets that cover almost the entire Netherlands, which are further subdivided into four quarters or submaps. Each quarter from the Nettekeningen is derived from four smaller maps in a scale of 1:25.000 called the Veldminuten, of which the data was gathered between 1836 and 1856 (Wolters-Noordhoff Atlasprodukties 1990).

The two submaps we have used for the map-labelling are sheet 32-3 and 39-2, both located in the provinces of Utrecht and Gelderland, in the central part of the Netherlands. The total area used in the dataset is about 500 km2.

The main outcome of the pilot is a labelled dataset marking recurring object classes relevant for archaeological/historical reconstruction of landscapes on historical maps from the Netherlands (e.g., woodlands and toponyms). This dataset serves as input for training a multimodal classifier that is able to automatically detect further instances of those classes in comparable maps based on a combination of textual and graphical elements. In this paper we will present the dataset and discuss the outcome of the trained multimodal classifier.

Once the pilot is concluded, the classifier will be made available through Github. Since few labelled datasets for historical maps are available so far, ours will be published in an open repository (e.g., Zenodo) with an accompanying data paper in the CAA proceedings. Part of this publication will be the annotation guidelines developed in the project for segmenting and annotating historical maps that can be used as starting points for similar research and enhances reusability.

Potential applications of this novel approach include but are not limited to:

- Extraction of vanished archaeological/historical sites and objects for archaeological research and heritage management;
- Studying the relation between archaeological sites and past landscape;

- Extraction of vanished elements of historical land/water management, natural resources, etc. as a basis for the development of historically grounded climate change mitigation strategies;

- Documentation and analysis of political/ imperial/colonial map making strategies that impact regional/local diversity, identity, and heritage.

References

Can YS. and Kabadayi ME, 2021. Text Detection and Recognition by using CNNs in the Austro-Hungarian Historical Military Mapping Survey. In: Proceedings of the 6th International Workshop on Historical Document Imaging and Processing (HIP '21), 25–30. https://doi.org/10.1145/3476887.3476904

Garcia-Molsosa A, Orengo HA, Lawrence D, Philip G, Hopper K and Petrie CA, 2021. Potential of deep learning segmentation for the extraction of archaeological features from historical map series. Archaeological Prospection 28: 187–199. https://doi.org/10.1002/arp.1807

Wolters-Noordhoff Atlasprodukties (ed.) 1990. Grote historische atlas van Nederland, schaal 1:50. Groningen.

190. Machine Learning and Generative AI for Archaeological Application

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The application of machine learning (ML) methods to improve the quality and range of both quantitative and qualitative data captured in non-destructive site surveys (i.e., Unmanned Aerial Vehicles [UAVs] and LiDAR-enabled smartphones), and to streamline digital analysis of archaeological data is extremely appealing. In 2022, we tested this approach in our return to fieldwork after a three-year hiatus. Despite challenges encountered when training our algorithm for the first time, and the initial classification of only a small range of objects (i.e., sherds, stones, leaves, and sticks) using the YOLOv5 object detection model, the initial results were informative and intriguing, but also statistically marginal. We obtained a precision score of 0.28 due to the small dataset of only 56 images used for training the algorithm during our pilot study. In our initial experiment, we also discovered that architecture and site components such as canals and roads recorded with off-the-shelf UAVs were highly recognizable at elevations of 50 or 100 meters, but that it was necessary to photograph small objects using our smartphones to capture added details including artifacts that we observed on the ground. We expected that when trained on a larger dataset consisting of both high-quality remotely sensed and near-surface imagery, the algorithm would be much more successful at detecting and classifying both anthropogenic and natural objects and would thus provide expediently captured multi-scalar datasets for higher-level analysis.

During our second year, we aimed to improve the accuracy of the object detection model and returned to the field to record additional UAV footage and subsequently re-train the YOLOv5 model. Upon our 2023 return to the field, however, we encountered an unexpected obstacle. Extensive invasive vegetation which is the result of the pending major El Niño cycle covered nearly the entirety of the archaeological site we aimed to record, thus necessitating modification to the procedure implemented for training the YOLOv5 model in the previous year. We ran the survey as planned and returned from the field with new UAV data not knowing what to expect.

This paper discusses both improvements made in areas of object detection accuracy with the expanded 2023 dataset, and advances made through the application of generative AI that was used to eliminate and avoid noise caused by invasive vegetation. These techniques allowed us to document and expand our understanding of site characteristics, including some changes that occurred between 2022-2023. This research expands on what we learned using YOLOv5 and improves the training process despite complexities in aerial and terrestrial data captured in 2023. In cases like ours where the success of research is dependent on data captured during short field seasons, generative AI and ML applications for remotely sensed and near-surface data provide several important advantages for non-destructive site surveys. In expanded site-monitoring applications, we see these tools as nearly indispensable additions to our computational archaeological toolkit.

64. Statistical Image Processing (Decorrelation Stretch) and Deep Learning (CycleGANs) to Restore Images of Faded Artworks

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The deterioration of artworks over time is attributed to various factors, encompassing irradiation energy from sources like ultraviolet and infrared radiation, degradation of organic matter caused by fluctuations in temperature and humidity, and the accumulation of dust and foreign matter on the surface of the artwork. Many pieces in the collections of Japanese museums are especially sensitive to changes in light, temperature, and humidity. Once a piece has faded, the only means of restoration is physical.

In this study, a method was developed to restore the pre-faded image solely using the image without resorting to physical restoration. Initially, a photograph of the artwork was captured, following which the color profile of the image was improved and clarified through statistical image processing (Decorrelation stretch) to enhance and bring clarity to blurred motifs. The Decorrelation stretch is a technique used to enhance the colors of a raster image by altering its color profile. However, during the conversion of the color profile, the original artwork's colors undergo significant alteration, compromising the artwork's original artistic value. Therefore, the use of deep learning (CycleGANs) allowed us to verify the authenticity of images where color profiles were altered through decorrelation stretching and images depicting similar works with minimal fading.

The CycleGANs effectively transferred the color and textures of well-preserved gold sutras on dark blue paper onto the decorrelation-stretch-processed faded sutra images, while also transferring the color and textures of the decorrelation-stretch-processed faded sutras onto the well-preserved sutra images (Figures 1 and 2). The faded and well-preserved sutra images used in this study were derived from artworks dating back to the Heian period, specifically the 11th century.

Apart from the Adversarial Loss function, which is the primary algorithm of the Generative Adversarial Network (GAN), the CycleGANs have two Cycle Loss functions (Figure 3), as well as the Identical Loss function, to ensure that the transformed images revert back to the original images.

In this study, an attempt was made to restore images by learning from multiple images of similar artworks that differed from the faded work and exhibited lesser degrees of fading. As a result of applying this method to a sutra buried in the ground, which had experienced text and image blurring due to rainwater seepage, we successfully restored the image to its original clarity before fading. It was possible, as a result, to restore the faded artwork images in the museum's collection to their original state without compromising the original value of the work.

This method did not impose any physical burden on the artwork and successfully restored the image to its pre-faded state without compromising the original value of the artwork. If this method becomes widespread, it is anticipated that the potential value of numerous works in museum collections will be reassessed, further promoting the utilization of cultural property.

References

[1] Itagaki Masatoshi, Kawano Kazutaka, and Fujita Haruhiro. "Reconstruction of Faded Wooden Tablets by Uncorrelated Stretch and Cycle GAN." In Proceedings of 1st Workshop of Deep Learning in Archaeology and Cultural Properties, November 2021.

[2] Kawano Kazutaka, Miyao Toru, and Yamamoto Ryo. "Practice of Humanities Informatics Using Principal Component Analysis and Deep Learning of Images of Cultural Properties." Tofu-seisei: The Bulletin of Kyushu National Museum 17, March 2022: 55–66.

[3] Miyao Toru, Fujita Haruhiro, Itagaki Masatoshi, Ichikawa Kenta, Nagumo Ayaka, and Kawano Kazutaka. "Voxel programing for 3D-RGB Jomon Potteries' deep learning cluster analyses and evaluation on 3D-data resolutions." In 46th Conference Proceedings of Japan Society of Archaeological Informatics, Vol.26, March 2023: 66–71.

116. Deep Learning using Sidescan Sonar for Detection of Underwater Aircraft Wrecks from U.S. Conflicts

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Introduction

This project focuses on the development of an edge-based remotely sensed data and deep learning approach for detection of submerged aircraft sites from various U.S. conflicts, including World War II. The objectives of this work are to evaluate the application of deep learning for detection of aircraft wrecks, and whether these models are implementable in near real-time. To address this, a training dataset and tested deep learning frameworks for aircraft detection have been compiled. This work is central to providing fullest possible accounting of the United States service members missing in action for the families and the nation. If successfully implemented, machine learning has the potential to facilitate aircraft search efforts, increase the rate of detections, and increase the likelihood of air craft wreckage association.

There is little published work on the use of machine learning for the detection of underwater aircraft wrecks, or shipwrecks. The work that does exist is limited by the lack of training data. Deep learning, while particularly appropriate for the challenging task of detecting aircraft wreckage which is likely to look non-uniform, requires massive amounts of training data. Some studies attempt to generate synthetic data to address this issue. We compiled a large training dataset by using archival and newly collected data across nine separate field campaigns in five different countries. This has provided the team with the opportunity to develop a robust and generalizable model for accurate wreck predictions. This work builds on related work focused on deep learning for shipwreck detection (Character et al. 2021).

Methods and materials

Training data consisted of archival sidescan sonar data collected since 2019 as well as data that the team collected as part of the machine learning work over the past year. A small number of sonar images of aircraft wreckage (approx. 10) were also gathered from online sources. Additionally, there is magnetometer data that we are also working to incorporate into the model. Data were collected with two REMUS100 autonomous underwater vehicles (AUV), each outfitted with a sidescan sonar and a laser pumped cesium magnetometer. Data were collected in Croatia, Denmark, Federated States of Micronesia, Marshall Islands, and the United States of America, and from the internet, and include approximately 40 aircraft augmented to produce 500 training images, as well as a diversity of true negative background topography. Aircraft in the training dataset vary in size and morphology, including both small and large aircraft nearly intact and in pieces. Magnetometer data exists for three of the aircraft sites.

We used SonarWiz (Chesapeake Technology) to generate sidescan and magnetometer images. To determine the optimal balance between computational speed and model accuracy, we tested several different approaches to sonar image generation, including a single mosaic, line-by-line images, and two mosaics composed of every other line. We annotated data using ArcGIS Pro (Esri), creating feature class boxes around aircraft wreckage. We then used an ArcGIS Pro tool to convert the feature class file to bounding boxes. This tool does not generate the bounding boxes in the necessary formats for input into deep learning models, therefore we then used a combination of Python scripts and Excel to properly format annotations. We used an annotation tool to generate bounding boxes for the internet data.

We have completed testing of several different versions of the first deep learning model, YOLOv7 (Wang et al. 2023). We plan to compare the performance of YOLOv7 to that of Faster R-CNN (Ren et al. 2015) this winter. We have experimented with several variations of input tile size, batch size, and epochs, comparing performance across runs. We also plan to test different ways of displaying and visualizing the sonar, similar to what is customary with lidar digital elevation model (DEM) data.

Results

Due to the overlapping nature of the sonar data collection, we found that generating two mosaics, one composed of even-numbered sonar lines and the other composed of odd-numbered sonar lines, provided the optimal balance between computational efficiency and model accuracy. Tile sizes of 640 x 640 pixels worked best for YOLOv7 model input, along with a batch size of 16 and 100 epochs.

The model produced a precision score of 0.7, a recall score of 0.79, and an F1-score of 0.74. We also tested the model on new data collected in Micronesia in April and June of this year and successfully detected three out of four new aircraft in the test dataset.

Discussion

Our current work focuses on testing a Faster R-CNN model. While YOLO architectures run more quickly than the R-CNN architectures, they have been shown to sometimes be less accurate. Moreover, as with YOLO models, R-CNN models have also been shown to perform well for detection of aircraft wrecks and shipwrecks. Therefore, we want to compare the performance of both model types. We are also interested to see how different ways of visualizing or displaying the sonar might contribute to model performance. There is no published work on this topic.

The product of this work will be a manual, trained model, and code that enable individuals who have basic Python proficiency, to run the model for aircraft wreckage detection in new data. This work provides new insights and tools to apply to past, current, and future data collection in support of their mission.

References:

Character, L., Ortiz Jr., A., Beach, T., L.-B., S. 2021. “Automatic identification of shipwrecks using lidar, sonar, and deep learning.” Remote Sensing 13(9): 1759.

Ren, S., He, K., Girshick, R., Sun, J. 2015. “Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks.” Advances in Neural Information Processing Systems 28: 1-9.

Wang, C.Y-., Bochkovskiy, A., Liao, H.-Y. M. 2023. “YOLOv7: Trainable bag-of-freebies sets new state-of-the-art for real-time object detectors.” Proceedings of the IEEE/CVG Conference on Computer Vision and Pattern Recognition (CVPR): 7464-7475.

72. Archaeological Predictive Models, Machine Learning Algorithms and Unbalanced Datasets: A Case Study in the Rock Art Sites of the Pajeú Watershed, Pernambuco/Brazil

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The development of technologies such as surveying equipment, remote sensing, geophysics, and laboratory analyses has spearheaded an increasing amount of archaeological data and methodologies to analyze them, in particular for the study of spatio-temporal patterns (Huggett 2020). One of the tools used in spatial analysis is Archaeological Predictive Modelling (APM), popularized since the 1960s in CRM projects, which has shown to provide quick and reliable outcomes for understanding and predicting spatial patterning of settlement and other human activities (Verhagen and Whitley 2020).

By the end of the 20th century the improvement of computer hardware and software allowed for the introduction of the use of Artificial Intelligence (AI) in APM. One of the branches of AI is Machine Learning (ML) defined as series of algorithms capable of “learning” from a given layer of data and thus to apply its knowledge to information that is still unknown (Barcelo 2018). This technique will be used in this work.

AI has been used in APM in a myriad of applications. Some of them try to find specific characteristics from remote sensing images or even extracting directly from raster data, the feature patterns that could indicate relations between archaeological remains and socio-environmental features.

This paper develops an APM using ML in order to search for recurrent patterns that relate social-environmental features to rock art archaeological sites. This helps us to find rupestrian vestiges in the Pajeú Watershed, a region in the State of Pernambuco in Northeastern Brazil. Furthermore, we offer a methodological basis that could be applied in other regions of the Northeastern semiarid area of Brazil and help not just academic projects, but also private ones.

The APM developed tries to distinguish between two classes, one with rock art vestiges (positive class) and another one without (negative class). Here we call places with vestiges archaeological sites, and the negative classes absences. There is a disparity in the quantity of data from these two groups, as there are many more absences than archaeological sites, constituting an unbalanced dataset.

The data referring to rock art sites were inserted in a GIS, together with the information that represents the absences, both obtained through navigation GNSS equipment. To address the environmental determinism issue related to most of APM, we used three groups of purely environmental features (topography, catchment resources, sun exposure) as well as socio-environmental ones, separated into two categories (visibility index and accessibility). Most of the features, excluding the catchment resources, were extracted from the SRTM DEM (30 m resolution) satellite images. All features went through a statistical analysis in order to relate the location of the archaeological sites or absences to the socio-environmental characteristic. Two different metrics were applied: the median and the standard deviation. Each of these became a column in the final data set, resulting in 48 variables.

We then exported the analysis results to be processed in Python. For this, we had first to transform our spatial database in QGIS into a CSV format. We imported the tabulated information and removed all the null data. After that, we split our data set in three parts (70 % training, 15 % validation, 15 % test). Finally, we also re-normalized our data values to fit within the same range.

To deal with the unbalanced nature of the dataset (1266 negatives against 155 positives instances), we worked with different types of resampling methods in the training set: the Synthetic Minority Oversampling Technique (SMOTE), K-means + SMOTE and the Adaptative Synthetic Sampling Approach (ADASYN). All these techniques use an oversampling method to deal with the unbalanced data set, which means that they try to balance the data by creating extra samples in the minority class. After that, we used different types of ML algorithms for each resampling technique chosen, in order to test and compare different behaviors. We ran a Decision Tree, a Logistic Regression, a Random Forest and a Multilayer Perceptron.

We also considered ML algorithms that directly take into account unbalanced datasets. The Balanced Random Forest and the Balanced Bagging both use an under-sampling strategy where samples are taken from the majority class in order to equalize them to the minority one. Ultimately all the ML methods considered were combined in a single model, which we call the ensemble method.

The models were evaluated observing the recall, precision, F2 score and through a confusion matrix. As Brandsen (2022) states, archaeological prediction tasks usually seek to achieve a high recall as this statistical metric is focused on the true positive samples. The precision intends to check all the positive instances (true and false positives) and the F2 score is the weighted mean of precision and recall, putting more emphasis on recall. Finally, the confusion matrix is the organization of the results in a NxN matrix, where the values of True Positive, True Negative, False Positive and False Negative, are presented.

After evaluating the model, data with unknown classes, that is, those that are neither absence nor presence, were inserted and the model was fitted based on the training data. In simpler terms, the model was tested with new data to see how well it could predict outcomes beyond the data it was trained on. In the end, all the data were returned to QGIS as vectors, so we had to rasterize this. Finally, we got a map designed with a color scale showing 5 different probability classes: low (0 - 0.2) , low/medium (0.21 - 0.4) medium (0.41 - 0.6) , high/medium (0.61 - 0.8), high (above 0.8).

The predictive maps generated from the model show that some areas are highlighted regardless of the ML algorithm used. From this, we conclude that some features, such as aspect, curvature profile, visibility index, and insolation during sunrise, were particularly important to include in the model. The achieved results can be corroborated with a test of the model trained in the Pajeú, in another well-studied semiarid region.

Also, the model was used to plan the survey strategy for a field activity carried out at the end of 2022. During this research we found five more archaeological sites inside the Pajeú Watershed, (one in a low, one in a medium, and three in a high probability area), all this in just 4 days of work. It is important to point out that the archaeological sites found in low and medium probability areas have specific characteristics which are difficult to extract from SRTM images. This is why it is important to observe not only areas of high probability, but also the lower ones.

References

Barcelo, Juan. 2018. “Artificial Intelligence”. In The Encyclopedia of Archaeological Sciences, organizado por Sandra L. López Varela, 1–6. Newark: JohnWiley & Sons. https://doi.org/10.1002/9781119188230.saseas0044.

Brandsen, Alex. 2022. “Digging in documents: using text mining to access the hidden knowledge in Dutch archaeological excavation reports”. PhD Thesis, Leiden University, 2022. https://scholarlypublications.universiteitleiden.nl/handle/1887/3274287

Huggett, Jeremy. 2020. “Is Big Digital Data Different? Towards a New Archaeological Paradigm”. Journal of Field Archaeology 45 (sup1): S8–17. https://doi.org/10.1080/00934690.2020.1713281.

Verhagen, Philip and Thomas G. Whitley. 2020, “Predictive Spatial Modelling”, in: Gillings, M., Hacıgüzeller, P. & Lock, G. (eds.) Archaeological Spatial Analysis: A Methodological Guide. London: Routledge Taylor & Francis Group, p. 231-246.

81. Standardisation in the Area of Big Data: Example of Automated Features Detection in Archaeology

Mathias Bellat (University of Tübingen); Thomas Scholten (University of Tübingen)*

Background:

Recent years have seen an increasing use of automatic solutions to detect archaeological structures (Argyrou and Agapiou, 2022). New applications of machine learning processes to detect forms based on remote sensing data (UAVs or satellites) have led to many solutions, ranging from custom programming in languages like R and Python to integrated software such as e-Cognition and ArcGIS. This diversification has extended to divers geographical areas, types of structures detected, and a wide chronological timescales, fostering a rich tapestry of practices. The data produced are rarely comparable, and the metrics used to describe the models' efficiency are difficult to compare. Additionally, the transparency of model pre-processing and training parameters is often lacking, making cross-study comparisons challenging. This presentation aims to give a handbook of good practices for more interdisciplinarity and point out the bad habits in the automated archaeological structure detection field.

Subject:

We undertook an analysis of 25 articles pertaining to archaeological structure detection and extracted and categorised best practices among researchers. We considered the type of model employed for automated detection, the pre-processing steps, and the classification approach (supervised, semi-supervised, or unsupervised). While transfer learning and segmentation are recognized as prerequisites for modern studies, their adoption and mention vary among publications. Among models, Convolutional Neural Networks (CNNs) are the most used and specifically, Mask R-CNN, extremely well suited for site detection (Altaweel et al., 2022). The use of RGB images also must be discussed as they are not optimised for structure detection (Felicetti et al., 2021). Systematics use of F1 score and confusion matrix is not attested and will lead to non-standardised output. Another important problem is the test and training data set, that are not always described and even more the pre-process which is often omitted.

Discussion:

- The variability in practices among archaeological researchers engaged in automated site detection can be attributed to multiple factors:
- The need for a comprehensive handbook or a coordinating framework to unify practices.

- Data set training of archaeological site of different geographical and chronological context.

- The rapid development of new models and data input that hinder the establishment of standardized datasets or models.

- The interactions between archaeologists and computing science are not very efficient until now, as modern machine-learning applications are rarely taught in archaeological classes.

It leads to autodidact practices which cannot be standardised.

This paper aims to open a debate on more standardised practices for archaeological site detection and promotes the creation of a community around shared methodologies.

References

Altaweel, M, A Khelifi, ZH Li, A Squitieri, T Basmaji, et M Ghazal. 2022. "Automated Archaeological Feature Detection Using Deep Learning on Optical UAV Imagery: Preliminary Results". Remote Sensing 14 (3). https://doi.org/10.3390/rs14030553.

Argyrou, A., Agapiou, A., 2022. "A Review of Artificial Intelligence and Remote Sensing for Archaeological Research". Remote Sensing 14 (23). https://doi.org/10.3390/rs14236000

Felicetti, A., Paolanti, M., Zingaretti, P., Pierdicca, R., Malinverni, E., 2021. "MO.SE.: Mosaic image segmentation based on Deep cascading Learning". Virtual Archaeology Review 12, 25–38. https://doi.org/10.4995/var.2021.14179

27. Performance Evaluation of Deep Learning Methods for Archaeological Object Detection in Airborne LiDAR Data

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Introduction

The introduction of lidar data in archaeological object detection has introduced new opportunities and new challenges. Starting with the opportunities, the lidar data, which is a detailed mapping of the landscape surface, may reveal archaeological objects that have previously been overlooked. In many countries, lidar data is being collected for large areas and for other purposes than archaeology.

This means that archaeological object detection may now be possible in much larger areas than before. The challenges are mainly of two kinds: Firstly, one needs to have methods that are able to identify the archaeological objects. Secondly, there are vast amounts of lidar data to apply object detection on. The second challenge calls for automated tools to aid in object detection, since it is not possible to manually look through all the available lidar data in order to spot archaeological objects, within reasonable time and budgets. There may also be a third challenge: whether the lidar data is of sufficiently high resolution for the archaeological objects to be visible.

Over the past decade, a new method for image recognition has emerged in computer vision: deep learning, based on deep neural networks. Image recognition based on deep learning is mimicking the human vision system in the human brain. The main principle is to train the deep neural network with thousands or millions of examples of images of the objects of interest. The current state-of-the-art of these methods is that they are able to process large amounts of image data, but that they are making some mistakes. Thus, a manual visual inspection of the predicted archaeological objects is needed. Also, they do not work directly on the 3D lidar point cloud data. The 3D lidar data must be converted to a 2D visualizations, e.g., local relief model (Hesse, 2010), before being input to the deep neural network.

In this study, we wanted to evaluate and compare some of the machine learning and deep learning methods that have recently been used for cultural heritage object detection in airborne lidar data.

By training the methods on the same data, and testing them on a separate dataset not seen during training, the methods could be compared in terms of false positive rates and false negative rates.

Materials and Methods

The airborne lidar data selected for this study covers areas with known locations of three types of cultural heritage: charcoal kilns, pitfall traps and grave mounds. The lidar data were split into three subsets: 'training', for optimization of method parameters; 'validation', for selecting the best set of method parameters encountered so far, and 'test', for evaluating and comparing the different methods on data not seen during training.

At the time of abstract submission, only two methods have been included in the evaluation: U-Net (Ronneberger et al., 2015) and Faster R-CNN (Ren et al., 2017). However, we are reporting on an ongoing study, and plan to include more methods in time for the CAA 2024 conference.

Results

As expected, none of the evaluated methods are predicting without mistakes, i.e., the false positive and false negative rates are larger than zero, which means that manual visual inspection of the prediction results is needed when using the methods.

Having said that, we observe that U-Net and Faster R-CNN perform almost equally well in terms of false negative rates, i.e., they are both able to locate almost the same number of cultural heritage locations in data not seen during training. However, U-Net has about ten times higher false positive rate, which means that manual inspection of the predicted locations would be more time-consuming with U-Net than with Faster R-CNN.

However, the comparison is biased, since Faster R-CNN was pretrained on a large number of natural images, while no pretraining was done for U-Net. This may explain the higher false positive rate for U-Net.

In order to compensate for this, we plan to extend the size of the training data set by inserting small subimages of known cultural heritage locations into images of landscapes with no visible cultural heritage locations.

Figure 1. Extension of training data by inserting subimages of cultural heritage objects into images of landscape with no visible cultural heritage locations. (a) Landscape image before insertion. (b) Landscape image after insertion. (c) Location of inserted charcoal kiln (red), grave mound (green) and pitfall traps (blue).

Discussion

The comparison between Faster R-CNN and U-Net was done on data with cultural heritage objects that are near-circular, meaning that position and size were sufficient to describe each object. However, for elongated objects, like, e.g., stone fences or hollow roads, U-Net would be more suitable, since it does not presume a specific shape but does semantic segmentation.

U-Net may be pretrained by replacing the first half of the deep neural network with a pretrained ResNet. Then the second half must also be replaced to match the architecture of the first half. However, it is still challenging to make a completely unbiased evaluation, since the pretraining of the methods may be on different data. A more realistic ambition is to compare the best versions of each method.

However, if one eventually is able to identify the best existing method, this is still only a temporary situation, as the evolution in artificial intelligence is still rapid. Therefore, we plan to publish the source code, to make it easier to compare new methods with existing ones.

One promising new direction in artificial intelligence, which is used in Chat-GPT, is training on large amounts of unlabelled data. We hope to see this technique being used in the near future on 2D visualizations of airborne lidar data as pretraining for cultural heritage detection.

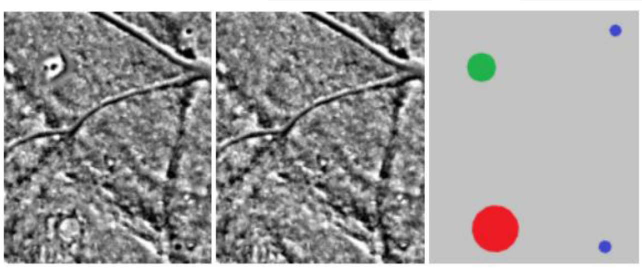
References

Hesse, R., 2010. Lidar-derived local relief models – a new tool for archaeological prospection. Archaeological Prospecttion 17, 67–72. https://doi.org/10.1002/arp.374.

Ren, S., He, K., Girshick, R., Sun, J., 2017. Faster R-CNN: towards real-time object detection with region proposal networks. IEEE Transactions on Pattern Analysis and Machine Intelligence 39 (6), 1137–1149. https://doi.org/10.1109/TPAMI.2016.2577031.

Ronneberger, O., Fischer, P., Brox, T., 2015. U-net: convolutional networks for biomedical image segmentation. In: Navab, N., Hornegger, J., Wells, W., Frangi, A. (Eds.), Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015. MICCAI 2015. Lecture Notes in Computer Science, vol 9351. Springer, Cham, pp. 234–241. https://doi.org/10.1007/978-3-319-24574-4_28.

Figures:



(a) (b) (c)

53. Issues and Solutions for Classification Models using Deep Learning for 3D data of Archaeological Materials

Ryo Yamamoto (Tokyo National Museum); Haruhiro Fujita (Niigata University of International and Information Studies); Kazuyoshi Kawahara (Niigata University of International and Information Studies); Kenta Ichikawa (BSN Inet); Ayaka Nagumo (BSN Inet)*

This study aimed to classify archaeological materials by deep learning. In particular, we utilized 3D-RGBA data, which becomes more common in the near future. However, there are various obstacles to deep learning of archaeological materials. This presentation will focus on solutions to these obstacles. Samples studied were 108 pieces of 6th century Sue pottery lid cups excavated in Japan, in the collection of Tokyo National Museum, with known types and dating criteria.

Among those various obstacles to deep learning of archaeological materials, a concern raised that missing or repaired parts of archaeological materials may become noise and affect the deep learning results, so we chose samples with perfect shapes. Inevitably, only 108 of the more than 600 sources from which data could be obtained were available. In addition, due to the computational resources available in this study, the 3D-RGBA data of 128x128x128 voxels may not have sufficient resolution for the analysis reflecting the detailed shape of the data[1].

Our team attempted to devise a solution for less biased data and developed a multi-head and multi-task model that made multiple inferences from multiple data. The multi-head and multi-tasking model could compensate for the low resolution of 3D-RGBA data in deep learning by adding high-resolution 2D orthographic images generated from the original 3D data together[2][3]. In addition, to accommodate bias in the number of data, we attempted to change the weighting the loss function for minority data, we defined a larger loss for misclassified minority data.

The inference accuracies of types and dating criteria were 58.65% [Confusion matrix1] and 71.15% [Confusion matrix2] respectively. These results were improvements of approximately 2 - 5% over the results without loss function weighting. Although the accuracy was not yet high enough. The solution is to increase the number of data, but also to devise ways to use the missing materials in addition to the complete materials for learning. For example, by masking or restoring missing parts through image processing, we may attempt to make them as usable for learning as if it were in its complete form.

References

[1]Miyao Toru, Fujita Haruhiro, Itagaki Masatoshi, Ichikawa Kenta, Nagumo Ayaka and Kawano Kazutaka. 2023. "Evaluation of Voxel data resolution and computational resources for Jomon pottery 3D deep learning cluster analysis." Papers and Proceedings of the Japan Association for Archaeoinformatics, Vol. 26(2023) : 66 - 71

[2]Yamamoto Ryo, Fujita Haruhiro, Kawahara Kazuyoshi, Ichikawa Kenta, and Nagumo Ayaka. 2023. "Model development of multihead - multitask 3D - 2D - CNN model cognition of Sue pottery." Papers and Proceedings of the Japan Association for Archaeoinformatics, Vol. 26(2023) : 62 – 65

[3]Fujita Haruhiro, Yamamoto Ryo, Kawahara Kazuyoshi, Ichikawa Kenta, and Nagumo Ayaka. 2023. "Model development of pseudo label supervised classification + clustering and visualization of model cognition by Grad-CAM." Papers and Proceedings of the Japan Association for Archaeoinformatics, Vol. 26(2023) : 56 – 61

172. A Framework for Integrating Domain Knowledge and Deep Learning for 3D Shape Analysis of Lithic Fragments

Steven Mills (University of Otago); Nirmal Das (Institute of Engineering and Management); Gerard O'Regan (Tūhura Otago Museum); Lana Arun (Tūhura Otago Museum); Tapabrata Dr. Chakraborty (University of Oxford); Richard Walter (University of Otago)*

Introduction

Advances in machine learning and artificial intelligence, and deep learning approaches in particular, have revolutionised many areas of analysis. These methods, however, are often quite opaque – they learn a mapping from the input data to the desired output, but are something of a black box. This raises challenges when incorporating expert knowledge about the process into a deep learning system. This is of particular concern when there are social or cultural aspects at play, as is often the case in archaeological and historical contexts. In this paper we propose an approach that allows us to open up the black box, at least in places, and insert more explicit reasoning, for the fine-grained analysis of 3D shape. In particular we target the analysis of lithic flakes from pre-contact Māori stone tool manufacture. This application is both of great archaeological interest, and provides an ideal test-case for the shape analysis network.

Domain Knowledge in Deep Learning

Recently there has been great interest in the machine learning and artificial intelligence communities in integrating explicit algorithms into the deep learning process. There are a wide range of methods, but the general approach is to ensure that a derivative can be computed for the explicit algorithm, enabling error signals to pass across when training the network. This approach goes by many names, but one general framework that has been recently proposed are Deep Declarative Networks (Gould, Hartley and Campbell 2021). In this framework explicit reasoning can be wrapped inside a 'declarative node', which can then be inserted into an artificial neural network. The standard neural network training approaches then learn to provide the appropriate input to the declarative node so that it produces the desired output.

As a concrete example of how this might work, consider the pipeline shown in Figure 1. In this case we consider the task of labelling the key parts of a flake produced during stone tool manufacture. There are two main stages to this process – segmenting the flake into its components, and then labelling each part. Good algorithms exist for segmenting points on a 3D model and labelling components based on descriptors, but learning the weights for segmentation or the features for component labelling are hard tasks to define mathematically. These later tasks are well suited to deep learning, so we propose a mix of explicit algorithms (orange boxes) and learned features from neural networks (blue). These explicit algorithms can then be designed or adapted to incorporate expert knowledge.

One advantage of this approach is that the entire system can be trained 'end-to-end'. That means that the early stage feature extraction used for segmentation can be chosen in order to ensure that the segments that are produced are suitable for the later processing stages (labelling in our example). More importantly, it allows us to use machine learning when appropriate, while still retaining the benefits of more explicit reasoning when we can. This provides a clearer understanding of what computation is being performed.

Application

We are in the initial stages of implementing a demonstrator of the approach we propose. For the first steps we are developing segmentation and labelling methods in the declarative network framework on generic 3D shape analysis benchmarks (Mo, et al. 2019). However, the archaeological application is an ideal test for more nuanced shape analysis. The flakes formed during stone tool manufacture have complex but patterned shape characteristics (Andrefsky Jr. 1998), but these can be obscured by gross variation in overall shape.

In particular, each flake is formed by a sharp tap to a flat part of the tool being formed – the striking platform. This causes a shock-wave to pass through the stone, creating a distinctive bulb of percussion. If skilfully struck, this shock-wave forms a clean flake, with a sharp, uniform edge. Since these flakes have little visual texture detail, 3D shape is the sole cue for identifying these features. Measuring these properties gives us important information about the manufacture of these tools, but hundreds of flakes are produced in the production of a single tool. Automating this process, therefore, will require the integration of the power of deep learning with domain-specific knowledge to provide interpretable and robust analysis.

Conclusion

The machine learning revolution will have a significant impact on all areas of research. There is, however, a growing realisation that the incorporation of domain knowledge into these systems is necessary to produce reliable systems that can explain as well as compute. While our initial application is in archaeological 3D shape analysis, we believe that the general approach of incorporating expertise through explicit, expert-informed algorithms into deep networks allows us to have the best of both worlds. We can learn to extract features from large datasets automatically, while still understanding the analysis that is made on the basis of those features.

Acknowledgments

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References

Andrefsky Jr., W. 1998. Lithics: Macroscopic Approaches to Analysis. Cambridge University Press.

Gould, S., R. Hartley, and D. J. Campbell. 2021. "Deep Decarative Networks." IEEE Trans. Pattern Analysis and Machine Intelligence.

Mo, K., S. Zhu, A. Chang, L. Yi, S. Tripathi, L. J. Guibas, and H. Su. 2019. "PartNet: A Large-Scale Benchmark for Fine-Grained and Hierarchical Part-Level 3D Object Understanding." IEEE Int. Conf. Computer Vision and Pattern Recognition, 909-918.

78. Their Final Resting Place: A Random Forest Approach to the Location of Early Iron Age Burial Mounds in Western Switzerland

*Timo Geitlinger (University of Oxford)**

Predictive models–understood as techniques designed for the prediction of the location of certain items in a particular landscape (Verhagen, Whitley 2020)–are well-established tools for CRM-related purposes as well as the study of human locational behaviour. In the past, linear or logistic regressions have mostly been applied as statistical evaluation tools. However, in recent years machine learning approaches such as maximum entropy or random forests have become increasingly popular for archaeological approaches to predictive modelling. As case study, this paper presents a predictive model of the locations of Early Iron Age burial mounds in western Switzerland using random forest algorithms. In western Switzerland, Iron Age burial mounds are abundant and conspicuous landscape features. Despite their clear perceptibility, the connection between mounds and their landscape setting has traditionally been neglected and sometimes even been fully denied by past researchers.

As points of presence, I reconstructed and validated the location of roughly 250 burial mounds through literary sources and lidar maps. I prepared two sets of 250 points of absence, resulting in two different predictive models: by only excluding today's locations of rivers and lakes as well as the immediate surrounding of the burial mound sites, one set consisted of random points within the area of investigation. The other set was derived from random points on the area of today's motorways. Most motorways in western Switzerland were built during the last 50 years and have been thoroughly archaeologically investigated. From an archaeological perspective, motorways can thus be seen as "real" areas of absence. I based the predictive model on a selection of 22 input parameters, extracted from maps representing topographical factors (elevation, slope, aspect, curvature…), classifications of landscape features (planes, peaks, channels, ridges, pits…), soil (agricultural suitability), distance to water, accessibility (distance to historic routes, total cost raster), and visibility (total viewshed, cumulative viewsheds from mounds). To approach a more realistic picture of possible Iron Age choice of site location, the selection of geographical data, thus, aimed at including also socio-cultural factors such as visibility and movement. The maps were derived from a digital elevation model and prepared in ArcGIS and Landserf. Using Esri's forest-based classification tool, the predictive models were first trained with all variables. To further refine the model, I increasingly restricted the input variables to those variables revealing the highest model importance. The resulting models were depicted as uncertainty surfaces in R.

The final models were statistically surprisingly sound, having sensitivities, activities, F1 scores, and out of bag errors of around 80%. The models clearly suggest that the locational behaviour of Early Iron Age burial mounds follows predictable patterns, especially emphasising the importance of factors such as visibility, accessibility, and slope. Nevertheless, the evaluation of the resulting models also points to certain caveats in the use of machine learning algorithms for predictive models:

- Points of absence: Though the second set of points represented "real" points of absence, the resulting model was relatively unspecific. In fact, since motorways themselves follow specific topographical patterns, the second model seemed better suitable for the prediction of the points of absence than potential mound sites. To train the model, it thus seems important to ascertain spatial randomness even among verified absence points.

- Spatial autocorrelation: Even though the model clearly also revealed areas in which burial mounds are not yet known at all, visual evaluation of the model revealed that spatial auto correlation potentially biased its performance. To gain a more realistic impression of the predictive power of the model, further validation techniques such as k-fold cross validation seem crucial (Castiello, Tonini 2021).

- Algorithms: It would have gone beyond the scope of this paper to further evaluate different machine learning algorithms. As recent studies suggest (Yaworski et al. 2020), in the absence of true-absence points random forests are not necessarily the best performing regression algorithms for archaeological purposes despite their wide use.

References

CASTIELLO, M. E. & TONINI, M. 2021. An Explorative Application of Random Forest Algorithm for Archaeological Predictive Modeling. A Swiss Case Study. Journal of Computer Applications in Archaeology, 4, 110-125.

VERHAGEN, P. & WHITLEY, T. G. 2012. Integrating Archaeological Theory and Predictive Modeling: a Live Report from the Scene. Journal of Archaeological Method and Theory, 19, 49-100.

YAWORSKY, P. M., VERNON, K. B., SPANGLER, J. D., BREWER, S. C. & CODDING, B. F. 2020. Advancing predictive modeling in archaeology: An evaluation of regression and machine learning methods on the Grand Staircase-Escalante National Monument. PLOS ONE, 15, e0239424.

S8: Maritime Horizons: Modeling Movement and Navigation

Thursday 11th April, 15:20 –17:00, 260-073 OGGB4

Karl Smith, Unaffiliated
Emma Slayton, Carnegie Mellon University

The theme of this CAA is Across the Horizon, which is itself a concept drawn from maritime mobility. Computational modeling and seafaring analysis is itself crossing an horizon in our field, as the topic is becoming more researched. These horizons include those who are approaching both computational methodologies and seafaring theory. We also recognize the relevance of regional connection to Pacific navigation, and we feel the discussion of maritime heritage and seafaring theory is an important aspect of New Zealand based archaeology and seafaring modeling. This session focuses on computational models for maritime movement and navigation – a growing area of research that has benefitted from several past CAA sessions (see below). The particular focus of this session is twofold: on computational approaches to modeling maritime movement – how and where ships, canoes, rafts, etc. move over bodies of water, and approaches to modeling navigation – the means by which the people in those watercraft find their way to their destinations. Neither of these questions are new to the wider communities of terrestrial or maritime movement (e.g. Lock and Pouncett 2010; Smith 2020). Some examples of methodologies for modeling movement include least-cost-path analysis, agent-based models, isochrone route-finding. Examples of computational approaches to modeling navigation include visibility analysis, coastal affordances, and celestial markers. Most analyses of maritime movement deal with both of these issues, as they can be difficult to separate – assumptions about navigation can be found in most maritime movement models. Examining how these two concepts are entangled is important to developing shared methodologies to understand past seafaring practice. The field of computational water-based modeling movement is still relatively new, and as such there is much that can be added to how we approach technical aspects of the model as well as theoretical considerations we place as boundaries to their use. Conversely, as researchers develop new techniques they can create parallel methodologies or ways of processing data. Several researchers are using the same approach in the same region (e.x. Blakley 2018 and Poullis et al 2019), producing different results that allow for evaluation of the fidelity of different projects.

We would like to invite applicants to this session to submit papers that engage with themes of navigation and maritime movement, for example: case studies involving computational models that describe seafaring or route-finding; terrestrial movement analyses that engage with maritime spaces, such as coastal interactions; analyses of maritime or coastal visibility; discussions of maritime heritage within the archaeological record and its connection to broader understandings of seafaring practice; exploration of computational maritime archeology for the Pacific Region; and generating environmental datasets and/or incorporating them into maritime movement analyses. We also invite the submission of papers that address the theoretical basis for maritime modeling, issues with datasets used to create maritime models, or the broader state of the field.

Through this session we hope to foster a discussion of topics related to navigation and maritime movement, thereby providing a forum for researchers already working on these topics, and hopefully encouraging others to create their own models and further develop our shared computational practice. Recent work in developing methodologies for modeling maritime movement and navigation include the Computational Archaeology and Seafaring Theory (CAST) conference in 2022, the formation of the Computational Modeling Water-Based Movement special interest group, and sessions/roundtables at previous CAAs (i.e. Slayton 2023; Kyriakidis et al. 2022; Slayton et al. 2022; Slayton and Smith 2021). This session builds on these successes and shares their main goals: to connect researchers who are already working on issues of maritime movement and navigation, and to encourage new researchers interested in these topics.

References

Blakely, S. (2018). Sailing with the Gods: serious games in an ancient sea. thersites. Journal for Transcultural Presences & Diachronic Identities from Antiquity to Date, 7.

Lock, G. and J. Pouncett 2010. Walking the Ridgeway Revisited: The Methodological and Theoretical Implications of Scale Dependency for the Derivation of Slope and the Calculation of Least-Cost Pathways, in: Frischer, B., J. Webb Crawford and D. Koller (eds.), Making History Interactive. Computer Applications and Quantitative Methods in Archaeology (CAA). Proceedings of the 37th International Conference, Williamsburg, Virginia, United States of America, March 22-26 (BAR International Series S2079). Archaeopress, Oxford, pp. 192-203.

Kyriakidis, P., Gravanis, E., Demesticha, S., Reepmeyer, C. Moutsiou, T., Bar-Yosef, B., Chliaoutakis, A., Zervakis, H., Theodorou, K., Xoplaki, E., and Montello, D. (2022) CAA Oxford. Session 27: Modelling prehistoric maritime mobility Jarriel, K. (2018). Across the Surface of the Sea: Maritime Interaction in the Cycladic Early Bronze Age. Journal of Mediterranean Archaeology, 31(1).

Smith, K. (2020). Modeling Seafaring in Iron Age Atlantic Europe. PhD Dissertation, University of Oxford: Oxford.

Slayton, E. (2023) CAA Amsterdam. Session 38: Computational Modeling Water-Based Movement.

Slayton, E., & Smith, K. (2021). Session 26: Moving Over Seas: Modeling Seafaring Routes to Analyze Past Connections. Presented at the Computer Applications and Quantitative Methods in Archaeology, Cyprus.

Slayton, E, Borreggine, J. Farr, R. H., Jarriel, K., Leidwanger, J., El Safadi, C., Davies, B., and Smith, K. (2022) CAA Oxford. Session 23: Computational archaeology and seafaring theory.

S8: Maritime Horizons: Modeling Movement and Navigation	
15:20-15:40	*50. A Primer for Seafaring Modeling: CAST's Approach to Leveraging a Community of Practice to Develop Core Tenants of a Sub-field* *Emma Slayton (US)*; Katherine Jarriel (Purdue University); Marisa borreggine (Harvard University)*
15:40-16:00	*31. Toward the Sea or the Land: Cultural Identity and the Choice of Movement on the Water* *Hongpeng Luo (Tianjin University)*; Jie He (CN)*
16:00-16:20	*108. 4D Visibility Surfaces for Maritime Navigation Models* *Karl J Smith (Unaffiliated)**
16:20-16:40	*26. Voyaging Back in Time: New Experiments with Virtual Vaka Computer Simulation* *Simon H. Bickler (Bickler Consultants Ltd)*; Benjamin Davies (Tufts University; University of Utah)*

50. A Primer for Seafaring Modeling: CAST's Approach to Leveraging a Community of Practice to Develop Core Tenants of a Sub-field

Emma Slayton (US); Katherine Jarriel (Purdue University); Marisa borreggine (Harvard University)*

As new technologies develop and new quantitative methods are deployed to answer fundamental questions within the field of archeology, scholars must simultaneously devise best practices. As an emerging field matures, a myriad of projects may develop rapidly while the gap between established resources and new tools widens . These truths certainly apply to the burgeoning field of seafaring modeling applications for maritime mobility demonstrated in the archaeological record. Past efforts to connect members in this field of study have included bringing together researchers at conferences (e.g., the Computer Applications and Quantitative Methods in Archaeology [CAA] meeting) or through one-off gatherings such as the 2022 Computational Archeology and Seafaring Theory (CAST) workshop. While these efforts have supported the network growth, we recognize that there remains a desire for a guide to the intricacies of the field and an accessible discussion of general trends or best methods. In response to this need, the CAST group is developing a primer that will help orient and prepare scholars new to the field to model past maritime mobility. This paper will discuss the details of the guides contained within our primer, as well as the development of the work to provide insight into the process of building community-driven guides.

The CAST primer is broken down into themes related to the practical application of and guiding theory in computational seafaring models. This includes: a discussion of the state of the field for computational archaeology and seafaring theory (in vein of CAA sessions), evaluation of seafaring and navigation in theory and in practice (in vein of Berard 2016), an in-depth guide to the history of field and current methods approaches (in vein of Davis et al. 2015; Slayton 2018), a look into how past communities have dealt with disasters, risk, and resilience (in vein of Jariel 2018), and a glossary of terms that can orient the reader to the field. This paper will go into depth on these themes, as well as address specific case examples of research from various authors of the primer.

We will also discuss the impacts of the CAST 2022 keynote address and the authors of this talk's contributions to the field, as evaluated in the primer. The keynote delivered by seafaring practitioners Alson Kelen and Larry Raigetal delves into their work to advocate for and continue the traditions of vessel construction and wayfinding practices in the Pacific through educational programs and public advocacy.

Our hope is that this paper will serve as an introduction to the field for those beginning their journey as archaeological seafaring modelers, providing points of reference to new works and case examples of practical approaches and methods. In addition, we aim to update researchers enmeshed in this work with new progress in the field and contextualize possible future trends.

References

Bérard, B., Billard, J. Y., L'Etang, T., Lalubie, G., Nicolizas, C., Ramstein, B., & Slayton, E. (2016). Technologie du fait maritime chez les Kalinago des Petites Antilles aux XVIe et XVIIe siècles. Journal de la société des américanistes, 102(102-1), 129-158.

Davies, B., Bickler, S. H., & Traviglia, A. (2015). Sailing the simulated seas: A new simulation for evaluating prehistoric seafaring. Across Space and Time: Papers from the 41st Conference on Computer Applications and Quantitative Methods in Archaeology, Perth, 25–28 March 2013, 215–223. Amsterdam: Amsterdam University Press.

Jarriel, K. (2018). Across the Surface of the Sea: Maritime Interaction in the Cycladic Early Bronze Age. Journal of Mediterranean Archaeology, 31(1).

Jarriel, K., Borreggine, M., Farr h., Leidwanger, J., & Slayton, E. (2023) The State of the Field of Seafaring Modeling: Conversations from the CAST Workshop. Computer Applications and Quantitative Methods in Archaeology (CAA)

Slayton, E. R. (2018). Seascape corridors: Modeling routes to connect communities across the Caribbean Sea. Leiden University.

Slayton, E., Jarriel, K., Borreggine, M., Farr h., & Leidwanger, J., (2023) Seaing the Value of Communities of Practice: Connecting computational archeology research to community engagement and seafaring practitioner expertise. Computer Applications and Quantitative Methods in Archaeology (CAA)

Smith, K. (2022) CAA Oxford. Session 23. Computational archaeology and seafaring theory.

31. Toward the Sea or the Land: Cultural Identity and the Choice of Movement on the Water

Hongpeng Luo (Tianjin University); Jie He (CN)*

There is a long-standing belief in the maritime movement that initial settlements on most islands will likely consist of only small groups of people. However, for these populations to survive and flourish independently on islands, a sufficient number of people is necessary. Without large ships, a constant supply of resources, or a large enough population, it would be difficult to establish and sustain civilization on new islands, and the spread of culture would be extremely challenging.

Researchers now generally agree that around 7,000 to 5,000 years ago, the Austronesian people, who lived on the southeastern coast of mainland China, began to spread across the Taiwan Strait and into the South Pacific Ocean. The movement of populations brought about changes in social structures, fluctuations in supply and demand for resources, cultural shocks, and the creation of trade, all of which could be dangerous for an early society. Therefore, it raises the question of why this maritime movement occurred and what the cultural identity behind it was. The Austronesian people reached a broad area of the globe through the islands. Did they believe that there was land beyond the islands as they moved from one island to another?

The study aims to explore the relationship between cultural identity and the direction of movement. What cultural identity factors may influence the decision to travel by sea? Is there a preference for travel by sea or land? What are the cultural characteristics of the landscapes associated with each of these choices? Including: a. How does cultural recognition of ocean travel occur(Kuhn, Raichlen, and Clark 2016)? Moving on the ocean is more uncertain and dangerous than moving on land. While involuntary purposeless movement at sea may happen, the study focuses on purposeful situations. Understanding maritime mobility requires a clear cultural context. What drives movement at sea and what cultural identity is reflected in maritime movement? Was it for settlement, trade, or religion? b. Whether the ongoing sea movement was intended to reach the next island or to find eventual land? This raises focus on the relationship between chance and cultural identity(Ihara et al. 2020). Maritime movements are subject to randomness due to factors such as storms, disorientation, and currents. It is still possible for humans to arrive at unanticipated islands or land. Some scholars have also pointed out that random, purposeless islands make it more difficult to sustain human reproduction. However, this consideration is necessary if the movement continues. c. Did early humans choose to stay or move? What spatial characteristics would be presented by choosing the ocean as a means of movement versus choosing the land as a means of movement? The question of moving on or staying is not an easy one for early humans. Staying requires a sufficient population, time, and resources to sustain civilization(Bradshaw et al. 2019). But this also does not match the way in which the cultures of the Austronesian peoples continued to spread. Therefore, what cultural landscape identifiers or spatial features are associated with oceanic movement routes that distribute people to various regions of the globe?

The study selected Pingtan island, Taiwan island, and the surrounding islands on the southeast coast of China as the object of movement diffusion, possibly also considering the Guangdong-Hong Kong Macao Greater Bay Area, to explore possible social contexts and cultural motivations. In addition, since the ability to master movement in inland basins may be seen as a prerequisite for maritime movement, the Tongtian River Basin of the South Asian Silk Route was selected to discuss the difference between choosing river and choosing land route movement in the context of a more distinctive destination, which drives from religion culture. The different cultural landscapes that can be characterized by these two choices.

The study uses the method of cross-analysis of textual geographic information. On the one hand, cultural information is combined with space through historical and textual materials to facilitate intuitive understanding of the question of identity and choice in the process of cultural transmission. On the one hand, GIS, historical remote sensing imagery, spatial analysis, and movement and settlement modeling are utilized to depict the spatial characteristics of choice of sea and land.

Understanding the relationship between cultural identity, sea route selection and cultural transmission is crucial to comprehend the connection between civilization and the ocean. It helps to understand the possible spatial relationship from cultural identity to diffusion. It may help to comprehend the spread of culture, commerce, and settlement migration in more complex, broader, and longer time span movement road networks, such as the Maritime Silk Road.

References

Bradshaw, Corey J. A., Sean Ulm, Alan N. Williams, Michael I. Bird, Richard G. Roberts, Zenobia Jacobs, Fiona Laviano, et al. 2019. “Minimum Founding Populations for the First Peopling of Sahul.” Nature Ecology & Evolution 3 (7): 1057–63. https://doi.org/10.1038/s41559-019-0902-6.

Ihara, Yasuo, Kazunobu Ikeya, Atsushi Nobayashi, and Yosuke Kaifu. 2020. “A Demographic Test of Accidental versus Intentional Island Colonization by Pleistocene Humans.” Journal of Human Evolution 145 (August): 102839. https://doi.org/10.1016/j.jhevol.2020.102839.

Kuhn, Steven L., David A. Raichlen, and Amy E. Clark. 2016. “What Moves Us? How Mobility and Movement Are at the Center of Human Evolution: Mobility and Movement Are at the Center of Human Evolution.” Evolutionary Anthropology: Issues, News, and Reviews 25 (3): 86–97. https://doi.org/10.1002/evan.21480.

108. 4D Visibility Surfaces for Maritime Navigation Models

*Karl J Smith (Unaffiliated)**

This paper presents a methodology for (and demonstrations of) the creation of coastal visibility datasets that can be easily incorporated into maritime movement models. Coastal visibility is a crucial factor in non-instrumental navigation – especially for voyages in which mariners lose sight of the coast. In these cases a navigator’s ability to see land and to recognise landforms may determine whether or not the voyage is successful. As such the incorporation of coastal visibility into maritime movement models has been an important focus for the broader community of maritime movement modellers. Visibility metrics have been used as factors in affordance-modelling, as conditions for movement in least-cost-path movement models, and as navigation factors in agent-based movement models. In these various applications different methodologies have been used to quantify 'visibility'. This paper does not seek to create a standard for maritime visibility analysis, but rather to suggest a data format that can easily integrate different types of visibility analysis into movement models, and can also be used in comparisons of different visibility-quantification techniques.

Quantifying the 'visibility' of landscape elements is a complicated and ultimately phenomenological exercise that encompasses many different GIS approaches (see Wheatley & Gillings 2000). Modern-day proxies for maritime visibility (i.e. the visibility of the land from the sea) tend to be either highly formalised, involving sea-marks of standardised shape, size and colour, or else passed along as 'rules of thumb' (see, for example, McGrail 1998). Coastal visibility can be affected by a very wide range of factors, including weather conditions, atmospheric optical effects, and the geological appearance of the coast. In this paper I use several different computational approaches to quantify coastal visibility. The first is based on the measurement of the apparent size of the coast – the 'area' that it subtends in an observer's field of view. The second is based on skyline prominence – that is the apparent 'height' of the coastline as it appears on the horizon. The third is based on coastal landmarks – specifically how many of them are visible from a particular location. These measurements are intended as proxies for three different components of maritime visibility, respectively: the visibility of land in general; the visibility of prominent features that can be used to orient oneself along a coastline; and the visibility of known landmarks, which mariners with knowledge of these landmarks can use to orient themselves precisely in space. These approaches are based on techniques pioneered by Bernardini et al. (2013), and on scripts developed as part of my doctoral research.

These three approaches – visual area, skyline prominence, and landmark count – are computed using ArcGIS geoprocessing tools, coordinated by Python scripts. This method uses a DEM to compute skylines for a given point and elevation, identifies landmarks that intersect those skylines, and then transforms the vertices in that skyline to create a 2D representation of the skyline from the perspective of an observer situated at the given point. The area subtended by landforms in the skyline is then computed, and the skyline's prominence is calculated by the script. This process is then repeated for a 4D grid of points (spaced at regular X, Y, Z, and time intervals), and values for these points are exported as bins into a NetCDF file. NetCDF files are commonly used to represent aerodynamic and hydrodynamic datasets – and can therefore be incorporated into navigation models that accept multidimensional inputs. Using NetCDF as an output has several advantages: by precomputing visibility values into a multidimensional dataset, scripts that would otherwise use considerable resources calculating 3D visibility can be made to be more efficient; and by developing interchangeable datasets using different visibility metrics it should become possible to compare the effects of different types of visibility analysis on the performance of maritime movement models.

Ultimately, all non-instrumental means of navigation (and pilotage) rely on observation, and therefore on visibility. Mariners tend to rely on combinations of observations to fix their positions, including the observation of landmarks, wind / current / swell patterns, and animal behaviour. Although this paper focusses on the visibility of coastlines and landmarks, there is considerable scope for further development of maritime visibility analysis as a component of navigation models. By demonstrating how one of these types of observation can be quantified in GIS and expressed as a 3D surface, I hope to help inspire the creation of other maritime visibility datasets and thereby inspire conversations about the use of visibility analysis in modelling maritime movement.

References

Bernardini, W. et al. (2013). Quantifying visual prominence in social landscapes. Journal of Archaeological Science. 40 (11), 3946–3954.

McGrail, S. (2014). Ancient boats in North-West Europe : the archaeology of water transport to AD 1500. Oxford: Routledge.

Wheatley, D., & Gillings, M. (2000). Vision, perception and GIS: Developing enriched approaches to the study of archaeological visibility, in G. R. Lock (Ed.), Beyond the map: Archaeology and spatial technologies (pp. 1-27). Amsterdam: IOS Press.

26. Voyaging Back in Time: New Experiments with Virtual Vaka Computer Simulation

Simon H. Bickler (Bickler Consultants Ltd); Benjamin Davies (Tufts University; University of Utah)*

Seafaring is central to many narratives of human history; however, our ability to investigate ancient seafaring archaeologically is constrained by the preservation of maritime technology and the practical limitations of investigating seafaring events over deep ocean spaces. These uncertainties leave open a wide range of historical possibilities, but also present opportunities to explore them by way of computational modeling. In this presentation, we update progress on the agent-based simulation tool Virtual Vaka (Davies and Bickler 2021), introducing new capabilities for navigation, vessel performance, environmental data and modelling. Drawing on documented archaeological cases, we demonstrate some of these new mechanisms to examine some of the major arguments relating to settlement and interaction in the southwestern Pacific, and assess the use of voyaging as a lens on past and present climate change.

References
Davies, B. and S.H. Bickler. 2021. Virtual Vaka: A Computational Tool for Thinking About Seafaring. Computer Applications in Archaeology Conference, Cyprus (Virtual).

S9: Between the Nile and the Brahmaputra: Computational Methods to Study Ancient Societies, Landscapes and Riverine Systems Straddling Asia and Africa

Thursday 11th April, 14:20–15:00, 260-073 OGGB4

Maria Elena Castiello, Institute of Archaeological Sciences, University of Bern and Institute of Heritage Sciences (INCIPIT-CSIC)
Navjot Kour, Landscape Archaeology Research Group (GIAP), Catalan Institute of Classical Archaeology
Nazarij Bulawka, Landscape Archaeology Research Group (GIAP), Catalan Institute of Classical Archaeology

The vast areas stretching from Egypt through Western Asia, Central Asia and South Asia are considered home to some of the earliest civilisations (Van De Mieroop 2016; Steadman and McMahon 2011; Magee 2014; Lyonnet and Dubova 2021, Possehl 1993). Notably, during the Middle and Late Bronze Age, there was extensive evidence of deep trade ties between those areas, which intensified since antiquity (Arnott 2022; Cobb 2018; Mattingly 2017). The landscape of the mentioned areas is diverse and transitional, dramatically shifting between the arid and hyper-arid regions of Northern Egypt and the Central Arabian Peninsula, through the dry savanna of the Eastern Sahel to the semi-arid steppe in the coastal regions and mountain piedmonts of Western Asia, towards the layered climatic complexities of South Asia ranging from temperate to tropical and cold regions (Rubel and Kottek 2010; Husain 2022; Kuper and Kröpelin 2006). It includes areas where permanent settlements emerged and persisted in time owing to multifaceted factors of the presence of huge perennial rivers, the development of irrigation systems, sufficient rain regimes, and in some areas the decisive role played by summer monsoons, which all sustain, even in such diverse environment, fertile ecosystems and productive lands. In the desert areas, crossing lands, connections and exchanges require following riverine routes and stopping by water bodies, defining mandatory paths and attraction spots for trading, networking and borders (Gatto 2011; Arbuckle and Hammer 2019). In contrast, in the tropical monsoonal belt, the itineraries require an unceasing adaptation not only to the land topography but also to the seasonal variations, because the water bodies play the key role of endless remodelers of the landscape. This massive diversity in these environments share a common ground in the relationship between cultures and water bodies that played a pivotal role in the rising of social and technological complexity, economy, movement, trade and the commencement of civilisations (Rost 2022; Zhuang and Altaweel 2018). Despite the territorial morphology and local environmental conditions made the economy of each area developing an individual pathway, these cultures rapidly became intertwined in the maritime and land trade networks, boundary disputes and conflicts.

This session aims to transcend traditional geographic and cultural boundaries and to consider a unified perspective across the vast areas between the Nile to the Brahmaputra. This approach seeks to connect the archaeological narratives and landscapes of the mentioned regions, highlighting shared features, interactions, and influences that shaped human history from prehistory towards medieval times. A wide array of computational methods can be employed to address this intricate subject and vast geographic range. These include satellite remote sensing, geophysics, laser scanning, 3D modelling, LiDAR, unmanned aerial vehicles (UAVs), mobile GIS, historical legacy datasets, mapping and management cultural heritage systems, statistics, spatial analysis, machine learning, deep learning, predictive modelling, network analysis, agent-based modelling, or least-cost path analysis for instance (to cite a few: Boogers and Daems 2022; Castiello 2022; Garcia-Molsosa, Orengo, and Petrie 2023; Resler et al. 2021) We warmly welcome papers on computational methods centred around such topics as:

- Social Complexity and technological advancement in connection with water bodies
- Heritage preservation
- Landscape archaeology
- Machine Learning
- Mountain archaeology
- Network analysis
- Predictive modelling
- Remote sensing
- Sedentarization and Nomadism
- Settlement patterns
- Trade and movement modelling
- Water management

References

Arbuckle, B. S., and E. L. Hammer. 2019. 'The Rise of Pastoralism in the Ancient Near East'. Journal of Archaeological Research 27 (3): 391–449. https://doi.org/10.1007/s10814-018-9124-8

Arnott, R. 2022. Crossing Continents: Between India and the Aegean from Prehistory to Alexander the Great. Oxford: Oxbow Books. https://books.google.es/books?id=Y2ppEAAAQBAJ

Boogers, S., and Daems, D.. 2022. SAGAscape: Simulating Resource Exploitation Strategies in Iron Age to Hellenistic Communities in Southwest Anatolia. Journal of Computer Applications in Archaeology 5 (1): 169–87.

Castiello, M.E. 2022. Computational and Machine Learning tools for archaeological site modeling. Chams: Springer. Cobb, M.A. 2018. The Indian Ocean Trade in Antiquity: Political, Cultural and Economic Impacts. Taylor & Francis.

Garcia-Molsosa, Arnau, Hector A. Orengo, and Cameron A. Petrie. 2023. 'Reconstructing Long-Term Settlement Histories on Complex Alluvial Floodplains by Integrating Historical Map Analysis and Remote-Sensing: An Archaeological Analysis of the Landscape of the Indus River Basin'. Heritage Science 11 (1): 141. https://doi.org/10.1186/s40494-023-00985-6

Gatto, M.C. 2011. The Nubian Pastoral Culture as Link between Egypt and Africa: A View from the Archaeological Record. In Egypt in Its African Context Proceedings of the Conference held at The Manchester Museum, University of Manchester, 2-4 October 2009, edited by K. Exell, 21–29. BAR International Series 2204. Oxford: Archaeopress.

Husain, M. 2022. Geography Of India. Edited by Tasawwur H. Z.. 10th ed. Chennai: MC Graff Hill.

Kuper, R., and S. Kröpelin. 2006. 'Climate-Controlled Holocene Occupation in the Sahara: Motor of Africa's Evolution'. Science 313 (5788): 803–7. https://doi.org/10.1126/science.1130989

Lyonnet, B., and N. A. Dubova. 2021. The World of the Oxus Civilizations. Edited by B. Lyonnet and N. A. Dubova. Routledge. Magee, Peter. 2014. The Archaeology of Prehistoric Arabia: Adaptation and Social Formation from the Neolithic to the Iron Age. Cambridge University Press.

Mattingly, D.J. 2017. Trade in the Ancient Sahara and Beyond. Trans-Saharan Archaeology. Cambridge University Press. https://books.google.es/books?id=6ug7DwAAQBAJ

Possehl, G., ed. 1993. Harappan Civilisation: A Recent Perspective. New Delhi. American Institute of Indian Studies and Oxford & IBH Publishing Company

Resler, Abraham, Reuven Yeshurun, Filipe Natalio, and Raja Giryes. 2021. 'A Deep-Learning Model for Predictive Archaeology and Archaeological Community Detection'. Humanities and Social Sciences Communications 8 (1): 295. https://doi.org/10.1057/s41599-021-00970-z

Rost, S., ed. 2022. Irrigation in Early States New Directions. Chicago: Oriental Institute of the University of Chicago.

Rubel, F., and M. Kottek. 2010. 'Observed and Projected Climate Shifts 1901–2100 Depicted by World Maps of the Köppen-Geiger Climate Classification'. Meteorologische Zeitschrift 19 (2): 135–41. https://doi.org/10.1127/0941-2948/2010/0430

Steadman, Sharon R., and G. McMahon. 2011. The Oxford Handbook of Ancient Anatolia: (10,000-323 BCE). OUP USA.

Van De Mieroop, M. 2016. A History of the Ancient Near East, ca. 3000-323 BC. 3rd ed. Blackwell History of the Ancient World. Wiley.

Zhuang, Y., and M. Altaweel, eds. 2018. Water Societies and Technologies from the Past and Present. London: UCL Press. https://doi.org/10.2307/j.ctv550c6

S9: Between the Nile and the Brahmaputra: Computational Methods to Study Ancient Societies, Landscapes and Riverine Systems Straddling Asia and Africa	
13:40-14:00	*175. Computational Approaches to the Long-term Relationship between Human Societies and the River Morphodynamics in the Alluvial Plains of the Indus Basin* *Arnau Garcia-Molsosa (Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology)*; Hector A. Orengo (Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology); Cameron Petrie (University of Cambridge); Iban Berganzo-Besga (Institut Català d'Arqueologia Clàssica (ICAC)); Francesc C. Conesa (Catalan Institute of Classical Archaeology); Navjot Kour (Institut Català d'Arqueologia Clàssica)*
14:00-14:20	*126. Between Kaveri and Vaigai: A computational analysis of ancient settlement patterns and socio-political dynamics in South India* *P.S. Rizvan, University of Hyderabad*

175. Computational approaches to the long-term relationship between Human societies and the river morphodynamics in the alluvial plains of the Indus basin

Arnau Garcia-Molsosa (Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology); Hector A. Orengo (Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology); Cameron Petrie (University of Cambridge); Iban Berganzo-Besga (Institut Català d'Arqueologia Clàssica (ICAC)); Francesc C. Conesa (Catalan Institute of Classical Archaeology); Navjot Kour (Institut Català d'Arqueologia Clàssica)*

Introduction

The alluvial plains of West and South Asia have been critical in the emergence of intensive agropastoral economies and urban societies. The long-term interaction of human societies with those riverine environments has resulted in a rich archaeological record, which has been the base on which models about the formation and development of complex economic and political systems have been built. Although big urban centres and its monuments have traditionally concentrated the attention, archaeologists have long recognised the importance to approach also the landscapes they were part. From an historical landscape perspective, alluvial plains of great rivers are characterised by strong dynamism, and this dynamism continually transforms the landscape through avulsion and shifting watercourses and the associated redistribution and incision of sediments, all of which influence the distribution of ancient settlements, and act to obscure and reveal elements of its history. On top of that, alluvial floodplains are also targeted for urban and agricultural expansion, which both have the potential to difficult the comprehension of its past dynamics and identify elements of its cultural heritage. All of that together poses critical challenges to the study of its long-term History.

This paper will explore the capacities of historical cartography, series of satellite imagery and archaeological databases to reconstruct aspects of the historical river network and long-term settlement patterns. The presentation will focus on the alluvial plains of Punjab, using study cases focused on the modern district of Multan (Punjab Province, Pakistan). Today, the landscape of the Punjab plains presents the relatively homogeneous aspect of an agrarian irrigated land. That setting is the result of intensive investment in hydraulic engineering along the Indus and its tributaries since the late 19th Century. Underneath, however, its archaeology evidences a long-term history of human settlement in an environment that presents a strong dynamism. In that aspect, the region has been the home of complex urban societies since prehistory, being one of the areas on Earth with a longer history of urban occupation. Nevertheless, that past urbanisation has not been homogeneous, neither in time nor in space. Tracking its complexity is the first step towards contextualising the archaeological evidence and exploring the socio-cultural and economic dynamics that have shaped South-Asian landscapes.

Methods

For that purpose, we have developed an integrated method to remotely map the relationship between hydrology, palaeohydrology and features of archaeological interest in a region that has a complex interplay between hydrology and archaeology. To carry out the analysis has been necessary to analyse large areas of high detailed geographic datasets, including the historical series (1900-1940) of the Survey of India topographic maps and EO datasets (Landsat, Sentinel and TanDEM-X).

Computational approaches have been a key instrument to process those datasets (see bibliographic references for details). Two main types of methods have been implemented:

- Machine Learning for the automatic detection of elements of archaeological interest, focusing on mound-type features.

- • Enhancing visualization techniques for the analysis of the topography and vegetation changes related to relict elements of the landscapes (Multi-scale Relief Model, Seasonal Multi-Temporal Vegetation Indices and Spectral Decomposition Techniques).

Results and discussion

The study developed in the Punjab province has detected c. 650 mound features of high archaeological interest and more than 6,000 kilometres of relict river channels. The use of historical sources have allowed to detect features that are not visible in the present landscapes, and that could only been detected using the workflow performed here. Works developed in parallel and subsequently in other parts of the Indus basin are giving similar positive results. Ground-truthing is currently undergoing, and a first assessment and chronotipological analysis based also on previous published datasets will be discussed in the presentation.

Results have been very valuable as a pre-exploratory instrument, providing the location of features of interest for historical research and heritage management. The combined analysis of the relict water systems and settlement has also give us the possibility to explore the processes of formation of the archaeological record and to initiate a regressive analysis of landscape characterisation and historical evolution of both the settlement patterns and hydrological networks. In the final discussion we will outline the identified advances obtained by our analyses and the remaining methodological and conceptual challenges encountered.

References

Garcia-Molsosa, Arnau, Hector A. Orengo, and Cameron A. Petrie. ‘Reconstructing Long-Term Settlement Histories on Complex Alluvial Floodplains by Integrating Historical Map Analysis and Remote-Sensing: An Archaeological Analysis of the Landscape of the Indus River Basin’. Heritage Science 11, no. 1 (10 July 2023): 141. https://doi.org/10.1186/s40494-023-00985-6.

Berganzo-Besga, Iban, Hector A. Orengo, Felipe Lumbreras, Aftab Alam, Rosie Campbell, Petrus J. Gerrits, Jonas Gregorio de Souza, et al. ‘Curriculum Learning-Based Strategy for Low-Density Archaeological Mound Detection from Historical Maps in India and Pakistan’. Scientific Reports 13, no. 1 (12 July 2023): 11257. https://doi.org/10.1038/s41598-023-38190-x.

Orengo, Hector A., Francesc C. Conesa, Arnau Garcia-Molsosa, Agustín Lobo, Adam S. Green, Marco Madella, and Cameron A. Petrie. ‘Automated Detection of Archaeological Mounds Using Machine-Learning Classification of Multisensor and Multitemporal Satellite Data’. Proceedings of the National Academy of Sciences 117, no. 31 (4 August 2020): 18240–50. https://doi.org/10.1073/pnas.2005583117.

126. Between Kaveri and Vaigai: A Computational Analysis of Ancient Settlement Patterns and Socio-political Dynamics in South India

P.S. Rizvan, University of Hyderabad

This study utilizes computational methods including satellite remote sensing, predictive modeling, and least-cost path analysis to examine settlement patterns and socio-political dynamics in South India during the Early Historic period from 500 BCE to 500 CE. The core analysis focuses on the river basins of the Kaveri and Vaigai, major arteries supporting the rise of the Tamil Sangam kingdoms of the Cheras, Cholas, and Pandyas. Remote sensing analysis using multi-spectral imagery and digital elevation models reveals a close relationship between archaeological site locations and the river network, indicating the primacy of riverine transport. Spatial clustering and density mapping of sites highlights zones of contact and exchange between kingdoms centered on strategic crossing points like mountain passes and delta regions.

Predictive settlement models based on logistic regression identify core agricultural zones in coastal plains and inland valleys, tied to specialized production of commodities like textiles and metals for international trade. Least-cost path modeling reconstructs ancient overland routes connecting major coastal ports to interior urban settlements and zones of resource extraction in highland areas rich in iron ore and gemstones. Elevation data, hydrology, and hypothesized political boundaries are key variables in calculating optimal paths reflecting accessibility and transport efficiency.

GIS-based viewshed analysis illuminates how site placement afforded surveillance over riverine trade routes as well as defense from emerging rivals. Hydrological modeling examines flood risk, soil fertility, and irrigation potential helping explain the predominance of certain areas for intensive wet rice agriculture that supported dense population centers.

Together these computational techniques provide insights into how geography and access to riverine transport shaped settlement patterns and facilitated the emergence of complex sociopolitical entities in South India. Spatial analysis quantitatively examines relationships between terrain, hydrology, production zones, trade routes, and political boundaries. Settlement densities act as proxies for delineating spheres of influence of major kingdoms during the Sangam period. Apparent gaps or overlaps in settled areas raise questions about inter-kingdom dynamics and competition for control of trade and resources.

The Chera core territory encompassed upland areas favorable for iron metallurgy and gemstone mining, exporting these goods via west coast ports like Tyndis. Chola lands focused on wet rice agriculture and east coast trade linking to northern India and the Ganges valley via the port of Arikamedu. The Pandyas occupied southern extremities controlling pearl fisheries and ports on both coasts, ideally positioned to intermediate and control trade. Zone analysis enables reconstruction of overland routes for moving goods between coasts avoiding sea passage around Sri Lanka.

Overall, the computational analysis provides a data-driven perspective on how control of riverine systems and strategic coastal locations enabled the rise of early South Indian polities. It also sheds light on their economic foundations based on specialized production zones and integration into the emerging Indian Ocean trade sphere. The quantitative techniques demonstrate relationships between environmental factors, connectivity via transport networks, productive capacities, and the geopolitics of South India’s formative Sangam kingdoms.

Keywords: South India, Sangam period, predictive modeling, least-cost paths, remote sensing, spatial analysis, geopolitics, trade networks, Indian Ocean.

S10: CAA in the Real World: Making Computational archaeology commonplace

Wednesday 10th April, 13:00–15:00, 260-073 OGGB4

Dr Andrew Brown, Horizon Archaeology
Dr Lawrence Shaw, Bournemouth University
Dr Derek Pitman, Bournemouth University

Researchers regularly develop innovative approaches in the use of computational applications and quantitative methods within the archaeological discipline. It is less common, however, to see this research practically implemented in a manner that is adopted within or benefiting the larger discipline. While specialisms in archaeology should be celebrated, they also serve to silo aspects of the discipline that can make them seem inaccessible to those outside. The CAA community is no exception. It is this core issue that this session aims to address: How do we as the CAA community make our approaches implementable and democratic within the larger discipline, while simultaneously maintaining cutting edge, pioneering computational archaeological research?

This session therefore serves to celebrate the development and implementation of "practical" real world change when using computational research within archaeology, heritage management and the historic environment. We wish to share papers which demonstrate how our research area has best utilised developing technologies, mobile GIS, gaming technologies, deep learning, open software and much more to better deliver practical change within our discipline, drawing in speakers from both the CAA community and beyond. Enhancements may vary from informing planning or land management decisions, improving field work and survey, advancing public participation or furthering engagement and education.

This session aims to be deliberately open to encourage papers from all areas of CAA. We hope to remove the often siloed nature of thematic approaches which prevents CAA members from learning from within the larger community. Instead, we hope to demonstrate how multiple computational applications in archaeology approaches have delivered change and benefits to practical deliveries, outside of the research bubble. We welcome papers from a broad range of computational applications in the hope of highlighting how our research is changing the profession for the better. Papers that focus on practical and widely accessible approaches will be prioritised, those that will stimulate a discussion on the role of CAA in the wider discipline. Over all, the session will ask not what archaeology can do for CAA, but what CAA can do for archaeology!

S10: CAA in the Real World: Making Computational archaeology commonplace	
13:00-13:20	*49. From Deep Learning to User Requirements - Creating a Search Engine for Dutch Archaeology that Works for the ‘Average Archaeologist’* *Alex Brandsen (Leiden University)*; Karsten Lambers (Leiden University); Milco Wansleeben (Leiden University)*
13:20-13:40	*55. Large Scale Infrastructure Events and Archaeology - Intrasis in the Real World* *Bengt H Westergaard (The Archaeologists, National Historical Museums)*"*
13:40-14:00	*32. Democratising Digital Data Processing: How Can We Unlock the Value of Born Digital Data?* *Derek S Pitman (Bournemouth University)*; Rich Potter (University of Gothenburg); Lawrence Shaw (Forestry England)*
14:00-14:20	*144. Community Mobile GIS as a ‘New’ Tool for Topographic Memorialization* *Luigi Magnini (Ca' Foscari University of Venice)*; Jacopo Paiano (Ca' Foscari University of Venice); Martina MB Bergamo (Ca' Foscari University of Venice); Andrea Lo Verso (Ca' Foscari University of Venice); Monica Calcagno (Ca' Foscari University of Venice); Diego Calaon (Ca' Foscari University of Venice)*
14:20-14:40	*148. Fostering Field Data Publication in Archaeology and Paleontology through Agile Web Visualisation: the archeoViz Open Source Application and its Web Platform* *Sebastien Plutniak (CNRS)**

49. From Deep Learning to User Requirements - Creating a Search Engine for Dutch Archaeology that Works for the 'Average Archaeologist'

Alex Brandsen (Leiden University); Karsten Lambers (Leiden University); Milco Wansleeben (Leiden University)*

The archaeological domain creates huge amounts of text, from books and scholarly articles to unpublished grey literature fieldwork reports. We are experiencing a significant increase in archaeological investigations and easy access to the information hidden in these texts is a substantial problem for the archaeological field. In the Netherlands alone, it is estimated that 4,000 new grey literature reports are being created each year, as well as numerous books, papers and monographs. Making these documents searchable and analysing them is a time consuming task when done by hand, and will often lack consistency.

Within the EXALT project at Leiden University, we are creating a semantic search engine for archaeology in and around the Netherlands, indexing all available, open-access texts, which includes Dutch, English and German language documents. Within this context, we are developing state-of-the-art Deep Learning language models, and using technically complicated Information Retrieval methods. However, when talking to potential users of this system, we find time and time again that they don't care about the technology behind the system, it just needs to "work" for them in their daily research.

In this talk, we will outline our process, from gathering initial user requirements, to evaluating the system with case studies. An initial case study on Early Medieval cremations shows an increase of 30% of known sites, when compared with previous literature review, which is now changing our views on Early Medieval burial practices. We will also share how we involved non-computational archaeologists and how to tailor systems to their requirements. These insights should be transferable to any system or tool aimed towards 'real world' change in our archaeological practice, catering beyond our CAA and computational archaeology sphere. Besides changes to our research itself, this also involves changing how we approach funding opportunities, with more funds and time that should be allocated to making tools useable, testing them, and talking to users, and not just focusing on the creating yet another state-of-the-art – but largely unused – proof of concept that ticks the current buzzwords.

55. Large Scale Infrastructure Events and Archaeology - Intrasis in the Real World

*Bengt H Westergaard (The Archaeologists, National Historical Museums)**

Contract archaeology inevitably means running into large scale societal projects, be it infrastructural or other. The way to handle these challenges from an archaeological viewpoint, varies from time to time and, not least, from country to country. Even between regions, variations may occur.

Ill conceived concepts such as standardization and conformity, among academic archaeologists, becomes necessary and tools to meet these demands are increasingly sought after.

An example will be given from ongoing large-scale excavations in the early modern town of Gothenburg/Göteborg, Sweden. The ongoing excavations represent the first major project in which Intrasis has been integrated into mobile/field methodologies. The application of Intrasis allowed for refined workflows and real-time data acquisition which not only drastically saved time but also reduced incidents of human error during documentation, increasing the overall scientific fidelity of the final product.

Gothenburg/Göteborg was founded as a fortified town in 1621. Sofar, the excavations have yielded fortifications, maritime constructions, households and 10 shipwrecks. Coordinating these large excavation areas with different targets and goals at hand, requires discipline and software that can handle numerous of inputs and outputs simultaneously. Intrasis is the answer to these requirements.

32. Democratising Digital Data Processing: How can We Unlock the Value of Born Digital Data?

Derek S Pitman (Bournemouth University); Rich Potter (University of Gothenburg); Lawrence Shaw (Forestry*

Digital technologies are now a core component of archaeological and cultural heritage research and 'born digital' data sets are now commonplace within the discipline. Yet, despite significant efforts within the digital community, there exists an increasing gap between approaches that generate data, and those that analyse and interpret it, with the latter requiring a significant depth of specialism. This gap between ease of capture, and complexity of interpretation creates a lag between innovation and wider adoption.

Here we discuss the value of 'democratising' these processes. That is to say: how can we open complex digital approaches to as wide a user group as possible? Not in a way that undermines specialisms, but which increases the amount of digital data that can be analysed and interpreted in novel ways.

Using the aerial survey as an example, this paper aims to stimulate a discussion about the value of democratisation within digital workflows. It explores key terminology and criteria that have an impact on the democratisation process and highlights the importance of self-reflection and 'future proofing' in how we publish methods. Ultimately this paper argues that everyone benefits from a broadening approach to digital data capture, analysis, and dissemination, and hopes to contribute to the ongoing discussions of 'digital affect' and methodological curation within archaeological research.

144. Community Mobile GIS as a 'New' Tool for Topographic Memorialization

Luigi Magnini (Ca' Foscari University of Venice); Jacopo Paiano (Ca' Foscari University of Venice); Martina MB Bergamo (Ca' Foscari University of Venice); Andrea Lo Verso (Ca' Foscari University of Venice); Monica Calcagno (Ca' Foscari University of Venice); Diego Calaon (Ca' Foscari University of Venice)*

In the last years, archaeologists have finally fully embraced the public and community aspects of the archaeological discipline, acknowledging that community involvement, decolonization processes and multi-vocal approaches to the past are the answer to a complex and global arena. One of the most effective and impactful methodologies is fostering public participation in archaeological research. We notice that a large number of the studies around public involvement and community participation are more focused on the social, economic and political outcomes of the archaeological research, only making minimal use of the great potential offered by technologies (sometimes perceived as vectors of disparity in the cultural sphere) and mostly employes for dissemination and engagement purposes (e.g., Gamification, AR and VR in museums or archaeological parks). The potential offered by the digital archaeology experience is not fully exploited or methodologically recognized. The contents' sharing opportunities, the co-creation of local and regional archaeo/historical narratives and the multivocality prospects are underestimated.

In this fragmented framework, our contribution aims to highlight the potential of a joint application of local community participation in archaeological research process and tools with new mobile GIS technologies both from a theoretical and practical perspective. The research is an ongoing process as part of the CHANGES - CREST project, whose objectives include the creation of shared frameworks for: 1) co-design cultural heritage sustainable touristic opportunities, 2) defining a hybrid process of community-based heritagization in an age of global challenges; 3) applying innovative digital solutions for promoting and disseminating new and old 'cultural heritage'; 4) promote processes of de-heritagization or decolonialization, acknowledging a changing social framework.

Two geographical areas within the Veneto Region (northern Italy) but with totally different environmental characteristics were chosen as test sites. The Venetian Lagoon in the north Adriatic region, with the metropolitan city of Venice. Venice and its watery manmade surroundings landscapes host a chronologically rich archaeological heritage, with stable occupations since the protohistoric period. The site is paradigmatic for its preservation challenges posited by climate changes, mass tourism and global migration issues.

The Asiago Plateau, on the other hand, is a mountainous geographical region close to the Alps and in direct connection with the Po Valley. Three main chronological phases can be recognized in this area: from the Recent Bronze Age to the Second Iron Age, from the Late Middle Ages to the fall of the Serenissima Republic of Venice and the First World War. The area is a good model where to test community heritage issues in peripheral region quite well preserved in naturalistic terms, where tensions arouse between economic development and conservation anxiety.

From a methodological point of view, two separate projects we are implementing on a free mobile GIS platform, updating the different available raster data (satellite images, regional cartography, aerial photographs) from time to time. Communities are involved in the use of the platform to register points and areas of interest through dedicated scheduled meetings. Communities are welcome to recognize and mark new point with a 'cultural interest' disregarding the chronological or archaeological accuracy. Community is stimulated to associate narratives (both individual and social) to the archaeological evidence. Public meeting and focus groups are being used as social arena where debating these narratives. During the training period, we are adopting a 'mixed' approach to using mobile GIS in which archaeologists and citizens are working side by side in the field survey. In other phase of the research we are using mobile GIS tools to discuss strategies for future excavations or valorization projects. Subsequently, the projects were shared on the personal devices of interested users. This allowed greater autonomy of choice in relation to the type of cultural heritage to be mapped.

These two experiences will also provide the necessary know-how to apply these methodologies of digital analysis and community engagement also on a third case study within the so-called archaeology of us. The current social condition of several Italian cities, including the district of Marghera, where communities with different origins cohabit, provides an ideal test site for studying the formation of the contemporary archaeological record.

As we were expecting, a technological approach showed a greater involvement of the less advanced age groups or those who already used similar equipment for hobby (e.g., trekking/cycling GPS). The use of the drone for community remote sensing activities has also been an attractive driver to bring people into the study/ perception of the landscape from a 'different perspective'. In this case, the analysis was conducted both on lieux de mémoire and on anomalies visible on the available remote sensing data, consisting mainly of satellite and UAVs imagery.

The technological approach is showing how digital tools can in the end constitute a common language between archaeologists and/or heritage practitioners and the community. The necessary codification and simplification of the data to be discussed, equally the need of digital 'fixed point' in the landscape reconstruction to re-narrate complex and entangled histories is proving to help decolonization processes. A language popularization (from archaeological jargon to common sense language), the open sharing process of the 'uncertainty' of the archaeological interpretation (against the traditional assertive reconstruction of the past typical of academic narrative).

Both case studies are highlighting how, alongside more traditional approaches to population involvement, new technologies, and in particular (free) mobile GIS, are a powerful tool for the sharing of knowledge of the territory by the communities that live it (more or less regularly). Public/ Community Archaeology and Digital Archaeology should be considered as a complex intertwined system of theories, tools and practices to provide a contemporary global concept of archaeological activity.

148. Fostering Field Data Publication in Archaeology and Paleontology through Agile Web Visualisation: the archeoViz Open Source Application and its Web Platform

*Sebastien Plutniak (CNRS)**

A 2015 ARIADNE survey revealed that (1) lack of handy tools, (2) lack of training in data management, (3) lack of time to prepare data for publication, and (4) lack of recognition related to it are factors explaining the insufficient publication of field archaeological data. There is a persistent imbalance between the time-consuming field data recording work and subsequent analysis and re-analysis work: the generated datasets are usually kept in the excavation's documentation, limiting their accessibility and reusability. In this context, the "archeoViz" application was developed to contribute to removing these barriers. Embedded in an open source R package, this Shiny application makes it possible to visualise, interactively explore, and communicate archaeological or paleontological field data on the web. It generates interactive 3D and 2D plots, cross sections and maps of the remains and their refitting relationships. Data analysis can be performed either by using the embedded methods (convex hull, regression surfaces, 2D kernel density estimation) or by directly exporting the data to third-party online applications (for seriation, classification, multivariate analysis).

"archeoViz"'s minimal interface (viz. issue 1) and the simple data structure it requires (CSV files with five mandatory variables) (viz. issues 2, 3) make it handy, easy and fast to use. The app has been conceived as the building brick of a decentralised web system: users can deploy "archeoViz" instances specific to their data on the server of their choice. The "archeoViz portal" (https://analytics.huma-num.fr/archeoviz/home) is intended to index the datasets deployed with the app, increasing their discoverability and audience on the web (viz. issue 4).

“archeoViz” is not properly a data repository but a covering tool making published or unpublished data visible, thus indirectly contributing to fostering data publication (on third-party proper repositories) and reuse by archaeologists. So far, 42 archeological datasets are available (about 360,000 objects), the software is supported by a maintenance team (3 persons), a user community (about 50 persons), and extensive documentation (https://archeoviz.hypotheses.org).

S11: 3D Modelling in Perspective

Tuesday 9th, 11:20–17:00; Wednesday 10th April, 10:20–17:00, 260-092 OGGB3

Simon Wyatt-Spratt Discipline of Archaeology, University of Sydney
Lauren Franklin, School of Anthropology, University of Arizona
Thomas Keep, Classics and Archaeology, University of Melbourne
Madeline Robinson, Discipline of Archaeology, University of Sydney

3D modelling has revolutionised archaeology across multiple scales (Benjamin et al. 2019; Grosman et al. 2014; Magnani et al. 2020). 3D models have been used as an alternative to analog forms of archaeological illustration and recording (e.g. Douglass, Lin and Chodoronek 2015; Magnani 2014), have allowed for highly accurate and complex analyses of a wide-range of archaeological material and features (Evin et al. 2016; Jalandoni and May 2020; Wyatt-Spratt 2022) and have even been used to reconstruct gaps in the archaeological record (e.g. Delpiano et al. 2019; Robinson et al. 2019). Beyond their illustrative and analytical uses, models have also been used for archiving, exhibitions, teaching, and other types of public outreach (e.g. Ahmed, Carter and Ferris 2014; Keep 2022). The rapid proliferation of 3D modelling across the different subfields of archaeology has led to a diverse array of approaches to making and using models. This diversity includes different methods of modelling (computer tomography, laser/light scanning, and photogrammetry), different scales of modelling (micro-, macro-, and terrestrial), and the different purposes that models have been used for (analysis, archiving, illustration, pedagogy, and conservation). However this has also led to a situation where the different branches of archaeology's approaches to modelling have become increasingly siloed. Given that 3D modelling is becoming an increasingly common component in the archaeological toolkit it is important that archaeologists take stock of how the field has grown and share knowledge of the latest developments across the field.

The aim of this session is to bring these diverse perspectives on 3D modelling together. By bringing together multiple experts on archaeological applications of 3D modelling, we want to start conversations about how these different approaches to 3D modelling could be applied to different archaeological contexts. To do so, we invite submissions, with a particular focus on the following topics:

- Innovative methodological approaches to model making
- 3D modelling as a tool for documentation or illustrative landscapes, features, excavations, and/or eco/artefacts
- Case studies involving understudied archaeological material
- Novel approaches to the analysis of 3D models
- 3D modelling as a multipronged approach to archaeological analysis
- Ethical questions, such as applying FAIR Data Principles to 3D modelling, modelling human remains, indigenous data sovereignty, and repatriation of cultural materials

- Gaps in how and where 3D modelling is used, whether that be reflect socio-economic inequalities, methodological challenges, and theoretical biases
- 3D modelling as tool for teaching, conservation and public outreach

Papers in this session are not limited to a particular region or historical period. We particularly encourage contributions from students and early career researchers who wish to present preliminary results and presentations that incorporate collaboration with First Nations communities. Papers looking at methodological innovations, archaeological case studies, and theoretical issues are all welcome.

References

Ahmed, N, Carter, M and Ferris, N. 2014 Sustainable archaeology through progressive assembly 3D digitization. World Archaeology 46(1): 137–154. DOI: https://doi.org/10.1080/00438243.2014.890911

Benjamin, J, McCarthy, J, Wiseman, C, Bevin, S, Kowlessar, J, Astrup, PM, Naumann, J and Hacker, J. 2019 Integrating aerial and underwater data for archaeology: digital maritime landscapes in 3D. In:. McCarthy, JK, Benjamin, J, Winton, T, and van Duivenvoorde, W (eds.). 3D Recording and Interpretation for Maritime Archaeology. Coastal Research Library. Cham: Springer International Publishing. pp. 211–231. DOI: https://doi.org/10.1007/978-3-030-03635-5_14.

Delpiano, D, Cocilova, A, Zangrossi, F and Peresani, M. 2019 Potentialities of the virtual analysis of lithic refitting: case studies from the Middle and Upper Paleolithic. Archaeological and Anthropological Sciences 11(9): 4467–4489. DOI: https://doi.org/10.1007/s12520-019-00779-7.

Douglass, M, Lin, S and Chodoronek, M. 2015 The application of 3D photogrammetry for in-field documentation of archaeological features. Advances in Archaeological Practice 3(2): 136–152. DOI: https://doi.org/10.7183/2326-3768.3.2.136.

Evin, A, Souter, T, Hulme-Beaman, A, Ameen, C, Allen, R, Viacava, P, Larson, G, Cucchi, T and Dobney, K. 2016 The use of close-range photogrammetry in zooarchaeology: Creating accurate 3D models of wolf crania to study dog domestication. Journal of Archaeological Science: Reports 9: 87–93. DOI: https://doi.org/10.1016/j.jasrep.2016.06.028.

Grosman, L, Karasik, A, Harush, O and Smilansky, U. 2014 Archaeology in three dimensions: computer-based methods in archaeological research. Journal of Eastern Mediterranean Archaeology and Heritage Studies 2(1): 48–64.

Jalandoni, A and May, SK. 2020 How 3D models (photogrammetry) of rock art can improve recording veracity: a case study from Kakadu National Park, Australia. Australian Archaeology 86(2): 137–146. DOI: https://doi.org/10.1080/03122417.2020.1769005.

Keep, T. 2022 The Mernda VR Project: The Creation of a VR Reconstruction of an Australian Heritage Site. Journal of Computer Applications in Archaeology 5(1): 238–254. DOI: https://doi.org/10.5334/jcaa.91.

Magnani, M. 2014 Three-dimensional alternatives to lithic illustration. Advances in Archaeological Practice 2(4): 285–297. DOI: https://doi.org/10.7183/2326-3768.2.4.285.

Magnani, M, Douglass, M, Schroder, W, Reeves, J and Braun, DR. 2020 The digital revolution to come: photogrammetry in archaeological practice. American Antiquity 85(4): 737–760. DOI: https://doi.org/10.1017/aaq.2020.59.

Robinson, MGP, Porter, A, Figueira, W and Fletcher, R. 2019 Neolithic temples of Malta: 3D analysis points to novel roof reconstruction. Digital Applications in Archaeology and Cultural Heritage 13: e00095. DOI: https://doi.org/10.1016/j.daach.2019.e00095.

Wyatt-Spratt, S. 2022 After the Revolution: A Review of 3D Modelling as a Tool for Stone Artefact Analysis. Journal of Computer Applications in Archaeology 5(1): 215–237. DOI: https://doi.org/10.5334/jcaa.103.

S11: 3D Modelling in Perspective	
11:20-11:40	*106. Exploring 3D Modelling Technologies for Difficult Heritage with a Case Study from Treaty 6 Territory, Canada* *Madisen Hvidberg (University of Calgary)*; Peter Dawson (University of Calgary)*
11:40-12:00	*183. Towards Digitising a Fleet, a Maritime Museum Case Study* *Michael Rampe (Rampe Realistic Imaging Pty Ltd)*; David O'Sullivan (Australian National Maritime Museum); Mr Snow (Australian National Maritime Museum)*
Lunch	
13:00-13:20	*87. Semi-automated and High-throughput Photogrammetry of Stone Artefacts* *Alex Dixon (Auckland Bioengineering Institute)*; Robin Laven (Auckland Bioengineering Institute); Joshua Emmitt (University of Auckland); Samuel Richardson (University of Auckland); Rebecca Phillipps (University of Auckland); Simon Holdaway (University of Auckland); Poul M. F. Nielsen (The University of Auckland)*
13:20-13:40	*179. Fast, Good, and Cheap - You Can Have All Three with Desktop 3D Scanning for Lithic Analysis* *Steven Mills (University of Otago)*; Hamza Bennani (University of Otago); Gerard O'Regan (Tūhura Otago Museum); Lana Arun (Tūhura Otago Museum); Tapabrata Dr. Chakraborty (University of Oxford); Richard Walter (University of Otago)*
13:40-14:00	*54. A 3D Analysis of Expedient Cores from Puritjarra* *Simon J Wyatt-Spratt (University of Sydney)**

S11: 3D Modelling in Perspective	
14:00-14:20	*125. Comparing Regional Māori Toki Manufacturing Technology using 3D Model Assemblages* *Christopher G Jennings (Southern Pacific Archaeological Research, University of Otago)**
14:20-14:40	*95. Rock Art Conservation by Digital Record: Monitoring Degradation Over Time in the Blue Mountains* *Lauren A Roach (University of Sydney)**
14:40-15:00	*92. The Use of 360 Video Devices for Rock Art Research* *Fritz E. G. Hardtke (Macquarie University)**
Afternoon Tea	
15:20-15:40	*42. Constructing a Virtual Authenticity: Virtual Repatriation of West Arnhem Land Bark Paintings* *Calum U Farrar (Griffith University)*; Andrea Jalandoni (Griffith University)*
15:40-16:00	*160. 3D Modelling in Stone: An Animated Reconstruction of an Angkorian Workshop* *Thomas Chandler (Monash University)*; Mike Yeates (Monash University); Martin Polkinghorne (Flinders University); MIchael Neylan (Monash University)*
16:00-16:20	*99. Once Part of Gothenburg's Old Defence – Soon Part of the Town's Historical Narrative in 3D. Work in progress.* *Carina Bråmstang Plura (Arkeologerna)*; Niklas Ekholm (Arkeologerna); Teobaldo Ramirez (Arkeologerna); Mikael Lindahl (Arkeologerna)*

S11: 3D Modelling in Perspective

16:20-16:40	*35. Architectural Experiment based on 3D Model of the Kayukovo 2 Neolithic Defensive-Residential Complex in the North of Western Siberia* *Ekaterina Girchenko (Surgut University, Institute of the Archaeology of the North, Institute of Archaeology and Ethnography)*, Oleg Kardash (Surgut University, Institute of the Archaeology of the North, Institute of Archaeology and Ethnography)*
16:40-15:00	*89. An Australian Overview: The Creation and Use of 3D Models in Australian Universities* *Jackson Shoobert (University of New England); Thomas J Keep (The University of Melbourne)*; Jessie Birkett-Rees (Monash University); Madeline GP Robinson (University of Sydney)*
Day shift	
10:20-10:40	*122. Developing a 3D Virtual Reconstruction of the Lawrence Chinese Camp, Central Otago, New Zealand: Method and Impacts on Descendant Aspirations* *Isaac H McIvor (University of Otago)*; Richard Walter (University of Otago); James Ng (Lawrence Chinese Camp Charitable Trust)*
10:40-11:00	*24. Scientific Model, Historical Fiction, or Frankenstein's Monster: The Prospects and Perils of 3D Reconstruction for Archaeology in Aotearoa New Zealand* *Simon H. Bickler (Bickler Consultants Ltd)*; Thomas MacDiarmid (Independent)*
11:00-11:20	*4. Are We There Yet? A Case Study in 3D Scanning Applications on Mobile Platforms for Resource-Limited Museums within the South Island, New Zealand* *Jennifer T Copedo (Tūhura Otago Museu)**
11:20-11:40	*170. Enmasse Scanning and Curation of Small Objects using MicroCT* *Riley C W O'Neill (University of Minnesota)*; Katrina Yezzi-Woodley (University of Minnesota); Jeff Calder (University of Minnesota); Peter Olver (University of Minnesota)"*
11:40-12:00	*189. The Virtual Goniometer: A Novel Tool for 3D Molar Segmentation and Occlusal Wear Surface Angle Measurements* *Risa L Luther (University of Minnesota)*; Riley C W O'Neill (University of Minnesota)*

S11: 3D Modelling in Perspective	
Lunch	
13:00-13:20	*39. Characterising 1000 Years of Byzantine Era Dog Cranial Morphology: A 3D Geometric Morphometric Approach* *Loukas G Koungoulos (Australian National University)*; Ozan Gündemir (İstanbul University-Cerrahpaşa, Istanbul); Margot Michaud (University of Liège); Vedat Onar (İstanbul University-Cerrahpaşa, Istanbul)*
13:20-13:40	*69. Quantifying Classification: Performing GMM Shape Analysis of Archaeological Artefacts using 3D Models Produced by Photogrammetry* *Emily Tour (University of Melbourne)**
13:40-14:00	*193. Complex Survey Methodologies. Documentation, Modeling and Communication of the Forum of Nerva in Rome* *Martina Attenni (Sapienza, University of Rome)*; Carlo Bianchini (IT); Carlo Inglese (IT); Alfonso Ippolito (IT); Prof. Tommaso Empler*
14:00-14:20	*88. How Much is Too Much? Overcoming Difficulties Associated with Large Photogrammetry Data Sets* *Corey Noxon (Ritsumeikan University)**
14:20-14:40	*97. 3D Modelling and Spatial Data Integration for the Documentation of Large-scale Heritage Infrastructure: A Case Study of the Wooden Trestle Bridge of Nowa Nowa, Victoria, Australia* *Marko Radanovic (University of Melbourne); Brian J Armstrong (University of Melbourne)*; Jacinta Bauer (Heritage Victoria); Martin Tomko (University of Melbourne)*
14:40-15:00	*101. Spatial Analysis of Crater Cove* *Samantha Judges (Sydney University)*"*
Afternoon Tea	

S11: 3D Modelling in Perspective	
15:20-15:40	*83. Facial Reconstruction in the Context of Interdisciplinary Archaeological Research in Banat (Romania)* *Lucian M Micle (Polytehnica University of Timisoara)*; Dorel Micle (West University of Timisoara); Erwin-Christian Lovasz (University Politehnica Timisoara)*
15:40-16:00	*40. Photogrammetry and 3D Modeling: Refining a method for use in digital education Kelly J Baer (Northern Arizona University)**
15:40-16:20	*151. Active participation of the public in the 3D documentation of museum collections makes archaeology open* *Atsushi Noguchi (Center for Next Generation's Archaeological Studies, Komatsu University)*; Seicho Miyoshi (Board of Education, Hida City); Hironobu Sasaki (Kohoku Junior High School, Nagano City)*

87. Semi-automated and High-Throughput Photogrammetry of Stone Artefacts

Alex Dixon (Auckland Bioengineering Institute); Robin Laven (Auckland Bioengineering Institute); Joshua Emmitt (University of Auckland); Samuel Richardson (University of Auckland); Rebecca Phillipps (University of Auckland); Simon Holdaway (University of Auckland); Poul M. F. Nielsen (The University of Auckland)*

Introduction

In Aotearoa New Zealand, there is a need to enhance our knowledge of pre-colonial Māori society. This knowledge can be derived by analysing taonga including flaked stone artefacts. To this effect, many artefacts are collected and stored, however due to the specialised analysis required, only a small number are selected and analysed for archaeological reporting. There is also a need to rapidly document a significant number of these types of artefacts in heritage mitigation work driven by land development. Therefore, a cost-effective method is needed for identification, measurement, and interpretation of large numbers of artefacts.

Photogrammetry technology enables accurate measurement of shape and texture of artefacts, whilst being of relatively low-cost compared to other 3D scanning technologies. However, the analytical potential of the technology at this scale has yet to be realised [1]. This work aims to address the previously identified need for large-scale scanning and automated classification of stone artefacts. We present the initial step of this work with the development of a custom photogrammetry-based 3D scanner that enables high-throughput measurement of stone artefacts in a semi-automated manner.

Methods and materials

A 3D scanner was developed to acquire images for 3D reconstruction using photogrammetry. This scanner consisted of 3 cameras with LED illumination rings and a custom motorised turntable to scan artefacts in an automated manner. Artefacts were mounted between two adjustable rods with rubber pads. This design enabled quick mounting (< 10 seconds) and could accommodate various artefact shapes and sizes up to a limit of 120 mm.

The 20-megapixel cameras (FLIR, BFS-U3-200S6M-C) with 12 mm lenses (computar, V1226-MPZ) were mounted to a vertical breadboard with camera-to-camera angles of 30 deg at working distance of 200 mm from the artefact. Attached to each camera lens was a programmable RGB LED ring to illuminate the artefact. The turntable comprised a motorised rotation stage with controller (Thorlabs, KPRM1E/M) and custom rotary plinth mechanism. The plinth, which held the artefact mount, had a shaft held in two self-aligning bearings and was attached to the rotation stage via a rotary coupler. This mechanism was used to reduce wobble present in the motor during rotation.

The cameras, LEDs, and turntable motor were programmatically controlled via a custom LabVIEW program to acquire images of artefacts at rotation steps of 15 deg for each illumination wavelength. This scanning routine gave the scanner 72 virtual cameras, for a full rotation about the artefact, for 3D reconstruction. The scanning time for each artifact was typically 90 seconds.

The virtual cameras were calibrated by rotating a calibration cube, that consisted of 6 charuco board targets, in the scanner at 3 different heights throughout the imaging volume. The calibration process is described in [2]. The calibration estimated the intrinsic parameters for each of the 3 real cameras, extrinsic parameters for each of the 72 virtual cameras, and the axis of rotation of the motorised turntable. 3D reconstruction, using the calibration parameters and scanner images, was performed using the ACMMP algorithm, as described in [3].

Results & Discussion

3D point clouds for three flaked stone artefacts are shown in the figure. The point colour is estimated from separate measurements of red, green, and blue illumination wavelengths. The point clouds provide detailed representations of the artefacts, including concave surfaces.

The 3D scanner for this work was developed with the intention of high-throughput scanning of many artefacts in the lab or the field. The acquisition process was semi-automated, only requiring a user with basic training to briefly remove and insert artefacts. The 3D reconstruction process was fully automated, generating a coloured point cloud of the artefact. We also found that the scanner and calibration was robust, with the 3D reconstruction quality not degrading after many artefact scans over a period of two months for a single calibration.

The new tool presented in this paper will enable relatively quick and low-cost generation of large databases of artefacts by archaeologists for archiving and analysis. Using this scanner and the datasets acquired from it, along with training data from experts in the field, we plan to develop software for automatically and rapidly identifying artefact morphologies, including artefact class, presence of usewear and retouch, and dorsal surface features. This may enable complex analysis of large datasets gathered over multiple locations to help understand spatial and temporal variability across Aotearoa New Zealand and help piece together our past.

References

[1] M. Magnani, M. Douglass, W. Schroder, J. Reeves, and D. R. Braun, “The Digital Revolution to Come: Photogrammetry in Archaeological Practice,” Am. Antiq., vol. 85, no. 4, pp. 737–760, Oct. 2020, doi: 10.1017/aaq.2020.59.

[2] Robin Laven et al., “High Precision Calibration of Multi-View Stereo Systems With Imperfect 3D Targets” (in review).

[3] Q. Xu, W. Kong, W. Tao, and M. Pollefeys, “Multi-Scale Geometric Consistency Guided and Planar Prior Assisted Multi-View Stereo,” IEEE Trans. Pattern Anal. Mach. Intell., pp. 1–18, 2022, doi: 10.1109/TPAMI.2022.3200074.

151. Active Participation of the Public in the 3D Documentation of Museum Collections Makes Archaeology Open

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3D documentation of archaeological material, cultural heritage and related museum collections is beneficial and effective for dissemination and promotion because of its rich information, intuitive clarity for understanding, and interactivity. We attempted to introduce this technology to solve multiple socio-educational issues with the active participation of the public, mainly aimed at school children. In this paper, we report the results of our practical experiments and discuss their potential.

Archaeology and related museums are still uncommon academic fields and cultural institutions that attract the attention of enthusiasts who already have interests. We must call for more engagement and continuous participation of diverse people with different motivations and interests. Archaeology must be more open to accepting those various participants and make them satisfying. In this regard, we’d like to focus on 3D documentation of archaeological museum collections with the public because it looks more acceptable, attractive, interactive and enjoyable than conventional forms of publication and dissemination.

While most archaeological material has complex arbitrary forms, pont-cloud-based 3D documentation is suited for acquiring and representing rich information about their shape and texture. Techniques and equipment of 3D measurement have rapidly become more sophisticated, accessible and easy to use in recent years. 3D photogrammetry allows almost anyone to achieve essential 3D documentation by learning to capture images with a digital camera. Smartphones and tablets with LiDAR sensors, which are now consumer products, enable quickly acquiring 3D data of a certain quality through easy-to-use apps. These technological advancements open the documentation work for the public rather than enclosed to the well-trained experts. 3D data is also highly affixed to online publishing and other web technologies as born-digital data. It is suitable for dissemination and promotion as well. When we involve the public in the documentation work of museum collections, the public will be contributors rather than visitors. Public participation will be more active, and communication between the experts and the public will change to more interactive from a passive one-way style. These are our basic concepts to start the 3D documentation hands-on workshop in the Hida Miayagawa Archaeology and Folk Museum, Hida City, Gifu Prefecture, Japan.

During the pandemic of COVID-19, most museums in Japan have been forced to close and lost opportunities for education and dissemination. It was critical, especially for local small museums in the remote area. Hida Miyagawa Archaeology and Folk Museum is one of the cases. Due to the lack of workforce and its location being too distant from the city's centre, the museum opened only 30 days a year, even before the pandemic. Annual number of visitors were less than 200 in 2017-2018. In 2019, Hida City started a new public engagement program, "Sekibo Club", and organised workshops and lectures. Then the number of visitors was increased to 436. It was about three times larger than the previous. However, in 2020, it fell to 201 due to the pandemic affection. In addition, the museum's management faced another difficulty: the retirement of elderly caretakers. The ageing population of the city has reached about 40%. Shortage of workforce is a common problem in the public sector in the region.

For sustainable management of the museum, there was an urgent need to increase the population, not only residents but also visitors, by raising interest within and outside the local community. The solution derived by "Sekibo Club" is more public engagement in the museum operations. Organising a series of hands-on workshops on the documentation of collection is a case. People, both from inside and outside the local community, participate in workshops, learn how to treat museum collections from the curator, and how to do documentation, either photography or 3D photogrammetry. For most participants, it is the first fresh experience entering the museum's backyard, touching the original materials and learning the documentation work on collections. This experience invokes more interest in archaeology and museums among them.

Moreover, when the achievements of participants are published online with the credits of participants 1), participants recognise that many people look at and respond to their works on social platforms. After a series of experiences, participants grow more attached to archaeology, the museum, and the region. Some extend their interests to different fields of archaeological sites or museums, and others join different volunteer activities in Hida City. Our workshops succeed in invoking people's interests and willingness to participate in diverse ways.

In the meantime, we recognise that the 3D documentation of museum collections is also available for school children. We called only adult participation in Hida Miyagawa Archaeology and Folk Museum workshops. However, there were a couple of children with participants, and they also did 3D documentation. A 6-year-old girl achieved an iPhone LiDAR scan on Jomon pottery, then 3D-printing. Another junior high school child completed 3D photogrammetry. These results encourage us to involve more school children.

Then, we plan to start another workshop at Nagano Municipal Museum with Kohoku Junior High School students. We aim to connect the class of history and archaeological materials with the experience of a museum workshop. However, the interests and focuses of students are more diverse. Few students are interested in archaeology or regional history. Instead, they are interested in movie creation, AR and VR, 3D gaming, website construction, online publishing and various subjects. We carefully designed and organised the workshop to involve those students. We never set the priority to understand museum collections archaeologically. The students approached the same museum collection differently, based on individual interests and concerns. An action of 3D documentation and data became the visible bridge to connect their various interests and the original object. All students are motivated differently but have the same experience through our workshop. We never forced the students to be interested in archaeology, but they are interested in it eventually. This result is impressive to the museum. Through the workshop, the museum can acquire 3D data and new stakeholders differently from conventional museum activity.

The 3D documentation of archaeological material in the museums is for more than scientific purposes. The 3D documentation is not the technology for experts. The 3D data attracts more people with various interests. Our experiments show that 3D documentation can make archaeology more open with the active participation of the public in academic activities. It applies to children as well. We create the future of archaeology with the advanced technology.

42. Constructing a Virtual Authenticity: Virtual Repatriation of West Arnhem Land Bark Paintings

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Introduction

Repatriation of cultural materials and data collected by researchers to the communities and countries they were collected from is a growing global phenomenon. A reason for exemption from repatriation cited by institutions is that certain cultural materials are too fragile to be moved from their current storage. In cases where this is a substantiated concern, alternative means of allowing communities access to their cultural materials must be explored. Virtual collections of 3-D scanned objects have become a popular method for allowing access, however, most of these desktop or mobile based virtual collections have limited interaction with the object. Furthermore, they do little to liberate the object from the institutionalised space which acts to strip away their cultural context.

This paper examines virtual repatriation and authenticity through the development and deployment of a virtual reality (VR) program which aims to restore objects held in museum collections to an authentic context. The objects at the centre of this paper are bark paintings variously collected and commissioned by Baldwin Spencer and Paddy Cahill from peoples in West Arnhem Land during in the early 20th century and retained by Museums Victoria. This builds upon recent research to identify the artists of these paintings in collaboration with their descendants

(Taçon et al. 2023). This paper continues this collaboration, examining how VR can facilitate meaningful and authentic interactions by descendant communities and cultural heritage materials.

Methods

As part of the previous work outlined in Taçon et al. (2023), photogrammetric 3-D reconstructions of the bark paintings held at the Melbourne Museum were produced allowing for them to be readily adapted to VR. The photogrammetry models were initially created in Agisoft Metashape and cleaned and prepared in Blender before being imported into the Unity game engine. In total, thirty bark paintings were included in the final version.

The bark painting models were placed into a virtual environment constructed to replicate key elements of the Western Arnhem landscape and traditional bush camps. This was not intended to be a one-to-one reproduction of a known site, rather an amalgamation of authentic elements arranged to support platform limitations and other game design considerations. The target VR platform was the Meta Quest 2. This choice allowed for untethered use and hand-tracking interaction. The program went through multiple iterations, including feedback from initial demos with Gunbalanya (West Arnhem Land) community members.

Results

Community feedback from demonstrations in Gunbalanya produced surprising results, particularly with how people engaged with environmental aspects of the virtual setting and how prominently it featured in individual feedback. Furthermore, recommendations were made to expand the virtual experience to have more fantastic elements, rather than make it strictly 'realistic'.

Discussion

This study has demonstrated that photogrammetry models, now commonly used in archaeological practice, can be readily adapted from analytical to experiential applications. The decision to contextualise the bark paintings with authentic environmental elements, rather than the typical virtual museum setting, exceeded expectations. The results suggest that expanding interactivity to the whole environment and not only the material culture will create a more immersive and authentic experience. Additionally, the suggestion of including fantastical elements by participants indicates that an adherence to an objective ideal might be limiting the potential of a virtual heritage setting for creating authentic experiences.

References

Taçon, Paul S.C., Luke Taylor, Sally K. May, Joakim Goldhahn, Andrea Jalandoni, Alex Ressel, and Kenneth Mangiru. 2023. "Majumbu ('Old Harry') and the Spencer-Cahill bark painting collection." Australian Archaeology 89 (1): 14-31. https://doi.org/10.1080/03122417.2023.2177949

99. Once Part of Gothenburg's Old Defence – Soon Part of the Town's Historical Narrative in 3D. Work in Progress.

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Introduction & Background

Since 2018, large scale excavations have been undertaken in conjunction with the construction of a new railway tunnel under the city centre of Gothenburg, Sweden: The West Link Project. The excavations primarily focused on the remains of Gothenburg's massive fortifications, the construction of which started when the city was founded in 1621. The excavations will continue until 2025 and have revealed several bastions, defense moats, city block of wooden buildings, a harbour and 9 shipwrecks. Furthermore, parts of a medieval fort, “the Gullberg fortress”, were excavated where remains of a cellar, tangibly of a defensive tower and defensive walls were found.

This paper presents our work in progress to create 3D-reconstructions from the data gathered from the excavations in Gothenburg, to be used in public outreach, as well as an analysis toolbox for interpretating spatial relationships between archaeological features.

Methods and materials

The foundation for the project is an already existing 3d-model of how Gothenburg was situated the year 1697, made 2016 by the city council and town museum. The model is made with the game engine Unreal engine 4 and is based on historical maps and records.

The result of this project is meant to update and refine this model with the archaeological result from the recent excavations. Accordingly, the material used for the reconstruction derives from the geo-referenced GIS-database: Intrasis, photogrammetry and laser-scanning of excavated features along with DEMs (Digital elevation models) and historical maps to reconstruct the historical landscape.

The data has then been processed and reconstructed in the open-source 3D software Blender (3.6) and then exported to the 3D game engine Unreal Engine (5.3) to later be merge with the existing 3d model.

Results

A feasible pipeline of transforming archaeological data has been identified, similar to the work of Ferdani et al (2020, 142). This pipeline allows the transformation of archaeological data to 3d-reconstruction: GIS 3D-database/ photogrammetry/ laser-scanning/ historical records > Blender > Unreal engine.

In the development of the pipeline, a technical demonstrator has been created to explore the possibilities and limitations of the workflow. The demonstrator aimed at reconstructing part of the medieval fort “The Gullberg fortress”. The demonstrator was used to test different methods of reconstructing houses and walls as well as the spatial relationships of excavated features, aiding the analysis and final scientific report. Furthermore, a range of media was produced such as still images, 360-degree stills, and short films as a demonstration of how the model can be used for mediation.

The positive results have opened the possibility to continue digitalising other historical sites in Gothenburg, as a part of the archaeological work done in The West Link Project. These sites include a harbour, shipwrecks, bastions and rest of the fortification of the city.

Discussion

We believe that this approach allows for flexibility within the process of analyzing as well as mediating archaeological data. New contexts and structures can be added, removed and tweaked synchronously when new data and new interpretations emerge. Spatial relationships can be visualized and understood in an immersive environment rather than a top-down GIS perspective, opening up the possibility to accurately explore otherwise hard-to-reach perspectives within the analysis (Sciuto et al. 2023, 100).

In the same way, we believe that these immersive environments can be used within outreach products; as we rely on game engines, we have confidence in that the possibilities are vast. These can range in complexity. In one end of the spectra, high quality stills and films and web-based 360-degree experiences where a spectator can explore a limited area. In the other end open world games where a player can move around in the historical landscape with the interpreted archaeological features and control aspects such as time of day, weather, season and year.

References

Dell'Unto, Nicolo, and Giacomo Landeschi. 2022. 'Archaeological 3D GIS'. In , 1st ed. London: Routledge. https://doi.org/10.4324/9781003034131.

Ferdani, Daniele, Bruno Fanini, Maria Claudia Piccioli, Fabiana Carboni, and Paolo Vigliarolo. 2020. '3D Reconstruction and Validation of Historical Background for Immersive VR Applications and Games: The Case Study of the Forum of Augustus in Rome'. Journal of Cultural Heritage 43 (May): 129–43. https://doi.org/10.1016/j.culher.2019.12.004.

Sciuto, Claudia, Anna Foka, Mattis Lindmark, and Jim Robertsson. 2023. 'Exploring Fragmented Data: Environments, People and the Senses in Virtual Reality'. In Capturing the Senses: Digital Methods for Sensory Archaeologies, edited by Giacomo Landeschi and Eleanor Betts, 85–103. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-23133-9_5.

125. Comparing Regional Māori Toki Manufacturing Technology using 3D Model Assemblages

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Introduction

Adzes are ubiquitous throughout Polynesian archaeological sites and have been a focus of archaeological inquiry since the late 19th Century. In the early-mid 20th Century, culture-historical studies drove investigations focusing on typological study and regional comparisons. Later investigations shifted to the study of adze manufacture at quarries and working sites, although regional comparisons of adze production are rare. This is partially related to a lack of standardised terminology of artefacts representing different stages of the reduction sequence (e.g. blanks and preforms), but also due to the voluminous nature of adze manufacture assemblages and difficulties accessing multiple assemblages housed in various, sometimes foreign, locations. 3D modelling of artefacts provides an avenue for comparative studies, allowing access to digital assemblages where there are usually impediments to accessing and handling their physical counterparts.

Murihiku is the location of two major stone sources used for toki (Māori adze) manufacture during the earliest period of the Polynesian settlement of Aotearoa New Zealand. Bluff Argillite and Tihaka argillite are indurated metasedimentary rocks with similar geological origins. The two major sources of these rocks are located on the Foveaux Strait coast at Colyers Island, Bluff Harbour and Tihaka, Colac Bay, and both sites were extensively quarried for toki manufacture. Comparison of assemblages from different sites is crucial for the investigation of different resource acquisition strategies and toki production technologies in southern Aotearoa New Zealand. This study demonstrates how regional-level studies of Polynesian adze technology can be achieved using archived and new digital assemblages for direct comparison.

Methods and materials

This study compares three digital assemblages as a case study for regional comparison of Polynesian adze production. Photogrammetry and 3D laser-scanning were used during different data collection periods to create assemblages of 3D models of toki, blanks and preforms from the three case study sites of Colyers Island (data collected in 2020), Tiwai Point (2018) and the Tihaka quarry (2023). The existing 3D model assemblages from Colyers Island and Tiwai Point, now stored in different locations, could be freely compared to newly produced models of the Tihaka quarry assemblage. The three digital assemblages were used to identify blank raw material selection, measure the dimensions of the artefacts, analyse reduction strategies, determine the types of toki produced at the two sites, and demonstrate different stages of reduction undertaken at the sites using the Scar Density Index (SDI) (Clarkson 2013).

Results

Preliminary analysis of the three assemblages shows that all states of reduction were undertaken at the Tihaka quarry, in contrast to Bluff Harbour, where quarrying and initial blank reduction took place at Colyers Island before transport to Tiwai Point for late-stage reduction and toki completion. Similar reduction patterns were observed on some toki across the three assemblages, indicating an existing technical approach to the manufacture of certain toki forms. Conversely, different raw material forms available at Colyers Island and Tihaka also resulted in different approaches to adze manufacture, with adaptations frequently employed on Bluff argillite toki not represented on Tihaka argillite toki. Another similarity noted at both sites was the production of skillfully manufactured toki for export, while smaller, underproduced, yet functional toki were also made, presumably for personal use.

Discussion

The results of this study show similar approaches to toki production in Bluff Harbour and at Tihaka, with underlying differences related to the characteristics of the raw material. This study also demonstrates how 3D modelling can be used to compare technologies from different, although relatively contemporaneous, sites in southern Aotearoa New Zealand. As more quarry assemblages are digitised as 3D models, further regional and interregional studies can be undertaken, including the investigation of adze technology development across other Polynesian island groups. Using existing digital model assemblages, future scholars will not need to rely on data collected by previous researchers and can tailor their own methods of data collection depending on their study.

References:

Clarkson, Chris. 2013. "Measuring core reduction using 3D flake scar density: a test case of changing core reduction at Klasies River Mouth, South Africa." Journal of Archaeological Science 40 (12): 4348-4357.

88. How Much is Too Much? Overcoming Difficulties Associated with Large Photogrammetry Data Sets

*Corey Noxon (Ritsumeikan University)**

The accessibility of 3D scanning technologies available today provides for a variety of new approaches to archaeological investigative tasks. We can record more data than ever before, create more complete recordings of archaeological sites, features, and artifacts, and share those digital recordings more easily to individuals all over the world. By creating thorough and accurate recordings, researchers can examine additional measurements and conduct further analyses of the materials after the conclusion of the recording session that might not have been feasible while on site. While we have yet to reach the full potential of these technological advances, we are starting to come up against some important limitations. For this discussion I will be focusing on the mismatch in the amount of data we can capture and our ability to process and effectively utilize that data. While future technological advances will likely help to alleviate this problem to a certain extent, we are still left with the task of attempting to maximize the potential of these new approaches in the meantime. This presentation will describe an ongoing photogrammetry project aimed at recording and utilizing 3D data gathered from Jomon period pithouse reconstructions in Japan. I will discuss some of the limitations that have been encountered during the course of the project, and some of the techniques and methodologies that are being used to utilize the gathered data to its greatest potential to achieve the project goals.

The initial goal of the project has been to attempt to quantify differences of material and energy costs between different pithouse configurations. Throughout the course of its over 10,000 year history, the most recognizable dwelling structure during the Jomon period was the pithouse. These structures were not monolithic in design, and exhibited a significant amount of variation both regionally and over time. Some pithouse types were fairly circular, while others were more elongated and oblong. Interior support structures in the dwellings varied in type, number, and location. While the reasoning for these changes is unknown, a significant difference in material and energy costs might indicate that these structural changes were tied to changes in residential mobility (Kelly, Poyer, and Tucker 2006; McGuire and Schiffer 1983). While the exact designs of these pithouses beyond the positioning and size of the main dwelling pits and associated postholes are unknown, Japan has a long history of interpretive reconstructions of these dwellings. Pithouse reconstruction designs can vary quite a bit and historical research into these reconstructions has suggested that the designs often serve as a better reflection of society at the time they were built than the period that they are intended to represent, which necessitates a degree of caution and skepticism (Ertl 2021). Despite the initial cautions, reconstructions often follow the original floor plans recorded from archaeological excavations, and their decades of existence provide valuable information on the general lifespan and lifecycle of the different pithouse configurations made. The general variety and range of configurations and material choices used in these reconstructions can be used as a conservative basis for material and energy cost estimates of the original structures.

Working from this basic foundation, the initial work of pithouse recording was started, and has been generally successful. Capture times typically range between one and two hours, reducing the impact that the recording process would have on prospective visitors to the sites. The recording process itself involved the use of a high resolution camera to allow for a high level of data capture, a custom lighting rig was used to compensate for dim lighting within the pithouse reconstructions, and a powerful computer and photogrammetry software were acquired to process the gathered data. To help reduce the number of necessary images and ensure an adequate image overlap for photogrammatic reconstruction, a wide focal length lens was used. Despite this, models often consist of one thousand or more images. On one hand, this has resulted in the production of high resolution models that displayed a large amount of detail, achieving another goal of the project. On the other hand, measurement options have been limited in the main photogrammetry software and these large models, consisting of a billion or more polygons, have been too large to utilize in other software programs. While a general approach would be to decimate the model to a more manageable size, the simplification process to reduce that model size also reduces the accuracy of the model, especially when sizes are greatly reduced. This led to a major problem, the capture quality had surpassed the ability to easily utilize the captured data.

A variety of alternative workflows were explored in the attempt to try to retain as much applicable data as possible while minimizing the overall size of the models. This included model division and separation, selective decimation, cross sectioning, as well as advanced simplification processes. These different approaches each have their own benefits, drawbacks, and potential applications depending on the model in question and overall project goal. These different workflows will all be discussed, including associated software options related to each method, pointing out potential pitfalls, and hopefully providing some useful tips for other researchers looking to be able to make the most of their 3D data.

References

Ertl, John. 2021. “Survey of Prehistoric and Ancient Period Architectural Reconstructions in Japan.” Japanese Journal of Archaeology 8 (2): 157–200.

Kelly, Robert L., Lin Poyer, and Bram Tucker. 2006. “Mobility and Houses in Southwestern Madagascar: Ethnoarchaeology among the Mikea and Their Neighbors.” In Archaeology and Ethnoarchaeology of Mobility, edited by Frédéric Sellet, Russell Greaves, and Pei-Lin Yu, 75–107. Gainesville: University of Florida Press.

McGuire, Randall H., and Michael B. Schiffer. 1983. “A Theory of Architectural Design.” Journal of Anthropological Archaeology 2: 277–303.

35. Architectural Experiment based on 3D Model of the Kayukovo 2 Neolithic Defensive-Residential Complex in the North of Western Siberia

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There are more than seven thousand various archaeological sites from the Upper Paleolithic to the Late Middle Ages that have been discovered on the territory of the North of Western Siberia. Neolithic settlements make up at least a thousand of the total number, but only one of them is fortified. Kayukovo 2 is located in the middle reaches of the Ob river in the Khanty-Mansi Autonomous Okrug-Yugra. It is dated by the turn of the 7th-6th millennium BC. This is the earliest example of defensive residential architecture in the North of Siberia.

Methods and Materials

Such defensive-residential complexes are not typical for the cultures of ancient hunters and gatherers. The site consists of the remains of a wood-and-earth fortified structure. It is circular in shape with a cruciform planning structure, which is formed by five main buildings connected by corridors. All of them are surrounded by a wall with a covered tunnel. Every dwelling is a semi-dugout building measuring 4x5 m. Small corridors measuring 1x1 m are leading to the central building. The depth of the pit is 0.6 m from the level of the ancient surface. The walls were made of logs 8–12 cm wide, installed vertically along the perimeter. The walls and the ceiling were covered with a layer of soil.

At first, we made a three-dimensional model in the Blender program. The created 3D model was the result of a detailed reconstruction based on archaeological data and the experience of experimental reconstructions of other sites. Quadcopter surveys, field drawings and full-fledged drawings of all the buildings of the settlement were used as sources. The materials known from ethnography of the indigenous peoples of the North of Western Siberia, who up to these days preserve archaic forms of architecture, were taken into account.

Some of the parameters of the dwellings were reproduced on the basis of archaeological materials: the size of the elements, the materials, the method of fastening the inner and outer parts, the depth of the pit, etc. But it was impossible to determine the height of the structure itself, the length measure, tools and raw materials used. So some of the parameters were relatively accurate, and some were approximate.

The next step was to build the complex full-scaled without nails, so the entire structure could be supported only by pillars. Authentic tools (including those for digging a pit) such as axes, adzes, digging sticks, etc. were reconstructed according to the materials found during the excavations of Neolithic sites in the region. Some of the tools made of wood, bone and leather (wedges for splitting wood, beaters, digging sticks, measuring poles, leather stretchers made of deer skin) were not preserved, and they needed to be reconstructed. The duration of certain works was recorded on video in order to capture the veracity of the experiment.

Results

During the reconstruction of two dwelling and a fragment of the outer defensive wall, we found out what set of tools and parametric features (measurement methods, dimensions, amount of required soil for thermal insulation, etc.) were the most effective. As construction progressed, technical problems were being solved, for example, how to lay a right angle without special tools and make a flat floor. The floor level was measured using a leveling pole.

The problem of metrology was solved by 3D models and experimentally: measurement systems were supposedly recreated; they were based on the human organometric parameters. Calibration of structural elements was carried out using the index fingers and thumbs pinched together. The internal height of the dwelling was 2.25 m, which is the average height of a human with his arm raised up. The depth of the pit was determined using a measuring pole, which was 75 cm high, this approximately corresponds to the human waist. The structure was build from dry tree trunks with a diameter of 10-12 cm, which were then covered with earth. The pressure of soil walls on formwork was also investigated. The waterproofing of the roof and walls was most likely made from birch bark or animal skins, which prevented sand and moisture from entering inside. In one of the facades there was a ventilation hole necessary for air circulation and lighting a fire in the hearth. The outer wall was mounted together with the buildings and served as the outer formwork for the earthen walls of all buildings.

The results of the experiment showed that if the tools were prepared in advance, which took most of the time and were very labor-intensive, such a structure could be created by a team of 10-20 people within one summer period (about three months).

Discussion

The experimental construction has lasted four years already. The first walls made during the experiment in 2020 and three years later prove their stability in different natural conditions, even in winter time with strong winds and heavy snowfalls. With the use of 3D model it was possible to reliably reconstruct the parts of buildings, which were not clearly recorded during excavations. Based on the results of the experiment, a number of hypotheses were put forward, they concern the purposes, social structure of the settlement and the reasons for the cessation of its existence. The architectural investigations are not complete; further excavations and experimental verification are required. Obtaining new data will allow us to get closer to determining the cause of the emergence of this complex planning architecture, untypical for these period and area. It could have appeared both as a result of the development of societies based on a highly productive appropriating economy, but also this tradition could have been brought to the north from somewhere outside. The model was created as part of the projects “Architecture of Ancient Ugra. Stage 2: Project “Museum of Archaeological Experiment in the Salym Kray” and “The Ancient Fortresses of Northern Asia: Excavations of the Kayukovo 1 Settlement (No. 22-2-000453)”. The Neolithic defensive complex is being built as an experimental site for the Museum of Archeology of the region in Salym settlement (Nefteyugansk region of Khanty-Mansi Autonomous Okrug-Yugra).

69. Quantifying Classification: Performing GMM Shape Analysis of Archaeological Artefacts using 3D Models Produced by Photogrammetry

*Emily Tour (University of Melbourne)**

In recent years, a rapid increase in the digitisation of artefact collections has enabled the adoption of innovative new methods to aid in our exploration and analysis of material culture. One such method is shape analysis through geometric morphometrics (GMM), a way of quantifying morphological shape utilising geometric coordinates. GMM was originally developed in the field of evolutionary biology, but has been increasingly adopted into archaeological research – not only in adjacent areas, such as the study of early hominin biology and evolution, but also to aid in the analysis of material culture, exploring both variations and connections between artefact types across time and space. To date, GMM has most commonly been used in lithic analysis, and many of these studies have focused on two-dimensional forms, which can be measured using photographic images. However, recent publications have applied this technique to artefacts as diverse as Taiwanese pots and northwest European ships (Wang and Marwick 2020; Dhoop et al. 2020). As highlighted in the latter study, such analyses are increasingly being carried out in three dimensions, aided by the improved accessibility to 3D models.

This paper will discuss the process of using 3D models, such as those produced through photogrammetry, to conduct shape analysis. The different types of GMM – from landmark analysis to outline analysis – will be introduced, with a discussion of their respective advantages and disadvantages in the context of archaeology. In particular, the utility of GMM to study material culture will be considered, providing a framework to consider shape in a more quantitative way than has traditionally been the case, and moving away from descriptive and qualitative judgements to form more data-driven and reproduceable classificatory systems for different artefact types. As noted more generally by Whittaker et al. (1998), "consistency in classification is one of the most studiously ignored problems in discussions of archaeological typology" (31). GMM, in conjunction with 3D modelling, may be one avenue to help tackle this ongoing issue.

I will be focusing on the utilisation of 3D models and GMM analysis in my own PhD research. My project is aimed at exploring more quantitative, data-driven approaches to understand and compare the different administrative systems used during the Bronze Age period in the Aegean, a region that comprises modern-day Greece, Crete and their surrounding islands. Three different administrative systems were in use throughout the Bronze Age in this region, each based around a different script and its associated repertoire of administrative devices (various types of tablets, dockets, labels and sealings) that were employed for the purposes of trade and accounting – these are the Cretan Hieroglyphic (CH) and Linear A (LA) systems, mostly associated with Minoan sites on and around Crete, and the later Linear B (LB) system, found at Mycenaean sites on both Crete and mainland Greece.

More specifically, I am comparing the different types of administrative devices that were used in each system, to determine where commonalities and contrasts exist. This has interesting implications for understanding the interactions and exchange of ideas between the systems and the respective Minoan and Mycenaean cultures that they are associated with. Previous studies attempting to connect the different systems and identify common types between them have failed to provide any explicit data or reasoning to support their classifications. It is not clear, for example, why we should consider the "discshaped" combination nodules in both the CH and LB administrations to be the same type of device, rather than two different types with a superficially similar shape (especially since the CH and LB systems are separated by multiple centuries in the current excavation record, making the existence of a common type a very significant claim). Or what exactly distinguishes the ambiguously named "prismatic" and "pyramid-shaped" combination nodules in the LB system. Without clear criteria (as is currently the case in Aegean archaeology), such decisions are left to individual opinion and intuition, in line with Whittaker et al.'s concerns above. Coupled with a lack of published, multi-angle images of the majority of these administrative devices, this prevents other scholars from both interrogating prior categorisations and the claims they are used to support, as well as accurately applying such systems of classification to new finds.

Therefore, I am looking to take a more quantitative approach to the categorisation of these items in my research, including the way we use shape in these definitions, with an aim to bring greater transparency and clarity for those referring to such categories in future. A major part of my project involves producing 3D models for a large number of these administrative devices, focusing on types that been used to propose different connections or discontinuities between the different systems. Using these models, I will be able to then carry out an analysis of their respective shapes using GMM, examining the clustering of different devices according to morphology via statistical methods such as principal component analysis (PCA) (as used in both Wang and Marwick 2020 and Dhoop et al. 2020). Preliminary results from my investigation will be presented as a part of this paper.

This study has the potential to reveal information about the level of variation (and standardisation) in shape of device types across different locations and time periods, and consider the reasons behind such trends, such as distinct scribal traditions, local construction techniques or physical constraints, such as the type of object being sealed. It may also help elucidate whether items that have been classified as "common" between different administrative can be considered as truly similar in shape, as well as provide clearer quantitative boundaries to define different sub-types of devices based on morphological form.

It is intended that this paper will showcase GMM as one of the many innovative applications that 3D modelling techniques can support in archaeological studies, with the potential to greatly improve the systems of classification which underpin so much of our practice.

References

Dhoop, Thomas, Sarah Stark, Juan-Pablo Olaberria, and Julian Whitewright. 2020. "Quantifying Ship Shape in Archaeology: Evaluating 3D Geometric Morphometrics." International Journal of Nautical Archaeology 49 (1): 49–64. https://doi.org/10.1111/1095-9270.12413.

Wang, Li-Ying, and Ben Marwick. 2020. "Standardization of Ceramic Shape: A Case Study from the Iron Age Pottery from Northeastern Taiwan." SocArXiv. https://doi.org/10.31235/osf.io/q8hn9.

Whittaker, John C., Douglas Caulkins, and Kathryn A. Kamp. 1998. "Evaluating Consistency in Typology and Classification." Journal of Archaeological Method and Theory 5 (2): 129–64.

92. The Use of 360 Video Devices for Rock Art Research

*Fritz E. G. Hardtke (Macquarie University)**

Context and the role of landscape are key concepts to be considered in any archaeological investigation and it could be argued that Rock Art research places an even greater emphasis on these aspects. As with other archaeological pursuits, Rock Art research has benefitted over the past decade or so from the inclusion of increasingly sophisticated digital techniques for the recording and analysis of rock art panels and motifs. Digital devices continually improve in their capture fidelity as well as in their ease of access to researchers. The placement of rock art localities in a context is typically undertaken, as with archaeology generally, via GIS and GPS – enabled methods. While critical to the analysis, this results in a two-dimensional, plan view with very little information or perspective into the landscape in which the rock art is situated. The need and utility of digital mapping supplemented with on the ground, navigable viewpoints has already been demonstrated for everyday life through technologies such as GoogleEarth/Maps ™ and Google Street View ™. Use of 3D capture, photogrammetry, Reflectance Transformation Imaging (RTI) and so on have been active for many years in Rock Art research, however these are most often deployed for the capture of specific aspects of the localities and panels. What remains is the ability to capture rapidly and easily, more broadly, the context of the rock art within landscape. This is particularly important in areas under threat and subject to landscape modification by quarrying, mining and other destructive activity. It will be argued that devices capable of recording 360 video offer great utility, accessibility and relatively low cost to Rock Art research and archaeological survey to this end. These devices not only provide navigable 360-degree records of the passage through rock art bearing landscape such as valleys, but also offer the ability to anchor these via GPS to a digital map, provide immersive engagement and a rapid means of creating 360 panoramic virtual tours of rock art localities. These will be covered in this paper along with the results of trials conducted in Egyptian Rock Art research.

122. Developing a 3D Virtual Reconstruction of the Lawrence Chinese Camp, Central Otago, New Zealand: Method and Impacts on Descendant Aspirations

Isaac H McIvor (University of Otago); Richard Walter (University of Otago); James Ng (Lawrence Chinese Camp Charitable Trust)*

Virtual reconstruction of historical places and objects is an invaluable tool for engaging and connecting descendant communities with their heritage in more visceral ways than historical photographs, drawings, and text may do alone. These reconstructive technologies are particularly powerful when the remains of historical places are ephemeral or are no longer visible on the ground surface.

Established in 1867, the Lawrence Chinese Camp (LCC) in Central Otago was the first Chinese settlement in New Zealand. The Provincial Government invited the occupants into Otago from the gold fields of Victoria and South Australia after a decline in gold revenues in Otago led miners to prospect on the West Coast. The village thrived through the last decades of the nineteenth century, with the last resident dying in the 1940s. Since then, the camp has sat as a flat paddock with a single abandoned structure – the old Chinese Empire Hotel.

For the last two decades, a group of Chinese descendants and Lawrence residents, led by Dr James Ng, have been trying to develop the Camp as a focus of New Zealand Chinese identity. Four archaeological excavations at the Camp have revealed a clear but complex picture of the structures, material culture and aspects of daily life. However, these findings remain fairly abstract in archaeological reports and museum collections. The original intent of the descendants and Lawrence residents was to physically reconstruct the camp as a focal point around which the aspirations of the New Zealand Chinese community could be realised. These aspirations included understanding the origins of and growing the unique New Zealand Chinese identity, the desire of the descendant community to understand the lifeways of their ancestors, a place where New Zealand Chinese culture could be celebrated during Chinese New Year, and the development of a visitor's centre at Lawrence. Unfortunately, current heritage legislation prevented the physical reconstruction.

In developing a 3D model of the Camp, we attempt to bring it out of the ground and into the real world – presenting daily life in a way that is accessible and engaging for descendants, Lawrence residents and visitors. This paper describes the workflow of developing a 3D model of the LCC and its benefits for the LCC descendant community. The model was built in the gaming development software, Unreal Engine 5.3, from late nineteenth and early twentieth-century photographs, photogrammetric models of extant buildings, and records of archaeological excavations in four seasons between 2008 and 2014.

89. An Australian Overview: The Creation and Use of 3D Models in Australian Universities

Jackson Shoobert (University of New England); Thomas J Keep (The University of Melbourne); Jessie Birkett-Rees (Monash University); Madeline GP Robinson (University of Sydney)*

Digital modelling of heritage objects is a growing area of teaching and research in the archaeology departments of Australian universities, with major institutions investing in evolving production techniques, archival principles, research methodologies, and teaching practices. The growth in Object-Based Learning as a pedagogical principle in archaeological classes coincided during the COVID-19 pandemic with a 'digital stampede' to produce online-accessible digital resources to facilitate continued object-based learning practices under remote learning conditions. Since the removal of lockdown requirements, digitisation programs have continued across many Australian institutions, although these programs are often exercised piecemeal and in isolation from one another. Without established best practices in the digitisation of archaeological collections, it is likely that institutions are developing their own workflows, methodologies, and practices that may not be easily adaptable, raising concerns over the future-proofing of produced models to be shared, studied, and archived between institutions. This paper proposes to bring together academics and technicians working at different universities across Australia to share their techniques and practices in the interest of encouraging a dialogue on best practices.

The creation of digital 3D models from heritage collections can be accomplished through a variety of approaches, with structure-from-motion photogrammetric modelling, structured light scanning, and laser scanning being the most commonly adopted in university settings. The method of digitisation influences the nature and characteristics of the produced model, which has implications for how the model is used in teaching and research. The array of methodologies that have been adopted by prominent academic institutions such as the University of New England, University of Melbourne, Monash University, and the University of Sydney will be discussed whilst also examining the consequential impact of these selections.

The diverse approaches to the digitisation and digital archiving of archaeological collections also prompt us to reflect on current teaching and learning practices in archaeology (Chatterjee et al. 2015). Technologies occupy an important place in archaeological education and techniques for computer-aided digital visualisations have been employed and evolved in archaeological classrooms for more than 30 years. The proliferation of digital collections has made digital objects more accessible and familiar, and online or 'blended' learning encourages the integration of digital collections in course materials. Recent evaluations have also indicated teaching advantages in the use of 3D digital models of archaeological collections through improved outcomes in both learning and engagement (Pollalis et al. 2018). The diversity of digital data is a strength and a challenge for teachers and students, and we are interested in how institutions and educators can best encourage students of archaeology to be constructive, critical users and creators of digital data. We comment on the integration of 3D models in object-based learning and inquiry-based pedagogy and consider the role of digital replicas in promoting 'deep learning' (Derudas & Berggren 2021). We also investigate the use of 3D models to contribute to digital literacy—the ability to use, understand and communicate about digital tools—and data literacy, building practical skills and promoting fluency in the wider intellectual and ethical frameworks of digital collections creation and research.

Jackson Shoobert is the 3D Digital Officer operating out of the Learning Media Team at the University of New England. Over the last four years, he has contributed over one thousand 3D models to digitisation projects across his institution using structure-from-motion photogrammetry, structured light scanning, and bespoke model design. The faculty-agnostic, holistic approach of his position has seen him work on materials from archaeological, paleontological, and geological collections at length. Recent efforts have been focused on bringing these resources into multimedia based virtual tours based on 360 imagery to facilitate digital learning opportunities at a larger scope.

Tom Keep is a PhD candidate and Digital Resource and Research Support Officer at the University of Melbourne, and has since 2022 been producing 3D models for the Faculty of Arts, primarily the Classics and Archaeology collections. In that time, he has been expanding on his practices to include the production of digitisation reports, incorporating cross-polarisation and focus stacking into his photography workflow, and exploring the potential of combining photometric stereo and structure-from-motion photogrammetry data for clearer representation of fine surface details.

Jessie Birkett-Rees is a senior lecturer in archaeology at Monash University's Centre for Ancient Cultures. She is a landscape archaeologist, specialising in spatial analyses, landscape reconstruction and modelling to address archaeological questions. Jessie works with material and digital objects in her teaching and research, has contributed to the production and curation of digital collections, and is interested in questions of authorship, ownership and accessibility of digital artefacts.

Madeline Robinson is a PhD candidate and Archaeology Support Officer at the University of Sydney. Throughout Madeline's role at the University, she has been involved in creating an online photogrammetry catalogue of archaeological, geological, and biological material from the Chau Chak Wing Museum, primarily used for Object-Based Learning classes. Additionally, Madeline creates photogrammetry models in the field, both aerial and close-range using drones and handheld cameras for University of Syd projects, and has recently been incorporating Terrestrial Laser Scanning into the workflow. Madeline also regularly trains photogrammetry to Honours and Post-graduate students and has written an introductory manual to photogrammetry for archaeology students, to be released in August 2024.

References:

Chatterjee, Helen J., Leonie Hannan, and Linda Thompson. “An Introduction to Object-Based Learning and Multisensory Engagement.” In Engaging the Senses: Object-Based Learning in Higher Education, 1–18. London: Routledge, 2015.

Derudas, Paola, and Åsa Berggren. “Expanding Field-Archaeology Education: The Integration of 3D Technology into Archaeological Training.” Open Archaeology 7, no. 1 (2021): 556–73. https://doi.org/10.1515/opar-2020-0146.

Pollalis, Christina, Elizabeth Joanna Minor, Lauren Westendorf, Whitney Fahnbulleh, Isabella Virgilio, Andrew L. Kun, and Orit Shaer. “Evaluating Learning with Tangible and Virtual Representations of Archaeological Artifacts.” In Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction, 626–37. Stockholm Sweden: ACM, 2018. https://doi.org/10.1145/3173225.3173260.

4. Are We There Yet? A Case Study in 3D Scanning Applications on Mobile Platforms for Resource-Limited Museums within the South Island, New Zealand

*Jennifer T Copedo (Tūhura Otago Museum)**

In the current world of digitising museum collections, the use of computer based professional 3D scanning and photogrammetry software such as Metashape has set a gold standard for producing intricate and detailed models. Such can be seen in the incredible 3D modelling of early Italic armour completed by Emmitt et al. (2021). However, this endeavour demands significant financial investment and a considerable commitment of time. Additionally, it necessitates a profound level of expertise and comprehension in photography, laser scanning, and related software. With the emergence of mobile applications on Android and Apple devices, a pertinent query arises: Could these readily available mobile applications, despite potentially lower resolution compared to established computer software such as LSDR and Metashape, offer a considerably quicker and user-friendly service, thereby serving as a practical alternative to expand digital offerings online?

This presentation aims to provide an overview of the ongoing investigation led by Tūhura Otago Museum staff around this question. The study focuses on a comparative analysis of three distinct 3D scanning applications: Polycam, Kiri Engine and Scaniverse, assessing the resolution of the generated models, the ease of usability, and the efficiency in terms of time consumption during the processes of capturing, scanning, and subsequent model processing.

The primary objective of this comparative study is to identify a superior 3D scanning application that strikes a balance between providing satisfactory resolution quality and optimizing efficiency, thereby enhancing staff productivity and time utilization, as well as avoiding the extraordinary financial cost of professional software. By scrutinizing these key parameters across different applications, the research aims to determine which app offers an optimal combination of decent resolution and expeditious processing, crucial for fulfilling the museum’s objectives effectively.

The study envisages a multifaceted purpose for the generated models: firstly, broadening public outreach by facilitating remote access to the museum’s collection via an online portal, secondly enhancing the museum visitor experience for the sight-impaired by providing replicas that they can touch, and finally, bolstering educational programs.

However, at present Tūhura’s staffing levels are inadequate, with only four full-time Collection Managers responsible for overseeing a collection exceeding 1.5 million taoka. The limited manpower leaves minimal time for their daily tasks, let alone pursuing digitization projects, and in the current financial climate unfortunately hiring more staff is not feasible. Also, many projects have been put to the side due to the lack of funding and appropriate resources. In a recent interview with am hub, Director Ian Griffin highlighted the disparity between Tūhura's annual funding telling viewers that Tūhura "gets $4 million a year in ratepayer funding from the local council but it costs $9 million to run the museum." Therefore, given the staffing numbers and lack of resources available, it is unfeasible to adopt 3D modelling via the professional path.

This investigation aligns with contemporary scholarly works in cultural heritage preservation and 3D modelling. Leveraging insights from Ch'ng et al. (2019) and Konstantakis et al. (2023), both offering guidelines for mass photogrammetry in crowdsourcing 3D cultural heritage, this study aims to contribute to the discourse by exploring the utilization of mobile 3D scanning applications within the museum context. By presenting an alternative approach tailored to resource-limited settings, this research complements existing methodologies, broadening the scope of accessible methodologies for digital preservation.

This study also resonates with the innovative strategies proposed by Munir et al. (2019) for employing photogrammetry and 3D scanning on mobile phones, our investigation into Scaniverse, Kiri Engines, or Polycam aims to assess their viability within a museum context constrained by limited access to high-level software.

Finally, this study also draws conceptual parallels with Shults (2017), emphasizing the potential of low-cost photogrammetry for cultural heritage preservation, aligning with our exploration of mobile 3D scanning applications as representative of affordable and accessible technology within the context of Tūhura Otago Museum.

By synthesizing insights from these influential works into the context of our ongoing investigation at Tūhura Otago Museum, we aim to contribute to the discourse surrounding digital heritage preservation and accessibility. Additionally, we seek to define the potential implications and future trajectories for employing mobile 3D scanning applications within resource-limited cultural institutions, potentially paving the way for broader access to museum collections and enhanced educational experiences.

References:

Ch'ng, Eugene, Shengdan Cai, Tong Evelyn Zhang, and Fui-Theng Leow. 2019. 'Crowdsourcing 3D Cultural Heritage: Best Practice for Mass Photogrammetry'. Journal of Cultural Heritage Management and Sustainable Development 9 (1): 24–42. https://doi.org/10.1108/JCHMSD-03-2018-0018.

Griffin, Ian. "Tūhura Otago Museum says it's facing $5m battle to operate, calls for Government assistance" Hewett, William. 27/03/2023 https://www.newshub.co.nz/home/new-zealand/2023/03/t-hura-otago-museum-says-it-s-facing-5m-battle-to-operate-calls-for-government-assistance.html

Konstantakis, Markos, Georgios Trichopoulos, John Aliprantis, Konstantinos Michalakis, George Caridakis, Athina Thanou, Anastasios Zafeiropoulos, et al. 2023. 'An Enhanced Methodology for Creating Digital Twins within a Paleontological Museum Using Photogrammetry and Laser Scanning Techniques'. Heritage 6 (9): 5967–80. https://doi.org/10.3390/heritage6090314.

Munir, Verda, Euan Dempster, and David Lyons. 2019. 'Innovative Strategies for 3D Visualisation Using Photogrammetry and 3D Scanning for Mobile Phones'. https://doi.org/10.14236/ewic/EVA2019.43.

Shults, Roman. 2017. 'New Opportunities of Low-Cost Photogrammetry for Culture Heritage Preservation'. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 42: 481–86.

40. Photogrammetry and 3D Modeling: Refining a Method for Use in Digital Education

*Kelly J Baer (Northern Arizona University)**

The exponential growth of digital technology has allowed archaeologists to adopt new techniques and digital tools for use in the field quickly. From the early days of analog recording and hand-drawn site plans to contemporary tools like photogrammetry and 3D modelling, the rapid evolution of technology has led to greater accuracy and efficiency when collecting and processing data. For this reason, archaeology students today are expected to be familiar with digital technology and to refine their technical skills over the course of their studies. But with greater efficiency in the field also comes the responsibility to disseminate information effectively. Here, I present a case study of photogrammetry for public archaeology at the well-visited site of Xunantunich in western Belize, and analyze the process of developing educational material alongside descendant and Indigenous communities. Using a tablet, DSLR camera, and a tripod, digital teaching models of fourteen structures within the site core were created and designed primarily for use by local tour guides, as well as by local K-12 classrooms. The goal of this project was to open new avenues for public archaeology and better serve the local and Indigenous communities in which archaeologists work. This pilot project serves as evidence that by using digital techniques like 3D modeling and photogrammetry, archaeologists can simultaneously collect data while also preparing more widely-accessible learning materials for the public.

95. Rock Art Conservation by Digital Record: Monitoring Degradation Over Time in the Blue Mountains

*Lauren A Roach (University of Sydney)**

Technological advancements have revolutionised the conservation of rock art by digital record. However, while the use of 3D scanning to record rock art sites is now considered best practice globally, the two principal methods of 3D scanning – photogrammetry and LiDAR – have not been widely tested in terms of their applicability to rock art recoding in the Australian context. Rock art studies utilising 3D modelling in the conservation of sites have been mostly confined to north-western Australia (Davis et al. 2017; Jalandoni and May 2020; Kowlessar et al. 2022). Of those that have had this focus, very few undertake a methodological comparison of photogrammetry and TLS LiDAR 3D models (Davis et al. 2017). This research aims to fill this gap, by conducting this comparison and framing it within the risk of permanent damage or loss of sites to climate change.

This research was undertaken as part of an honours thesis with the University of Sydney in 2023. The major research question is; can 3D scanning and modelling technology assist in the monitoring and recording of rock art sites over time, particularly in identifying degradation? The research has two main aims; to achieve high quality, accurate conservation by digital record which can help to monitor rock art sites over time. In order to achieve this, the second aim of this research is to compare the two methods of photogrammetry and LiDAR to identify which method is best in terms of accuracy, time and money. Additionally, this data is utilised to detect change over time by comparing the current site conditions to old photos of the sites in order to determine the usefulness of 3D models as conservation and management tools.

To identify noticeable signs of degradation over time, this research compares older photos with new photogrammetry and TLS (terrestrial laser scanner) LiDAR images. A secondary comparison is also undertaken of photogrammetry and TLS LiDAR methods. To achieve this, two case study sites have been chosen in the Blue Mountains to address a bias towards rock art recording and conservation projects in northern Australia, which has left the vast number of rock art sites in the Blue Mountains unstudied and unmonitored. In addition, the rock art in the Blue Mountains is particularly prone to damage from bushfire, making it more urgent than ever to improve and accelerate conservation and management methods in this region of Australia.

The photogrammetry for this research was done by taking thousands of photos for each site on a Canon EOS 80D DLSR camera, and processing of the 3D models was done using Agisoft Metashape Professional. The TLS data was collected using a Leica BLK360 G1 LiDAR scanner, and 3D models were then processed using the Leica Cyclone Suite.

The 3D model results were used to undertake a comparison of photogrammetry and TLS methods and their application to rock art conservation. This was done by conducting a time, cost, portability and accuracy analysis to determine which method is not only more accessible, but which is also better in terms of its representation of the sites. The results indicate that the photogrammetry models provide a higher quality model, in terms of point cloud alignment, mesh and texture quality. Photogrammetry is also a more cost and time effective method, and is more portable and achievable, particularly when working with sites that are remote access. The results were also used to undertake a secondary comparison of current site conditions to those in old photos of each site. Major signs of change over time were bushfire damage, which can clearly be seen at both sites. The research indicates that conservation by digital record is a useful method in monitoring for signs of change to sites, and also creates high quality records of the site which is valuable if they are damaged further or lost completely.

Thus, the research shows that these methods of digital conservation should be applied to other sites in the Blue Mountains, as well in other areas of Australia and even globally. It is important that people look after Indigenous sites and the knowledge they hold so as not to lose them. Within Australia, there has been an increase in bushfire activity as is demonstrated by the 2019/20 bushfire season. These major bushfire events are only going to increase as the effects from climate change worsen. The time to act in preserving Indigenous rock art sites and other sites is more urgent than ever before they are further damaged or permanently lost. 3D scanning and modelling of sites, particularly through photogrammetry, offers an effective and accessible method to create high quality records of these sites.

The data collected for this research can still be improved, particularly the TLS models by integrating high quality digital images taken for the photogrammetry onto the models to create a clearer and more detailed texture. Additionally, all 3D models used in this research will be uploaded to an accessible online platform in line with FAIR data principles so that they can be viewed and utilised by others, with a vision towards future monitoring to assess degradation over time. Further, it is important that all research done on Indigenous sites and the results be shared with community in a way which is accessible. Regardless of areas for improvement, the 3D models created through this research offer valuable conservation and management tools which can be used into the future to monitor for further signs of change to these rock art sites.

References

Davis, Annabelle, David Belton, Petra Helmholz, Paul Bourke, and Jo McDonald. 2017. “Pilbara Rock Art: Laser Scanning, Photogrammetry and 3D Photographic Reconstruction as Heritage Management Tools.” Heritage Science 5 (1): 25. https://doi.org/10.1186/s40494-017-0140-7.

Jalandoni, Andrea, and Sally K. May. 2020. “How 3D Models (Photogrammetry) of Rock Art Can Improve Recording Veracity: A Case Study from Kakadu National Park, Australia.” Australian Archaeology 86 (2): 137–46. https://doi.org/10.1080/03122417.2020.1769005.

Kowlessar, Jarrad, Ian Moffat, Daryl Wesley, Tristen Jones, Maxime Aubert, Mark Willis, Alfred Nayinggul, and the Njanjma Aboriginal Corporation. 2022. “Applications of 3D Modelling of Rock Art Sites Using Ground-Based Photogrammetry: A Case Study from the Greater Red Lily Lagoon Area, Western Arnhem Land, Northern Australia.” In Visual Heritage: Digital Approaches in Heritage Science, edited by Eugene Ch’ng, Henry Chapman, Vincent Gaffney, and Andrew S. Wilson, 93–114. Springer Series on Cultural Computing. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-77028-0_6.

39. Characterising 1000 Years of Byzantine Era Dog Cranial Morphology: A 3D Geometric Morphometric Approach

Loukas G Koungoulos (Australian National University); Ozan Gündemir (İstanbul University-Cerrahpaşa, Istanbul); Margot Michaud (University of Liège); Vedat Onar (İstanbul University-Cerrahpaşa, Istanbul)*

This paper describes the preliminary results of a digital morphological study of a large sample of archaeological dog skulls from the Byzantine (Roman) period in present-day Istanbul, Türkiye. Excavations at the Marmaray and Metro sites retrieved several hundred dog crania, covering over a millennium duration of deposition within the city of Constantinople’s Theodosius Harbour - from the 4th to 15th centuries AD. Most of the crania belong to adult dogs, and are of good to exceptional preservation quality, making them highly suited to morphological analyses. To date only traditional (caliper-based) and nonmetric studies have been undertaken, which suggest the vast majority were essentially stray or street dogs, rather than pets. Here, we report the first 3D geometric analysis of the Marmaray and Metro dogs. We discuss their morphological character, the extent of change and stability in their cranial forms throughout the millennium the sample covers, and their morphology relative to comparisons with present-day domestic and wild dogs.

83. Facial Reconstruction in the Context of Interdisciplinary Archaeological Research in Banat (Romania)

Lucian M Micle (Polytehnica University of Timisoara); Dorel Micle (West University of Timisoara); Erwin-Christian Lovasz (University Politehnica Timisoara)*

Trigger warning: Please be advised that this paper discusses topics such as death, maiming and human remains. Reader discretion is advised.

Facial reconstruction is a scientific concern with interdisciplinary approaches: medicine, forensics, archeology, etc.; with the support of technology, mechatronics applications and computer programs. In our study, the impact of facial reconstruction in the archeology of the Banat region (located in western Romania) could be of importance because it can help to identify and clarify the diversity of populations that passed through this area over the centuries. The method is little used in Romanian archaeology, although our region has many discoveries and artifacts whose processing and analysis with the help of specific methods and techniques could provide a more precise placement in the historical context.

Banat is a “contact” region of Romania characterized by the diversity of the population, resulting from an intense migration flow of various groups over time, with very different physiognomy and anatomical characteristics, from the native populations to those who came from Northern Europe or Central Asia. We know that certain periods brought a veritable mosaic of distinctive features, and reconstructing them could make it easier to understand the past.

Our approach is scientific and technical in nature, because we are not interested in making cultural attributions, but rather to understand and gain a better perspective on the cultural baggage of the region in which we live, Banat being considered even today an example of intercultural coexistence.

The ethics of displaying and reconstructing human remains is a thorny subject that has not been very flashed out in Romanian archeological discourse in the form of guidelines. We believe that this type of work must entail both an appropriate level of respect and dignity for the deceased while not compromising in any way on the research and expositional value of the paper or of the resulted reconstructions. In the case of our work, the amalgamation of factors, such as the period from which the remains hail (medieval), the unknown religious or ethnic origin or even identity of the individual coupled with the rescue excavation origin of the remains, consist in our view an unproblematic ethical base for our research material.

Our study is based on data and material collected by archaeologists from the West University of Timisoara and the National History Museum of Banat, within an agreement to share materials and knowledge. We want to create a database of the human remains discovered by archaeologists on the territory of Banat, through 3D scanning, in an inter-institutional collaboration (between archaeologists, engineers, doctors), which will allow specialists to analyze the remains and clarify the physiognomy of the individuals using techniques in facial reconstruction and 3D computer modeling. The method allows us to collect data and establish biometric indicators: dimensions of the skull, bone tissue, for the individuals found in our excavations, useful to the archaeologist for the reconstruction of the soft tissues of the face, but also for the management and administration of all this data by storing it in a digital archive with a unique code for each object.

References

1. GUPTA, S., and al: Forensic facial reconstruction: the final frontier. Journal of Clinical & Diagnostic Research. 2015. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4606364/, last accessed 2023/01/12.

2. WILKINSON, C.: Facial reconstruction--anatomical art or artistic anatomy? Journal of Anatomy, Vol. 216, Issue 2 (12 January 2010), pp. 235-250. DOI: 10.1111/j.1469-7580.2009.01182.x.

3. GARLEANU, L. : Interpretări bioarheologice asupra unui mormânt descoperit la Moșnița Veche-Obiectiv 16 (jud. Timiș). In ArheoVest II. JATEPress Kiadó, Szeged (2014). http://arheovest.com/simpozion/arheovest2/45.pdf, last accessed 2023/01/12.

106. Exploring 3D Modelling Technologies for Difficult Heritage with a Case Study from Treaty 6 Territory, Canada

Madisen Hvidberg (University of Calgary); Peter Dawson (University of Calgary)*

This paper will explore how we are using digital 3D modelling technologies to address community needs regarding the history and legacy of the Indian Residential School (IRS) system in Canada. The use of digital heritage, virtual realities, and 3D modelling practices to address concerns surrounding dissonant heritage and related social justice issues has seen various applications throughout the world, but none yet in a Canadian context. Our project seeks to show how this community directed project is implementing terrestrial laser scanning (TLS) and unmanned arial vehicle (UAV) documentation and data modelling in ways sensitive to the highly dissonant and political history of these sites as well as to Indigenous ways of remembering.

Dialogues created through heritage research across the globe are working to remember injustices of the past, recover subjugated knowledge, and create spaces for the silenced to be listened to. Heritage today challenges legacies of colonialism, racism, and oppression that the field was built on but also challenges unequal historical narratives that do not remember or represent these injustices (Johnston and Marwood 2017:818). Therefore, “doing heritage” does not simply refer to the preservation or celebration of the past, it also involves negotiating and making decisions about the past in the present (Johnston and Marwood 2017:818). The inherited past is part of political, community, and personal discourses in the present, and it is a structuring condition of our future. It is a “social and cultural process that mediates a sense of cultural, social and political change” (Smith 2006:84).

As a particularly contentious part of Canadian history, sites of and associated with Canada’s Indian Residential School system are examples of heritage that are highly politicized and dissonant. IRS were government-sponsored religious institutions that were established with the direct aim of assimilating Indigenous children into the accepted Euro-Canadian culture (Hanson 2019; Miller 2012). As a federal initiative, over 130 residential schools were opened and operated across Canada between 1831 and 1996, and more than 150,000 children attended (Miller 2012). Attendance for the children brought to these schools was mandatory and they were frequently taken from their families by force, often sent to schools far from their home with the intent of further severing connections to their Indigenous roots. To avoid rigorous legal issues many survivors have dealt with the trauma alone or turned to destructive means of coping such as substance abuse. The impacts of intergenerational trauma are becoming more and more evident, and there is a nation-wide issue of disconnect between future generations and cultural traditions.

Of the 130 schools that were in operation, few of these buildings still remain standing in Canada. Often repurposed for other uses, subject to neglect, or purposefully destroyed these buildings have largely been an overlooked marker of this darker aspect of Canadian history. Nevertheless, the schools that remain standing, the grounds where they once stood, as well as the cemeteries and unmarked graves of missing children exist as “sites of conscious” and “witnesses to history” (Dawson 2019; Parry 2017). Consequently, establishing a national strategy for remembering and commemorating IRS structures is among the Calls to Action (78ii; 82; 83) issued by the Truth and Reconciliation Commission of Canada (TRC) (TRC 2015). In this project, we have so far documented three former residential school buildings in Alberta using TLS and UAV. With permission and collaboration of Indigenous community partners and following the principals of OCAP, this paper will use the documentation of carriage house of the former Edmonton Indian Residential School (EIRS) as the main case study for this paper.

In October 2020, the carriage house structure was documented using a combination of TLS, using a Z+F5010X IMAGER and Z+F5016 IMAGER simultaneously to capture the interior and exterior of the site. In addition, the exterior of the building and its immediate surroundings were documented using a DJI Mavik Pro UAV to produce photogrammetric models. Since October 2020, we have been working closely with our Indigenous partners to explore a variety of ways in which these 3D modelling technologies can meet community needs regarding preservation, management, and reconciliation concerns. To date, this has included 3D printing models to use in engaging educational packages, the use of digital and physicalized 3D models as pneumonic devices to help survivors recall memories, and the creation of a virtual museum to share survivor's perspectives and histories more broadly across Canada and the world. In this presentation we will discuss the documentation of the site, our community-based research initiatives, as well as touch on some of the on-going ethical questions surrounding this research regarding data use, storage, and sovereignty.

References

Dawson, P. 2019. Unpublished Transcript of Developing a Strategy for Commemorating and Preserving Former Residential Schools in Alberta: A Workshop. 20-22 February. Notes on file, Department of Anthropology and Archaeology, University of Calgary, Calgary, AB.

Johnston, R, and K. Marwood. 2017. Action Heritage: Research, Communities, Social Justice. International Journal of Heritage Studies 23(9):816-831.

Hanson, E. 2019. The Residential School System. First Nations and Indigenous Studies, The University of British Columbia. Electronic document, https://indigenousfoundations.arts.ubc.ca/the_residential_school_system, accessed October 20, 2023.

Miller, J. 2012. Residential Schools in Canada | The Canadian Encyclopedia. Electronic document,: https://www.thecanadianencyclopedia.ca/en/article/residential-schools accessed: 20 February 2021.

Samuels, K. L. 2019. Deliberate Heritage. The Public Historian, 41(1):121–132.

Smith, L. 2012. Discourses of Heritage: implications for archaeological community practice., Nuevo Mundo Mundos Nuevos. Nouveaux mondes mondes nouveaux - Novo Mundo Mundos Novos - New world New worlds.

Truth and Reconciliation Commission of Canada (TRC). 2015. Truth and Reconciliation Commission of Canada: Calls to Action. Electronic document, http://trc.ca/assets/pdf/Calls_to_Action_English2.pdf, accessed on October 20, 2023.

97. 3D Modelling and Spatial Data Integration for the Documentation of Large-scale Heritage Infrastructure: A Case Study of the Wooden Trestle Bridge of Nowa Nowa, Victoria, Australia.

Marko Radanovic (University of Melbourne); Brian J Armstrong (University of Melbourne); Jacinta Bauer (Heritage Victoria); Martin Tomko (University of Melbourne)*

Large scale heritage listed infrastructure poses challenges for ongoing maintenance, management, and preservation, particularly given the ongoing threats posed by floods and wildfires. One such example is the Nowa Nowa bridge, one of the longest trestle bridges in Victoria, constructed in 1916. Heritage Victoria commissioned a project in conjunction with the University of Melbourne Department of Infrastructure Engineering to provide an integrated and interactive 3D model of the bridge, to be used by structural engineers and heritage practitioners for the assessment of its condition and the visualisation of architectural details.

Here we present a digital platform developed in a game engine as a one-stop integrated solution for a detailed inspection and accurate measurements of the Nowa Nowa bridge. The platform uses an innovative approach of multilayered documentation of cultural heritage, where several different datasets, namely the point cloud, the polygonal mesh surface model, and images, are used as interconnected layers of the integrated model. We present some of the benefits of such an integration, such as the ability to perform accurate measurements on images based on the underlying 3D data. Furthermore, we present and discuss the challenges of collecting and processing the data and creating 3D models of a large-scale and geometrically complex object such as the Nowa Nowa trestle bridge.

193. Complex Survey Methodologies: Documentation, Modeling and Communication of the Forum of Nerva in Rome

Martina Attenni (Sapienza, University of Rome); Carlo Bianchini (IT); Carlo Inglese (IT); Alfonso Ippolito (IT)*

Introduction

The proposal here presented aims at developing an integrated activity through the direct involvement of specialists in all the research areas connected to archaeology (survey, modeling, communication).

The awareness of archaeological heritage implies its scientific investigation through the analysis of all its material and immaterial properties. This process starts from documentation and develops itself through the identification of research perspectives to reach a profound knowledge of the investigate object through collaboration and integration of different skills and methods.

Starting from this, the project aims to design and manage a three-dimensional database containing data related to the subject involving all the innovative procedures of capturing, managing and using knowledge for investigation and even for promotion opportunities related to new interactive tools.

The research focuses on archaeological investigation with a multilayered, multidisciplinary and cooperative approach with this aims:

- validate the research methodology for survey operations;
- design and test a complex information system containing the heterogeneous data related to the research;
- amplify and improve the knowledge of the case study.

Main topic

The chosen case study is the Forum of Nerva, in the central archaeological area of Rome, as part of one the most impressive examples of architectonic complex. The central area of the Imperial fora in Rome has and continues to be the focus of several studies, investigations and excavation campaigns conducted from 1882 to 2022 [1].

Even if throughout history the application of a cooperative method still can be considered as an exception, currently some general changes are quickly overcoming past resistances and naturally leading to a more global and multidisciplinary approach. New technologies do play a very relevant role in this scenario: new documentation methodologies and techniques (i.e. 3D capturing, 3D modeling, GIS systems, mobile app) provide reliable data and models both for architects and archaeologists investigations [2].

Concerning architectural surveying operation, integrating methodologies and acquisition processes have already become a well-established practice, what is still an issue is an effective procedure for data integration; in fact, it frequently is called upon in the construction of three-dimensional models poorly integrated, poorly interoperable and hence hard to work with. Quite apart from the strictly scientific implications, this whole process seems to become crucial also for the sustainability of archaeological management. The increase of the knowledge level immediately corresponds to an improvement of the “level of confidence”, that is the actual possibility of finding a better point of balance between conservation and exploitation (also in economic terms). A deeper knowledge directly leads to a better design and less invasive restoration or retrofitting activities; thus to a more effective conservation and resilience to external pressures (i.e. tourism).

Applications

In the field of Research methodology, architectural survey is a complex process that brings together both quantitative and qualitative data related to metric, geometric, morphologic and proportional features of the investigated object. The research methodology here presented focuses on three phases:

- data capturing, as an objective and quantitative investigation, it aims to give the scientific base to develop further analysis;

- data analysis and interpretation, as a subjective and qualitative investigation; starting from quantitative data, it aims to combine them generating new knowledge about a certain phenomenon;

- information communication, as a merging phase of both quantitative and qualitative information; it is referred to all these operations that are focused on organizing, managing and creating contents that are devoted to the dissemination of what has been accomplished before.

These three phases are materialized in the digital environment by simulating the very same process of research which begins at the stage of excavating and proceeds by successive stratigraphic layers to arrive at an interpretation of the context with all its transformations. With the 3D digital model, realizeb by VPL (Visual Programme Language) [3], the process of enquiry sheds its temporal and spatial limitation; the very same model can be subjected to investigation all the time and - what is more - always in a reversible manner; the same model, moreover, can be discretized and account can be taken only of its parts and stratigraphic layers useful for the data to be understood. These properties of the digital model ensure that the archaeological monument can be visualized according to parameters and research procedures much more efficacious than those that can be applied in loco.

Quite apart from the scale and the location of the investigated object the research aims to validate a procedure for the preliminary setting up of an information system suitable for capturing, interpreting and archiving such a heterogeneous sources of data. In this complex information system, every typology of data may be referred to one of these three main categories:

- historical and cultural, related to a preliminary understanding of the manufact;

- quantitative, derived from surveying activities and from diagnostic operations;

- - qualitative, whose source lies in the interpretative capacities of the researcher.

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Starting by this very first distinction among an undefined number of data typologies, it is possible to design a semantically aware and hierarchically organized system. This complex system is conceived to be built as a 3D virtual model in a 3D virtual and shared environment. This possibility triggers a very fruitful exchange process that implies not only the “geometric” data but, in a wider sense, the results of a multilevel documentation process (historical, bibliographical, constructive). The final complex data set represents the information that currently is used while investigating the archaeology: an open database on one side able to host the different information, on the other suitable for further enrichments.

The research defines a theoretic and procedural workflow able to build up the information system using informatics and technological tools to support the process and design advanced features in data integration. A 3D digital environment was populated with survey data, 3D models, and archaeological interpretations to allow architects, archaeologists, and historians to make their own considerations using only one shared 3D database as a support.

References

[1] Viscogliosi, A. 2000. I Fori Imperiali nei disegni d'architettura del primo Cinquecento: ricerche sull'architettura e l'urbanistica di Roma. Roma: Gangemi editore.

[2] Arrighetti A., Pansini R. (eds.) 2022. Sistemi e tecniche di documentazione, gestione e valorizzazione dell'architettura storica. Alcune recenti esperienze, «Archeologia e Calcolatori», 33, 1 (http://www.archcalc.cnr.it/journal/idyear.php?IDyear=2022-07-25).

[3] Vandenabeele, L., Loverdos, D., Pfister, M., Sarhosis, V. 2023. Deep Learning for the Segmentation of Large-Scale Surveys of Historic Masonry: A New Tool for Building Archaeology Applied at the Basilica of St Anthony in Padua, International Journal of Architectural Heritage, DOI: 10.1080/15583058.2023.2260771

183. Towards Digitising a Fleet, a Maritime Museum Case Study

Michael Rampe (Rampe Realistic Imaging Pty Ltd); David O'Sullivan (Australian National Maritime Museum); Mr Snow (Australian National Maritime Museum)*

Maritime museums worldwide hold significant items relating to a crucial and important element of human history. "Maritime museums are popular because of the metaphorical power of ships, which appeal as emblems of memory and identity... and they similarly define individual identity by evoking a life journey of discovery, a spiritual voyage of pilgrimage through ordeal and trial." (Hicks 2001, 171) The Australian National Maritime Museum in particular houses over 160,000 historic artefacts - the largest in the southern hemisphere. Of these, 53 are historic vessels, 12 of which are floating.

Digitisation programs are well underway in many museums but often this is relegated to digitising analogue records or taking photos of items for online catalogues. In a post-pandemic world there is now a renewed appetite and fervour for full scale high resolution 3D imaging, which is especially relevant to large assets such as vessels in maritime museums. With improvements in 3D digitisation speed, scale and application over the last 5-10 years, maritime museums are now seriously considering whole-of-fleet digitisation. Given the capability and enthusiasm currently present, the authors have begun a program of work to begin 3D digitising the fleet and other maritime assets at the Australian National Maritime Museum.

"The ship is a seductive artefact, and museums have succeeded in attracting audiences because of the promotion of authenticity in preserved ships, or the conflation of original vessels and replicas" (Hicks 2001, 171). Given this authenticity, why is 3D digitisation seen as a must have to a modern large scale maritime museum? The purposes for 3D digitisation in this sector is broader than many non-maritime efforts and is borne out in several distinct ways, all of which can benefit collectively from a good high res 3D imaging process.

Conservation

Conserving and maintaining collections in a maritime museum poses significant challenges. They also grapple with issues of scale. The largest accessioned item in any museum collection in Australia is currently floating in Sydney's Darling Harbour.

Preservation and conservation of assets that are degrading and changing overtime is a constant and perpetual task for the maritime museums and the maritime industry itself especially when an important part of the collection is in the water.

Metrics

As the vessels are often very large, the result of imaging can also be used to confirm schematic drawing, measurements, and other related information about the items for the purpose of vessel movement, vessel housing and creation of displays.

Access

Digitisation can also be used in the context of difficult, dangerous, or otherwise inaccessible interior spaces on the larger vessels which allows visiting members of the public to get virtual views otherwise unavailable. It also helps share the collection nationally and internationally which is a core purpose of a large national publicly funded museum.

Remediation

Digitisation of the hulls of vessels that usually sit in water can be done during dry dock cycles and increasingly is seen as a core element of documenting remediation work alongside the usual cleaning and painting activities undertaken. 3D imaging provides an important snapshot of condition over time and can be useful for planning remediation cycles, interventions and success.

Reconstruction

Sadly, eventually some vessels need to be scrapped, regardless of the remediation undertaken, and many vessels are also accessioned that are not fully intact, especially as is the case with sunken or recovered shipwrecks. 3D digitisation is a breakthrough assistant when it comes to digital and/or physical reconstructions or preservations in terms of replicas.

Interpretation

Once digital assets are in hand, they can also be used for outreach and education programmes on web platforms or for interpretation, signage and interactive elements of the physical displays themselves.

Research

Although it may not need direct articulation for this audience, there are several unique research opportunities related to digitising vessels with 3D imaging. This includes vessels in museums, on or in the water, and those still being discovered and/or recovered from the sea floor.

It is clear now that "the potential of a well-resourced 3D-laser-scan survey to rapidly record a substantial collection of traditional watercraft in a relatively short time, and to develop the data captured in the field into a variety of outputs that serve multiple objectives" (Cooper et al 2018, 440) is within reach for maritime fleets. Moreover, institutional recognition regarding the benefits of these outputs is now both clearly understood and articulated.

With a focus on the utility of these areas above, this paper will showcase methods used for an initial set of fleet 3D digitisation and talk about the challenges specific to this gigantic task. "The collection that we work with can be a challenge for both photography and 3D data capture. Majority of the collection comprises of quite complex industrial artefacts, with glass elements and metal surfaces, often covered in glossy paint." (Pilarska, n.d.) From small indigenous craft up to a massive military destroyer, a variety of case studies will be discussed from a technical 3D digitisation point of view including novel methods and multi-modal bespoke solutions for these particularly difficult subjects.

References:

Hicks, Robert D. 2001. "What Is a Maritime Museum?" Museum Management and Curatorship, 19:2, 159-174, DOI: 10.1080/09647770100401902

Pilarska, Marta n.d. "Scanning The Horizon: Preserving the maritime heritage of Scotland" Accessed Oct 25, 2023. https://www.capturingreality.com/preserving-the-maritime-heritage.

Cooper, J.P., Wetherelt, A., Zazzaro, C. and Eyre, M. 2018, "From Boatyard to Museum: 3D laser scanning and digital modelling of the Qatar Museums watercraft collection, Doha, Qatar". International Journal of Nautical Archaeology, 47: 419-442. DOI: 10.1111/1095-9270.12298

170. Enmasse Scanning and Curation of Small Objects using MicroCT

Riley C W O'Neill (University of Minnesota); Katrina Yezzi-Woodley (University of Minnesota); Jeff Calder (University of Minnesota); Peter Olver (University of Minnesota)*

Modern archaeological methods increasingly utilize 3D virtual representations of objects, computationally intensive analyses, high resolution scanning, large datasets, and machine learning. While high resolution scanning provides more resolution, it also increases challenges surrounding memory, computational power, and storage. Processing and analyzing high resolution scans often requires memory-intensive workflows, which are infeasible for most computers and increasingly necessitates the use of super computers or innovative methods for processing on standard computers. As such, researchers must find more efficient and effective methods for the production, processing, and curation of 3D models of objects. Recently, methods utilizing batch-scanning via medical and micro-CT have emerged that allow the efficient creation of 3D models of archaeological materials (Göldner, Karakostis, and Falcucci 2022; Yezzi-Woodley, Calder, et al. 2022). The continued development and improvement of these methods is paramount to the implementation and innovation of new data extraction and processing pipelines from large 3D mesh datasets (e.g. Yezzi-Woodley, Terwilliger, et al. 2022).

Here we introduce a novel, semi-automated Micro-CT (µCT) scanning protocol and processing scripts for en-masse scanning of small objects that offers an efficient workflow for processing µCT scans in a memory-limited setting. Our processing methods never bring the entire scan simultaneously into memory - any machine with at least 16GB of memory (and extracted sub-volumes less than this size) can use our methods. This allows those without access to intensive computing resources but still suitable storage space to use our methods. We scanned 1,500 animal bone fragments with only 10 µCT scans that were then post-processed into individual PLY files. The bone fragments were derived from ungulate (Cervus canadensis, Bos taurus, Ovis aries, Equus caballus, and Odocoileus virginianus) appendicular skeletal elements experimentally broken by carnivores (Crocuta crocuta) or the use of stone tools. By packing the objects into a tiered 3D grid structure and creating CSV files that track the layout of objects in each tier, several hundred objects can be scanned simultaneously. This method implements memory-efficient processing scripts in Python that require minimal human intervention for scan subsampling, bounding box identification, sub-volume extraction, and surfacing. This builds off prior work utilizing a semi-automated post-processing on medical CT on a 2D grid (Yezzi-Woodley, Calder, et al. 2022).User intervention is only required in initial scan rotation/cropping of the scan and the workflow for bounding box identification on the subsampled volume, which takes but a few minutes. The remainder of the pipeline is completely automated. Sub-volume extraction and fragment surfacing are the most time-consuming portions of the workflow, but these require no user intervention. Crucially, our methods apply not just to the processing of bone scans, but any object (with a density discernible from the packaging material). This makes this method applicable to a variety of inquiries and fields - not just within anthropology, but paleontology, geology, electrical-engineering, materials science, or any discipline using mass µCT scanning of small objects.

The capacity to create voluminous amounts of data is only the first step. Handling large amounts of data after-the-fact can be a complex process. This is especially true within archaeology, where researchers must synchronize and dually work between collections in both their physical form and digital form along with the associated metadata that provides the all-important context necessary in our field. Furthermore, excavation and research at archaeological sites are generally ongoing meaning that collections (physical and virtual) oftentimes continue to expand over time. The sheer amount of data and metadata can be confusing and overwhelming, especially for those who are accessing these collections with minimal prior experience with either the collections or the methods utilized to create them (e.g. students, early-career researchers, independent research groups, and educators). Such expansion in the sheer amount of data coupled with the goal of optimizing access to broad audiences amplifies the curatorial and infrastructural needs for building organizational frameworks that support the usability of shared data.

The work presented herein is a component of a larger program facilitated by the international and multi-disciplinary research consortium known as Anthropological and Mathematical Analysis of Archaeological and Zooarchaeological Evidence (AMAAZE). AMAAZE brings together experts in anthropology, mathematics, and computer science who are actively exploring and developing methods for mass-scale virtual archaeological research. Some of the core tenets of AMAAZE are reproducibility, replicability, availability, and usability of our data and methods. Here we discuss the ways in which these data, metadata, protocols, and code are embedded within this larger vision and will be curated and disseminated to the broader research community and general public through open-access resources. We present AMAAZE's ongoing efforts to establish a convention on how to build appropriate and consistent infrastructure that accommodates ongoing scanning of the same collection as well as lasting open-source code repositories and virtual collections. Guided by FAIR and CARE principles, we recognize ways in which open access to data does not always dismantle discriminatory power structures, but can reinforce structures of inequity and the steps we are taking to minimize such effects. Overall, our new scanning method, processing workflows, and curation tenets lay the groundwork and set the standard for future mass-scale, high resolution scanning studies.

References:

Göldner, Dominik, Fotios Alexandros Karakostis, and Armando Falcucci. 2022. "Practical and technical aspects for the 3D scanning of lithic artefacts using micro-computed tomography techniques and laser light scanners for subsequent geometric morphometric analysis. Intro- ducing the StyroStone protocol." Plos one 17 (4): e0267163.

Yezzi-Woodley, Katrina, Jeff Calder, Mckenzie Sweno, Chloe Siewert, and Peter J Olver. 2022. "The Batch Artifact Scanning Protocol: A new method using computed tomography (CT) to rapidly create three-dimensional models of objects from large collections en masse." arXiv preprint arXiv:2205.02691.

Yezzi-Woodley, Katrina, Alexander Terwilliger, Jiafeng Li, Eric Chen, Martha Tappen, Jeff Calder, and Peter J Olver. 2022. "Using machine learning on new feature sets extracted from 3D models of broken animal bones to classify fragments according to break agent." arXiv preprint arXiv:2205.10430.

189. The Virtual Goniometer: A Novel Tool for 3D Molar Segmentation and Occlusal Wear Surface Angle Measurements

Risa L Luther (University of Minnesota); Riley C W O'Neill (University of Minnesota)*

Over the last 20 years, improved applications of 3D scanning technologies and modeling techniques advanced dental and dietary analyses from two dimensions to more detailed dental topographic analyses, which have become quintessential to analyzing hominin and primate dietary patterns (Berthaume, Lazzari, and Guy 2020). However, the majority of these studies are restricted to whole-crown, largely unworn teeth, which not only limits the sample size, but limits the scope of most studies to a restricted period of the organism's life, growth, and development. Although such studies provide qualitative comments on localized wear patterns in certain regions of the occlusal surface, they lack the necessary quantitative measures to assess how and when different components of the tooth change as a function of wear over the course of a primate's lifespan, with the exception of longitudinal studies on primates at research centers that primarily consume "monkey chow." which is far from primates' diets in nature. Although this food may meet the dietary and nutrition requirements of those primates, it has different mechanical properties than that of a diet of a wild primate. Current methods face further challenges and limitations when applied to the vertebrate fossil record where teeth are most abundant and central to reconstructing environmental preferences, behavioral characteristics, and systematic affinities of their owners, in addition to their more obvious information: diet.

Here we advance a quantitative method for measuring local occlusal wear surface angles. Our study includes 3D scans of over 130 moderately to heavily worn mandibular second molars representing extant frugivores (Bunopithecus hoolock, Hylobates lar, Pan paniscus, Pan troglodytes), folivores (Gorilla gorilla), and hard-object consumers (Pongo pygmaeus). We show the efficacy of the Virtual Goniometer (Yezzi-Woodley et al. 2021) as a novel 3D dental topographic metric for occlusal wear surface angles with high accuracy and efficiency as well as a novel tooth segmentation tool. With success here with modern primates, the aim is to expand these methods to fossil specimens, both non-human primates and and hominins.

We utilize the Software for the Analysis and Mapping of Surfaces (SAMS) Hecate package (Gao 2021) as a means to consistently align and subdivide molars into five patches, which roughly coincide with the five cusps of the lower molars. We segment each patch using the Virtual Goniometer, which segments the occlusal surface from the side wall (i.e., corresponding buccal, lingual, mesial, and distal surfaces) and gives a normal vector corresponding to the plane of best fit for each segment. We then measure three key quantities: the angle between the occlusal surface and side wall, the angle between the occlusal normal and x-y plane, and the angle between the upper occlusal normal and the x-axis to fully capture the orientation of the plane. The angle between the occlusal surface's plane of best fit normal and x-y plane is very similar to the average inclination of the occlusal surface segment (angle between the surface normal and the x-y plane) (Berthaume, Lazzari, and Guy 2020); however, preliminary results suggest the inclination measurement from the virtual goniometer is far more robust than the average inclination of points in the occlusal surface, which is more susceptible to variations in local point densities and the surface's parameterization.

Overall, this and recent studies underpin the importance of computer applications in archaeology to the field overall and the transferability of applying technology beyond its original scope and it demonstrates how this tool can be utilized on many materials across anthropological settings to address a broad range of questions. It is a persuasive example of ways in which new applications and approaches to preexisting questions in anthropology and archaeology can be fruitful, and allow more detailed studies than previously possible. The virtual goniometer, which has largely been used for strictly archaeological and zooarchaeological inquiries until now, can be employed more broadly within the field of anthropology as we demonstrate here with the use of primate dentition, in addition to possible applications in the fossil record and modern human dentistry. Evolution builds off past successes, why should technological evolution do the same?

101. Spatial Analysis of Crater Cove

*Samantha Judges (Sydney University)**

Crater Cove is situated on Dobroyd Head within the Sydney Harbour National Park, in the municipality of Manly. From 1810 to the 1860s a number of land grants were given in Manly, with the exception of the areas of North Head and Dobroyd Head that were reserved for defence purposes. It was not until 1871 that Dobroyd Head was gazetted as Defence Reserve land and while military fortifications were constructed on other reserved lands, Dobroyd Head was never developed.

Dobroyd Head remained as Defence Reserve until April 1975 when the Australian Federal and the New South Wales Governments established the Sydney Harbour National Park, of which it became a part of. It was during Crater Cove's time as Defence Reserve that seven small huts were constructed by civilians without permission, between the early 1920s and late 1960s. These structures are now managed by the National Parks and Wildlife Service with the aid of two voluntary caretakers who were previous users of the huts.

The huts are accessed by an unmaintained bush track and four are located on a steep cliff face and three in the dense bushland behind. This research will investigate the informal spatial patterning by the Euro-urban population of a user/builder space created solely by social preference and not by formal planning or municipal regulations. The investigation will focus on the degree of consistency in the spatial organisation including room size, use of topography, distance between buildings and the orientation of the structures. The research will also investigate if the spatial pattern was retained regardless of the site's change in function over time that included fishing weekender, permanent residency and squatter camp.

To date there has been no significant research on this location and this study will examine how Crater Cove fits into the contemporary archaeology of Sydney and the significance of archaeology as a source of information during a period where rich textual information exists. Part of this research involves recording the hut structures using photogrammetry and mapping of the area using an Unmanned Aerial Vehicle (UAV). The program being used for the photogrammetry is Metashape.

The use of photogrammetry as a tool for recording archaeological data allows for the production of high quality models that can be presented in 2D or 3D form and that contain an accurate geometry of the structure as well as being photorealistic in texture (Chibunichev, Knyaz, Zhuravlev 2018, 236). The models produced from photogrammetry will allow an accurate record of the huts that includes but is not limited to the structure, materials used, natural features, exterior and interior views, floor plans and measurements.

The use of UAV technology enables the collection of images of large areas of land in a reasonable time frame and at low cost. It has enabled photogrammetry of areas that may not have been accessible before and the ability to produce 3D maps (Marín-Buzón, Pérez-Romero, López-Castro, Imed, and Manzano-Agugliaro 2021, 2-6). The use of UAV in this project will assist in obtaining data for one of the huts that is impossible to photograph on foot due to the dangerous terrain. It will also be used to produce a 3D map covering the area where the huts are situated. This map will assist in the accurate recording of the location of the huts, the topography, measuring distances between the huts and identifying other structures or formations in the area that may have not been visible while studying the location on foot but may be relevant to the research.

The use of photogrammetry for recording the hut structures is also important for heritage and conservation purposes. Cultural heritage is a vast concept that includes physical objects and is passed from generation to generation and is forever at risk of being lost as a result of natural phenomena or deliberate acts (Chanda, Chaudhuri, and Chaudhury 2018, 47). The recording of these structures in this form will provide detailed and valuable models in the event of the huts being damaged or lost.

Although the use of photogrammetry is only one of the methods used in this project, it will greatly assist in addressing the aims of this research. The value of the modelling produced so far has also been acknowledged by the National Parks and Wildlife Service who have requested to use this material for their Conservation Management Plan for the huts.

References:

Chanda, B., Chaudhuri, S., & Chaudhury, S. (2018). “EpiX: A 3D Measurement Tool for Heritage, Archaeology, and Aerial Photogrammetry”. In Heritage Preservation. A Computational Approach, edited by Bhabatosh Chanda, Subhasis Chaudhuri and Santanu Chaudhury, 47–66. Singapore: Springer Pty Limited.

Chibunichev, A., Knyaz, V., Zhuravlev, D. , and Kurkov, V. 2018. “Photogrammetry for Archaeology: Collecting Pieces Together.” The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII no. 2: 235-240. https://doi.org/10.5194/isprs-archives-XLII-2-235-2018.

Marín-Buzón, C., Pérez-Romero, A., López-Castro, J. L., Imed, B. J., & Manzano-Agugliaro, F. (2021). “Photogrammetry as a new scientific tool in archaeology: Worldwide research trends”. Sustainability 13 (9): 1-27. doi:https://doi.org/10.3390/su13095319

24. Scientific Model, Historical Fiction, or Frankenstein’s Monster: The Prospects and Perils of 3D Reconstruction for Archaeology in Aotearoa New Zealand

Simon H. Bickler (Bickler Consultants Ltd); Thomas MacDiarmid (Independent)*

The emergence of new-generation gaming development software has opened up unprecedented possibilities for the digital reconstruction of archaeological sites, with previously unparalleled level of quality, scale, and affordability. This paper provides an overview of the evolution of 3D site reconstruction usage in Aotearoa New Zealand, discussing its past applications and how these experiences inform future advancements. Our aim is to showcase how these reconstructions model archaeological data obtained from diverse sources such as surveys, excavations, topological studies, and environmental research, facilitating the creation of comprehensive scientific narratives elucidating Aotearoa New Zealand’s rich history. We also emphasise the potential for these reconstructions to conceal underlying assumptions and biases within the data, creating new fictions. Such fictions can and must be challenged using both archaeological evidence and the lens of matauranga Māori. Finally, we highlight the transformative potential of these innovative tools in reshaping public engagement with archaeology throughout Aotearoa New Zealand on a national scale, offering new avenues for immersive and interactive experiences that foster a deeper connection with the country’s rich cultural heritage.

54. A 3D Analysis of Expedient Cores from Puritjarra

*Simon J Wyatt-Spratt (University of Sydney)**

3D lithic analysis is now a well-established approach to studying stone artefacts. Studies are global in scope, and combine a variety of methodological approaches to answer an increasingly diverse range of archaeological questions (Wyatt-Spratt, 2022). The majority of 3D lithic studies are of bifaces, bifacially flaked points, and other heavily retouched “standardised” artefacts. In this, 3D lithic analysis is replicating the intellectual biases present in lithic analysis more widely (Dibble et al., 2017). These studies generally focus on cultural transmission, cultural evolution, and hominid cognition.

This has led to some significant regional and temporal gaps in 3D lithic studies, particularly in parts of the world where expedient, informal, and simple lithic technologies were prevalent. This gap is particularly noticeable in the archaeology of Indigenous Australia, where, despite the pioneering work of researchers at Australian institutions in the early development of the field, few 3D lithic analysis studies have been published. There is now a pressing need to explore how 3D lithic analysis can contribute to the study of expedient and informal toolkits, and to address questions of curation, raw material use, reduction continuums and technological strategies.

This paper will present a case study from Puritjarra, a stratified rockshelter in Kukatja Country, in the Cleland Hills in Central Australia. The occupation history of the site spans the Pleistocene through to the Holocene and was still in use after the British invasion of Australia in 1788 (Smith, 2006). A 3D analysis of the cores – both expedient and formal – from the assemblage was conducted, which incorporated vector analysis, platform angle, surface area and volume measurements. Detailed measurements were also made of each negative flake scars and cortical surface areas, and qualitative data for each was also recorded. The results of this study will help answer the questions:

- 1) What information can analysis of “informal” cores reveal compared with an analysis of “formal” cores,
- 2) What can a close analysis of “informal” cores reveal about Indigenous Australian societies, 3) Can a 3D lithic analysis of “informal” cores be as informative as a similar analysis of “formal” cores, and 4) Can a 3D lithic analysis of “informal” cores provide additional data than traditional methods of analysis?

References

Dibble, H. L., Holdaway, S. J., Lin, S. C., Braun, D. R., Douglass, M. J., Iovita, R., McPherron, S. P., Olszewski, D. I., & Sandgathe, D. (2017). Major fallacies surrounding stone artifacts and assemblages. Journal of Archaeological Method and Theory, 24(3), 813–851. https://doi.org/10.1007/s10816-016-9297-8

Smith, M. A. (2006). Characterizing Late Pleistocene and Holocene stone artefact assemblages from Puritjarra rock shelter. Records of the Australian Museum, 58(3), 371–410. https://doi.org/10.3853/j.0067-1975.58.2006.1470

Wyatt-Spratt, S. (2022). After the Revolution: A Review of 3D Modelling as a Tool for Stone Artefact Analysis. Journal of Computer Applications in Archaeology, 5(1), Article 1. https://doi.org/10.5334/jcaa.103

179. Fast, Good, and Cheap - You Can have all Three with Desktop 3D Scanning for Lithic Analysis

Steven Mills (University of Otago); Hamza Bennani (University of Otago); Gerard O'Regan (Tūhura Otago Museum); Lana Arun (Tūhura Otago Museum); Tapabrata Dr. Chakraborty (University of Oxford); Richard Walter (University of Otago)*

Introduction

We report on our initial experience using a commercial desktop scanner to capture detailed 3D models of lithic flakes from pre-contact Māori stone tool manufacture. Such models are useful for automating measurements of large flake collections, and offer the potential for more nuanced analysis through machine learning. The increasing availability and accuracy of consumer and prosumer grade equipment means that scan qualities that previously required expensive laser scanners are available on a more modest budget. Specifically, we use an EinScan SP scanner that retails for approximately NZ$4,000, so is a similar price to a high-quality DSLR or mirrorless camera and lens kit. While some experimentation is required to determine the optimal scan settings for a given application, once these are determined we find that it is a simple process to capture highly detailed scans with minimal manual intervention. Scanning takes 10-15 minutes per flake with the settings we found most effective, although there is potential to reduce this time. Visual comparison of the scans and original flakes indicates that fine surface details are captured reliably, although sharp edges can be smoothed slightly in the mesh-fitting process.

Methods and Materials

Our initial sample of 30 lithic debitage flakes is from the Wairau Bar stone tool manufacturing site at the north of the South Island of New Zealand, a source of adzes for trade around the country (Walter, Jacomb and Bowron-Muth 2010). This includes 11 flakes that we have used for previous analysis based on photogrammetric analysis (Bennani, et al. 2017). The flakes were scanned using an EinScan SP desktop scanner and the associated (proprietary) EXScan software. The EinScan scanner uses stereo cameras with structured light to capture multiple depth images of an object mounted on an automated turntable, and can also be used on a tripod for larger objects.

Flakes were mounted vertically on the scanner as shown in Figure 1 (a) and two scans were taken with a 180° rotation to ensure that both ends of the flake were captured (b). The two parts are then stitched together within the software, and a watertight mesh fitted to create the final model

Some manual clean-up is often required before stitching the scans, in order to remove mounting material that is often included in the scan. This process is generally fast and easy to do, since it is generally acceptable to remove some of the scanned flake near the mounting material as long as there is sufficient overlap to allow the stitching of the two parts, and the entire flake is visible in at least one of the cleaned scans. In some cases, a third scan is necessary to capture the entire flake, this being taken with a half-rotation of the flake. Postprocessing tools within the EXScan software can also be used to sharpen or smooth the mesh, fill holes, etc.

Results

The EXScan software allows the user to set a number of settings. We found that we needed to set quite long exposure times (due to the dark stone), and a small number of images was found to be most effective. It is possible to select how many images are taken in one revolution of the turntable and we found that 8 views gave the best results. This was somewhat surprising as we would have expected more images to lead to better quality scan. We found that using more images led to an increased rate of misalignment leading to the need to re-scan. The speed of the turntable can also be controlled, and we found the slowest setting was the best, so that the flakes do not move – firmer mounting could reduce this (and decrease scan time) but would require care not to damage the objects.

Traditional photogrammetry can be time-consuming for individual flakes, and our earlier work on reconstructing multiple flakes in parallel gave much less detail (for one small flake, about 27,000 points compared to 254,000). Visually the scans are more complete, and the EXScan software is able to automatically combine multiple scans at different orientations without the need for manual or approximate alignment approaches (Petrie, et al. 2019).

Discussion

Our initial visual inspection of the scans indicates that there is a high level of detail captured by prosumer desktop scanners. The scanner produces metric data with 3D point locations in millimetres. We are currently preparing to measure the principle dimensions of the flakes in order to make a direct comparison with our earlier analysis using photogrammetry from consumer camera images (Bennani, et al. 2017). These measurements can be made automatically, but the scanned 3D models will first need to be oriented so that the flaking axis aligns with a fixed co-ordinate axis.

Further work will investigate the use of machine learning to extract fine-grained shape features and classify surface details such as automatically detecting the striking platform and flaking axis direction. We also intend to develop a publicly available dataset of scanned flakes to encourage further development of analysis tools, and provide a benchmark for comparison of techniques. Based on our initial experiences, however, the scans that are produced capture fine surface details well, and are suitable for further analysis. The ability to capture such high-fidelity 3D scans easily on comparatively inexpensive devices also opens many avenues for collection- rather than object-scale analysis.

Acknowledgments

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References

Bennani, H, S. Mills, R. Walter, and K. Greig. 2017. "Photogrammetric Debitage Analysis: Measuring Māori Toolmaking Evidence." Proc. Image and Vision Computing New Zealand (IVCNZ).

Petrie, F., S. Mills, H. Bennani, R. Walter, and K. Greig. 2019. "Stitching Partial 3D Models with an Application to Modelling Stone Flakes." Proc. Image and Vision Computing New Zealand (IVCNZ).

Walter, R., C. Jacomb, and S. Bowron-Muth. 2010. "Colonisation, Mobility, and Exchange in New Zealand Prehistory." Antiquity 84 (324): 497-513.

Figures

(a)

Figure 1: Overview of the scanning process with the EinScan SP desktop scanner (a). Two or more 360° scans of the flake are made (b), ensuring that the entire surface is visible in at least one scan. The mounting material is then manually removed; the two parts automatically stitched together, and a watertight mesh is fitted to the model (d).

(b)  (c) 

160. 3D Modelling in Stone: An Animated Reconstruction of an Angkorian Workshop

Thomas Chandler (Monash University); Mike Yeates (Monash University); Martin Polkinghorne (Flinders University);*

The ancient Cambodian culture is best known through its splendid and unique monumental architecture at Angkor, a major cultural centre and home to various capitals which flourished during the Angkorian period, from the beginning of the 9th to the 15th century. It is also known for its sculpture and statuary.

The production of Angkorian statuary was truly prodigious. In addition to the thousands of sculptures that survive to the present-day, the foundation stele from the sprawling temple of Preah Khan, dedicated in 1191/92 CE, provides a remarkable indication of the scale of fabrication during the reign of Jayavarman VII. It declares that 20,400 statues rendered in precious metals and stone were distributed across the kingdom. This one temple complex alone housed 430 deities surrounding the central image, with another eighty-five deities residing in nearby shrines. Other temples of the same reign indicate the immense scale of production. Ta Prohm, dedicated in 1186 CE, housed 260 deities surrounding the principal icons and hosted an annual festival with offerings to 619 deities who were present there.

Although there were likely numerous centres and workshops of statuary manufacture, to date only three workshops have been verified through archaeological excavation.

A stone and bronze workshop northeast of the Royal Palace in Angkor Thom and another stone workshop north of the Hariharālaya Royal Palace at Prei Monti preserve unfinished sculptures and the archaeological waste of stone and copper-base alloy production. Another stone workshop may have existed at Phnom Dei north of Angkor Thom.

The workshop northeast of the Royal Palace in Angkor Thom is the subject of this paper. The close proximity of the known workshops to Royal Palaces and the physical and ceremonial centres of the kingdom imply that the royal court directly commissioned their products. Specialized artisans, including sculpture stonemasons and bronze casters, were of great significance to the political administration, who employed their outputs to confer and maintain political legitimacy and spiritual authority. Additionally, the specific position of ateliers north or northeast of the Royal Palace may reproduce a tradition of urban planning observed throughout Cambodian history.

This paper outlines the digital, 3D animated reconstruction of an operational Angkorian stone workshop near the Royal Palace in Angkor Thom. It describes the gradual, evidence-based process of building a 3D scene into a detailed virtual reality experience, featuring active stone sculptors working amongst the soundscape of a living medieval city. Moreover, it interweaves historical sources with material evidence,and attempts to incorporate eyewitness observations from the accounts of Zhou Daguan, a Chinese emissary and 13th century visitor to Angkor. Zhou was a keen observer of the comings and goings around the palace, and it is likely that he resided somewhere close by in the year that he spent at Angkor. Unfortunately, most of Zhou's original accounts have been lost to history, but enough survives in his vivid makes and detailed chapters about Angkor that he is remains a key historical source about Angkor's daily life. social hierarchy and sumptuary laws.

Although Zhou makes no specific mention of the workshops near the Royal Palace, he records the 'chenjialan' (the palace servants) in detail; 'At the lower level there are also the so called chenjialan, servant women who come and go … inside the palace and number at least a thousand or two… They shave back the hair on the top of their head… They paint the area with vermillion, which they also paint on to either side of their temple. In this way they mark themselves out as being chenjialan. They are the only women who can go into the palace; no-one else below them gets to go in. There is a continuous stream of them on the roads in front of and behind the inner palace".

In this paper, we will detail how these disparate sources, one historical and the other archaeological, might be combined in a single reconstruction; an animated moment in time. Additionally, we will outline how 3D scanned sculptures from museum collections might be incorporated into the schema of reconstruction; the integration of real world, material forms into virtual worlds.

S13: Computational Approaches to Archaeological Mega-Projects

Wednesday 10th April, 10:20–12:00, 260-055 Case Room 3

Andrew Bevan, University College London
Barney Harris, University College London
Kate Welham, Bournemouth University

This session will bring together contributions that seek to draw out common archaeological themes and shared computational methodologies around the concept of 'mega-projects'. We define the latter term as referring to a relatively diverse range of physically large-scale, often monumental, and infrastructurally-challenging initiatives that seem to push the existing labour pools, material resources and know-how of a given society, and can often have their own mobilising momentum in terms of altering the terms of social, economic and political coordination. Examples in the archaeological record include individual mausoleums and collective tombs, dams and aqueducts, integrated transport systems, megalithic and/or mega-earthen assembly places, fortifications and large-scale storage facilities. Computational approaches often have a central role to play in archaeological understandings of such projects, and we would anticipate but would not limit our methodological scope to the role of high resolution LiDAR, multi-instrument geophysics, both 3d surface models and hyper-real 3d physically-based renders, advanced modelling of radiocarbon or dendrochronological dates, spatial statistical models and/or landscape-scale advanced GIS. Starting themes might include best practice with regard to archaeological prospection of mega-projects as physical features in the landscape, chronological modelling of project duration and continuity, calculation of the often colossal energetic inputs of labour, identification of upscaling patterns in contemporary craft practices, assessment of wider positive and negative environmental impacts, and/or modelling of wider resource landscapes. This session also leaves room for anyone interested in the different-and-yet-complementary isights that might exist when considering how computational and data science approaches underpins archaeology's engagement with infrastructural mega-projects in the present-day.

S13: Computational Approaches to Archaeological Mega-Projects	
10:20-10:40	*188. Imperial Logistics and the Mausoleum of China's First Emperor: Computational, Compositional and Spatial Perspectives* *Andrew Bevan (UCL)*; Xiuzhen LI (UCL); Mike Charlton (UCL); Marcos Martinón-Torres (University of Cambridge); Patrick Quinn (UCL); Yin XIa (Emperor Qin Shihuang's Mausoleum Site Museum); Ying Yang (UCL)*
10:40-11:00	*147. Quantifying Monumentality, Labor, and Power Display in pre-Roman Hillforts through Quantitative Methods* *Giacomo Fontana (University College London)**
11:00-11:20	*22. Building Xunantunich: Energetic Results & Openly Engaging Our Audiences* *Leah McCurdy (The University of Texas at Arlington)**
11:20-11:40	*76. The Palimpsest "Mega-project" of Tamawhera, Ahuahu (Great Mercury Island), Aotearoa New Zealand* *Thegn N Ladefoged (University of Auckland)*, Matiu Prebble, Natasha Phillips, Alison Dijs, Pierre Roudier, Ben Jolly, Alex Jorgensen, Alexandra Queenin, Paul Augustinus, Sarah Sowerby, Zac McIvor, Rebecca Phillipps, Simon Holdaway*
Poster	*129. Evaluating Initial Upper Paleolithic Dispersal in Central/East Asia using Least Cost Path Modelling* *Andrew L Jenkins (University of Wollongong)*; Sam C Lin (University of Wollongong); Fei Peng (Minzu University of China); Lydia Mackenzie (University of Tasmania)*

188. Imperial Logistics and the Mausoleum of China's First Emperor: Computational, Compositional and Spatial Perspectives

Andrew Bevan (UCL); Xiuzhen LI (UCL); Mike Charlton (ulc); Marcos Martinón-Torres (University of Cambridge); Patrick Quinn (UCL); Yin XIa (Emperor Qin Shihuang's Mausoleum Site Museum); Ying Yang (UCL)*

Research Context

Qin Shihuang's successful unification of China for the first time in 221 BCE has traditionally been explained as the result of a strict political hierarchy, high levels of direct economic management and systematic use of new technologies. As part of that explanation, the First Emperor's mausoleum has often been invoked as an example of a wider Qin capacity to marshal human labour, specialist craft knowledge and industrial quantities of raw materials. With its Terracotta Army of thousands of lifelike ceramic soldiers, but also a much bigger complex stretching across ~56 sq.km and many other sunken accessory pits, this tomb is quintessentially a 'mega-project' (in the terms of this CAA session) that (a) not only added its own 'mobilising momentum' to very significant changes to China's society, economy and politics in the later 1st millennium BCE, but that (b) can also help illuminate wider changes of industrial scale and scope in an 'Axial Age' of imperial transformation across Europe and Asia. Computational, instrumental, spatial and statistical approaches should loom large in investigating this complex and our presentation will draw out this emphasis whilst reflecting on almost ten years of internationally-recognised cooperation.

Main Themes

How to grasp both the sheer scale of a mega-project such as the First Emperor's tomb and his famous accompanying warriors? Our project has sought to complement the considerable amount of high-quality existing research on this topic, but with a particular focus on the crafting of bronze, iron, wooden and ceramic objects. In this endeavour, calculations of overall labour cost, measures of artefact standardisation, quantitative assessment of object micro-style, modelling of 2d and 3d spatial structure, all complement the project's other core attention to material science. New prospection methods also have a part to play in uncovering as yet unnoticed aspects of craft practice. Key themes arising from this work focus on questions of quality control and standardisation, workshops practice and mass production, as well as the wider resource landscapes upon which the mausoleum builders drew.

Suggested Implications

A very interesting strand emerging from this work relates to the vying fortunes of bronze and iron technologies, during a period which was already 'Iron Age' but in which the much-heralded Qin armies seem to have continued mostly to use bronze weapons (or at least to bury them in the mausoleum). Attention to these issues in such a well-preserved large-scale context, allows us to model patterns of taphonomic recovery, and differential emphasis in useful new ways. Another major set of implications revolves around spatial and statistical comparison of stamped, incised or ink marks on the objects in the tomb and the micro-style or micro-composition of these objects, as this brings out new aspects of Qin workshop organisation and how small productive units were upscaled to such a large, monumental endeavour, as well as how the equipping of a pit in the tomb may have played out. There are also wider ecological and environmental implications to this mausoleum (and related Qin constructed projects) that are as yet not fully appreciated but that are starting to receive new, quantitative treatment.

147. Quantifying Monumentality, Labor, and Power Display in Pre-Roman Hillforts through Quantitative Methods

*Giacomo Fontana (University College London)**

Pre-Roman hillforts are a prominent feature in Italy, most notably in the region historically known as Samnium (central-south Italy). Dominating mountainous terrains, these large-scale fortifications serve as unmistakable territorial markers. They are characterized by impressive walls that can extend up to 6 km in length and reach heights of 12 meters. Despite their imposing presence and cultural significance, surprisingly little research has been dedicated to understanding their physical and symbolic roles. Furthermore, the ecological and societal implications of their construction and maintenance on the communities that engineered these projects remain largely unexplored.

This paper introduces a study aimed at filling this research gap. It employs a multi-disciplinary approach, leveraging remote sensing, architectural energetics, and geospatial statistics to examine Samnite fortified landscapes. The initial phase of the study utilized large-scale LiDAR data (Fontana, 2022) to assemble a comprehensive dataset, offering a more accurate representation of these sites than previously available. Subsequent fieldwork enriched this dataset by providing detailed information on the fortifications through both land and aerial-based 3D modeling. Building on this data, we developed a statistical methodology for analyzing and comparing dry-stone masonry, with a particular focus on polygonal walls (Fontana and Bernard, 2023). This methodology allowed us to quantify the labor inputs required for the construction of each hillfort, yielding the first cumulative labor estimate for the Samnite fortified landscapes. To understand the strategic and symbolic considerations behind the hillfort locations, Point Process Models were employed in a geospatial analysis, revealing the importance of visibility in the landscape design.

The paper reviews the methodologies adopted and further developed in this research, critically assessing both their potential and limitations for future comparative studies. Additionally, it delves into how these empirical findings interface with historical accounts of Samnite society. The results highlight that the focus of hillfort construction appears to be more rooted in symbolic expressions of communal identity and power, rather than solely serving defensive purposes, thereby challenging conventional interpretations.

References

Fontana, G. (2022) ‘Italy’s Hidden Hillforts: A Large-Scale Lidar-Based Mapping of Samnium’, Journal of Field Archaeology, 47(4), pp. 1–17. doi: 10.1080/00934690.2022.2031465.

Fontana, G. and Bernard, S. (2023) ‘A new method for the energetics analysis of polygonal masonry in Samnite hillforts (Italy)’, Journal of Archaeological Science. Elsevier Ltd, 153(January), p. 105730. doi: 10.1016/j.jas.2023.105730.

22. Building Xunantunich: Energetic Results & Openly Engaging Our Audiences

*Leah McCurdy (The University of Texas at Arlington)**

The El Castillo political-ritual complex of Xunantunich, Belize, is one of the ancient Maya monuments of Belize today. The material, labor, and time invested to construct El Castillo, over its many phases of construction, often marvel contemporary visitors. Architectural energetic analysis of construction phasing, founded on both excavation and survey data, offers a computational methodology to reconstruct how such a large-scale complex was built over approximately 1000 years, and how that time and scale translate into human labor. This presentation details the person-day estimates of labor investment required to construct this mega-project. Furthermore, this presentation considers what these mega numbers and complex computational analyses mean to the modern audiences of archaeology: the tourists, the scholars, and most importantly, the local communities/descendants of the ancient Maya. How best do we communicate the results of energetic analysis? How can stories relate this data to engage our most important audiences in ways they haven't been engaged before? Who should have access to these results? How 'open' should they be and why?

76. The Palimpsest "Mega-project" of Tamawhera, Ahuahu (Great Mercury Island), Aotearoa New Zealand.

Thegn N Ladefoged (University of Auckland), Matiu Prebble, Natasha Phillips, Alison Dijs, Pierre Roudier, Ben Jolly, Alex Jorgensen, Alexandra Queenin, Paul Augustinus, Sarah Sowerby, Zac McIvor, Rebecca Phillipps, Simon Holdaway*

Ahuahu (Great Mercury Island) was one of the first places in Aotearoa New Zealand settled some 700 years ago by Polynesians from Hawaiki. The small ca. 19 km2 island situated 6 km off the Coromandel peninsula would have been a welcome sight for the ancestors of Ngāti Hei and Ngāti Huarere who trace descendancy from Te Arawa to Ahuahu. The microclimate of Ahuahu is warmer than the mainland, with no recorded frosts and ample winter and summer rains. When first settled the island would have been forested, although less densely so than the mainland, and therefore easier for colonists to establish their horticultural plots of taro and, perhaps later, kūmara (Holdaway et al. 2019). The transition from native forest to a horticultural landscape is recorded in palaeoecological evidence from Tamawhera swamp in the Northwest of Ahuahu (Prebble et al. 2019). The swamp is in a valley bottom which was narrower pre-human arrival, and only with anthropogenic activity on the surrounding hillslopes did the valley infill to create a rich zone for horticulture and wild resources. Three of the hills bounding the swamp were intensively occupied (McIvor and Ladefoged 2016). The first was developed into a fortified pā and the second an undefended kāinga ("village" or occupation zone). Through the analysis of sediment cores, excavations, GPS pedestrian surveys, and high-resolution LiDAR data we document processes of niche construction in this 18 ha settlement.

The results of our transdisciplinary approach suggest that the ecodynamics and selective conditions of Tamawhera (and nearby Waitetoke) changed over time. Processes of inceptive niche construction included perturbations from forest clearance and subsequent erosion and valley infilling, and the introduction of taro and other edible weedy plants which altered the symbiotic relationships of the early swampland. Subsequent forms of inceptive and counteractive niche construction involved constructing horticultural infrastructure, including ditches and raised beds for wet taro cultivation; and alignments, terraces, and mounds for dryland kūmara production. The use of soil additives such as charcoal, mussel periostracum, and fire cracked rock altered the feedback relationships of soil nutrients. Other actions of Māori promoted the growth of nitrogen fixing vegetation and waterborne algae. By integrating diverse datasets, we provide insights into the reciprocal causation and intergenerational ecological inheritance of niche construction processes that led to the creation of the palimpsest landscape of Tamawhera and the emergence of the “mega-project” occupied by late 18th century Māori.

References:

Holdaway, S., Emmitt, J., Furey, L., Jorgensen, A., O’Regan, G., Phillipps, R., Prebble, M., Wallace, R., and T.N. Ladefoged. Māori settlement of New Zealand: The Anthropocene as a process. Archaeology in Oceania. 54:17-34.

McIvor, I.H. and T.N. Ladefoged. 2016. A Multi-scalar analysis of Māori land use on Ahuahu (Great Mercury) Island, New Zealand. Archaeology in Oceania 51:45–61.

Prebble, M.J., Anderson, A.J, Augustina, P., Emmitt, J., Fallon, S., Furey, L.L., Holdaway, S.J., Jorgensen, A., Ladefoged, T.N., Matthews, P.J., Meyer, J., Phillipps, R., Wallace, R., and N. Porch.

S14: Modelling Monumental Landscapes in 4D: A Novel Approach to Understanding Architectural Settlement

Wednesday 10th April, 15:20–17:00, 260-055 Case Room 3

Cristian Gonzalez Rodriguez, University College London
Giacomo Bilotti, Institute of Pre-and Protohistory, CRC 1266, Kiel University

The progressive evolution of computational methodologies has revolutionized our interpretation of archaeological data, granting us the capacity for in-depth spatial and temporal analyses. Ancient monumental sites stand out as pivotal archaeological landmarks, their significance stemming from their roles in settlement patterns, economic systems, and religious practices. Though many studies have delved into these monumental structures, they are generally confined to a static chronological framework. This limitation results in landscape reconstructions that lack dynamism and potentially obscure economic, social, geopolitical or ontological interactions and change. That is why this session on "Modelling Monumental Landscapes in 4D" ventures into the groundbreaking utilization of 4-dimensional models to assess ceremonial, mortuary, and ritual sites as dynamic technologies and scenarios. This vision transcends merely spatial considerations; since it emphasizes the temporal dynamics intrinsic to architectural landscapes. Introducing the fourth dimension—time—provides a transformative lens, illuminating evolving burial and ceremonial customs, site progressions, and interactions with living communities over various epochs.

Traditionally, 3-dimensional models focusing on visibility, accessibility, and sensory analysis have offered vibrant visualizations of monumental sites. By integrating the dimension of time, we can shed light on the chronology of site usage, patterns of re-use, and the temporal importance of architectural attributes. Techniques like Point Pattern Analysis, previously utilized for studying ancient monument distribution, have shown flexibility in incorporating chronological aspects, as does Bayesian Modelling. Advances in chronological modelling, encompassing radiocarbon distribution, and time-related uncertainty management, herald a new era in interpretative model creation. The present juncture calls for the amalgamation of these chronological frameworks with a well-entrenched inquiry into site intensity and interaction patterns. The abundance of archaeological sites, the accessibility of temporal information and the use of probabilistic methodologies for managing uncertainties in archaeological modelling allow a formal integration of the conventionally unidimensional scrutiny of population density (e.g. date as data approach) with the multi-dimensional facets of the landscape.

Noteworthy patterns, such as site abandonment, reuse and imprinting in the cognitive landscape, permeate human history. For instance, Early Neolithic megalithic burials in Northern Europe experienced reuse in the subsequent Middle and Late Neolithic, even in the absence of cultural continuity. Classical periods also witnessed such phenomena, with Late Helladic sites and edifices being assimilated into Classic Greek religious practices and lore. Similarly, pre-Colombian landscapes converged and mingled with the Christian beliefs built by the Spaniards and later on by the criollos, in a similar way to what happened in Europe with the establishment of Christianity. These phenomena are observed in many different parts of the World and happened throughout human history. However, due to the difficulties of dealing with this type of data, quantitative and statistical analysis often are missing.

We warmly extend an invitation to researchers exploring quantitative methods and reconstructing landscapes, especially those centred on ancient monumental sites. Regardless of the specific function of these monuments – be it cultural practices, funerary rituals, or others – we welcome submissions from all geographical regions and historical periods across the globe. Our goal is to foster a holistic view, one that fully embraces the dynamic interplay between people, monuments, and time. By converging diverse perspectives, we hope to deepen our collective understanding of ancient landscapes and the rich tapestry of histories they hold. This session serves as a unique platform for sharing insights, methodologies, and findings. This invites researchers from diverse backgrounds, aiming to accentuate the nexus between monuments and their evolving landscapes over time, creating what is called the "four-dimensional landscape". Through various case studies, attendees will appreciate how integrating time and space offers a profound comprehension of past civilizations, enhancing our grasp of their monumental landscapes and significance.

S14: Modelling Monumental Landscapes in 4D: A Novel Approach to Understanding Architectural Settlement	
15:20-15:40	*117. Comparative Approaches to the Computational and Landscape Modelling of the Andean Chullpa Phenomenon over Time* *Cristian N Gonzalez Rodriguez (University College London)**
15:40-16:00	*33. Exploring the Temporal and Spatial Dimensions of Neolithic and Bronze Age Monuments in the South Western Baltic Region* *Giacomo Bilotti (University of Kiel, CRC 1266)**
16:00-16:20	*195. Modelling the Maya Landscape* *Lutz Schubert (Universität Köln)*; Daria Stefan (TU Wien); Thomas Guderjan (University of Texas at Tyler)*

117. Comparative Approaches to the Computational and Landscape Modelling of the Andean Chullpa Phenomenon over Time

*Cristian N Gonzalez Rodriguez (University College London)**

During the Regional Development Period (~900–1450 CE), the Andean Plateau was densely occupied, and by the time of the Spanish Conquest (~1532 CE), large ethnic chiefdoms had emerged and appears to have been involved in large-scale interregional exchanges and distinctive rituals. One of the most distinctive features of this region and from these periods is the open above-ground tower-shaped monuments called chullpas. Although multiple functional interpretations exist, these structures are most often thought to be burial places with the most elaborate being for the internment of local leaders who constructed their chullpas along major travel routes. However, these chullpas varied based on local architectural traditions, natural topographic features, and existing population centres. These chullpas likely were an essential feature in the emerging identity and social hierarchy within each ethnic group and cosmology (Mantha 2022). However, there has been few architectural and landscape quantitative investigation or absolute scientific dating to address the chullpa-type architectural variability on an interregional scale. I present such an approach using an enhanced landscape and chronological study for chullpa construction in the Southern Andes and maintenance that will improve our understanding of the region's prehistory and to this enigmatic monument type.

Three different Regional Development Period provinces each associated with different chullpa traditions have been selected to evaluate their architectural, landscape and chronological features. These qualities will be examined to find shared patterns in spatial organisation, their interaction within communities and the evolving landscape engagements. The regions include around four hundred chullpas distributed in the Northern Plateau Cusco Region, Central Plateau Carangas Region, and Southern Plateau Atacama Region.

Four computational methods have been chosen to address the problem in an integrative structure and employing quantitative methods:

- (a) Hierarchical Clustering Modelling is employed to find architectural and spatial regularities across the regions,

- (b) Point Pattern Processing and Permutation Tests are used to understand the level of clustering, hierarchy, and centrality at intra and intersite levels according to landscape models (Carrero-Pazos, Bevan and Lake 2019),

- (c) 3D Vectorial Visibility and Horizon Analyses are used to assess chullpas orientation, interaction, and landmark engagements (Higginbottom et al., 2023),

- (d) Synthesis of chronological studies and the AMS radiocarbon dating of new samples is used to assess the continuities and changes in the abovementioned patterns.

Chullpas variability is distinguished for their architectural styles involving angled stone, adobe, rustic stone mortar traditions, and coloured adobe. Even though these traditions have been reported for in previous research, an integrative comparative study found that the central areas of the Andean Plateau have larger and more monumental chullpa styles (angled stone, double wall rustic traditions, adobe and coloured adobe), while the periphery has generally smaller rustic stone mortar traditions. Although this variability exists between regions, hierarchical clustering modelling demonstrates that, at an intra-site level, distinctive chullpas (those which are larger, paired, or more elaborate construction features) share patterns of location on rocky outcrops or platforms with higher intervisibility and centrality levels. This result suggests that chullpas express a hierarchy at a site level (p-value <0.01). Similarly, the clustering and intensity of chullpas construction also played a role in a broader spatial organisation where some chullpa-sites are located near liminal, agricultural and waterscapes (p-value <0.01). In other words, denser and more complex sites are located closer to economically and socially important places that reflect the Regional Development Period settlement pattern.

Visibility analysis also indicates that chullpas were constructed in landscape locations and with their entrances orientated to observe important local volcanoes, walled hilltops, and wetlands (p-value <0.01). These sites were also oriented to the sunrise during particular times of the year. These different traditions may reflect transformations over time, where the Regional Development Period chullpas view landmarks, the Inka Period relied on sunrise orientations, and the Colonial Period were oriented towards solar and other calendar events.

A regional, multi-scalar, and quantitative analysis of the chullpa phenomenon through their formal architectural features, landscape engagements, and diachronic transformations provided a better understanding of regional variability and patterns within the placement. The results indicate how different chiefdoms inhabiting the Andean Plateau organised their ancestors according to local architectural traditions. This piece of evidence suggests a hierarchy where prominent topographic features or platforms with central location and higher visibility to assert the most powerful ancestors and their lineages. Thanks to the clustering and intensity analysis of sites within these regions, the results document that chullpas are frequently associated with agriculture, water, and herding areas. These conditions might indicate regional variability where some chullpa-sites played a more relevant role for each chiefdom's local settlement pattern. A cosmological relationship is also observed and addressed quantitatively. The results also indicate that these cosmological relationships changed from landscape features to sunrises over time.

References

Carrero-Pazos, Miguel, Andrew Bevan, and Mark W. Lake. "The spatial structure of Galician megalithic landscapes (NW iberia): A case study from the Monte Penide region." Journal of Archaeological Science 108 (2019): 104968.

Higginbottom, Gail, A. César González-García, Benito Vilas-Estévez, Víctor López-López, and Felipe Criado-Boado. "Landscape, orientation and celestial phenomena on the 'Coast of Death'of NW Iberia." Journal for the History of Astronomy 54, no. 1 (2023): 76-106.

Mantha, Alexis. "Cosmology, ancestors and mortuary monuments: Principles of political authority in the Rapayán and Tantamayo region of the upper Marañón in the central Andes of Peru during the Late Intermediate Period (1000-1450 CE)." Journal of Anthropological Archaeology 67 (2022): 101441.

33. Exploring the Temporal and Spatial Dimensions of Neolithic and Bronze Age Monuments in the South Western Baltic Region

*Giacomo Bilotti (University of Kiel, CRC 1266)**

This contribution focuses on the diachronic study of Neolithic and Bronze Age monuments in the South Western Baltic region. Funerary and ritual monuments are a widespread class of archaeological sites within the study area, as well as some of the most well-preserved features in the landscape dating to this period. Prehistoric monuments have always attracted the attention of archaeologists. Yet, in many cases, their architectural and structural features do not allow a precise chronological determination.

Moreover, the fact that many of them were excavated long ago or not at all results in an incomplete understanding of short and medium-term temporal dynamics. This paper investigates the influence of monuments from different historical periods on the spatial distribution and arrangement of subsequent sites, combining spatial statistics and chronological modelling.

The earliest monuments in this region are the megalithic burials erected during the Funnel Beaker period (4100-2800 BC). However, their construction can be restricted to the period between the Early Neolithic II and the Middle Neolithic II (3500-3000 BC). Subsequently, and until the Late Neolithic (2300-1700 BC), these monuments were still visible and in some cases reused for secondary burials.

During the Nordic Bronze Age (1700-500 BC), various types of funerary monuments were built, including mounds, cairns and stone settings. These monuments are often interpreted as markers or memorials and, at times, are found in proximity to one another, forming clusters within the landscape. This phenomenon highlights the attractive influence of certain monuments, likely tied to their function or significance for local communities. Most of these sites were erected between Bronze Age periods I and IV (1700-900 BC), with a peak in construction activity during periods III and IV (1300-900 BC). In the Late Bronze Age (900-500 BC), fewer and smaller monuments were built, while some older ones were used for secondary burials.

Evidently, both Neolithic and Bronze Age monuments represent pivotal components of the landscape, persisting in the collective memory of local communities long after their creation and, in some cases, despite marked socio-cultural changes.

Recent advances in computational archaeology opened up many new possibilities for modeling. Spatial statistics, such as Point Pattern Analyses (PPA) and environmental modeling, have provided a more formal framework for assessing first and second-order effects, thereby offering a more robust understanding of site location preferences and site relationships. Additionally, chronological modelling using large datasets of radiocarbon dates enhanced the precision of temporal analysis. Nevertheless, radiocarbon curves (as Summed Probability Distributions or Cumulative Kernel Density Estimations) are primarily employed as demographic proxies in the "dates as data" approach, with the drawback of reduced spatial resolution, which is crucial for reconstructing landscapes.

In both cases, there is a risk of underestimating the significance of the monumental landscape in shaping the cultural and physical space of local communities, either in terms of chronological precision or medium to small-scale dynamics. Indeed, the establishment of a monument in a specific time and place may have influenced the landscape's affordances and, in turn, the location patterns of certain areas over time, altering patterns of space utilization in specific regions.

This paper investigates how monuments from different periods have influenced the spatial distribution of subsequent sites and monuments. This is achieved by combining radiocarbon curves, probability simulations, and landscape modeling. Specifically, well-dated sites are binned into fixed time windows, while sites without precise dates (e.g., labeled as "Bronze Age") receive simulated dates based on the probability of locally available radiocarbon dates. The simulation process is reiterated, and the output is used to generate a probabilistic surface representing past human activity for each time window. This surface is computed by interpolating the assigned dating probabilities using a distance decay function. For instance, the 100% surface only represents the area around the well dated sites at a given window, not different from a "traditional" catchment calculation. On the other hand, the

0% surface is equivalent to the entire area.

The models produced can then be used to carry spatial analyses, ultimately leading to enhanced temporal resolution. The results of each time window is used as predictor for sites location of the subsequent periods. Moreover, their patterns of repulsion or attraction over time are studied (second-order effects).

All analyses are conducted following a fully documented approach, relying exclusively on Free and Open Source Software (FOSS). Additionally, the data used are sourced from regional and national databases, which are, in most cases, freely accessible.

195. Modelling the Maya Landscape

Lutz Schubert (Universität Köln); Daria Stefan (TU Wien); Thomas Guderjan (University of Texas at Tyler)*

Over recent years, our understanding of and view on the Mesoamerican archaeological landscape has changed substantially (Ashmore, 2015). From our original conception of a native jungle with sparse, but vast cities, to an overpopulated, highly managed landscape with cities and villages, and major farmlands in-between (Guderjan and Mathews, 2023). The impact of this change cannot be underestimated, as it transforms the archaeological landscape significantly:

In a wild, uncontrolled landscape predominated by jungle overgrowth, monumental buildings would be hidden for the majority of the population. Sustenance would primarily rely on hunting and gathering for the majority of the population, with agricultural produce being reserved for the elite. Yucatan is constituted of microclimate areas that serve different produce better, from maize over squash to cocoa, which means that no single polity can provide all necessary goods for its region, but instead has to rely on other regions. Even if polities would collaborate on some level, e.g. for managing farmland, they would still be separated by a wild landscape that would make any immediate control difficult. Instead, polities ruling over different areas will more likely have traded exotic goods and foodstuff on regulated markets across regions. This necessitates a complex network of communication and transportation.

With the new model, we are talking about a highly organised and manipulated landscape with a vast road network ("sacbe") connecting cities and farmland. Such a landscape is dominated by farmland to sustain the large population. Monumental architecture is not only a representation of aristocracy, but is a way to shape the landscape with landmarks visible from afar. Sacbes turn from individual roads connecting major cities over long distances, into a network of small and large routes that connect all types of markets throughout.

Basing on recent LIDAR scans in Belize, we investigate different means to prototype the Maya landscape under different assumptions, from overgrown jungle to strongly maintained farmland. We thereby look at the impact of such assumptions on multiple factors, including:

- size and reach of polities
- frequency and size of markets
- extension of the road network
- hunting & gathering vs farming

but also investigate the relationship of these factors to building sizes and types. The Maya landscape is assumed to be highly symbolic with pyramids representing mountains (and the according gods), ballcourts referring to the Popol Vuuh as a sign for jurisdiction etc.

In our approach, we use a mix of procedural and static generation of different building types on basis of the LIDAR data. We examine different ways of identifying building types from LIDAR, using a mix of AI support and knowledge about how Maya space is organised (Guderjan and Mathews, 2023). This allows us to generate quick visual impressions of how the Maya landscape could have been experienced and thus how its experience may have influenced visual style, symbolism and organisation.

This approach is flawed in many respects, as the building types, heights and styles vary in reality much more than by the factors assumed here. However, it allows us to get a quick impression of the landscape as a whole and thus of which factors could have played a role in visual styles. However, it probably does not allow to examine the individual polities and their specific organisation, as the level of details should be too low. It is one of the purposes of this presentation to discuss the value and limits of such a modelling approach.

With this work we not so much investigate how landscape changes over time in Mesoamerica, but how our perception of it changes over time, depending on archaeological insights, but also cultural perceptions.

References:

Guderjan, T.H., Mathews, J.P., 2023. Construction of Maya Space: Causeways, Walls, and Open Areas from Ancient to Modern Times. University of Arizona Press, Tucson.

Ashmore, W., 2015. What Were Ancient Maya Landscapes Really Like? Journal of Anthropological Research 71, 305–326.

S15: Keep it simple, just not too simple — Challenges and (Best?) Practices in Managing and Integrating Archaeological Data

Thursday 11th April, 09:00–12:00, 260-055 Case Room 3

Steffen Strohm, Department of Computer Science, Kiel University
Hartwig Bünning, Research Group Ecosystem Research, Geoarchaeology and Polar Ecology, Kiel University
Lizzie Scholtus, Institute of Prehistoric and Protohistoric Archaeology, Kiel University
Oliver Nakoinz, Institute of Prehistoric and Protohistoric Archaeology, Kiel University

Archaeology is a diverse field, bringing numerous disciplines together to combine expertise from humanities, social and natural sciences as well as engineering. All these disciplines come with their own research traditions, educational concepts, interests, and their very own methodologies. This (certainly incomplete) selection of aspects relevant for shaping the personal background of researchers has a strong influence on their ways in perceiving the world around them. Additionally, research is usually carried out in a certain project context, with respective funding schemes and differing national or other regulations. The variety of perspectives and contextual preconditions go along with differing views on what (available) information is relevant to describe objects or phenomena of interest, and is then reflected in the large heterogeneity found in archaeological data and corresponding preservation efforts.

In the pursuit of organizing and preserving the various information used in archaeological research, numerous initiatives aim to create infrastructure to serve this purpose. Systems for information type specific (e.g. radiocarbon dates) or broader scopes (often in the form of repositories) have been designed and implemented over the last decades. Here, a general trade-off seems to exist between “correctness through completeness” and usability of the system. Whether the system is a spreadsheet or database where a data model is required to organize concepts and attributes, or the system is a repository where metadata is required to sufficiently represent a data collection in a FAIR sense — the trade-off still occurs and is affecting the design process and later success in terms of participation and therefore relevance to the community.

There is no optimal way of digitally representing information about the section of the world we are interested in. Data formats, extent of description and technologies used for observation as well as preservation are usually project and context specific. Therefore, there is no superior alternative to project specific efforts, especially with limited resources and the diversity of backgrounds mentioned. Over the course of such projects, some decisions may turn out better than others in achieving project goals. These decisions may affect characteristics such as the workload needed to input new data in the system, retrieve information from the system, the maintainability or usability of the system or the sustainability of the solution after the project (and its funding) ends. This session aims to provide an opportunity to reflect on enabling, enhancing or limiting effects of decisions made in the process of managing archaeological data and developing information systems for it. Submissions to the session should provide an on-point description of the project context of their data managing or data integration experience, including a characterization of the data involved, the goals of the data management or integration process, approaches to achieve these goals and an evaluation on what goals were (not) achieved and why. As pointed out before, there most likely does not exist any optimal way of organizing certain data, so we cannot expect to get to something like a unified model of archaeological data management. However, researchers should be enabled to learn from former experiences in the community. This will help to avoid mistakes in the future and it may lead to a more efficient use of the limited resources available. Submissions to the session should consider this learning experience as a session goal and contextualize their lessons learned with relevant aspects of their project goals, staffing, the regulatory or financial environment, competencies required and all those factors that had an impact on the data processing or system design from the submission authors' perspective.

S15: Keep it simple, just not too simple — Challenges and (Best?) Practices in Managing and Integrating Archaeological Data	
09:00-09:20	*149. From Interdisciplinary Complexity to FAIR Research Outcomes - Challenges, Implications and Design Decisions* *Steffen Strohm (Kiel University)*; Hartwig Bünning (Kiel University); Matthias Renz (University of Kiel)*
09:20-09:40	*59. The Tale of Three Cities: Strategies for Improving Accessibility and Reusability of Heritage Data* *Alphaeus G W Lien-Talks (University of York, Historic England, Archaeology Data Service)**
09:40-10:00	*187. Australasian pXRF Archaeological Researchers Collective* *Michelle J Richards (La Trobe University)*; Andrew McAlister (Auckland University); Brendan Kneebone (CFG Heritage Ltd)*
Morning Tea	
10:20-10:40	*109. Flowing through the Nets. Dealing with Archaeological Data Integration in and around the Lagoon of Venice* *Martina MB Bergamo (Ca' Foscari University of Venice)*; Jacopo Paiano (Ca' Foscari University of Venice); Diego Calaon (Ca' Foscari University of Venice)*
10:40-11:00	*16. Intrasis FieldRec: Archaeological Data Made Easy* *Sebastian Liahaugen (The Archaeologist/The Swedish History Museum)**
11:00-11:20	*120. The Challenges in Creating Databases for Pacific Ceramics* *Kristine Hardy (ANU)*; Mathieu Leclerc (ANU)*

59. The Tale of Three Cities: Strategies for Improving Accessibility and Reusability of Heritage Data

*Alphaeus G W Lien-Talks (University of York, Historic England, Archaeology Data Service)**

Heritage data is heterogeneous due to the diverse backgrounds of researchers and the variety of project contexts. This poses challenges for organising and preserving information in a way that is findable, accessible, interoperable and reusable (FAIR) (Wilkinson et al., 2016). Initiatives to create infrastructure for managing heritage data must balance completeness and usability (Richards, 2017). Furthermore, there are always trade-offs when deciding how to digitally represent information (Kintigh et al., 2015). This paper examines strategies for enhancing the accessibility and reusability of heritage data based on lessons learned from the UK historic town High Street Heritage Action Zone (HAZ) projects.

Methods included qualitative analysis of stakeholder interviews and quantitative analysis of questionnaires regarding data reuse experiences. Data collection focused on understanding successes, challenges, and recommendations related to heritage data management within the HAZ initiatives.

The key findings demonstrate the need for transparent data management planning from project onset, use of open formats, raw data over synthesised outputs, deposition in trusted repositories, and computational techniques like APIs and text mining to link disparate resources. Implementing FAIR data principles through these strategies can mitigate issues such as copyright restrictions, inaccurate metadata, and limited proprietary software datasets whilst simultaneously promoting training, outreach, and collaboration (Wilkinson et al., 2016).

However, barriers, like limited funding and reluctance toward open data, require continued engagement across sectors (Kansa et al., 2011). Copyright posed a major challenge, with 50% of questionnaire respondents indicating it restricted reuse. Furthermore, 80% of respondents considered useful heritage datasets to be only stored in people's minds, highlighting issues of tacit knowledge. Therefore, strategies like capturing oral histories can help preserve this intangible data.

This paper promotes FAIR data principles which have the potential to enhance knowledge discovery from heritage data if applied appropriately, based on project context (Wilkinson et al., 2016). Further work is needed to develop tailored solutions that recognise barriers while capitalising on new opportunities like emerging computational techniques. Promoting accessibility and reusability of diverse heritage data is an ongoing process but implementing collaborative, transparent strategies can yield significant benefits for researchers, practitioners, and the public.

References:

Kansa, E.C., Kansa, S.W. and Watrall, E., 2011. Archaeology 2.0: New approaches to communication and collaboration. Cotsen Digital Archaeology Series, 1.

Kintigh, K.W., Altschul, J.H., Beaudry, M.C., Drennan, R.D., Kinzig, A.P., Kohler, T.A., Limp, W.F., Maschner, H.D., Michener, W.K., Pauketat, T.R. and Peregrine, P., 2015. Cultural dynamics, deep time, and data: Planning cyberinfrastructure investments for archaeology. Advances in Archaeological Practice, 3(1), pp.1-15.

Richards, J.D., 2017. Twenty years preserving data: A view from the United Kingdom. Advances in Archaeological Practice, 5(3), pp.227-237.

Wilkinson, M.D., Dumontier, M., Aalbersberg, I.J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.W., da Silva Santos, L.B., Bourne, P.E. and Bouwman, J., 2016. The FAIR Guiding Principles for scientific data management and stewardship. Scientific data, 3(1), pp.1-9.

109. Flowing through the Nets. Dealing with Archaeological Data Integration in and around the Lagoon of Venice

Martina MB Bergamo (Ca' Foscari University of Venice); Jacopo Paiano (Ca' Foscari University of Venice); Diego Calaon (Ca' Foscari University of Venice)*

The paper discusses the almost entirely digital workflow to integrate excavation data (databases and geodatabases) from the Roman and Medieval Venice Lagoon area and insert them into a structured system. The aim is to have those data available to cross-refer them to landscape archaeological data and legacy data from institutional archives: we need to quickly shift from a very detailed set of controlled stratigraphic data to an unsystematic set of information to evaluate their quality and build an integrated archaeo-historical interpretation.

Since 2012, the team of Ancient Topography from Ca' Foscari University of Venice has been conducting archaeological investigations in various sites of the Lagoon of Venice and its surroundings (Calaon, Bressan, and Cottica 2019). The project involves the study of ancient landscapes and topography between the Roman Age and the Middle Ages (Calaon and Cottica 2020). Two main sites have been excavated up to now: the Early Medieval emporium of Torcello and the Roman site of Lio Piccolo. Five archaeological excavations were conducted in this wetland environment.

Since 2017, an integrated digital workflow has been developed. The approach aims to store data about stratigraphy, samples, and finds but also to create, directly in a GIS environment, topographic products such as drawings and distribution and density maps, integrating them with raster data (orthophotomosaics and digital elevation models) to build a fluid system. We are also collecting archaeological, historical, and geomorphological data at a regional scale to observe trends occurring in the same area and explore patterns in settlement configuration from a diachronic perspective. Many archaeological studies in the past 60 years focused on this region, mainly to unravel the origins of the Medieval city of Venice, failing to integrate sets of landscape data connecting pre-medieval and Roman sites with the Serenissima. Although the amount of collected data is ample, significant differences are evident regarding qualitative standards and the availability of primary data. Also, many biased historical interpretations (often based on local historiographical traditions, not sufficiently archaeologically tested or confirmed) have profoundly influenced past archaeological practices and, subsequently, the published record. Recent studies gathered new information about material culture with up-to-date methodology. They hinted at the importance of rivers and channels between Late Antiquity and the Early Middle Ages as trade and connective networks between the coasts and the mainland. However, despite the apparent abundance of data, many issues related to the ancient landscape of the region have yet to be addressed in a general lack of broad-scale verified studies.

In order to answer these questions, a dedicated new system was designed, with a specific focus on the river axes that connected cities and settlements of the mainland with their lagoonal and coastal wetlands. Taking into consideration these landscape connections, the modeling strategies adopted were dedicated, at the same time, to archaeological and geoarchaeological features.

The project involves the design of a relational geodatabase connected to a GIS system, both realized with open-source software. It contains information about the sites, geoarchaeological and geomorphological data, and previous archaeological investigations (past excavations, coring campaigns, non-systematic surveys, etc.). For relevant contexts selected by the quality of the available information, the system can manage data about excavation phases, structures, finds, and archaeometric and bioarchaeological analyses coming from recently published archaeological reports as well as ongoing excavations.

The main goal was to create an easy-to-use, flexible, and multiscale system capable of representing, in the same digital environment, elements referring to a medium scale (regional and sub-regional areas) up to a micro-scale (site and excavation). Integrating different types of archaeological data, in the broadest sense, facilitates topographic observation and, consequently, the development of new perspectives. Such dataset could then be used to elaborate further spatial analyses and applications and to develop interpretative models ready to be tested in other contexts. The model has also been developed to be applied in different river basins of the region for comparative purposes.

Critical issues already emerged in the design phase of the system. We must deal with many legacy data, often unstructured or collected with outdated standards. Past interpretative preconceptions are sometimes prominent in literature and reports, so constant reconsideration is needed. The quality of the data and the level of information provided have to be checked to compare elements coming from different sources and produce reliable datasets. Moreover, to model interpretative and chronological aspects of our system, we had to consider the ontology of archaeological data and the formation process of archaeological records to shape our entities and their representation (Lock 2003).

Although the project is ongoing, preliminary results and the first methodological and archaeological outcomes will be presented. From a methodological perspective, being able to switch fluidly between the scale of representation of collected data and precisely manage the quality of the added records have shown to be effective tools for refining our interpretative framework. Furthermore, from an archaeological viewpoint, the system underlined the relevance of rivers and channels between Roman cities on the coasts and the emerging lagoonal Early Medieval sites. As part of the project, the data collection will extend to similar areas of the region with comparable ancient landscapes and archaeological features.

The study aspires to consider critical issues that emerged in comparing our datasets to other projects, looking for better modeling solutions.

References:

Calaon, D., M. Bressan, and D. Cottica. 2019. Vivere d'acqua. Archeologie Tra Lio Piccolo e Altino. Antiga Edizioni.

Calaon, D., and D. Cottica. 2020. 'Tutta Un'altra Storia? Spazi e Funzioni Tra Altino e Il Suo Litorale in Epoca Antica'. In Archeologi Nelle Terre Di Bonifica. Paesaggi Stratificati e Antichi Sistemi Da Riscoprire e Valorizzare, M. S. Busana, E. Novello, A. Vacillotto (Eds), Padova, 35–61.

Lock, G. R. 2003. Using Computers in Archaeology: Towards Virtual Pasts. Psychology Press.

187. Australasian pXRF Archaeological Researchers Collective

Michelle J Richards (La Trobe University); Andrew McAlister (Auckland University); Brendan Kneebone (CFG Heritage Ltd)*

This paper presents an update on and preliminary results from the establishment of an 'Australasian Portable x-ray fluorescence (pXRF) Archaeological Research Collective' that seeks to address common issues faced by archaeological and First Nations researchers wanting to use pXRF. Researchers in archaeological science frequently employ and adapt methods from the hard sciences to answer questions about the past. The benefits of such approaches are also appreciated by First Nations communities seeking to reclaim ownership of information and gather their own data from cultural materials often held in museums or other institutions. PXRF is a preferred technique for chemical characterisations of artefacts because it is non-destructive. It is also appealing because pXRF instruments are often marketed as 'out-of-the-box-ready-to-go', however the practical realities for research are not always so straight forward. This extends to training communities on these instruments. Key issues include custom calibrations, radiation safety (state legislation), realistic field applications and data quality. The solution to these issues requires much more collaboration between researchers and institutions in Australasia. Importantly, our current research must now confront how archaeologists curate databases for Open Science to meet the UNESCO "Findable, Accessible, Interoperable, Reusable" and "Collective Benefit, Authority to Control, Responsibility, Ethics" (FAIR and CARE) principles especially when working with First Nations communities. Work towards solutions is being achieved through this project by connecting multiple archaeology departments in different institutions across Australia and New Zealand to establish a network of accessible research-ready instruments across Australasia.

16. Intrasis FieldRec: Archaeological Data Made Easy

*Sebastian Liahaugen (The Archaeologist/The Swedish History Museum)**

Since the summer of 2023, the Archaeologist, Swedish History Museum has embarked on an ongoing project to develop a mobile data collection application for the Intrasis software, aptly named "Intrasis FieldRec". FieldRec's primary objective is to facilitate the effortless yet adaptable collection of data during archaeological excavations. Our project builds upon the strengths of Intrasis, a powerful software that seamlessly combines a complex yet streamlined database with geographical information, adoptable with CIDOC CRM/CRMarchaeo. By integrating Intrasis's SQL database at its core, FieldRec becomes more than just an isolated tool; it becomes an integral part of the archaeological data ecosystem.

This paper delves into the journey from the initial concept of a mobile data recording app, the evolution of ideas, the actual app development process, and the subsequent test deployments. While FieldRec is still a work in progress, it has undergone testing in two significant archaeological excavations. The first being Dalköpinge, Sweden, a sprawling 200,000 m2 settlement area encompassing Neolithic and Iron Age longhouses, as well as a burial site. The second test took place at Asmundtorp, Sweden, covering a 35,000 m2 Iron Age settlement area. These field tests provided invaluable insights into how the application functions in real-world scenarios, especially when employed by 30 archaeologists initially unfamiliar with the application. In doing so, it mirrors the challenges faced by many in the archaeological community when striving to create data management and information systems that are effective, flexible and user-friendly.

Looking ahead, we will outline the future trajectory of FieldRec, its roadmap, and the prioritization of feature implementation. This forward-looking approach resonates with the ongoing discussions within the archaeological community regarding the optimization of data systems and what information we want to record and how we want to record it.

In conclusion, we will assess the possibilities and weigh the advantages and disadvantages of utilizing a custom-built mobile application for field data collection. By sharing our experiences and lessons learned, we aim to contribute valuable insights to the broader conversation on how archaeological data can be collected and managed.

149. From Interdisciplinary Complexity to FAIR Research Outcomes - Challenges, Implications and Design Decisions

Steffen Strohm (Kiel University); Hartwig Bünning (Kiel University); Matthias Renz (University of Kiel)*

In data engineering Big Data is usually identified using an altering number of V-characteristics, e.g., volume, variety, velocity. Data engineering tasks are always framed by a project context and in this context, characteristics - especially similar to the before-mentioned three - can be identified as constraining and pushing factors for (information) solution designs. These project-specific characteristics can be recognized among others in the number of stakeholders, their diversity of roles, backgrounds and interests as well as in (substantial) differences in skillsets, methodologies and workflows.

Archaeology is a broad and diverse domain in itself, already consisting of various research interests, methodologies and traditions. In the interdisciplinary research environment of this work, additional disciplines are brought in to participate in creating even richer pictures of past phenomena and expand conceptual understanding as well as methodological tool sets, potentially resulting in fruitful collaboration and innovative research outcomes.

In order to achieve both of the latter results, a plethora of challenges of social and technical nature need to be acknowledged, addressed and dealt with. These challenges originate from the (A) project structure (e.g. resources, time frame, regulations), (B) people involved (e.g. scientific background, skillset, role and workload, technical affinity, familiar procedures) and (C) the interdisciplinary interactions (e.g. leave their own comfort zone, find common understandings, manage expectations, build trust).

Handling such complexity and overcoming these challenges is costly, it may involve time-consuming detailings, lots of additional communication, numerous tasks seen as administrative (as in not interesting). However, these costs are also an added motivation, why research outcomes (raw or derived data, scripts, software, virtual environments, documentation, publications) should be designed, delivered and preserved in (at least) a FAIR [1] (findable, accessible, interoperable, reproducible) manner. The criteria are mostly clear and progress has been made in providing infrastructure for FAIR data (preservation and reusage via data repositories), software [2] (via git repositories and usually built-in versioning), as well as research procedures (via specifying workflows [3] and automating reproducibility). But how exactly does a group of researchers introduce and maintain necessary routines to stay on track with providing FAIR research outcomes?

Often, researchers in organising or leading roles such as Principal Investigators (PIs) are involved in multiple endeavours or projects, all introducing different amounts of administrative overhead. They do not have the capacity to deal with all the details involved in fulfilling FAIR requirements and they are not involved in the ground work, where most of the FAIR requirements are fulfilled. An approach that is meant to successfully implement procedures for FAIR research outcomes in a larger project or organization needs to tackle all organizational layers and involve all necessary stakeholders, who can roughly be categorized in decision makers, scientists and organizational/

technical staff.

Coming from the authors' experience in designing a (partial) solution for digital management in an interdisciplinary research environment, this work starts with a systemization of the sources of complexities mentioned above. This outer context is then used to derive implications for the solution design, which includes not only the information system (software components, APIs and internal processes, usability) but also organizational aspects such as roles and processes. The illustrated solution and selected design decisions are then used to take a step back and generalize to come up with a framework of (best) practices and measures. These measures involve the before-mentioned stakeholder groups, relevant processes such as project decision making and training as well as their timing with respect to the time frame of the given project and the (iterations of) corresponding research data life cycle.

The discussion of these practices shall contribute to and progress the idea of a knowledge base for interdisciplinary research projects and support institutional learning among different projects, such that new project teams don't have to repeat starting at or close to zero.

References

[1] https://www.go-fair.org/

[2] Barker, M., Chue Hong, N.P., Katz, D.S. et al. Introducing the FAIR Principles for research software. Sci Data 9, 622 (2022). https://doi.org/10.1038/s41597-022-01710-x

[3] Chee Sun Liew, Malcolm P. Atkinson, Michelle Galea, Tan Fong Ang, Paul Martin, and Jano I. Van Hemert. 2016. Scientific Workflows: Moving Across Paradigms. ACM Comput. Surv. 49, 4, Article 66 (December 2017), 39 pages. https://doi.org/10.1145/3012429

120. The Challenges in Creating Databases for Pacific Ceramics (Poster)

Kristine Hardy (ANU); Mathieu Leclerc*

Petrographic fabrics, the mixtures of different mineral and rock inclusions in clay pastes of pottery sherds, provide geological signatures that can help identify the site of production, and can indicate the degree of variability within a pottery community or changes in techniques over time. In petrographic analysis, thin sections of pottery, mounted on microscope slides, are viewed under different filters to identify the minerals and rocks and characterise the fabrics.

The results of ceramic petrographic analysis can be challenging to present, interpret and compare and this has been exacerbated by past limitations on publishing colour images. Variable ontologies and methods of quantifying or describing the inclusions, also add to the difficulties in understanding petrographic reports. Unfortunately, often thin sections are also not archived, or if kept, are difficult to access.

The geologist, William Dickinson extensively characterised the fabrics of archaeological pottery found throughout the Pacific (Dickinson 2006). His collection of 2291 thin-sections, is held by the Bishop Museum of Hawai'i and digital copies of his associated reports are archived at several places, including the Australian National University Archives. We aimed to use his reports and thin-sections to seed databases for petrographic images and the quantitative mineral/rock abundances of the fabrics of Pacific pottery.

Using the reports we created a relational database (kuden) with 'fabrics', 'sites', 'slides/sherds' and 'reports' tables. The fields for the fabrics table include quantitative measures for the different minerals, and the presence or absence of different rock types. We have created a Django web interface for the database, to allow users to search for fabrics that match certain mineral/rock abundances, and/or are found at certain locations. The kuden database also includes links to example images of the fabric. To facilitate the viewing of images at different magnifications, and with the different filters, we used the Open Microscopy Environment Remote Objects (OMERO) opensource software system. OMERO was designed for archiving and managing biological slide images (Burel et al. 2015).

Slide scanners such as the Axioscan7 have made it easier to obtained high resolution images of whole slides, under multiple filters. OMERO is able to serve these files in a tiled, memory efficient manner, resulting in a 'virtual microscope'. Using whole slide scans and more simple TIF image stacks we have imaged approximately half of the fabrics of Pacific pottery in an OMERO implementation, VIMIPO and found that OMERO software is an effective way of presenting ceramic petrographic data.

We are investigating converting the kuden relational database to a CIDOC-CRM graph-based database, with the future possibility of using linked data to address questions such as how pottery technology changes related to other temporal changes in the Pacific.

References

Burel, Jean-Marie, Sebastien Besson, Colin Blackburn, Mark Carroll, Richard K. Ferguson, Helen Flynn, Kenneth Gillen, et al. 2015 "Publishing and sharing multi-dimensional image data with OMERO." Mammalian Genome 26:441–447. https://doi.org/10.1007/s00335-015-9587-6

Dickinson, William. 2006. "Temper Sands in Prehistoric Oceanian Pottery: Geotectonics, Sedimentology, Petrography, Provenance." Geological Society of America Special Paper 406:1–164. https://doi.org/10.1130/SPE406.

S17: Conversations across the (Digital) Ditch

Tuesday 9th April, 13:00–17:00, OGGB-098

Katharine Watson, Christchurch Archaeology Project
Joshua Emmitt, Auckland War Memorial Museum
Rebecca Phillipps, University of Auckland

Archaeological data management has been the subject of much discussion for many years at the CAA conference. Conferences like this one are often spaces where conversations between different spheres of influence in heritage management, including academic and commercial, can take place, but often languish outside of such contexts. Academic discussions of data management are historically hidden behind paywalls, and are largely inaccessible to those working outside of the academy. In addition to the challenges of data semantics, the sovereignty of data must also be meaningfully engaged with (e.g. Heilen and Manney 2023). In this session we wish to promote conversations across these different spheres of archaeological research, including academic, cultural resource management, museums, government agencies, and community groups with a focus on the challenges of archaeological data management.

Submissions could include any of the following. The challenges of digital data acquisition in field contexts, including logistical challenges. The management of archaeological data including database structure, semantic issues, the challenges of archaeological data as a living archive, resourcing, and long-term curation. The challenges of addresses concerns around data sovereignty including pressures of open access, legal obligations, and ontological issues regarding digital matter.

References

Heilen, M., & Manney, S. (2023). Refining Archaeological Data Collection and Management. Advances in Archaeological Practice, 11(1), 1-10. doi:10.1017/aap.2022.41

S17: Conversations across the (Digital) Ditch	
13:00-13:20	*191. Ethics and Accountability: Research Data Management Planning for Digital Archaeology* *Aleksandra Michalewicz (University of Melbourne)**
13:20-13:40	*130. ArchSite and Archaeological Data Management in Aotearoa/New Zealand: Refresh, Reboot, Redesign* *Alex F Jorgensen (Auckland Council)*; Christopher G Jennings (Southern Pacific Archaeological Research, University of Otago); Karen Grieg (University of Otago); Anais Schaenzel (Eagle Technology)*
13:40-14:00	*143. Connecting ""Outstanding Universal Value"" to Digital Imperialism* *Alexandra J Warminski (University of Exeter)**
14:00-14:20	*119. A City in Code: Creating an Archaeological Database for the Christchurch Dataset* *Jessie Garland (Christchurch Archaeology Project; La Trobe University)**
14:20-14:40	*86. Managing and Utilizing Data from Multiple Contexts: A Case Study from the URU Fayum Project North Shore Survey* *Joshua Emmitt (Auckland War Memorial Museum)*; Rebecca Phillipps (University of Auckland); Simon Holdaway (University of Auckland)*
14:40-15:00	*85. Colonial Legacies, Community Archaeology, and Digital Data at Kisese II, Tanzania* *Kathryn Ranhorn (Arizona State University)*; Samantha Porter (University of Minnesota); Husna Katambo (Arizona State University); collective collective (Kondoa Deep History Partnership)*
Afternoon tea	
15:20-15:40	*34. Tales from Two River Banks? Spanning a Digital Divide between Development Funded Archaeological Practice and Research Funded Archaeological Practice?* *Keith May (Historic England)*; James Taylor (Department of Archaeology, University of York)*

S17: Conversations across the (Digital) Ditch	
15:40-16:00	*41. Archaeological Data Management: A Singular Problem, Twin Challenges, and a Triple Threat* *Sandra Schloen (Forum for Digital Culture, University of Chicago)*"*
16:00-16:20	*46. Keeping High Speed 2 on Track: Managing a Decade of Asynchronous Archiving and Dissemination* *Teagan K Zoldoske (Archaeology Data Service)*; Holly Wright (University of York)*
16:20-16:40	*180. Mind the Gap: Multivariate Data Integration and Analysis in Early Bronze Age Southern Levantine Archaeology* *Tucker Deady (University of Toronto)**

191. Ethics and Accountability: Research Data Management Planning for Digital Archaeology

*Aleksandra Michalewicz (University of Melbourne)**

In the digital age, Research Data Management Plans (RDMPs) have become indispensable for guiding the acquisition, preservation, and dissemination of research data. RDMPs outline how research data and associated materials will be managed, stored, documented and secured. They encourage planning for what will happen to data and related materials following completion of a research project, including retention and archiving, accessing, sharing, publishing, possible data disposal requirements, and any conditions or restrictions for sharing the data. The aim of an RDMP is to provide explanatory details of the data, the processes and decisions, and to identify roles and responsibilities. These may seem obvious to researchers but without articulating our methods and practices we cannot advance the work we do, especially given ever expanding amounts of data and increasing application of digital tools and methods. In short, RDMPs should be developed as fundamental research project management; there is no research without data and data requires management.

Archaeologists deal with many data types which require specialized understanding and handling. Therefore it is important to understand roles and responsibilities as they pertain to the data and which can sometimes be unclear. Data roles include data providers, cultural custodians, data stewards, data curators, data requestors, governance committees and technical advisory panels. Articulating such roles in an RDMP can help reveal and guide research decisions, and ameliorate potential issues throughout the research lifecycle.

Other factors to consider include: levels of data sensitivity, segmentation and aggregation, version control, accompanying documentation, infrastructure access, secure storage and backups, data migration, stable formats, data integrity, data sustainability, data repositories, platform hosting, research co-, esign and collaboration, dynamic consent models, tensions between the individual and communal, intellectual property, personal data and records, legal frameworks, relationship capture, metadata enrichment, and data return.

Suites of documents might include data governance frameworks and data request application forms. Additionally, data sharing may necessitate some form of data transfer agreements, data access agreements, data sharing agreements and data licenses. These are not always mandated but are often necessary for data work and therefore project dependent. Such systems and frameworks are becoming increasingly robust and will continue developing in coming years. Simultaneously, there is growing recognition of the need for robust frameworks for digital and data ethics. Institutions might require ethics clearances for particular research projects but precise articulation of research ethics leads to more ethical research practice.

Data frameworks such as the FAIR principles and the Five Safes framework offer a holistic approach to risk assessment associated with open data and data sharing. While these frameworks promote open data, work with First Nations data requires further consideration. For example, First Nations people may not wish to share their data given that institutional infrastructures can be unsuitable where ownership of data can lie within institutional infrastructure. A formal document such as a data governance framework can be used to articulate, document and formalise mechanisms for Indigenous Data Governance. Such a document can support communities to manage, control and protect their information both externally and internally. Relevant governing frameworks to consider include the First Nation Principles of OCAP and the CARE Principles. In Australia, the AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research (2020) is one of the most important resources for working with First Nations data in Australia.

RDMPs are a means by which to document not just research data but likewise research project management and thereby ethical research practice. These are a means by which researchers and research projects can demonstrate best practice academic rigour, respect for communities, regard for cultural data, and ethical accountability. For example, they can help demarcate intellectual property as compared to cultural property. Further, digital data is an artefact in itself and must be recorded as we would any other artefact. Archaeologists are very well placed to lead such conversations, especially as they deal with digital and physical data, big and small datasets, quantitative and qualitative data, as well as tangible and intangible data.

In the age of research encompassing big data and fast outputs across domains RDMPs also respond to the frequent interdisciplinarity of our work as well as aspects of our work predicated on small data and slow research. Finally, RDMPs, as well as clear ethics statements, should be accepted as non-traditional research outputs.

130. ArchSite and Archaeological Data Management in Aotearoa/ New Zealand: Refresh, Reboot, Redesign

Alex F Jorgensen (Auckland Council); Christopher G Jennings (Southern Pacific Archaeological Research, University of Otago); Karen Grieg (University of Otago); Chaitra Sridhar (Eagle Technology)*

"ArchSite" is an online database that contains information about recorded archaeological sites in Aotearoa/New Zealand. It uses GIS technology to manage and display information and is the national database of archaeological sites in New Zealand. It is operated by the New Zealand Archaeological Association (NZAA), with Heritage New Zealand Pouhere Taonga and the New Zealand Department of Conservation, and currently consists of over 77,000 recorded sites and over 178,000 ancillary digital documents. In partnership with Eagle Technology, a New Zealand-owned systems integration and information management company, the ArchSite Platform is currently being migrated from its existing bespoke GIS solution to an ESRI ArcGIS Online format. This upgrade project has served to highlight a number of practical and -conceptual issues with the digital storage of large amounts of archaeological geospatial data and user access to that data. As an archaeological "site" recording schema, the upgrade project grapples with the theoretical problems of treating sites as units of recording and observation (McCoy 2020). Once accessioned into the system, appropriate levels of spatial resolution for record display, and access to those various levels and by whom, are encountered. Additionally, how Indigenous Data Sovereignty concepts should be incorporated into the overall matrix of site recording and database management have required new approaches to be considered (Kukutai et.al. 2023). Ensuring functionality that will allow the use of ArchSite for both proactive and reactive heritage management, cross-disciplinary research, and predictive modelling in the face of threats to heritage such as climate change (Jones et. al. 2023) has also been at the forefront of design parameters.

While the ArchSite upgrade is still a work in progress, this paper will discuss the practical challenges faced by software engineers, archaeologists and other users in the application and design of modern data management practices to a living archive and the ontological issues that arise during the course the conversion of a bespoke GIS program derived from an analogue site recording scheme to a more powerful cloud-based geospatial database application.

References:

Jones, Benjamin D., Mark E. Dickson, Murray Ford, Daniel Hikuroa, and Emma J. Ryan. "Aotearoa New Zealand's coastal archaeological heritage: A geostatistical overview of threatened sites." The Journal of Island and Coastal Archaeology (2023): 1-21.

Kukutai, Tahu., Kyla Campbell-Kamareira, Aroha Mead, Kirikowhai Mikaere, Caleb Moses, Jessie Whitehead and Donna Cormack (2023) "Māori data governance model". Te Kāhui Raraunga.

McCoy, Mark D. "The site problem: A critical review of the site concept in archaeology in the digital age." Journal of Field Archaeology 45, no. sup1 (2020): S18-S26.

143. Connecting "Outstanding Universal Value" to Digital Imperialism

*Alexandra J Warminski (University of Exeter)**

"Outstanding universal value," or better known as just universality, has been defined by UNESCO to be, "…cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity" (UNESCO 2019). The concept of universality has been operationalized to justify the digitization of at-risk heritage and archaeology across the world—particularly in Syria where the universal value of their at-risk heritage and archaeology has been highlighted in international rhetoric to simultaneously denounce purposeful destruction during the war and promote internationally collaborative digitization initiatives to preserve at-risk heritage and archaeology. While well-intended, and arguably necessary for internationally collaborative heritage and archaeological preservation, invoking universality as justification to digitize has the capacity to blur the boundaries of cultural ownership over digitized heritage and digital archaeological data as it now complicates who has control over the data and its usage—to whom does the digitized heritage and archaeology belong to: to the culture it has been digitized from, to the practitioners who created the digital data, or to the countries who funded digitization efforts? By expanding upon previous research on the international rhetoric around digitizing at-risk Syrian heritage and archaeology for preservation, this paper aims to explore and understand the implications of invoking universality in justifying heritage and archaeological digitization initiatives for preserving Middle Eastern heritage and archaeology. This is done to assert that invoking universality as a justification for digitization can inadvertently lead to digital imperialistic outcomes. Outcomes that need an active engagement with the FAIR (https://www.go-fair.org/fair-principles/) and CARE (https://www.gida-global.org/care) principles to clearly establish the boundaries of ownership and future usage of the digital data from the onset of digitization projects, particularly in the context of Middle Eastern heritage and archaeology. Confronting the unintentional connection between "outstanding universal value" and digital imperialism would compel archaeologists and heritage professionals to develop better collaborative digital practices that more accurately represents the cultures and people they are trying to preserve.

References

"CARE Principles." 2023. Global Indigenous Data Alliance. January 23, 2023. https://www.gida-global.org/care.

"FAIR Principles." n.d. GO FAIR. Accessed October 26, 2023. https://www.go-fair.org/fair-principles/.

UNESCO. 2019. "Operational Guidelines for the Implementation of the World Heritage Convention."

119. A City in Code: Creating an Archaeological Database for the Christchurch Dataset

*Jessie Garland (Christchurch Archaeology Project; La Trobe University)**

Since the 2010 and 2011 earthquakes, an unprecedented quantity of archaeological work has been undertaken in Ōtautahi Christchurch, generating a significant archaeological and historical dataset that has, to date, existed in disparate files, locations and formats. The site-by-site and project-by-project nature of the CRM work carried out in the city and the lack of a formal archiving and/or data management system has limited the research potential of this dataset and its accessibility to the general public: despite an archaeological dataset that encompasses a whole city and the history of its land from the first settlers in the 14th century to the present day, it remained impossible to use that information at a city-wide scale or to access the data in way that reflected the complexity and connections of the city's history. Although highlighted by the scale of the Christchurch work, these issues of accessibility and comparability, especially for commercially generated archaeological data, also present a significant challenge for the archaeological profession on a national scale.

The Christchurch Archaeology Project (CAP), a not-for-profit organisation, was formed in 2022 to address these issues in the city's archaeology. In August 2023, with funding from Manatū Taonga, work began to create a relational database that will eventually hold all the archaeological data from Ōtautahi Christhurch in a format that is both accessible and appealing to the general public and that allows for multi-scalar comparative research and industry use. While the programming has been undertaken by an external company, significant work has been required to formalise the data and data structures encapsulated by the current Christchurch dataset. The challenges of integrating large scale and disparate archaeological datasets into one database have been well-documented (Cooper and Green 2016), especially for those dealing with urban archaeological data at a city wide scale (i.e. Murray and Crook 2005). These same challenges – standardisation of data, compatability, complex relationships between datasets, the definition of spatio-temporal relationships and data quality – have been encountered during the CAP database build, in addition to the commercially structured nature of the data and the need to have both a publically accessible and research compatible outcome. The specifically urban nature of the work undertaken further adds to the challenges of the required data structure: urban spaces are complex and dynamic and the relationships between land histories, people and archaeological remains reflect that complexity.

The CAP database has approached this through a simple database structure that allows for complex relationships: the fundamental basis of the database is the relationship between person, context and artefact, framed and defined by multiple spatio-temporal frameworks (building on the methods outlined in Holdaway et al. 2019). Such frameworks include but are not limited to historic land use, site and project entities, and phases of occupation, construction and archaeological activity, which sit alongside historical and archaeological biographies of people, contexts and artefacts. Information related to the original curation and creation of this data is also captured through archaeological methodology, legislative conditions and the commercial conditions that necessitated the original archaeological investigation.

While the construction and population of the CAP database remains ongoing, a prototype database created by the author during her doctoral thesis work showcases the research potential of this project. Investigation of this dataset, which encompassed all colonial-era artefact bearing deposits excavated in Ōtautahi Christchurch between 2010 and 2018 (approximately 75, 000 artefacts from 500 projects), included analysis of the size and type of archaeological deposit across the city, the relationship between the size, type and integrity of deposit, archaeological site formation, city topography and the type of construction work. Broader spatial-temporal analysis of the deposits provided insights into both the general scope of a large scale urban archaeological dataset and the effects of New Zealand legislative and industry approaches to urban archaeological investigation, while multi-scalar comparisons between commercial, domestic and industrial material culture could still be anchored in the nuances of individual historical narratives of people and place.

This paper presents a synthesis of the challenges and potential inherent in managing and curating a large, varied, living archive of archaeological and historical data in a format that fulfils our ethical obligation to make archaeological information acessible to the general public and useful for archaeological research and development. The Christchurch dataset provides an important opportunity to explore data management and curation for commercially generated archaeology on a large scale and it is hoped that the lessons learned from this project may contribute to addressing some of these issues on a national scale.

Acknowledgements

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References

Cooper, Anwen and Chris Green. 2016. "Embracing the Complexities of 'Big Data' in Archaeology: the Case of the English Landscape and Identities Project." Journal of Archaeological Method and Theory, 23: 271-304.

Holdaway, Simon, Joshua Emmit, Rebecca Phillips and Sina Masoud-Ansari. 2019. "A Minimalist Approach to Archaeological Data Management Design." Journal of Archaeological Method and Theory 26: 873-893.

Murray, Tim and Penny Crook. 2005. "Exploring the Archaeology of the Modern City: Issues of Scale, Integration and Complexity." International Journal of Historical Archaeology 9, no. 1 (Spring): 89-109.

86. Managing and Utilizing Data from Multiple Contexts: A Case Study from the URU Fayum Project North Shore Survey

Joshua Emmitt (Auckland War Memorial Museum); Rebecca Phillipps (University of Auckland); Simon Holdaway (University of Auckland)*

Archaeological research has been undertaken in the Fayum Depression, Egypt, for over 100 years (Caton-Thompson and Gardner 1934; Holdaway and Wendrich 2017). Over this time multiple projects from different institutions around the world have examined the early and middle Holocene material found on the surface and in stratified deposits in the region. Over the last twenty years, the URU Fayum Project has carried out fieldwork along the Fayum north shore, which overlaps with the areas investigated by previous projects. Projects in the 1920's (Caton-Thompson and Gardner 1934), 1960's (Wendorf and Schild 1976), and the 1980's (Wenke et al. 1988), have each employed different recording standards which were in line with the theoretical, methodological, and technological changes of that time. In addition, many records and artefacts from the region are now in museum collections around the world (Emmitt 2017). The wide distribution of this data presented a challenge for the current project to concatenate past results with new data and to reevaluate past interpretations of human occupation in the region.

Aside from dealing with different mediums of data storage and presentation, such as field notes, stratigraphic drawings, landscape drawings, plate images, photographs, digital images, and geographic information, the institutions' data were stored in presented challenges, which influenced the research. Material was curated differently in different museums, and some material was simply inaccessible. Some material in museums, while attributed to the Fayum, had lost their primary contextual information due to the destruction of records (Caton-Thompson 1982), while others had degraded over time. In this paper, we will outline how historic records were integrated with those collected with contemporary recording methodologies. We also discuss future directions for the publication of data from the project and the challenges this brings when considering the multiple sources data are from.

References:

Caton-Thompson, G. & E.W. Gardner. 1934. The Desert Fayum. London: The Royal Anthropological Institute of Great Britain and Ireland.

Emmitt, J. 2017. The Neolithic Pottery of Egypt: Investigating settlement pattern in middle Holocene northeast Africa with ceramics. The University of Auckland. Unpublished PhD Thesis

Holdaway, S.J. & W. Wendrich. 2017. The Desert Fayum reinvestigated: the early to mid-Holocene landscape archaeology of the Fayum north shore, Egypt. Los Angeles (CA): Cotsen Institute of Archaeology

Wendorf, F. & R. Schild. 1976. Prehistory of the Nile Valley. New York: Academic.

Wenke, R.J., J.E. Long & P.E. Buck. 1988. Epipaleolithic and Neolithic subsistence and settlement in the Fayyum Oasis of Egypt. Journal of Field Archaeology 15: 29–51.

85. Colonial Legacies, Community Archaeology, and Digital Data at Kisese II, Tanzania

Kathryn Ranhorn (Arizona State University); Samantha Porter (University of Minnesota); Husna Katambo (Arizona State University); collective collective (Kondoa Deep History Partnership)*

In much, if not most of the world, archaeology has historically been conducted through a colonial lens of extraction. This has often manifested as researchers of European descent traveling to an area, excavating material without consultation or collaboration with local people, and then removing these materials for study or display at a different location - sometimes to a different continent, often losing significant contextual information in the process. In this paper, we discuss how our team, the Kondoa Deep History Partnership, is grappling with these legacies at the site of Kisese II (Tanzania). We will describe how we are working towards a more ethical approach to Paleoanthropological research, focusing on our use of digital methods of data collection, curation, and dissemination - both in terms of the positive outcomes and the pitfalls we have encountered.

Kisese II is located in the Kondoa region of Tanzania and is part of a series of painted rock shelters recognized by UNESCO as a World Heritage Center. It is considered to be a site of spiritual significance to the present day local Rangi community. It has a deep archaeological sequence going back at least 47,000 years and spanning the Middle to Later Stone Age transition (Tryon et al. 2017). Excavations were first carried out by Louis and Mary Leakey in 1951, and were furthered by Ray Inskeep in 1956. The archaeological materials from these excavations are currently housed in the National Museum of Tanzania, while human remains uncovered at the site were taken to the National Museum of Kenya. Very little was published from these initial excavations. Furthermore, the available archival records for this work until recently were sparse, consisting of a few 35mm slides and some graphics and notes housed at the McDonald Institute at the University of Cambridge. Archival analysis of these materials was initiated by Christian Tryon and Jason Lewis in 2011, and fieldwork was initiated by Katie Ranhorn and the Kondoa Deep History Partnership in 2017 (Tryon et al. 2019). This was followed by two additional fieldwork seasons in 2019 and 2022. In 2019, a great deal more documentation, including Inskeep's original excavation notebook, correspondence, and many additional photographs, were discovered in Oxford by Peter Mitchell. These were digitized in 2022, and are currently under review by the team.

The goals of these three seasons were largely to a) work with the community to develop goals for future research and conservation at the site and in the greater region, and renew access to and ownership of Tanzanian and specifically Rangi people to their own cultural heritage; b) assess the state of conservation of the site including both the rock art and the archaeological deposits; and c) gain a better understanding of the location and extent of the Leakey and Inskeep excavations in order to provide context for the already extracted collections.

From the beginning, digital documentation and data curation have been central to our approach despite limited access to the internet, hardware, and electricity. These digital interventions fall into three broad categories: provenience recording with a laser theodolite, 3D photogrammetric site reconstruction, and collaborative stewardship of digital heritage. Since 2017 point provenience data has been collected using a total station and EDM software developed by Harrold Dibble and Shannon McPherron. Artifacts are also tracked using pre-printed barcodes. The details of our implementation of this system have evolved each season, and we will discuss some interesting methodological, technical, and even semantic issues in code that we've encountered along the way as a result of having a team comprised of researchers initially trained in East African Paleoanthropology vs. European Paleolithic archaeology.

Secondly, we have found 3D photogrammetric models to be essential to nearly all aspects of our work. In our three years of work we have evolved from generating a single end of season 3D model in 2017, to employing a systematic 'excavation surface' protocol consisting of over 50 georeferenced models in 2022. This protocol can be used as a back up to a laser theodolite and is more accurate than recording measurements with measuring tape and plumb bob. We have also used 3D models to document the rock art (including enhancement with DStretch), to work in real time with collaborators across the globe to plan upcoming field seasons using Blender and 3Dhop, to monitor the effect of erosion and climate change from year to year (Patania et al. 2022), to create a virtual reality site visit for outreach and engagement, and to collaborate with the Forestry Service to design a shelter to mitigate further environmental damage to the site.

Finally, we will discuss our digital data curation and stewardship. So much of our work has been made necessary by the loss of previous excavation data. It is essential that we break this cycle for the next generation of researchers. Our efforts include daily backups of data and working with Tanzanian colleagues and data repositories to ensure access is as open as possible and closed as necessary. Slack and WhatsApp conversations increase transparency, broaden participation, and archive communications of the research process.

In conclusion, legacies of colonialism in Africa deeply shape research practice and output. We view digital tools as an essential part of our archaeological stewardship. We look forward to sharing our ongoing work in Kondoa as a case study in integrating digital methods into archaeology, especially as it applies to other sites grappling with similar colonial legacies.

34. Tales from Two River Banks? Spanning a Digital Divide between Development Funded Archaeological Practice and Research Funded Archaeological Practice?

Keith May (Historic England); James Taylor (Department of Archaeology, University of York)*

The Matrix project (AHRC/UKRI funded AH/T002093/1) has investigated how digital data from archaeological excavations can be made more consistent, cost-effective and thereby more useful to a range of users and audiences. It has worked towards a shared plan and methods to get such data more consistently recorded, analysed, disseminated, and archived in a way that is Findable, Accessible, Interoperable and especially to identify what is most Re-useable (FAIR).

The focus of digital archives and museums is switching from simply providing better online access to digital archives, to questions of how users in commercial archaeological units, curatorial organizations and academia can, along with broader public audiences, make best use of this growing body of digital data, information and better help the synthesis and integration of related knowledge.

The project (May, et al 2023) has identified several significant measures that could help improve the signposting of archives for re-use to potential researchers. The aim has been to identify common processes with coherent outputs that would enable finding and re-use of relevant data within archives e.g. a data package for stratigraphic and chronological data. This work has also informed the development of a prototype software tool for stratigraphic analysis (nicknamed "Phaser") that assists those archiving processes to improve re-use of archaeological data by other users, such as Bayesian chronological modellers.

The chronological modelling of archaeological data is dependent upon access to, and re-use of, primary stratigraphic data and associated dating evidence, which should form a principal component of archaeological datasets. However current practice for archiving of digital records of the stratigraphic data from excavations is still very variable internationally, and in many cases lacking, particularly for commercially excavated sites. Experience in the UK shows "comparison of the number of archives deposited with the Archaeology Data Service (ADS) against an estimated number of projects found that, at best, 2-3% of all commercial projects have been digitally archived with the ADS." (Tsang 2021). There is also no commonly accepted consistent practice for making sure that the primary stratigraphic data from excavations is included in the digital archive. Although there are valuable initiatives currently being undertaken to address what is included in the digital archive from excavations, such as the CIfA "Dig Digital Toolkit" (https://www.archaeologists.net/digdigital), the actual processes used in the post-excavation (PX) analysis stage of projects varies quite markedly and therefore the by-products from that stage of the process are far less consistent in the resulting digital archives.

For projects that do archive primary stratigraphic records from an excavation (Harris 1989), in most cases the grouping and phasing information from the analysis of stratigraphy is not associated with the primary stratigraphic data. This creates an hiatus in the stratigraphic archive, whereby it is not possible to follow the stratigraphic sequences through from the primary records made on the excavation, to the interpretive phasing of the stratigraphic matrix based on the associated finds assemblages and dating evidence. Most significantly the actual chronology for sites derived from the dating of stratigraphic units from finds objects and scientific dating of samples is not available unless the evidence from such analysis records are incorporated into the site grouping and phasing and these records are the least prevalent in the digital archives.

In current practice often only a PDF image of a matrix diagram is included in an archived report. Where primary stratigraphic relationships are archived, these may be recorded as separate columns in spread sheets and archived in Comma Separated Value (CSV) format, which is substantially better for preservation and reuse purposes. In other cases, the stratigraphic relationships will be held as part of the site database and will then be archived in a format that such database software enables to be digitally preserved and migrated as necessary. Even so, and in either case, that does not necessarily guarantee commonality in how the stratigraphic information within the data are represented and preserved and does not incorporate chronological data from the analysis of associated finds.

To be able to fully manage FAIR stratigraphic and related chronological data and its archiving we may need to take a new approach to data packaging and how it could help in making stratigraphic data more re-usable, and interoperable across different site records. The objective would be to improve data packaging to cover the range of archaeological outputs generated by the processes that use stratigraphic and chronological data with related data signposting in digital archives. The aim would be to better reflect data characterization of most common examples of re-use (or re-mixing, or re-cycling of data) based upon analysis of common use case scenarios, informed by conventions for typical user outputs in digital archives. Stratigraphic and chronological re-use examples can provide a sound basis for case studies.

To what extent are PX practices, techniques and documentation as well established as the methods for on-site recording and what are the opportunities and challenges, we still face? To address these issues with records and archives of stratigraphic data, a further new project is now being undertaken. The AG2GP-Handbook project (AH/X006735/1) is drawing upon the collective expertise of archaeological contractors across the UK and, in consultation with other stakeholders from the sector, is developing a consortium approach and online tools and resources to support best working practice for what is commonly termed stratigraphic analysis work.

Both these projects have investigated the re-use of stratigraphic data in archives and found a number of issues that impact on the re-use of data for stratigraphic and chronological modelling. This paper will consider a number of these proposals and options for improving the records and re-use of stratigraphic data (e.g., for chronological modelling), including developing an online handbook for post-excavation practices more generally.

References:

Harris, Edward. 1989. Principles of Archaeological Stratigraphy (2nd Edition). London: Academic Press.

May, K., Taylor, J.S. and Binding, C. 2023 Stratigraphic Analysis and The Matrix: connecting and reusing digital records and archives of archaeological investigations, Internet Archaeology 61. https://doi.org/10.11141/ia.61.2

Tsang, Claire. 2021 Red Sky at Night: digital archiving in England 2020, Internet Archaeology 58. https://doi.org/10.11141/ia.58.6

41. Archaeological Data Management: A Singular Problem, Twin Challenges, and a Triple Threat

*Sandra Schloen (Forum for Digital Culture, University of Chicago)**

It is generally non-controversial to suggest that archaeology has a singular data problem. Data collected by a typically destructive archaeology endeavor, by a typically diverse group of stakeholders, is highly granular, heterogeneous, often fragmentary, potentially sensitive, and contextualized in both space and time. A lot of different kinds of data (e.g., photographs, maps/ coordinates, measurements, prose description) are collected about a lot of different kinds of things (e.g., sites, artefacts, historical actors), in a lot of different formats (many digital, many not), by a lot of different people (e.g., scholars and students, surveyors and specialists, career archaeologists, or simply volunteers). Furthermore, the real value of such data is disproportionate to its face value. As stated on the website of the Ōtautahi Christchurch archaeological archive: "The data's not just important because of the destructive nature of archaeological excavation. It's important because of what we can learn from it, and because we can't learn that information from any other source" (https://www.christchurcharchaeology.org/the-tautahi-christchurch-archaeological-archive).

The archaeological data problem leads to twin challenges of archaeological data management, those of integration and collaboration, where there are complex technological considerations on the one hand and crucial human interactions on the other. If this were easy, there would be a generally accepted solution by now. Standardization of terminology and ontologies, and agreement on formats and methods, is not the answer to successful archaeological data management. Harmonizing data for the sake of integration diminishes the distinctiveness of the product, the people, and the process. Rather, what is needed is a computational platform that supports a variety of workflows and accommodates the complexity of archaeological data, respecting both the nature of the data and those who have contributed it.

After over two decades of rigorous use, the Online Cultural and Historical Research Environment (OCHRE) has proven to be an innovative, robust, comprehensive database solution for archaeological data management—a triple threat addressing the logistical, technological, and social challenges inherent in archaeological data management. Based on a graph data model (e.g., a network approach) rather than a relational data model (e.g., a tabular approach), OCHRE is agnostic as to space, time, and taxonomy (ontology), but highly customizable by the researcher to their project's needs. Internet based (freely downloadable) and designed for collaboration, OCHRE supports the full data lifecycle while giving easy access to project data worldwide—privately via access controls when needed, or openly on the Web via the OCHRE API (application programming interface).

While used by numerous archaeology projects on multiple continents, this presentation will take as its digital archaeology case study the Cerro del Villar excavations in Málaga, Spain—a joint American, Spanish, and German research venture. The wine and olive oil vessels in the households of the Phoenicians, the plastered vats of the Roman industrial garum (fermented fish sauce) production, and the historic destruction of the city by tsunamis, are documented digitally in OCHRE in real time by excavation staff, specialists, and students. Sophisticated technologies built into OCHRE for integrating photogrammetry and other geospatial data, and for plucking geographic coordinates from thin air (thanks to overhead satellites), along with streamlined workflows for linking photographs and for producing archive-quality barcode labels for catalogued artefacts will be demonstrated. The value of an item-based approach for data integration will be illustrated. But beyond the logistical and digital achievements, the technology has enabled meaningful collaboration, focusing and uniting this diverse team in their quest to wrest meaning from the past.

46. Keeping High Speed 2 on Track: Managing a Decade of Asynchronous Archiving and Dissemination

Teagan K Zoldoske (Archaeology Data Service); Holly Wright (University of York)*

Founded in 1996, the Archaeology Data Service (ADS) is an accredited, digital, open access repository for archaeological and cultural heritage data. Over the past 27 years, the ADS has archived more than 4 million files, creating around 45 TB of data.. Working with colleagues within both the academic and commercial sectors, the ADS actively promotes best practice and the use of data standards whilst providing archiving services that ensure the ongoing preservation and dissemination of datasets. As a part of this work, the ADS has been actively involved in archiving the archaeology and heritage data from the UK's High Speed 2 (HS2) rail project. HS2 is currently underway in the UK. It is the largest infrastructure project ever undertaken in the UK, but it is also the largest archaeological project currently underway in Europe. It is estimated that the data HS2 alone will generate and deposit with the ADS will double the ADS's data holdings over the next decade. The nature of HS2 means that much of this data is being deposited quite some time after creation, and after being passed through multiple hands. While HS2 has created a wealth of new information, it must first be properly collected, documented, and linked before any of that information can be disseminated to the general public, causing further delay.

To date, the ADS has received 15 TB of data and over 875 thousand files from 346 sites, as a part of Phase 1 of HS2. This data came to the ADS from 15 different archaeological organisations and the size of these archives varies significantly, with our largest being nearly 3TB, and consisting of over 154 thousand files. In order to mitigate risks and ensure that all data deposited into the ADS as a part of HS2 is handled properly, it is accessioned by hand and organised to fit a structure to help aid in the archiving and dissemination process. A key aspect of this is that the ADS is still receiving new data from sites even as we are releasing archives for the public to access. As such, a well-designed organisation and structure of this project within ADS has been vital from an archiving standpoint, but to also make the data searchable. This paper will discuss how the ADS has organised the HS2 data internally and how that in turn has allowed us to create new dissemination techniques for a project for which we are still actively receiving data.

180. Mind the Gap: Multivariate Data Integration and Analysis in Early Bronze Age Southern Levantine Archaeology

*Tucker Deady (University of Toronto)**

Archaeological research in the Southern Levant has a rich history of data collection, but the field is burdened by a multitude of chronologies, typologies, vocabularies, and recording methods. These challenges are compounded by gaps in documentation and a lack of communication between qualitative and quantitative scholars, discrepancies that become acutely apparent when addressing temporal change. In particular, traditional discussions of urbanization during the Early Bronze Age (EBA) revolve around a simplistic urban-rural dichotomy, in which the EB III and IV periods witness a stark transition from urban to rural settlements. Recent EBA scholarship has, however, advocated for a more nuanced understanding of temporal, spatial, and social networks, but collaborative, multivariate approaches are lacking (Chesson and Philip 2003). These issues are closely tied to the problems in recording inconsistencies, data accumulation, storage, and communication that have long affected EBA Southern Levantine archaeology.

This paper presents a nested approach to tackle these challenges. Data disparities are first addressed through the implementation of the Southern Levant Database (SLeD), part of the Computational Research on the Ancient Near East (CRANE) Project. SLeD shares CRANE's objectives to create a collaborative, adaptable platform to discuss long term human-environmental interactions and ethical means of data sharing and reproducibility (The CRANE Project, n.d). This non-relational database uses the adaptable framework of the Online Cultural and Historical Research Environment (OCHRE) and integrates spatial, environmental, and material data while allowing for comparisons across typologies and chronologies. The utilization of data from SLeD is then demonstrated through specific examples from ongoing doctoral research including the cemeteries from Khirbat Iskandar, Bab adh-Dhra', Tell es-Sultan, Tiwal esh-Sharqi, Dhahr Mirzbaneh, Tell el-Mutesellim, and Tell ed-Duweir. These case studies use multivariate data from SLeD and employ statistical analyses using the R programming language to examine EB IV tomb assemblages at intra- and inter-site scales. The high level of EB IV mortuary data representation in published material, the often-complete nature of burial assemblages, and the broad spatial distribution of excavated and surveyed mortuary landscapes provide a particularly fruitful foundation for conducting case studies. SLeD currently holds information on over 400 tombs within over 60 EB IV sites, covering a wide range of elements from ceramics to animal bones, plants, beads, metals, chipped stone, and architectural and environmental factors. This data is analyzed first at the intra-site scale through statistical analyses using R. Results of evaluations such as correspondence analysis indicate possible "tomb types" based on similarity measures. These insights guide further data reduction techniques and reveal patterns at different spatial scales. The intra-site perspectives serve as the foundation for larger-scale examinations of EB IV mortuary landscapes, which, in turn, give significant insight into communities of practice and offer indices for comparisons in subsequent research. Mortuary procedures function as examples of place-making routines, processes which contribute to the memories inscribed on a landscape that become evident in the archaeological record, particularly when recurring patterns can be identified over extended periods of time (Porter 2016).

This paper reviews the data curation processes, implementation, and practicality of the SLeD project, underpinning a broader conversation about data management and usage within more quantitative studies while making room for theoretical interpretations of results. It contributes to discussions about alternative trajectories of connections, settlement patterns, and human-environmental interactions of the EBA, offering new insights into the complexities of the field. By introducing this data-driven approach, the research further showcases how multivariate data can effectively address disparities in archaeological records, facilitating a more comprehensive understanding of Late EBA connectivity and mobility. As exemplified through case studies of EB IV tombs, the results continue to unveil the highly dynamic nature of social and spatial connections in the EBA. Each component of this study introduces an approach that together highlights new perspectives on how EBA people created and moved through their landscapes and their cognitive associations with their surroundings. Furthermore, the parallel development of SLeD ensures replicability and transparency, offering a platform for others to engage in similar research or test the methods presented here with diverse datasets. Ultimately, this research contributes to conversations about both deep-seated social and kinship connections and physical indicators of mobility, while serving as a catalyst for data integration in a region divided by different practices.

References

Chesson, Meredith S., and Graham Philip. 2003. “Tales of the City? ‘Urbanism’ in the Early Bronze Age Levant from Mediterranean and Levantine Perspectives.” Journal of Mediterranean Archaeology 16 (1): 3.

Porter, Anne. 2016. “The Materiality of Mourning.” In How to Cope with Death: Mourning and Funerary Practices in the Ancient Near East: Proceedings of the International Workshop, Firenze, 5th-6th December 2013, edited by Candida Felli, 157-188. Pisa: Edizioni ETS.

The CRANE Project. n.d. “About the Project.” Accessed October 26, 2023. https://www.crane.utoronto.ca/about-the-project.html.

S18: Digital Landscape Archaeology: New Possibilities and Old Problems

Thursday 11th April, 13:00–17:00, 260-092 OGGB3

Ian Moffat, Flinders University
Jarrad Kowlessar, Archaeology, Flinders University

Emerging digital methods have the potential to transform our understanding of archaeological landscapes. These methods include instruments to undertake high density data collection (such as multi-sensor geophysics, lidar and photogrammetry), computational approaches to interrogating voluminous data sets (such as machine learning or data fusion) and immersive visualisation techniques that facilitate new perceptions of the past. Despite this promise, we argue that their potential for understanding landscapes has not been realised because, to date, much research using these techniques in archaeology has been focused on a single method or on locating/mapping archaeological sites rather than understanding landscapes in a holistic way. We believe that the emerging discipline of digital landscape archaeology has the potential to overcome these challenges and integrate landscape and archaeological information in ways that have not previously been imagined, but first we must grapple with the possibilities and problems of these techniques.

One problem is that the high density data collection surveys in archaeology have been, unsurprisingly, focused on mapping archaeological sites or materials (ie. Trinks et al. 2018, Evans et al. 2013). These surveys generate extraordinarily rich data sets that provide novel information about the human past but few (such as De Smedt et al. 2022) take the opportunity to examine the landscape history through geophysical investigation of sedimentology and pedology. This absence precludes richer and more complex understandings of human-environmental interaction or prospecting directly for archaeological material in sites with extensive sediment aggradation (ie. Kowlessar et al. 2022).

A second issue is that high density data collection methods also have the potential to create enormous data sets that can't readily be understood using a singular or manual interpretation approach. A final landscape interpretation is often produced through examination of the results from each method in isolation, which are then collated in an unstructured way as part of the final interpretation. This risks losing much of the potential of these methods to be applied together to understand the broadest and most nuanced information about the archaeology and landscape history of these sites.

Thirdly, these data collection methods have now independently achieved highly detailed ways of visualising their specific data that can aid in cognitive understanding and increase interpretability. The trend has created an inherent need for researchers to use their familiarity with human sensory perception in order to make archaeological interpretations. Immersive visualisation techniques provide the best possible chance of achieving Tilley's (2010) aim of experiencing archaeological landscapes from a phenomenological perspective. Monteleone (et al. 2021) coined the term 'virtual cultural landscape' to draw attention to the landscape that is conjured in the mind of an interpreter as they investigate geospatial visualisations of past environments even when these visualisation are only representative of discrete aspects of the material culture present at a site. With a variety of modern high density data collections methods all producing highly detailed visualisations of archaeological data, we are presented with an opportunity to connect these separate virtual cultural landscapes in an unprecedentedly holistic way with a combined landscape visualisation approach. There is an emergence of combined visualisation approaches which include, GIS visualisation systems, discrete rendered videos and graphics and fully interactive computer game engines.

Despite the issues summarised above, all these approaches offer a new means of contextualising the separate sources of archaeological data into a combined system which offers new ways of seeing, interacting with and most importantly understanding, digital archaeological landscapes.

References

De Smedt, P, Garwood, P, Chapman, H, Deforce, K, De Grave, J, Hanssens, D and Vandenberghe, D. 2022 Novel insights into prehistoric land use at Stonehenge by combining electromagnetic and invasive methods with a semi-automated interpretation scheme. Journal of Archaeological Science 143:105557. DOI: https://doi.org/10.1016/j.jas.2022.105557.

Evans, DH, Fletcher, RJ, Pottier, C, Chevance, J-B, Soutif, D, Tan, BS, Im, S, Ea, D, Tin, T, Kim, S, Cromarty, C, De Greef, S, Hanus, K, Bâty, P, Kuszinger, R, Shimoda, I and Boornazian, G. 2013 Uncovering archaeological landscapes at Angkor using lidar. Proceedings of the National Academy of Sciences 110(31): 12595–12600. DOI: https://doi.org/10.1073/pnas.1306539110.

Kowlessar, J, Moffat, I, Wesley, D, Willis, M, Wrigglesworth, S, Jones, T, Nayinggul, A and Rangers, the N. 2023 Reconstructing archaeological palaeolandscapes using geophysical and geomatic survey techniques: An example from Red Lily Lagoon, Arnhem Land, Australia. PLOS ONE 18(5): e0283006. DOI: https://doi.org/10.1371/journal.pone.0283006.

Monteleone, K., A. E. Thompson, and K. M. Prufer 2021 Virtual cultural landscapes: Geospatial visualizations of past environments. Archaeological Prospection 28(3): 379-401.

Tilley, C. 2010. Interpreting Landscapes: Geologies, Topographies, Identities; Explorations in Landscape Phenomenology 3. Walnut Creek, UNITED STATES: Taylor & Francis Group.

Trinks, I, Hinterleitner, A, Neubauer, W, Nau, E, Löcker, K, Wallner, M, Gabler, M, Filzwieser, R, Wilding, J, Schiel, H, Jansa, V, Schneidhofer, P, Trausmuth, T, Sandici, V, Ruß, D, Flöry, S, Kainz, J, Kucera, M, Vonkilch, A, Tencer, T, Gustavsen, L, Kristiansen, M, Bye￾Johansen, L-M, Tonning, C, Zitz, T, Paasche, K, Gansum, T and Seren, S. 2018 Large-area high-resolution ground-penetrating radar measurements for archaeological prospection. Archaeological Prospection 25(3): 171–195. DOI: https://doi.org/10.1002/arp.1599.

S18: Digital Landscape Archaeology: New Possibilities and Old Problems	
13:00-13:10	*Introduction*
13:10-13:30	*29. Enhancing Archaeological Insights on Pa Sites in Tāmaki Makaurau Auckland using z-Based LiDAR Detection with Intensity Raster Analysis* *Ben D Jones (University of Auckland)*; Simon H. Bickler (Bickler Consultants Ltd); Mana Laumea (University of Auckland)*
13:30-13:50	*96. High Resolution Dynamic Geomorphological Analysis for Archaeology: A Case Study from the UNESCO World Heritage Budj Bim Cultural Landscape, Australia* *Brian J Armstrong (University of Melbourne)*; Bill Bell (bill@gunditjmirring.com); Martin Tomko (University of Melbourne); Adam Black (Gunditj Mirring Traditional Owners Corporation)*
13:50-14:10	*164. Computational Geomorphic Research and its use for Landscape Archaeology: Examples from Eastern South Africa* *Christian Sommer (Heidelberg Academy of Sciences and Humanities)*; Hanna Pehnert (Institute of Geography, Department of Geosciences, University of Tuebingen); Manuel Will (Department of Early Prehistory and Quaternary Ecology, University of Tuebingen); Volker Hochschild (Uni Tübingen)*
14:10-14:30	*133. Using Digital Landscape Models to better Understand Murujuga Stone Structures* *Emma Beckett (UWA)**
14:30-14:50	*62. Multi-dimensional Knowledge Systems: Insights into High-Alpine Hunting using Indigenous Archaeology and Digital Landscape Documentation* *Kelsey A Pennanen (University of Calgary)**
14:50-15:00	*197. Digital Archaeology of New Zealand's Historical Landscapes* *James Robinson and Simon H. Bickler*
Afternoon tea	

S18: Digital Landscape Archaeology: New Possibilities and Old Problems	
15:20-15:40	*20. From Near-emptyscapes to High Density Past: Game-changing Implications* *Stefano RL Campana (University of Siena)**
15:40-16:00	*128. Building a Low-cost UAV-based LiDAR Sensor for Landscape Archaeology* *Stephen K Rector (University of Missouri - Columbia)**

29. Enhancing Archaeological Insights on Pa sites in Tāmaki Makaurau Auckland using z-Based LiDAR Detection with Intensity Raster Analysis

Ben D Jones (University of Auckland); Simon H. Bickler (Bickler Consultants Ltd); Mana Laumea (University of Auckland)*

This research paper explores the potential of LiDAR (Light Detection and Ranging) intensity analysis for textural examination in the mapping of archaeological sites within the Tāmaki Makaurau Auckland region. Informed by the findings of Coren et al. (2005), the primary objective is to showcase the practical implementation of LiDAR intensity analysis in the context of Pacific archaeology. Emphasizing the effectiveness of intensity rasters as a means of scrutinizing human impacts on landscapes, we introduce a methodology for generating such rasters and contrasting them with conventional elevation-based visualizations using specific case studies from Maungakiekie and Maungarei.

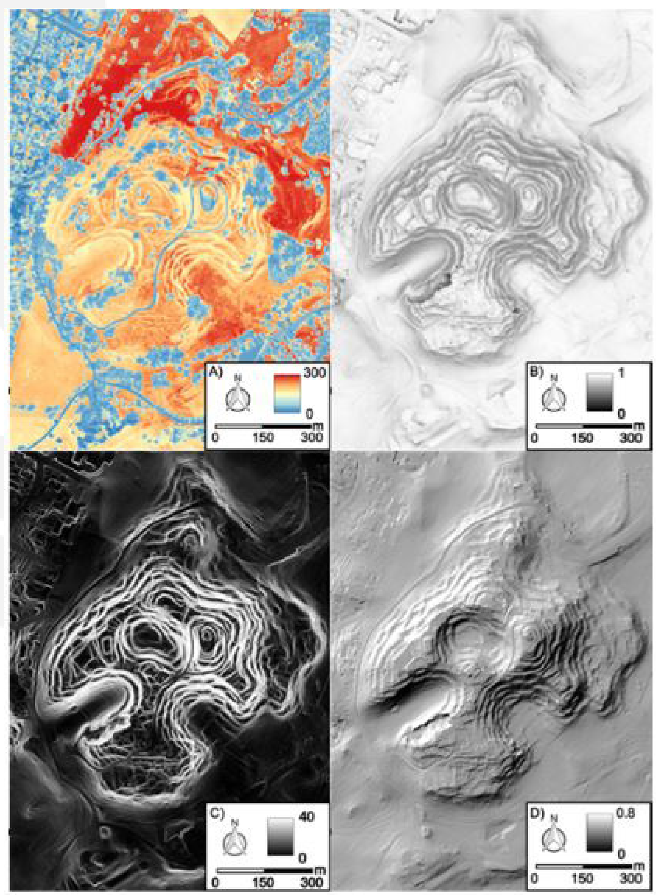
The amalgamated time series intensity maps derived from this approach serve to enrich archaeological interpretations and facilitate the management of potential site risks. Working closely with The Tūpuna Maunga (ancestral mountains, TM), which hold profound cultural and historical significance for the thirteen iwi and hapū of Ngā Mana Whenua o Tāmaki Makaurau (the Māori tribes of Auckland), we demonstrate how the integration of LiDAR intensity maps enables the ongoing monitoring of the impact of pedestrian traffic, storms, vegetation, and pastoral activities on the Maunga. Notably, significant findings from this research highlight: 1) pronounced surface changes in specific parts of Maunga over a span of six years, particularly evident in the paths encircling the crater rim, areas of heritage significance, 2) the identification of intense patches linked with substantial tree disturbances, revealing subsurface archaeology, and 3) the emergence of smaller or developing pathways on the peripheral mountain slopes, underlining the necessity for continuous monitoring in the future. This paper underscores the vital role of TM as katiakitanga, or guardianship, in the protection of these valuable archaeological taonga (treasures).

References

Coren, F., Visintini, D., Prearo, G., & Sterzai, P. (2005, May). Integrating LiDAR intensity measures and hyperspectral data for extracting of cultural heritage. In Workshop Italy-Canada.

Figures

Figure 1: A) Intensity Raster with High Penetration (Red) and Low Penetration (Blue), B) Skyview Factor, C) Slope (°), D) Multidirectional Hillshade.



96. High Resolution Dynamic Geomorphological Analysis for Archaeology: A Case Study from the UNESCO World Heritage Budj Bim Cultural Landscape, Australia

Brian J Armstrong (University of Melbourne); Bill Bell (bill@gunditjmirring.com); Martin Tomko (University of Melbourne); Adam Black (Gunditj Mirring Traditional Owners Corporation)*

This talk summarises recent experiences and perspectives using high-resolution Digital Elevation Model (DEM) datasets for Indigenous archaeology in Australia. Higher resolution datasets acquired using airborne Lidar using drones or through state data capture programmes are now available to assist detailed modelling and analysis of archaeological features and landscape modifications across extensive areas, hitherto impossible. The capability to detect sites and put them in context spatially has enabled enhanced landscape-scale reasoning about landscape use, modification, and the understanding of spatial relationships between sites.

Work at the UNESCO listed Budj Bim cultural heritage landscape in collaboration with the Gunditj Mirring Traditional Owners Corporation (GMTOAC) has demonstrated the value of high-resolution geomorphological analysis and Machine Learning for identification and understanding of systematic relationships between potential new sites (including stone dwellings and modifications to hydrological flows using weirs and channels of the aquaculture system), and thus offers insights into wider patterns of dynamic land use. The Traditional Owners community is now Increasingly using these detailed datasets for enhanced management of Country, with analyses assisted by DEM visualisation techniques and geospatial analysis.

Note that the work presented has been conducted for and on behalf of the Gunditjmara people of Victoria and that GMTOAC are the owner of all the results of this work.

164. Computational Geomorphic Research and its Use for Landscape Archaeology: Examples from Eastern South Africa

Christian Sommer (Heidelberg Academy of Sciences and Humanities); Hanna Pehnert (Institute of Geography, Department of Geosciences, University of Tuebingen); Manuel Will (Department of Early Prehistory and Quaternary Ecology, University of Tuebingen); Volker Hochschild (Uni Tübingen)*

South Africa is a hot spot for archaeological and anthropological research that offered many insights into human prehistory. Yet, our knowledge is biased by the dominance of cave and rock shelter sites, that are characterized by excellent conservation conditions, but allow little insight into early human behavior in the landscape. Therefore, Quaternary sediments, which are widespread in the eastern part of the country, represent ideal study objects for open air sites. Their accumulation on foot slopes reflects cycles of landscape activity, creating stratified deposits in which soils develop that serve as climatic archives and on which past populations left so-called knapping floors that represent intact snapshots of lithic tool manufacture. Because these sedimentary bodies were affected by gully erosion in the past as well as today, complex cut-and-fill successions developed that extend over larger areas and whose stratigraphy can therefore best be mapped and correlated using large-scale and high-resolution terrain models and orthomosaics. Recent gully erosion dissects these sedimentary bodies to depths of over 10 m, creating favorable conditions for archaeological prospection as knapping floors in the form of stone lines are evident in the gully walls and progressive erosion continuously exposes new walls.

We present methods and results of digital geomorphological research that support archaeological prospection and documentation at different scales. On the catchment scale, we used medium resolution remote sensing, digital elevation models and geomorphometric indices with machine learning classification to map quaternary sediments and the associated forms of gully erosion. In contrast to other applications of gully mapping, our approach distinguishes active from stable gullies, which helps to identify those sites that change intensively and thus expose new gully walls frequently, allowing repeated archaeological prospection.

At site scale, we present our setup using a range of mobile GIS, GPS, mobile forms and geoelectric resistivity imaging to digitally support archaeological prospection. UAV derived high resolution digital elevation models and orthophotos have proven to be indispensable to document and correlate the complex cut-and-fill stratigraphy, where geological contacts can be traced of larger areas. 3D models of the landscape also help to identify the locations of earlier excavations predating the age of GPS, where only photographies serve as documentation. Finally, such geographic information serves as input for physical numerical models, that aim to simulate the geomorphic evolution of the gullies and this help to understand the site formation (Khan et al., 2023; Omran et al., 2022; Sommer, 2021).

References:

Khan, S., Omran, A., Schröder, D., Sommer, C., Hochschild, V., & Märker, M. (2023). A QGIS-plugin for gully erosion modeling. Earth Science Informatics. https://doi.org/10.1007/s12145-023-01092-7

Omran, A., Schröder, D., Sommer, C., Hochschild, V., & Märker, M. (2022). A GIS-based simulation and visualization tool for the assessment of gully erosion processes. Journal of Spatial Science, 0(0), 1–18. https://doi.org/10.1080/14498596.2022.2133020

Sommer, C. (2021). Reconstruction of the Pleistocene Landscape of Southern KwaZulu-Natal, South Africa by means of GIS, Remote Sensing and Geomorphological Techniques [Dissertation, Eberhard Karls Universität Tübingen]. http://dx.doi.org/10.15496/publikation-63042

133. Using Digital Landscape Models to Better Understand Murujuga Stone Structures

*Emma Beckett (UWA)**

This paper describes the ways that landscape models (both 3D and 2D) can be used to better investigate and understand Murujuga stone structures in a more holistic way. These models are especially powerful when allied with field inspection, assessment and detailed recording. The Dampier Archipelago, or Murujuga as it is known by the Traditional Custodians, is located on the north-west coast of Western Australia. This region was nominated in 2023 for World Heritage and is well known as having one of the most significant rock art assemblages in the country. Murujuga also has a high density and variety of stone structures, but these have often been overlooked due to ongoing dispute regarding the nature of their origins (McDonald and Veth 2009:53). The controversy centres around whether natural features are being misinterpreted as anthropogenic constructions, and has been exacerbated by the rocky environment as well as the absence of detailed documentation for many of these places. Previous recordings often do not provide details about the nature of the sites or any justification for why they were assessed as being cultural constructions. To ensure this controversy did not impact on National Heritage listing, many known stone structures were not included during significance assessments (McDonald and Veth 2009:53) and it is likely that consultants have under-recorded this site type during heritage surveys undertaken for clearance works across the main island, now known as the Burrup Peninsula.

Digital landscape models described in this paper are built upon previous work that focuses on defining and classifying landform types. Tools used in landscape classification provide objective and detailed evidence that can help researchers understand the range of natural processes that might create a natural stone feature. The classificatory system designed by Hammond (1964:15) is foundational and has been adopted for an Australian context based on landforms outlined by Speight (2009). The goal of this work was not to classify landforms, but to isolate the defining ingredients (elevation, slope and profile) identified in these previous works. These ingredients are extremely useful for extracting details pertaining to landform and site formation processes.

Digital Elevation Models (DEMs) and ortho imagery were used to extract elevation, slope and profile (curvature) information around specific sites. These can be combined with orthorectified imagery to provide additional detail and projected in 2D or 3D. These datasets can also be compared or overlaid with other models to gain a more holistic understanding of the structure and its surrounds. This allows for visual assessment with quantifiable (and measurable) data that can be displayed and interrogated at a variety of scales. Scale is often constrained by the original data source, so a range of different datasets were utilised, including pre-processed Shuttle Radar Topography Mission (SRTM) data and Light Detection and Ranging (LiDAR) data. Photogrammetry was also used to create very high-resolution DEM data from aerial and terrestrial photography. The methods deployed and the accuracy constraints in this DEM data is also an important consideration that will be detailed as part of this paper.

The varied resolution of the datasets allowed these landscape models to assist in analysis at three main scales: micro, intra-site and regional. Models with high resolution provided micro level evidence that could be combined with in field observations of direct interaction such as flaking, patination and calcrete modification. Stone size and shape documented at this scale can also be combined with intra-site analysis for considerations of anthropogenic influences on stone selection. Intra-site and regional level evidence examines a range of potential processes that are at work in any landscape that could create clusters of rock that are misinterpreted as anthropogenic. These include mass movement, gilgai, lateral movement, vegetation, geology, modern disturbance and modern constructions. Patterns observed at a regional level also provide a filter for excluding or including processes not found on Murujuga due to skeletal soils or geological context.

This case study demonstrates the utility of digital tools for documentation and reconstruction of landscapes. 2D and 3D models are tools that can be used in conjunction with detailed in field recording to help better visualise Murujuga stone structures. They also provide greater confidence as well as an objective method that can be used to start to disentangle a long-standing controversy in a highly significant cultural and archaeological landscape.

References

Hammond, E.H. 1964 “Analysis of Properties in Land Form Geography: An Application to Broad-Scale Land Form Mapping”. Annals of the Association of American Geographers 54(1):11-19.

McDonald, J. and P. Veth 2009. “Dampier Archipelago Petroglyphs: Archaeology, Scientific Values and National Heritage Listing”. Archaeology in Oceania:49-69.

Speight, J.G. 2009 “Landform”. In Australian Soil and Land Survey Field Handbook, edited by National Committee on Soil Terrain, 15-72. Collingwood, Victoria: CSIRO Publishing.

62. Multi-dimensional Knowledge Systems: Insights into High-Alpine Hunting using Indigenous Archaeology and Digital Landscape Documentation

*Kelsey A Pennanen (University of Calgary)**

The melting of ice patches globally has resulted in a wealth of information on past hunting techniques revealed through a myriad of objects exposed from the melting ice. Until recently, little attention has been paid to necessary investigation on the landscapes surrounding these high-elevation phenomena. Using the ‘research as service’ framework, this work explores how digital documentation combined with Indigenous archaeological perspectives can inform human interactions within mountainous ice patch hunting landscapes. This project and outlined priorities were identified by local self-governing First Nations from Carcross/Tagish First Nation, Champagne and Aishihik First Nations, and Kwanlin Dün First Nation in Yukon Territory, Northern Canada. These cooperative learning interactions have allowed for the creation of digital replications of the landscape documented using 3-dimensional photogrammetric data of high-alpine hunting locales and ice patches captured using unmanned aerial vehicles, as well as ground-based immersive panoramic imagery imposed in virtual reality technology. To provide culturally relevant interpretation of these landscapes, Indigenous traditional knowledge was gained through interviews with hunters and Knowledge Keepers and documented in ethnographic literature.

Digital documentation was conducted using a combination of data collection; both from an aerial perspective as well as immersive virtual reality documentation of landscapes from a hunters’ perspective. This project uses 3-dimensional technology to help organize and relate the ecological, biological, and cultural components of a mountainscape. Tangible objects such as structures constructed on the landscape as well as artifacts recovered from melting ice and snow patches in the high alpine, were documented in detail. By merging data on archaeological recoveries, ecological activity, and Indigenous traditional knowledge we can obtain the objective of visualizing incongruent material records as informed by First Nations. Through a combined approach, experiences of the landscape can be understood holistically, integrating archaeological understandings as well as first-person experiences. By incorporating digital archaeology and Indigenous perspectives we are able to bridge epistemologies to inform risk-assessment and provide insights into decision-making to understand how knowledge is translated from the landscape to the user.

Solli (2018) uses Ingold’s ‘taskscapes’ to theorize the use of ice patch hunting landscapes in Norway. In the Americas, local Indigenous hunters and Knowledge Holders can provide a better basis on which to examine the processes and experiences of hunting in these locations. Most archaeological investigations have been focused on the Western colonial context and sensory understandings (Atalay 2006). Being in these places brings about various sensory experiences. The feeling of unrelenting wind in an unobscured landscape is so persistent it can wash away the voices of your neighbors, your hunting partners, even your own thoughts. The multi-sensorial experience of landscape use cannot be replicated using digital methods but integrating traditional knowledge through on-the-land experiences and conversations with local hunters, can allow for insights into how to best inform and interpret the past and add to a holistic understanding of landscape experiences. The use of multiple methods of digital documentation allows for these places to be translated in a cohesive manner. Combining 3-dimensional landscape and immersive documentation strategies with Indigenous knowledge allows for multiple knowledge systems to be examined together. Using the visible and tangible data of the constructed hunting blinds, we can examine how far away the hunter was stationed for shooting, as well as see evidence of blinds consisting of areas for observation and management of the various actors in the hunt. In documenting the landscape in 3-dimensions and working with local Indigenous hunters, we can analyze the inner workings of the decision-making process, one that is less visible. Using experiential knowledge of the landscape, we can then begin to tease out the immensity of knowledge of the landscape contained within the collective and individual, as evidenced by the artifacts and structures recovered and observed. Digital technologies are not neutral or passive tools- they must be connected to a broader sociopolitical landscape (Cook and Compton 2018, 38-39). As archaeologists, we must take responsibility for how our analyses are conducted. Incorporating ideas of multi-dimensional knowledge allows us to capture these landscapes in multiple ways, and with the detail, precision, and creativity that we owe these places, their pasts, and those who have learned and lived here.

References:

Atalay, Sonya. 2006. "Indigenous Archaeology as Decolonizing Practice." American Indian Quarterly 30, no. 3 & 4: 280-310.

Cook, Katherine, and Mary E. Compton. 2018. "Canadian digital archaeology: on boundaries and futures." Canadian Journal of Archaeology/Journal canadien d'archéologie 42, no. 1: 38-45.

Solli, Brit. 2018. "Reindeer hunting, materiality, entanglement and society in Norway." Journal of Glacial Archaeology 3, no. 1: 1-26.

20. From Near-emptyscapes to High Density Past: Game-changing Implications

*Stefano RL Campana (University of Siena)**

In the last two decades we have seen a revolution in the archaeological density of the past showing in some circumstance the potential for a near-total recovery of past evidence. Methodologies used for study of the ancient landscape now offer a wide and seemingly ever-expanding variety of 'new' remote sensing methodologies, increasingly widely deployed for archaeological exploration and mapping purposes. In addition to improvements in technical capabilities massive evidence has been identified through decades of development related large excavations. Integrated, large-scale and continuous archaeological prospection and development-related fieldwork (in particular, large-scale excavation) share responsibility for "the resulting flood of archaeological data". The outcomes of these studies find no parallel in the results of past surveys. It is a matter of resolution: the unprecedented high density of the information that such landscape investigations can now produce, as compared with the low density results achieved in the past. Based on the author experience (BREBEMI, EMPTYSCAPES and SOS projects) and on further available case studies, this paper is aimed to discuss the implications of such high-resolution representations of the past that have far-reaching archaeological consequences and have yet to be fully appreciated. In the first place, the archaeological outcomes show much more complicated landscapes dominated by labor, production, communication, and trade, and not just by settlements. In the Emptyscapes project, field boundaries and road systems, workshops and production sites, water features, dams and so forth, clearly predominate but obviously there are also settlements which, notwithstanding their remarkable sizes, are now somewhat in the background, clearly forming just part of a much broader picture. Within this framework it appears fairly evident that settlement is simply part of the productive system and not vice versa, closely interdependent with communication systems and agricultural production, a carefully maintained water basin and an overall landscape pattern including water management and irrigation systems, all of these elements in one way or another serving the needs of the ancient city and the inhabitants of the surrounding landscape. Methodologically, the implication of the results of landscape-scale geophysical survey and targeted minimalist excavation are nothing less than revolutionary. Obviously, these methods also have a whole series of limitations, and they certainly cannot identify sites that have been totally destroyed in the past. However, it is worth noting that in these kinds of research projects, survey does not constitute an end in itself or an isolated form of enquiry but it is a piece within a wider strategy. This is probably a crucial point: survey ought to be seen as just a part (an early one) of the ever-expanding and complex framework of the archaeological research design, within which remote sensing, terrestrial survey, geoarchaeology, bioarcheology, targeted test excavation, artefact analysis and related studies are interlinked elements within a single coherent and consistent whole aimed to answer archaeological questions.

128. Building a Low-cost UAV-based LiDAR Sensor for Landscape Archaeology

*Stephen K Rector (University of Missouri - Columbia)**

Introduction

LiDAR (Light Detection and Ranging) point cloud data is becoming increasingly important in archaeological field work. Used to develop digital elevation (DEM), digital terrain (DTM), and digital surface models (DSM), particularly in areas of dense vegetation, it has applications in archaeological prospection, site survey, and cultural heritage management and monitoring to name just a few (Opitz 2016, 35). While some areas, such as the United States of America, have publicly available LiDAR data for large areas of the country, LiDAR data may not be available, or difficult to access, for other countries. Regional LiDAR surveys can be expensive undertakings, and even localized drone-based systems typically cost tens to hundreds of thousands of dollars. For this reason alone, LiDAR technology is out of the budgetary ranges of many archaeological projects. This paper addresses this problem by building a low-cost LiDAR sensor for use on unoccupied aerial vehicles (UAV).

The LiDAR sensor for this project is based upon the Open Mobile Mapping System, OpenMMS v1.3, an open-source project developed by Ryan G. Brazeal as part of his doctoral degree research in Geomatics at the University of Florida to build a mapping system for use on remotely piloted aircraft systems/unoccupied aircraft systems (RPAS/UAS) (Brazeal 2021). The OpenMMS project provides complete details to build a sensor including software for data collection and initial processing, hardware specifications, and even printed circuit board design files, however, the system uses an expensive Applanix APX-18 GNSS-INS sensor. According to a forum post by Brazeal the total cost for the Applanix APX-18 INS (Inertial Navigation System) sensor, two Trimble AV14 GNSS antennae, and the commercial POSPac UAV software is $21,602 USD (Brazeal 2021).

This paper demonstrates the feasibility of building a lower cost solution based on the OpenMMS project and the Livox Mid-40 LiDAR sensor but replacing the expensive Applanix INS sensor with a custom solution using off-the-shelf GPS/GNSS

(Global Positioning System/Global Navigation Satellite System) modules and integrating a less expensive inertial measurement unit (IMU) to form an inertial navigation system (INS).

Methods and materials

Hardware

The Livox Mid-40 LiDAR sensor was chosen for its cost and features including a 260m detection range, a 38.4°circular field of view, a 100,000 points per second scan rate, a 2cm range precision, and 0.5°angular precision. The non-repetitive scanning pattern of the Livox Mid-40 means that the longer the integration time the greater the field of view coverage. At 0.1s the Mid-40 is equivalent to a traditional 32-line LiDAR sensor, while at 0.5s the coverage is equivalent to a 64-line LiDAR sensor.

The inertial navigation system (INS) consists of two SparkFun Ublox ZED-F9P GNSS boards, one to serve as a moving base and receive satellite correction data, the other to serve as the rover, and an Aceinna OpenIMU300ZI EVK development board used for the inertial measurement unit (IMU). The Sparkfun boards were selected because the Ublox ZED-F9P GNSS receiver offers multiband GNSS, high precision, a high update rate, and centimeter-level accuracy. The Aceinna OpenIMU300ZI EVK development board was selected because it is a 9 DOF (degree of freedom) inertial platform which compared favorably with the Applanix APX-18 specifications, offers an open-source 16-state Extended State Kahlman Filter for fusing the GNSS and IMU data, and offered an open-source INS application which supported the ZED-F9P. The INS provides accurate orientation, positioning, and heading information for the drone. Coupled with the Livox Mid-40 LiDAR sensor the system is able to gather geo-referenced LiDAR point cloud data.

The remaining pieces of hardware are a Raspberry Pi 4 Model B single board computer, an RPi printed circuit board and LED board, two GNSS multi-band helical antennae, and a pair of 915MHz SiK Radios to send RTCM (Radio Technical Commission for Maritime Services) correction data from the terrestrial base station to the moving base GNSS receiver on the UAV.

In the final construction the electronic components were assembled onto the OpenMMS RPi and LED boards. The RPi board was attached to the Raspberry Pi via the general-purpose input output (GPIO) pins, and the Mid-40 was attached to the Raspberry Pi by use of a screw block and a TTL to RS485 converter board. The two GNSS modules were connected, and the rover connected to the OpenIMU board. The rover GNSS module and the OpenIMU board were then connected to the Raspberry Pi by USB cables. A DJI Phantom 4 battery was used to power the system.

Software

The OpenMMS Operating System (OS) for Livox was installed on the Raspberry Pi and the OpenMMS software used for initial processing on a laptop. Because the OS was designed for use with the Applanix INS both the OS and processing software required substantial modifications to work with the custom INS solution.

Results

The total cost of the system, including a Tarot T18 drone kit and flight controller was less than $5,000 USD. Compared to the current cost of a DJI Matrice 300 RTK UAV and Zenmuse L1 LiDAR camera with a combined cost of $23,500 USD, this represents a savings of $18,500 USD. During testing some areas for improvement were identified including increasing the altitude, greater overlap, strip alignment issues, improvements to the processing workflow, integration of an RGB camera, and a more intuitive interface for inexperienced users. Overall, however, the results were very encouraging.

Discussion

This paper has demonstrated the feasibility of building a low-cost UAV-based LiDAR sensor for landscape archaeology. Leveraging the open-source OpenMMS project and lowering the barrier to entry helps to democratize the technology and make it available to the wider archaeological community. The potential for archaeological survey and landscape studies is particularly good, especially in areas where LiDAR data is not available. Researchers outside archaeology have also expressed interest in the system including geographers, anthropologists, geologists, and environmental scientists. Work is on-going to address the issues identified and to upgrade and improve the sensor.

References

Brazeal, Ryan. 2021a. “OpenMMS.” OpenMMS. August 10, 2021. https://www.openmms.org/.

———. 2021b. “OpenMMS - Applanix Alternative.” OpenMMS - Applanix Alternative. November 23, 2021. https://www.openmms.org/forums/topic/applanix-alternative/.

Opitz, Rachel. 2016. “Airborne Laser Scanning in Archaeology: Maturing Methods and Democratizing Applications.” In Digital Methods and Remote Sensing in Archaeology: Archaeology in the Age of Sensing., 35–50. Quantitative Methods in the Humanities and Social Sciences. Springer.

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References

Brazeal, Ryan. 2021a. “OpenMMS.” OpenMMS. August 10, 2021. https://www.openmms.org/.

———. 2021b. “OpenMMS - Applanix Alternative.” OpenMMS - Applanix Alternative. November 23, 2021. https://www.openmms.org/forums/topic/applanix-alternative/.

Opitz, Rachel. 2016. “Airborne Laser Scanning in Archaeology: Maturing Methods and Democratizing Applications.” In Digital Methods and Remote Sensing in Archaeology: Archaeology in the Age of Sensing., 35–50. Quantitative Methods in the Humanities and Social Sciences. Springer.

164. Computational geomorphic research and its use for landscape archaeology: Examples from eastern South Africa

Christian Sommer (Heidelberg Academy of Sciences and Humanities); Hanna Pehnert (Institute of Geography, Department of Geosciences, University of Tuebingen); Manuel Will (Department of Early Prehistory and Quaternary Ecology, University of Tuebingen); Volker Hochschild (Uni Tübingen)*

S19: Archaeological Heritage in Conflict Zones: From Data Gathering to Virtual Environments

Wednesday 10th April, 13:00–13:40, 260-055 Case Room 3

Stefano Campana, University of Siena
Anna Leone, University of Durham

The archaeological heritage has been at risk for a long time, fallen under the threat of damage or disappearance through armed conflict globally. Terrorism, too, has increasingly become a major part of daily threats through the spectacular and highly publicised destruction of heritage assets. It is important to keep always in our minds the methodical destruction at Palmyra and the ancient city of Aleppo, systematically targeting archaeological monuments dating from the prehistoric, Byzantine, Roman and Islamic periods, with no apparent consideration for the cultural, historical and socio-economic significance of such sites. The violence within these conflicts is not, of course, limited to the destruction of heritage sites, but also to looting and the increasing illicit trafficking of antiquities.

It is now a priority to recognize that when heritage sites, or parts of them, are no longer granted protection, documentation and public engagement are the only tools available for the recording, monitoring, understanding of them.

In this panel, we intend to address and confront globally strategies to document and monitor archaeological objects, sites and landscapes through new technologies. We aim to discuss applied methods of documentation, mapping, management, monitoring in conflict zone, as well as discuss the suitability of post-conflict virtual reconstruction of archaeological objects, sites and landscapes. The focus will be on new technologies, in the first instance computer applications and systems, that may help to improve every step of this process from data collection to inclusion within virtual environments. Attention will also be paid to current and future means for measuring and evaluating damage and transformations at institutions, sites and landscapes involved in conflicts of this kind. Finally, the panel will address strategies for data sharing through websites, open access systems, open data sets and open databases as well as through GIS.

S19: Archaeological Heritage in Conflict Zones: From Data Gathering to Virtual Environments	
13:00-13:20	*152. Mapping across Borders: Archaeological Insights from Remote-based Computational Approaches in North-western India* *Navjot Kour (Institut Català d'Arqueologia Clàssica)*; Francesc C. Conesa (Catalan Institute of Classical Archaeology); Arnau Garcia-Molsosa (Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology); Tajammal Abbas (Hazara University, Mansehra); Hector A. Orengo (Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology)*
13:20-13:40	*196. Archaeological Heritage in Conflict Zones: From Data Gathering to Virtual Environments* *Stefano RL Campana (University of Siena)**

152. Mapping across borders: archaeological insights from remote-based computational approaches in north-western India

Navjot Kour (Institut Català d'Arqueologia Clàssica); Francesc C. Conesa (Catalan Institute of Classical Archaeology); Arnau Garcia-Molsosa (Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology); Tajammal Abbas (Hazara University, Mansehra); Hector A. Orengo (Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology)*

Introduction

The monsoonal alluvial plains of north-western India in the present-day Union Territory of Jammu and Kashmir have been shaped over millennia by the depositions of major rivers such as the Chenab and the Tawi. Several ancient riverine cultures flourished within its fertile lands, as attested by the evidence of numerous well-preserved archaeological mounds. The plains attested to the north-western expansion of the Indus Civilisation (ca. 3300-1900 BCE), and recent field results suggest that many more settlements flourished during the Early Historic period (ca. 600 BCE-600 CE). In modern periods, the area followed distinct cultural and political paths in a succession of South Asian kingdoms and empires (e.g., the Mughal, the Sikh, and the British Raj) until the India-Pakistan partition in 1947.

Owing to many socio-cultural, religious and political factors, the international border has always been a bone of contention between the two countries. Unlike the prolonged border instability in the northern Kashmir region, the southern plains of Jammu have witnessed active, but relatively low-impact skirmishes during the last decade. Even though the periodic stability has created a unique cultural heritage legacy of the partition on its own, such as the elaborate border guard ceremonies on both sides, the reality is that the stalemate position has primarily led to the divide between the shared socio-cultural past and its archaeological heritage. Additionally, the territorial division makes it difficult to completely rebuild the archaeological landscape using conventional cartographic and survey methodologies.

In such contexts, muti-source and multi-temporal remote sensing procedures become essential to investigate large-scale archaeological patterns, land use trends and landscape change at multiple scales of observations. In recent years, South Asia has led a surge in the application of computational remote-based applications to study past archaeological landscapes and to monitor long to short-term risks to cultural heritage (e.g., Orengo et al. 2020, Berganzo-Besga et al. 2023, to name just a few). This thriving trend is placing South Asian landscapes and, in particular, is showing that the areas within the influence of the greater Indus Valley are optimal land laboratories for the development of novel methods and workflows that can be exported to and compared with other similar geographical and ecological areas with a long-standing tradition of remote-based investigations, such as North Africa or the Near East.

Here we present the remote-based methodologies of RIVERINE, a collaborative project which helped us to understand the dynamics of archaeological heritage in and beyond the territorial boundaries of Jammu In particular, we focus on 1) detecting and mapping the location of the ancient eroded and endangered mounds 2) recording the landscape transformation over the years to understand the various causes triggering the loss of archaeological heritage in the area. For the first time in the region, our observations expand to the neighbouring region of Sialkot in Pakistan to map "across borders" and promote sharing data inputs and outputs through collaborative research.

Materials and Methods

This research draws on similar approaches being developed in the Indus context primarily including the analysis of geospatial historical legacy data, incorporating a) the Survey of India historical topographic map series b) declassified footprints from the satellite photo-reconnaissance CORONA and HEGAXON missions. The application of HEXAGON archival photographs has never been tested before in South Asian archaeological contexts to understand landscape transformations. In addition, the usage of multi-modal and multi-temporal collections of satellite data in cloud-computing platforms (e.g., Copernicus satellites Sentinel 1-2 and high-resolution digital elevation models such as TanDEM-X, see also Orengo and Petrie 2018) are employed to understand how defensive infrastructures are built and take advantage of regional hydrological dynamism while occupying potential archaeological mounds, thus creating a complex post-conflict cultural landscape. Our remote observations have been used in systematic field surveys and ground-truthing campaigns for the validation of sites in Jammu and on the other side of the border through collaborations with Pakistan institutions and colleagues.

Results and Discussion

The historical maps have emerged to be of vital importance in the area as they constituted the first dataset to systematically document potential archaeological sites and various geopolitical processes. Furthermore, their incorporation is imperative as they document the landscape of pre-independent India. The CORONA and HEXAGON images, on the other hand, give a visual depiction of the landscape as it appeared in the 1970s and 1980s. Given the ground resolution of these images of 2m and 1m respectively, these preserve a high-quality picture of the archaeological landscape before their destruction. It has been noted that, in comparison to the CORONA which captured images of the landscape during the 1970s, the HEXAGON images offer a significantly enhanced visual representation of the region due to its superior ground resolution capabilities. In addition, over 11 years from CORONA to HEXAGON, there have been major landform transformations owing to the political and security demands of the war of 1971 near the bordering areas between India and Pakistan. This also includes changes in the appearance of the mounds around the border.

References:

Berganzo-Besga, I., Orengo, H. A., Lumbreras, F., Alam, A., Campbell, R., Gerrits, P. J., de Souza, J. G., Khan, A., Suárez-Moreno, M., Tomaney, J., Roberts, R. C., & Petrie, C. A. (2023). Curriculum learning-based strategy for low-density archaeological mound detection from historical maps in India and Pakistan. Scientific Reports, 13(1).

Orengo, H. A & Petrie, C. A. (2018). Multi‐scale relief model (MSRM): a new algorithm for the visualization of subtle topographic change of variable size in digital elevation models. Earth Surface Processes and Landforms 43 (6) 1361-1369.

Orengo, H. A., Conesa, F. C., Garcia-Molsosa, A., Lobo, A., Green, A. S., Madella, M., & Petrie, C. A. (2020). Automated detection of archaeological mounds using machine-learning classification of multisensor and multitemporal satellite data. Proceedings of the National Academy of Sciences, 202005583

196. Mapping Archaeological Damage and Destruction at Nineveh and Hatra (Iraq): Before, during and after the ISIS Occupation

*Stefano RL Campana (University of Siena)**

Since long, archaeological heritage has fallen under the threat of being damaged or erased during armed conflicts. In some areas, deliberate destruction has increasingly become a major part of daily threats. Since 2001, by bombing the Bamyian Buddhas, terrorists launched a new global strategy based on the deliberate destruction of archaeological heritage. The irreparable damage to the cultural heritage of Syria and Iraq brought on by the recent conflict is still under scrutiny and quantification by international agencies.

In this framework, we report the results of a six-years monitoring of sampled archaeological areas of the northern Iraqi territory, followed by an intensive ground survey aimed at recording the current state of conservation of the walled compound of the Neo-Assyrian capital of Nineveh and the ancient city of Hatra. Damage assessment has been focused in particular on the period of ISIS occupation - from 2014 to 2018 - but previous phases as well as post-war reconstruction were also taken into consideration by recovering all available satellite images and historical aerial photographs. Satellite image analysis (WorldView-2 and WorldView-3 images both visually interpreted) and fieldwork (four field campaigns from 2018 to 2023), based on high-resolution photogrammetric drone survey, terrestrial laser scanning and field walking survey, played a major role to implement a comprehensive assessment (https://doi.org/10.15184/aqy.2022.14; https://skfb.ly/oys7Q).

We present here an updated topographic map of Nineveh's walls and Hatra, the list of visible damages and we propose preliminary guidelines for the protection, conservation, and virtual investigation of this unique and iconic archaeological resources.

S20: The Legacy of Harold Dibble in Stone Artefact Archaeology in Australasia and Beyond

Wednesday 10th April, 09:00–15:00, OGGB-098

Sam Lin, University of Wollongong
Rebecca Phillipps, University of Auckland
Ben Davies, Tufts University

One of the great debates of lithic studies in the 20th century relates to the explanation of lithic assemblage composition as representing variability in style or function. Harold Dibble proposed an alternative to these interpretations by suggesting variability related to continuous change in artefact morphology through resharpening and reuse. Dibble's work not only transformed the interpretation of lithic assemblage variability worldwide, but also highlighted the importance of quantitative analysis, hypothesis testing and experimentation in archaeological research. Additionally, he played a pioneering role in the application of computer applications in both field and laboratory settings for data recording, modelling and electronic publication. His commitment to archaeology as a scientific endeavour continually challenged the lithic research community to empirically assess preconceived notions about lithic variability and the formation of archaeological assemblages. Dibble's analytical approach and methodological developments have served as a source of inspiration for subsequent generations of researchers, encouraging them to examine lithic assemblages from innovative perspectives. This session seeks to honour Harold Dibble's legacy by bringing together colleagues to present research programs that have drawn inspiration from his work, and to celebrate Dibble's impact not only in Australasia but across the broader archaeological community. The session welcomes presentations that cover various topics within lithic studies, including lithic reduction, raw material economy and transport, lithic taphonomy and assemblage formation, as well as methodological advancements in quantitative, statistical and/or computer-based techniques for lithic data recording and analysis.

S20: The Legacy of Harold Dibble in Stone Artefact Archaeology in Australasia and Beyond	
9:00-9:10	*Introduction*
9:10-9:30	*47. Harold Dibble's Legacy: Advancing Lithic Studies through Experimentation, Standardization and Open Science* *Li Li (University of Algarve)**
9:30-9:50	*105. Developing a Virtual Knapper Based on Controlled Experiments into Fracture Mechanics* *Shannon P McPherron (Max Planck Institute for Evolutionary Anthropology)**
9:50-10:00	*Discussion*
Morning Tea	
10:20-10:40	*10. Dibble's Dangerous Idea. The Importance of Reduction Induced Allometry, and Harold's Contribution to It* *Peter Hiscock (Universities of Queensland, Auckland and Griffith)**
10:40-11:00	*93. Continuous Retouch Model Applied to the Southern African Early Middle Stone Age* *Corey A. O'Driscoll (University of Wollongong (Wollongong, NSW))*; Alex Mackay (University of Wollongong)*
11:00-11:20	*77. From Scar to Scar. Reconstructing Operational Sequences of Lithic Artifacts using Scar-Ridge-Pattern-based Graph Models* *Florian Linsel (Martin Luther University of Halle-Wittenberg, Institute of Computer Science)*; Jan Philipp Bullenkamp (Martin-Luther University of Halle-Wittenberg, Institute of Computer Science); Hubert Mara (MLU - Instiut für Informatik)*
11:20-11:40	*28. Flake Selection and Retouch Probability as Determinants of Middle Paleolithic Assemblage Variability* *Sam C Lin (University of Wollongong)**

S20: The Legacy of Harold Dibble in Stone Artefact Archaeology in Australasia and Beyond	
11:40-12:00	*115. The Development of the Cortex and Volume Ratios* *Stacey Middleton (University of Auckland)*; Rebecca Phillipps (University of Auckland); Joshua Emmitt (Auckland War Memorial Museum); Simon Holdaway (University of Auckland)*
Lunch	
13:00-13:20	*75. It's All about the Source: Reuse, Mobility, and Lithic Assemblage Composition* *Matthew C Barrett (The University of Auckland)**
13:20-13:40	*118. Non-destructive Geochemical Characterisation of Non-volcanic Adze Stone in Oceania: An Example from New Zealand* *Brendan Kneebone (CFG Heritage Ltd)*; Andrew McAlister (University of Auckland); Dante Bonica (University of Auckland); Greg Gedson (Independent Researcher)*
13:40-14:00	*68. Towards Technological and Cultural Understandings of Aboriginal Stone Artefacts: A Case Study from Sunbury Ring G, Wurundjeri Woi-wurrung Country, Southeastern Australia* *Caroline Spry (La Trobe University)*; Elspeth Hayes (MicroTrace Archaeology); Richard Fullagar (Core Artefact Research); Bobby Mullins (Wurundjeri Woi-wurrung Elder) (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation); Ron Jones (Wurundjeri Woi-wurrung Elder) (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation); Allan Wandin (Wurundjeri Woi-wurrung Elder) (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation); Delta Lucille Freedman (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation)*
14:00-14:20	*168. Exploring a Lithic Adaptability Index: A New Measure of Stone Tool Complexity at Intra-type and Inter-assemblage Levels* *Parth R Chauhan (IISER Mohali)**
14:20-15:00	*Discussion*

118. Non-destructive Geochemical Characterisation of Non-volcanic Adze Stone in Oceania: An example from New Zealand

Brendan Kneebone (CFG Heritage Ltd); Andrew McAlister (University of Auckland); Dante Bonica (University of Auckland); Greg Gedson (Independent Researcher)*

Geochemical characterisation of stone artefacts is well-established in Oceania. This technique has provided a key means of identifying spatial distributions of raw materials and, by extension, social interaction, especially in regions where metal and ceramics were lacking. Artefact characterisation studies on Oceania have concentrated mainly on volcanic rock types, in particular basalts and obsidians. However, in regions with a continental geology, such as Australia, New Zealand and Papua New Guinea, sedimentary and metamorphic rocks were also important sources of tool stone.

In terms of characterisation techniques, destructive or partially-destructive methods have traditionally been preferred because they produce the most accurate geochemical data. However, in many jurisdictions, the use of these methods is becoming more restricted as indigenous peoples gain greater control over the curation of their heritage. Accordingly, research is focussing more towards non-destructive methods.

In this paper, through the application of portable XRF, we investigate greywacke, a fine-grained sedimentary rock that was commonly used for adze manufacture in New Zealand. Greywacke exposures occur throughout New Zealand but, to date, few quarry sites have been identified, with the Motutapu Island source, in the Hauraki Gulf of the Auckland region being the only one studied in any detail. Consequently, greywacke adzes are often attributed to this source without considering other possibilities. For this study, we collected adze-quality greywacke from several other locations in the Auckland region, and here we discuss the possibilities and limitations of non-destructive geochemical analysis of this material.

68. Towards Technological and Cultural Understandings of Aboriginal Stone Artefacts: A Case Study from Sunbury Ring G, Wurundjeri Woi-wurrung Country, Southeastern Australia

Caroline Spry (La Trobe University); Elspeth Hayes (MicroTrace Archaeology); Richard Fullagar (Core Artefact Research); Bobby Mullins (Wurundjeri Woi-wurrung Elder) (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation); Ron Jones (Wurundjeri Woi-wurrung Elder) (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation); Allan Wandin (Wurundjeri Woi-wurrung Elder) (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation); Delta Lucille Freedman (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation)*

Earth or stone rings comprising large, circular features are interpreted widely as locations of ceremonial activities by Aboriginal people in Australia. Several earth and stone rings around 20m in diameter have been documented on Wurundjeri Woi-wurrung Country, in Melbourne, southeastern Australia. While there is a lack of recorded information about how and when Ancestors of Wurundjeri Woi-wurrung people traditionally made and used these rings, a new technological, functional and refitting study of a small assemblage of flaked stone artefacts excavated at one of the rings in 1979 has generated new information for Wurundjeri Woi-wurrung people today about their Ancestors' use of fire, plants, animals and technology in the deep past. In this presentation, we present the results of this study alongside Wurundjeri Woi-wurrung Elders' cultural understandings of the artefacts and ring today. This study shows the value of combining Western scientific approaches to stone artefact studies, such as those pioneered by Harold Dibble (including analyses of reduction sequences), and traditional cultural knowledge to understand the deep past and develop a more enriched picture of Ancestors, place and Country.

93. Continuous Retouch Model Applied to the Southern African Early Middle Stone Age

Corey A. O'Driscoll (University of Wollongong (Wollongong, NSW)); Alex Mackay (University of Wollongong)*

Harold Dibble (1987, 1995) countered the dichotomy of style and function as determinants of retouch flake morphology, proposing that retouch reflected continuous reduction rather than imposed form. Dibble and his students then demonstrated the validity of this approach with respect to implements from the European Middle Palaeolithic contexts, including scrapers and denticulates.

In 2020 (O'Driscoll and Mackay, 2020), we explored and extended this proposition using artefacts from the southern African Early Middle Stone Age (Early MSA; ~315-80 thousand years ago). The lithic technology of the Early MSA has often been characterised as 'generic', with limited technological turnover. This is in part owing to the limited number and morphological variability of implement types. Such an approach helped buttress an existing belief in limited human behavioural evolution during the earlier parts of the MSA. Our prior research established two important points. First, following Dibble, retouch was likely progressively applied to key implement types of scrapers, notches and denticulates, such that the types 'notch' (flake with single notches) and 'denticulate' (flakes with multiple notches) could not be considered discrete. Second, the kind of retouched applied to artefacts sometimes varied as reduction increased, such that heavily retouched pieces might include portions of the margin that were scraper-like, and others that were notched. Thus, rather than a static imposition of form, the approach to retouch in the earlier MSA was dynamic, flexible, and likely contingent on imminent needs. We termed this a "maximum expediency" model of tool maintenance.

Our 2020 paper aggregated data from three sites in the Doring River catchment occupied over more than 50,000 years through Marine Isotope Stages (MIS) 5 and 6, potentially masking change through time. In this presentation, we reassess the 2020 conclusions through a detailed analysis of individual stratigraphic units of the same sites to determine whether there are identifiable changes in the application of retouch throughout the sequence. The results support our previous work, though with greater nuance. Reduction generally continues to fit our maximum expediency model, whereby people would produce, transport, and maintain larger flakes before discarding them near locations where replacements could be manufactured. In some cases, while reduction is progressive, it is also consistent in form – something we refer to as 'reduction-mediated typology'. This is most often the case with scrapers – an outcome similar to Dibble's (1987, 1995) work on Middle Palaeolithic scrapers. However, a high proportion of retouch pieces continue to feature 'mixed' retouch. Such pieces are prevalent in all units, with retouch applied in similar locations, forms, and intensity.

We find that the retouch assemblage of the Doring River Catchment Early MSA does not exhibit technological turnover, nor periods that can be defined by the production of a given implement type. Rather than view this as a static system lacking in innovation, we argue that the flexibility offered by the absence of normative types enabled Early MSA foragers to modulate technologies to meet contingencies. Like Harold Dibble, the thinking of Early MSA foragers was not constrained by typology, and the enduring legacy of both is an appreciation of the importance of flexibility-by-design.

References:

Dibble, H.L., 1987. The interpretation of Middle Paleolithic scraper morphology, American antiquity 52, 109-117.

Dibble, H.L., 1995. Middle Paleolithic scraper reduction: background, clarification, and review of the evidence to date., Journal of Archaeological Method and Theory 2, 299-368.

O'Driscoll, C.A., Mackay, A., 2020. On the Operation of Retouch in Southern Africa's Early Middle Stone Age, Journal of Paleolithic Archaeology 3, 1149-1179.

77. From Scar to Scar. Reconstructing Operational Sequences of Lithic Artifacts using Scar-Ridge-Pattern-based Graph Models

Florian Linsel (Martin Luther University of Halle-Wittenberg, Institute of Computer Science); Jan Philipp Bullenkamp (Martin-Luther University of Halle-Wittenberg, Institute of Computer Science); Hubert Mara (MLU - Instiut für Informatik)*

Lithic tools, fundamental to the early human technological advancement, provide a rich record of our ancestors' toolmaking practices, also known as knapping. Investigating the segmentation of scar areas and operational sequences of these knapping techniques has been a challenge in archaeological research. This study presents a two-part approach that combines scar area segmentation as a preprocessing step and directed scar-ridge graph models to reconstruct operational sequences using 3D meshes of lithic artifacts.

For creating our research, we used either open access or digitized in-house datasets (data publication in preparation). These meshes get then segmented either algorithmically or manually. In previous research (e.g. Bullenkamp et al. 2023), we segmented these scars either by a Morse theory or a random clustering-based approach, which could either be pipelined or adjusted by user input, which is available as an open-source code publication. For the segmentation algorithm, we used the multi-scale integral invariant (MSII) 2D surface curvature computed with GigaMesh (gigamesh.eu) as the basis of the analysis/scalar function. The goal of this approach, validated by manual segmentation, was created to provide guidance for an initial segmentation that needs to be adjusted by a user. The scar-ridge patterns can then be extracted as labels from the segmentation results or user-generated annotations, similar to drawings, but directly on the surface of the mesh. Thus, all labels are three-dimensional.

In Linsel et al. (2023), we further developed our workflow by using the segmented mesh as a source for 3D graph models. After the segmentation, we continued by extracting the ridges between adjacent scars as polylines. The resulting scar-ridge-patterns get simplified to an undirected adjacency graph that captures the spatial relationships between adjacent scars. The scars are as a result nodes and the adjacencies, also represented as ridges are the links between them. We have used the undirected adjacency graph models to study operational sequences (OS) with a parameter-based approach. A central problem for a complete OS of a complete artifact is the chronological relation between two neighboring scars. Therefore, we used relative differences in scar properties of adjacent scars to determine the OS. The parameters considered included the scar area, node degree, and betweenness centrality. These parameters are not commonly used to determine the OS of lithic artifacts and were only intended to demonstrate the potential of a graph model-based approach.

The current manual practice of determining the chronological relation between two neighboring scars is based on five attributes, according to Pastoors et al. (2015). In a sense, this approach of determining the chronological relation between scars according to attribute-based rules is already based on graph models. Building on the previous research on graph models and parameter-based chronological relation models, we reviewed these rules and identified two essential ridge-based rules that we integrated into our approach. The first rule we analyzed, “younger scar is deeper and more concave along the ridges than the older scar”, should be separated into two separate rules: the first part is the relative depth between the scars and the second part is the resulting difference in concavity along the ridges. In our study, we approximate the second part by calculating the MSII surface curvature on both sides of the ridges to determine the temporal relation. The second rule, “A younger scar contour follows the older scar contour and cuts across it.”, can be simplified as the curvature of the ridge polyline. Using the ridge polyline, we computed the MSII 1D curvature of the polyline to see in which direction the ridge “cuts across”.

To validate our approach, we applied it to several 3D datasets, including Proto-Aurignacian blades and bladelets from Grotta di Fumane, a Neolithic adze, and a laterally retouched Bronze Age blade from Troy. Additionally, we tested our method on experimental knapping series to ensure its applicability to both, experimental and real datasets.

Preliminary results of our 3D graph model approach indicate that it is case-transferable and it allows us to analyze in 3D the parameters commonly used to reconstruct the OS of lithic artifacts. This innovative method promises to improve our understanding of lithic tool production strategies and to automate this time-consuming research topic.

References:

Bullenkamp, Jan Philipp, Theresa Häberle, Florian Linsel, Susanne Krömker, and Hubert Mara. “Discrete Morse Theory Segmentation on High-Resolution 3D Lithic Artifacts.” Preprint, accepted in it - Information Technology, 2023.

Linsel, Florian, Jan Philipp Bullenkamp, and Hubert Mara. “Linking Scars: Topology-Based Scar Detection and Graph Modeling of Paleolithic Artifacts in 3D.” Zenodo, 2023. doi:10.5281/zenodo.8296269.

Pastoors, Andreas, Yvonne Tafelmaier, and Gerd-Christian Weniger. “Quantification of Late Pleistocene Core Configurations: Application of the Working Stage Analysis as Estimation Method for Technological Behavioural Efficiency”. Quartär 62 (2015): 63–84. https://doi.org/10.7485/QU62_3.

47. Harold Dibble’s legacy: Advancing Lithic Studies through Experimentation, Standardization and Open Science

*Li Li (University of Algarve)**

Harold Dibble’s legacy is deeply rooted in the advancement of methodological approaches encompassing quantitative, statistical, and computer-based techniques for (lithic) data recording and analysis. Lithic studies involve a broad spectrum of work, spanning from fieldwork to laboratory analyses, and even extending into computer modeling and simulation. Within this multifaceted domain, Dibble emerged as a pioneer, propelling the field of archaeology with his technological and theoretical contributions.

Dibble’s research was notably centered on rigorous testing of hypotheses and the application of quantitative analysis. He emphasized the standardization of data recording protocols, which not only facilitates the comparability of archaeological data across various assemblages, but also enhances our ability to interpret hominin behavior across diverse temporal and spatial contexts. In this paper, I will discuss three areas where we draw inspiration from Dibble's work: first, in the laboratory while conducting experimental research and present results from ongoing experiments that his work has inspired; second, his efforts for improving and standardizing the data collection process both in the field and in the lab; and third, his advocacy for open science principles in archaeology.

Dibble was a pioneering figure in the advancement of controlled experiments within lithic studies, advocating for the use of standardized materials and experimental apparatus. Experimentation has a long history in lithic studies, serving as an effective platform to generate and test hypotheses regarding the production and use of stone tools. Given the uniformity of stone properties, we can reasonably assume that the processes observed in contemporary stone fracture also existed in the past. This fundamental assumption allows archaeologists to verify hypotheses and draw inferences about ancient stone tool technology by replicating the observed forms of stone artifacts in archaeological records. From the 1960s onward, replicative flintknapping gained increasing attention within lithic studies and gradually integrated into the mainstream. Researchers adopted flintknapping as an experimental approach to explore various aspects of stone tool production. Replicative experiments provided archaeologists with a highly realistic framework for investigating a broad spectrum of topics within lithic studies, offering valuable insights into the changes in flake attributes at each stage of the knapping process. Nonetheless, the reliance on subjective observations and the expertise of modern knappers during replicative experiments imposed limitations on the precise quantification of individual knapping variables' impact on flaking.

Unsatisfied with the limitations of replicative experiments, Dibble sought solutions to better comprehend the fundamental principles of flaking and the individual impact of variables controlled by knappers on the flaking outcome (Dibble and Rezek 2009). Collaborating with his colleagues, Dibble significantly departed from the realm of replicative experiments and began to conduct experimental work that specifically addressed variables directly controllable by knappers during the flaking process, using mechanical apparatuses. He successfully secured funding from the National Science Foundation to establish a laboratory equipped with two powerful mechanical apparatuses for conducting controlled lithic experiments using standardized cores. A series of experiments conducted in this laboratory explored various aspects of flake production, inspiring similar studies conducted by fellow researchers.

The collaborative efforts of Dibble and his colleagues yielded a comprehensive flake formation model based on the outcomes of controlled experiments (Li et al. 2022). This model succinctly outlines that key variables in determining the final flake size and shape include the platform attributes of a flake (e.g., platform depth, exterior platform angle), and the hammer strike angle. Inspired by Dibble's experiments, we continue to investigate flake formation using a controlled experimental approach. We conducted a series of new experiments using both a drop tower setup and one of the original mechanical apparatuses initially used by Dibble and colleagues. In these experiments, we returned to the principles of fracture mechanics while incorporating inquiries related to the knapper's control during the flintknapping process. Our focus was to examine the impact of various variables associated with force delivery of the knapping process, such as hammer strike angle, hammer size, and hammer velocity. Our findings indicate the feasibility of measuring hammer strike angle and hammer size from flakes, allowing us to more accurately reconstruct hominins' knapping strategies from the archaeological record.

Dibble promoted standardized data collection procedures in both laboratory and field settings by providing detailed instructions for attribute definitions and data collection methods to minimize error while improving efficiency. He emphasized the importance of streamlining the data recording process and integration of software and electronic measuring tools to expediate data acquisition and reduce potential human errors. For survey and excavation work, Dibble, in collaboration with Shannon McPherron, developed the EDM program that allowed researchers to digitally and efficiently record data in the field, requiring minimum human intervention to rectify error (OSA 2023). For more detailed data entry in the laboratory, Dibble and McPherron created programs that were tailored to accommodate specific research needs, facilitating the efficient entry of data for various analyses. McPherron recently re-wrote both the EDM and data entry programs to ensure compatibility across multiple platforms to widen access and enable more researchers to benefit from their capabilities.

Dibble ardently advocated for open science principles. His vision for data entry and recording programs extended beyond their functionality. He intended these programs to be accessible to all, not only by making them freely available for download but also by ensuring user-friendliness. Furthermore, prior to his passing, he planned to the synthesize and publish results from the controlled experiments conducted in the previous decade. His goal was to provide researchers with enhanced insights into flake formation, and these findings also served as educational materials.

Harold Dibble's enduring contributions to the field of archaeology have left an indelible mark. His pioneering work led to advancements in controlled experiments, promoting standardized data collection practices, and advocating for the principles of open science.

References:

Dibble, Harold L., and Zeljko Rezek. 2009. "Introducing a new experimental design for controlled studies of flake formation: results for exterior platform angle, platform depth, angle of blow, velocity, and force." Journal of Archaeological Science 36, no. 9: 1945-1954.

Li, Li, Sam C. Lin, Shannon P. McPherron, Aylar Abdolahzadeh, Annie Chan, Tamara Dogandžić, Radu Iovita et al. 2022. "A Synthesis of the Dibble et al. Controlled Experiments into the Mechanics of Lithic Production." Journal of Archaeological Method and Theory: 1-42.

Old Stone Age, 2023. "EDM". https://www.oldstoneage.com/osa/tech/edm/. Accessed October 18, 2023.

75. It's All about the Source: Reuse, Mobility, and Lithic Assemblage Composition

*Matthew C Barrett (The University of Auckland)**

One of the many characteristics of Harold Dibble's work was his empirical interrogation of preconceived notions about variability in stone artefacts and the formation of archaeological assemblages. Dibble's reuse hypothesis as an alternative to the long-standing style vs function debate is a key example. This paper takes inspiration from Dibble's work to investigate alternative explanations for how lithic assemblage composition relates to past human mobility, with specific regard to the sourcing of stone artefacts.

Studies that draw upon raw material sourcing typically investigate the distribution of artefacts of different raw material types relative to the geological source from which those materials originate. Analysis of lithic variability often implicitly assumes that when in need of a stone artefact for some purpose, people would begin the manufacture process anew, accessing a geological source to acquire a new block of material to manufacture a new tool. Metrics such as frequencies and distance to the geological source form the basis for inferences about aspects of past behaviour such as trade and exchange, development of social networks, and territorial circumscription, each of which are underpinned by mobility. There is no question that such processes were in operation at different times and places in the past, nor is there any doubt that a stone artefact ultimately derived from a fixed geological origin. However, when carried through to analysis, such assumptions belie the many and varied ways in which stone can be acquired and move from one location to another.

Lithic reuse, thought of in terms of the acquisition of stone artefacts from deposits of previously used material, has implications for inferences about mobility that are based on assumptions about access to fixed geological stone sources. Thought of as a mechanism for distributing lithic objects across the landscape, reuse means discarded artefacts serve as new sources of raw material at places located in-between the geological origin and archaeological location of those artefacts. This paper explores the significance of these 'in-between' places for patterning in archaeological distributions of stone artefacts.

Understanding mobility through reuse requires data regarding the distribution and attributes of many artefacts located across the landscape to see patterning beyond that confined to a site or spatially restricted assemblage. To achieve this, agent-based modelling is used to experiment with a simple set of lithic acquisition, production, reuse and movement behaviours to generate expectations about the distribution of stone artefacts deriving from different geological sources. Empirical obsidian artefact distributions from Aotearoa New Zealand are used as tests of simulation outcomes. Under conditions of reuse, the results suggest qualitative similarities between simulation outcomes and the empirical record across common measures such as distance decay and changes in raw material proportions over time, providing an alternative interpretation to behavioural inferences about trade and exchange based on the location of geological sources. Ultimately, all these phenomena can be broken down to forms of mobility, though they are based on different sets of assumptions. The significance of this study lies not in inferring any one mechanism exclusively over another, but rather in highlighting the need to carefully assess underlying assumptions and understanding the basic set of processes and generative mechanisms that influence the patterning archaeologists observe. Following Dibble's example, this provides a way of empirically addressing preconceived notions about lithic variability.

168. Exploring a Lithic Adaptability Index: A New Measure of Stone Tool Complexity at Intra-type and Inter-assemblage Levels

*Parth R Chauhan (IISER Mohali)**

Changes or transitions in archaeological stone tool technologies have often been associated with environmental changes as a casual and dominant factor. Other factors that have also been explored include change in subsistence, population replacements, social interaction and so forth. Individual lithic specimens also display specific characteristics that can affect the overall nature of an assemblage composition through their frequency and techno-morphology. Unlike entire lithic assemblages, diversity at the intra-type level is often associated with a range of factors including individual style, raw material variation, cultural differences and/or functional adaptations (to name a few). This study takes Lower and Middle Palaeolithic bifaces (i.e. handaxes, cleavers, miscellaneous specimens) as a case study to develop a Lithic Adaptability Index (LAI) to quantify and rank techno-morphological variations using a 3D scanner and multivariate statistics. Using SPSS and other related analytical tools, key attributes such as dimensional values, degrees of edge angles, degrees of reduction, and variations in planform shapes, are collectively utilized to distinguish between different types of Mode 2 assemblages with varying types and frequencies of bifaces. This dynamic approach also attempts to explain potential factors for regional and global variations in handaxe-to-cleaver ratios. The resulting LAI is demonstrated on select 'test' lithic assemblages with high contextual integrity and also shown to be extendable to other lithic tool types in most Palaeolithic repertoires. This study, using a multi-method approach, has implications for not only better understanding lithic typological variability in individual assemblage compositions but also in delineating potential site functions and general adaptive complexity and versatility of a given lithic assemblage within its environmental context.

10. Dibble's Dangerous Idea. The Importance of Reduction Induced Allometry, and Harold's Contribution to It.

*Peter Hiscock (Universities of Queensland, Auckland and Griffith)**

Models of size reduction during the production of lithic artifacts have been proposed for more than 130 years, and they all recognise that the shape of the object changed as size reduced. Allometric relationships complicate the patterning and interpretation of any phenomena, and they may even refute fundamental classifications and the models of the world they imply. In lithic analyses the grand early example of the power of allometry to challenge interpretations was the way William Holmes rejected associations of crudeness and antiquity. Nearly a century later Harold Dibble presented a model of allometry in Middle Palaeolithic assemblages that challenged the meaning of not only European typologies, but the practice of lithic classification everywhere. Researchers typically responded to the challenge his schema represents in specific and empirical ways, by arguing it couldn't work on their collection or that it helped explain their collection and so on. Harold's model inspired lithic analysts world-wide to develop more nuanced interpretations of lithic variation.

However, what are arguably the most important implications of Harold's writings about reduction have barely been discussed. In this paper I explore the conceptual challenges that reduction induced allometry has for foundational thinking about concepts of ancient designs, the dynamics and explanation of form-function relationships, the evolution of lithic technology, and the limited and unreliable nature of typological practices. In his writings Harold effectively invited us to examine not merely the particularities of Neanderthal technology, but to also evaluate how we think about lithic analysis and material culture more generally. While Harold is sadly gone, his invitation to develop more thoughtful and nuanced understandings of our archaeological record happily remains.

28. Flake Selection and Retouch Probability as Determinants of Middle Paleolithic Assemblage Variability

*Sam C Lin (University of Wollongong)**

A central focus of Harold Dibble's influential work is to explain variation among Middle Paleolithic assemblages. His research into Mousterian inter-assemblage variation culminated in the 'Rolland and Dibble synthesis' (Rolland and Dibble 1990, Dibble and Rolland 1992), which postulates that Middle Paleolithic assemblage variability is primarily driven by raw material availability and place-use intensity. As hominins utilise a place more intensively, the model predicts an increase in the degree of lithic utilisation, resulting in the production of more flakes per core and more retouched artefacts. Intuitively, this prediction suggests that artefact density should positively correlate with the proportion of retouched objects. In other words, as lithic assemblage accumulates through repeated human activities, we should find a proportionally greater representation of retouched artefacts. However, empirical observations have repeatedly shown the opposite: Paleolithic assemblage retouched frequency typically correlates negatively with artefact density (e.g., Barton et al. 2011). Consequently, in contrast to the Rolland and Dibble model, studies tend to explain Paleolithic retouch variability in terms of hominin mobility and technological provisioning (e.g., Kuhn and Clark 2015), rather than the intensity of lithic utilisation.

Building on a previous study (Lin 2018), I demonstrate that the Rolland and Dibble model can explain the empirical negative relationship of Paleolithic retouch assemblages when considering two additional factors: flake size distribution and flake selection probability. Using computer simulation, I show that a relatively simple process of flake size selection can generate a negative correlation between retouched frequency and artefact density, without the need for additional mobility or technological parameters. Compared to existing models, I argue that this modified version of the Rolland and Dibble synthesis provides stronger explanations for Paleolithic assemblage variability as it can simultaneously account for two commonly observed assemblage properties: the negative relationship between retouched frequency and artefact density, and the larger size range of retouched artefacts than unretouched flakes. Applying the revised model to several Middle Paleolithic assemblages, I demonstrate that lithic assemblage variability is intricately linked to flake size selection criteria, which can be empirically estimated from the size distribution of retouched artefacts.

In summary, this study suggests that the widely described relationship between artefact density and retouch frequency among Paleolithic assemblages may reflect a fundamental aspect of assemblage accumulation and lithic utilisation, as proposed by Rolland and Dibble over 30 years ago. The revised model presented here offers a new framework for empirically evaluating Paleolithic assemblage variability in relation to hominin tool-use behaviours.

References

Barton, C. M., Riel-Salvatore, J., Anderies, J. M., Popescu, G. 2011. Modeling human ecodynamics and biocultural interactions in the late Pleistocene of western Eurasia. Human Ecology 39: 705–725.

Dibble, Harold L., and Nicolas Rolland. 1992. "On assemblage variability in the Middle Paleolithic of Western Europe: History, perspectives, and a new synthesis." In The Middle Paleolithic: Adaptation, behavior and variability, edited by Harold L. Dibble, and Paul Mellars, 1–20. Philadelphia: University of Pennsylvania Museum of Anthropology and Archaeology.

Rolland, Nicolas, and Harold L. Dibble. 1990. "A new synthesis of Middle Paleolithic variability." American Antiquity 55, no. 3: 480–499.

Kuhn, S. L., and Clark, A. E. 2015. Artifact densities and assemblage formation: evidence from Tabun Cave. Journal of Anthropological Archaeology 38: 8–16.

Lin, Sam C. 2018. "Flake selection and scraper retouch probability: an alternative model for explaining Middle Paleolithic assemblage retouch variability." Archaeological and Anthropological Sciences 10: 1791–1806.

105. Developing a Virtual Knapper Based on Controlled Experiments into Fracture Mechanics

*Shannon P McPherron (Max Planck Institute for Evolutionary Anthropology)**

One of Harold Dibble's long-lasting interests was in controlled experiments to better understand fracture mechanics. This interest started during his dissertation work when he first started dropping metal ball bearings onto plate glass to understand the role of variables like exterior platform angle and platform thickness. By the end of his career, his laboratory had two purpose-built machines for removing realistically sized and shaped flakes from raw materials of different types under controlled conditions, and he and his team published a series of papers primarily aimed towards building a model of flake formation centered around the types of variables that knappers could control (e.g. platform characteristics, flaking surface characteristics, hammer types, delivery variables such as angle of blow and applied force, etc.). A summary of these findings and the data were published posthumously by his team (Li Li et al. 2022).

Dibble also had a great love for coding, and so it was natural that he would try to code the results of these experiments into a flake simulator. His flake simulator, published in 1999 as part of his Virtual Dig classroom software (Dibble et al. 1999), allowed one to vary key aspects of the platform and removal surface before striking (clicking) the outlined core and producing a flake. The goal in this case was to convey an appreciation for how variables like platform depth and exterior platform angle impacted flake size and shape. This program, however, was developed without all of the insights subsequently gained from the above-mentioned machine experiments he conducted in his lab after this.

Just prior to his passing, in the context of an ERC grant awarded to Claudio Tennie, Dibble and I began work on a new 3D version of the flaking simulator, what I now call virtual knapper. This program uses the most current results from the Dibble controlled experiments and has the goal of producing a realistic enough simulation of flaking that it can contribute to the chain of inference we use to understand lithic variability in the archaeological record.

One outcome of this research effort used machine learning to simulate flaking and has already been published (Orellana et al. 2021). Here I focus on a parallel effort that takes a very different approach that aligns more closely with simulating first principles of fracture mechanics. The word simulate is stressed here because this new virtual knapper does not use the computationally expensive mathematics of fracture mechanics but rather tries to encode the statistical regularities of the Dibble controlled experiments into solid object geometry. In this regard it fits more closely to Dibble's original 2D flaking simulator of 25 years ago.

Here I will present this background and the latest results in comparison to data and scans of glass cores and flakes from the Dibble controlled experiments. The results highlight the feasibility of this approach but, like most modeling or simulation efforts, the results also highlight the gaps in our understanding of how conchoidal flaking actually works. An open question is whether this incomplete understanding is nevertheless sufficient to gain insights into the archaeological record of lithic production. Regardless, these exposed gaps motivate new controlled experiments that will hopefully result in better models.

References

Dibble, Harold L., Shannon P. McPherron, and Barbara J. Roth. Virtual dig: a simulated archaeological excavation of a middle paleolithic site in France. Mayfield, 1999.

Li, Li, et al. "A Synthesis of the Dibble et al. Controlled Experiments into the Mechanics of Lithic Production." Journal of Archaeological Method and Theory (2022): 1-42.

Orellana Figueroa, J.D., Reeves, J.S., McPherron, S.P. et al. A proof of concept for machine learning-based virtual knapping using neural networks. Sci Rep 11, 19966 (2021)

115. The Development of the Cortex and Volume Ratios

Stacey Middleton (University of Auckland); Rebecca Phillipps (University of Auckland); Joshua Emmitt (Auckland War Memorial Museum); Simon Holdaway (University of Auckland)*

Since its development by Harold Dibble (2005) the cortex ratio has been modified and applied to the archaeological record in Australia, New Zealand, China, Egypt, and southern and northern Africa. The application of the cortex ratio in areas with large amounts of cortical raw material can provide insight into the movement of material and the accumulation of material through space and time. The volume ratio was proposed by Phillipps (2012), and developed by Phillipps and Holdaway (2016), and Ditchfield et al. (2014) as an alternative or supplement to the cortex ratio that uses the loss of volume of an assemblage as a proxy for artefact transport and therefore human movement. Recent research has applied these concepts to lithic assemblages in Aotearoa New Zealand. However, the geological complexity of Aotearoa and the stone sources used by Māori presents a number of challenges including irregular shapes and sizes of raw material nodules and presence of cortical raw material. This has prompted the development of a number of novel approaches (e.g., Middleton and Phillipps 2022). We discuss the progress of this research to date and highlight issues and avenues for future development.

S21: Fair Reuse of Archive Data

Tuesday 9th April, 11:20–12:00, 260-073 OGGB4

Stephen Stead, Paveprime Ltd
Jane Jansen, Arkeologerna – Intrasis

The archaeological research community was an early adopter of digital tools for data acquisition, organisation, analysis, and presentation of research results of individual projects. (Richards 2022). As several projects have shown, digital data can be shared, but how can that data be used? To address those questions, principles and ontologies have been created and are ready to be applied.

One concept is FAIR data. FAIR data is data which meets the principles of Findability, Accessibility, Interoperability, and Reusability (FAIR). The acronym and principles were defined in the journal Scientific Data in 2016.

Digital archive access projects will revolutionise archaeological research and are vital if we want to attain the R in FAIR. However, it is necessary to apply an ontology to the data, otherwise the time needed to understand the semantics of each datasets is insurmountable. CRMarchaeo, an extension of the CIDOC CRM, is one way to link a wide range of existing documentation from archaeological investigations. It was created to promote a shared formalisation of the knowledge extracted from archaeological observations. It provides a set of concepts and properties that allow clear explanation (and separation) of the observations and interpretations made, both in the field and in post-excavation.

Using FAIR principles is critical to the creation of wider pictures of regions or periods and can also be a stepping stone to generating Big Data for further analysis.

Applying FAIR principles to data that contains elements of intangible heritage including living community engagement with cultural heritage sites is a nuanced task that is the topic of the session The Ethics of Open Data. Papers on this aspect are encouraged to apply to this session.

In this session we invite presentations from organisations or projects who are addressing these issues. We are particularly interested in applications of the CIDOC CRM and its extension CRMarchaeo but all approaches will be welcomed.

Richards, J. 2022, Presentation at CHNT Vienna

Motivation:

The motivation is to discuss the integration of a wide range of archaeological excavation archive materials using suitable ontologies, including CRMarchaeo. Healthy discussion of the application of the FAIR principles is required to ensure that best practice emerges by consensus rather than coup d'état. This means we need a body of proficient professional and amateur practitioners able, and willing, to discuss their approaches and experience. This may include the application of CRMarchaeo to describe and encapsulate the semantic meaning of archaeological archives of all eras but it may also encapsulate other ontologies and approaches.

The materials tackled could include historic daybook or narrative text descriptions of archaeological excavations or chance encounters as well as more modern context sheet paper records of systematic excavations. It is also intended to address electronic excavation databases of all flavours and vintages being made interoperable without the need to harmonise away the unique qualities and flavours of chosen excavation methodologies.

Target Audience:

The target audience is professional and amateur cultural heritage practitioners who enable access to archaeological excavation archives and wish to discuss their experiences in this arena. These could include archaeologists depositing new excavation archives or researchers attempting to provide access to existing archives to a wider professional and lay audience. Curators of museum deposits of archaeological excavation archives may also inform the debate based on their experience of providing access to the content of archives in their care. This would also apply to archivists who have similar historic excavation archive material in their care.

S21: Fair Reuse of Archive Data	
11:20-11:40	*67. Digital Reconstruction Resources as FAIR Data. Practical Use of Application Ontology for Preservation of Cultural Heritage 3D Models (OntPreHer3D)* *Igor P Bajena (Hochschule Mainz & University of Bologna)**
11:40-12:00	*167. True Integration: Continuing the Journey to Representing Archaeological Documentation with the CRM Family* *Stephen Stead (GB)*; Jane Jansen (Statens Historiska Museer Arkeologerna)*

67. Digital reconstruction resources as FAIR data. Practical use of application Ontology for Preservation of Cultural Heritage 3D Models (OntPreHer3D)

*Igor P Bajena (University of Bologna)**

Context

Preservation of 3D models of digital reconstructions requires ensuring access, transparency, interoperability, and reuse of published data. In the era of web 3.0 and linked open data (LOD), it is necessary to use ontologies to make the data machine-readable and to show the relationships between entries. In the cultural heritage sector standardized solution which allows to achieve it is CIDOC CRM. The basic model concerns only general concepts, which may turn out to be insufficient in describing the digital reconstruction. For this reason, official extensions are created to enable more detailed documentation of various aspects. An example in the context of digital reconstructions may be use of CRMinf, CRMgeo and CRMba, which enables the analysis of individual building elements and the relationships between them, as well as in terms of the origin of the presented reconstruction knowledge (Bruseker et al., 2015). Another approach is covered by creation of an application ontologies, which enables the addition of custom classes and properties to capture aspects relevant to a specific of the project. This approach was used in the digital reconstruction project of the New Synagogue in Wroclaw (Kuroczyński et al., 2021) by creating an Ontology for Scientific Documentation of source-based 3D reconstruction of architecture (OntSciDoc3D) . This ontology enables capturing the relations between the reconstruction and used source materials, historical background of the building, also considering the possibility of assigning a hypothesis level (uncertainty) to individual building elements.

Issues related to the documentation of 3D models of digital heritage and the use of these ontological solutions unfortunately require an additional contribution to the creation of an appropriate infrastructure, which many institutions cannot afford. In the face of these challenges, the prototype of a 3D model preservation infrastructure was created in the form of a 3D Repository (https://3d-repository.hs-mainz.de/), an open platform for publishing 3D models of cultural heritage using for documentation the CIDOC CRM base model with extension of the OntSciDoc3D application ontology mentioned above. A WissKI virtual research environment based on the Drupal content management system was used to build it. The created service was intended to provide a simple metadata form which aimed to enable linking of selected entities to external data repositories and authority files (e.g. ORCID, Getty AAT, or Wikidata), and to provide visualization of the 3D model in a web-based viewer. However, survey on user requirements showed the need for a more universal documentation scheme that does not focus only on digital reconstructions. At the same time, respondents pointed the need of possibility to document information specific to fields, such as archaeology or art history. In addition, the issue was noted regards model publication process and highlighting differences between the original model in native format, the exported file intended for visualization in the repository and the processed file by the system, which is displayed in the viewer.

Main argument

Digital reconstruction consists of two aspects: the historical study of an object and the use of digital modelling and visualization methods to present the obtained results in the form of a virtual simulation of the object's past. Mentioned ontological solutions focuses on documenting the historical research, but not used methods for obtaining visual results. To fully understand the process, it is also necessary to present used methodology form technical point of view, what can influence perception or level of accuracy of the model. The CRM family has an extension CRMdig focusing on capturing the process of the provenance of digital data, but it is limited to the broad process of digitization and automated data acquisition, without addressing the distinction of modelling methods related to digital reconstruction. It also does not sufficiently cover the topic related to the preservation of 3D models. Analyzing the life cycle of a digital resource, a key moment is its publication, as this enables entering the phases of archiving, acquisition and reuse. A properly conducted documentation of a published digital 3D reconstruction should include topics related to the goals of publishing, the methods used for digital modelling and its geometric representation, methods of visualizing of the presented results, as well as transparency in terms of historical research, used sources, evaluation of the hypothesis level and the scientific value of the model (Bajena and Kuroczyński, 2023).

In view of this premise, an Ontology for Preservation of Cultural Heritage 3D Models (OntPreHer3D) was developed to capture in detail the process of model publication (M5 Web-publication) and the creation of new repository entries (M6 Web-based entry) together with the distinction between the 3D file (M1 Digital Model) and its visualisation (M7 Web-visualisation) and using CRMdig and OntSciDoc3D to capture other aspects of the process. The 3D model publication process expressed by OntPreHer3D is shown in Fig.1 The ontology contains 35 classes from the CRM base model, 5 classes from CRMdig, 9 classes from OntSciDoc3D and introduces 16 new classes related to publication process including model characteristics (M15 3D Geometry, M16 3D Material), relationships between 3D models (M2 Versioning, M3 Variation, M4 Division) or classification of cultural heritage objects based od its size/scale based on the Getty AAT (M11 Single Built Work, M12 Furrnishing and Equipment, M13 Compnent, M10 Area).

Applications

The current level of work focuses only on the publication process, but further development is planned towards capturing the methodology of work on the 3D model, historical research on the object and the presentation of research hypotheses, including the use of further extensions of the CIDOC CRM family. It is also planned to verify the practical use of the proposed ontology as part of the construction of a new WissKI repository for the European CoVHer (Computer-based Visualisation of Architectural Cultural Heritage) project , where the use of new documentation and publication methods for digital reconstruction models in the higher education sector will be investigated. The presented approach to the documentation of 3D models based on OntPreHer3D can allow easier access to 3D data, a better understanding of the methods used from a technological point of view and contribute to an increase in the reuse of the 3D data the broad field of cultural digital heritage, not just limited to hypothetical digital reconstructions.

References

1. Bajena, I., Kuroczyński, P. (2023). Metadata for 3D Digital Heritage Models. In the Search of a Common Ground. In: Münster, S., Pattee, A., Kröber, C., Niebling, F. (eds) Research and Education in Urban History in the Age of Digital Libraries. UHDL 2023. Communications in Computer and Information Science, vol 1853. Springer, Cham. https://doi.org/10.1007/978-3-031-38871-2_4

2. Kuroczyński, P., Bajena, I., Große, P., Jara, K., Wnęk, K. (2021). Digital Reconstruction of the New Synagogue in Breslau: New Approaches to Object-Oriented Research. In: Niebling, F., Münster, S., Messemer, H. (eds) Research and Education in Urban History in the Age of Digital Libraries. UHDL 2019. Communications in Computer and Information Science, vol 1501. Springer, Cham. https://doi.org/10.1007/978-3-030-93186-5_2

3. Bruseker, G., Guillem, A., Carboni, N. (2015). Semantically documenting virtual reconstruction: building a path to knowledge provenance. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2, 33-40. https://doi.org/10.5194/isprsannals-II-5-W3-33-2015

167. True Integration: Continuing the Journey to Representing Archaeological Documentation with the CRM Family

Stephen Stead (GB); Jane Jansen (Statens Historiska Museer Arkeologerna)*

This continuing integration study considers how the body of archaeological excavation databases of The Archaeologists (a department within the National Historical Museums of Sweden) is being prepared for integration utilising the CRMarchaeo and other extensions of the CIDOC Conceptual Reference Model (CRM). The Archaeologists create many new Intrasis-databases each year and the project is looking at making the full richness of both observations and interpretations available as a queryable resource. In addition the para-data of how the transformation from the internal Intrasis data-structure to the CRMarchaeo representation is being performed, is being modelled using the CRM family of ontologies. This enables the full digital provenance of any individual element of the full data-set to be assessed as well as understand the evolution of techniques used. This will allow scholars to consider both the archaeologically investigated past and the techniques used to manage the documentation of this past: the history of the discipline so to speak.

There are two further areas of interest. The first is the documentation of competing interpretations of primary evidence and the reasons for the selection of one interpretation over another. This is being done using CRMinf. The second is the incorporation of the documentation of oral traditions about the areas where excavations have taken place. We feel that this is of particular interest in areas where deep traditions of oral history are more prevalent.

The presentation will showcase the work undertaken by Intrasis and Paveprime since last year to enrich both the archaeological record and the record of the documentation practice itself.

S22: The Ethics of Open Data

Tuesday 9th April, 13:00–17:00, 260-073 OGGB4

Leigh Anne Lieberman, Open Context / Princeton University
Melissa Cradic, Open Context
Sarah W. Kansa, Open Context

Archaeology faces immediate challenges in the ethical management of information, even as initiatives across the globe demonstrate that the potential and demand for open data have reached new heights. These include the National Science Foundation's (NSF) and U.S. Federal Government's 2023 Year of Open Science, UNESCO's Recommendation on Open Science (2021), the European Union's recent policy publications and investments in open science for digital futures, and interdisciplinary pushes to advance the FAIR Guiding Principles for open scientific data management and stewardship (Findability, Accessibility, Interoperability, and Reuse). Yet the need for ethical and equitable considerations of open data, in particular the adoption of the CARE Principles for Indigenous Data Governance (Collective Benefit, Authority to Control, Responsibility, and Ethics)–a guiding set of values developed by an international steering committee of Indigenous scholars based in Australasia, North America, Central America, South America, and Africa (Carroll et al. 2019, 2020, 2021)–has emerged as a priority for those creating, publishing, and (re)using archaeological data sets. More broadly, ethical, open data publishing in many global contexts, such as those with legacies of colonialism and those with marginalized, diaspora, and/or descendant communities, has also become an urgent concern among archaeologists practicing at all stages of data lifecycle–from data collection to processing, analysis, publication, and archiving–particularly as the "emancipatory narrative" of open data is called into question (Gupta et al. 2023: 77). Although the challenges of retrofitting legacy data, adapting existing or outdated technical infrastructures, and modifying already-published data so that they meet both FAIR and CARE criteria have proven to be a stumbling block for individual practitioners, data publishers, and community-curated data repositories (e.g., Open Context, tDAR, ADS, iSamples, Zooarchnet, Neotoma, and others) (Nicholson et al. 2023), the opportunities for shared governance create new pathways for equitable data futures and decolonization. These issues are particularly pertinent in regions such as New Zealand, where legal and ethical frameworks for CARE and Indigenous data sovereignty and governance are more mature than in other regions such as the United States and Europe.

Bridging FAIR and CARE principles requires reframing perspectives on data curation and management throughout the data lifecycle (see Kansa and Kansa 2022) in order to determine who has access and authority to control archaeological data; who benefits from these data and how; and how the capacity for data governance and sovereignty among rights-holding communities can be achieved (Gardner-Vandy and Scalice 2021; Gupta et al. 2023). FAIR is often viewed as data-centric, with an emphasis on data quality and reuse (Gupta et al. 2023), while the CARE framework, although necessarily dependent on data quality, explicitly emphasizes a purpose-driven, people-first, collaborative, and relationship-building philosophy (Carroll et al. 2021; Gardner-Vandy and Scalice 2021). Therefore, adherence to CARE may require retooling data infrastructures and research protocols; reallocating time and resources; partnering with stake- and rights-holding communities for shared data governance; securing or forfeiting access to sensitive data; engaging closely with Tribal Institutional Review Boards (IRBs); and incorporating detailed provenience information and Traditional Knowledge (TK) labels (Kimmel et al. 2023). It may also require that data practitioners be ready to adopt varied cultural ways of knowing, such as Two-Eyed Seeing, an integrative ontology that connects Indigenous and mainstream scientific frameworks (Bartlett, Marshall, and Marshall 2012; Reano 2020). Several concurrent initiatives run under the auspices of The Alexandria Archive Institute/Open Context in the US offer examples of collaboration across disciplines and heritage communities to build networks of practice that move FAIR and CARE integration forward; these include the NSF-supported FAIR Open Science Research Coordination Network Disciplinary Improvements for Past Global Change Research; the National Endowment for the Humanities (NEH) sponsored professional development program Networking Archaeological Data and Communities; and the Institute of Museum and Library Sciences (IMLS) funded project Advancing FAIR+CARE Practices in Cultural Heritage.

This session invites papers that grapple with the challenges and benefits of thinking "Across the Horizon" of FAIR and CARE, such as how data creators and users have approached ethics, equity, and decolonization in open data and restricted access data stewardship for researchers, stakeholders, and rightsholding communities. It aims to make the case that, through careful and thoughtful operationalization, these two sets of principles can successfully work in tandem for mutual benefit. This session welcomes submissions from archaeologists, cultural resource management (CRM) professionals, Tribal Historic Preservation Officers, museum specialists, heritage professionals, and data managers working on independent, collaborative, and interdisciplinary approaches to FAIR, CARE, and open data ethics in the digital archaeology ecosystem.

References

Barlett, C., M. Marshall, and A. Marshall 2012 Two-Eyed Seeing and Other Lessons Within a Co-Learning Journey of Bringing Together Indigenous and Mainstream Knowledges and Ways of Knowing. Journal of Environmental Studies 2: 331-340. DOI: http://doi.org/10.1007/s13412-012-0086-8

Carroll, S.R., D. Rodruigez-Lonebear, and A. Martinez 2019 Indigenous Data Governance: Strategies from United States Native Nations. Data Science Journal 18: 31, 1-15. DOI: https://doi.org/10.5334/dsj-2019-031

Carroll, S.R., I. Garba, O.L. Figueroa-Rodríguez, J. Holbrook, R. Lovett, S. Materechera, M. Parsons, K. Raseroka, D. Rodriguez-Lonebear, R. Rowe, R. Sara, J.D. Walker, J. Anderson, and M. Hudson 2020 The CARE Principles for Indigenous Data Governance. Data Science Journal 19(1): 43, 1-12. DOI: http://doi.org/10.5334/dsj-2020-043

Carroll, S.R., E. Herczog, M. Hudson, K. Russell, and S. Stall 2021 Operationalizing the FAIR and CARE Principles for Indigenous Data Futures. Scientific Data 8: 108. DOI: https://doi.org/10.1038/s41597-021-00892-0

Gardner-Vandy, K. and D. Scalice 2021 Relationships First and Always: A Guide to Collaborations with Indigenous Communities. An EDI Community Paper to the 2020 Planetary Science and Astrobiology Decadal Survey 2023—2032.

Gupta, N., Martindale, A., K. Supernant, and M. Elvidge 2023 The CARE Principles and the Reuse, Sharing and Curation of Indigenous Data in Canadian Archaeology. Advances in Archaeological Practice 11(1): 76-89. DOI: 10.1017/aap.2022.33

Kansa, E.C. and S.W. Kansa 2022 Promoting Data Quality and Reuse in Archaeology through Collaborative Identifier Practices. Proceedings of the National Academy of Sciences 119(43): e2109313118 DOI: http://doi.org/10.1073/pnas.2109313118

Kimmel, A.P., S.A. Katz, M. Lewis, and E. Wilk 2023 Working with Indigenous Site Monitors and Tribal IRBs: Practical Approaches to the Challenges of Collaborative Archaeology. Advances in Archaeological Practice 11(2): 224-231. DOI: http://doi.org/10.1017/aap.2023.2

Nicholson, C., S. Kansa, N. Gupta, and R. Fernandez 2023 Will It Ever Be FAIR? Making Archaeological Data Findable, Accessible, Interoperable and Reusable. Advances in Archaeological Practice 11(1): 63-75. DOI: http://doi.org/10.1017/aap.2022.40

Reano, D. 2020 Indigenous Research Frameworks in the Multiple Contexts of Research, Teaching, Mentoring, and Leading. The Qualitative Report 25(11): 3902–3926. DOI: 10.46743/2160-3715/2020.4317

S22: The Ethics of Open Data	
13:00-13:20	*165. Moving from FAIR to CARE: Why Understanding Archaeological Data Reuse is Critical to Developing Ethical Practice* *Kristy-Lee Seaton (University of York)*; Holly Wright (University of York)*
13:20-13:40	*37. FAIR & CARE in Southern South America: Examining Archaeological Data in Córdoba Province, Argentina* *Andrés D. Izeta (IDACOR. CONICET & Universidad Nacional de Córdoba)*; Roxana Cattaneo (IDACOR. CONICET & Universidad Nacional de Córdoba)*
13:40-14:00	*19. When Paradata becomes a Paradox? Limits and Extents of Process Transparency in Archaeological Documentation* *Isto Huvila (Uppsala University)**
14:00-14:20	*184. A FAIR-er Archaeological Archive? Experiments in Decolonial Intervention* *Anne H Chen (Bard College)**
14:20-14:40	*57. Reimagining Archaeological Data Management Workflows through the Lens of Reuse* *Holly Wright (University of York)**
14:40-15:00	*Discussion*
Afternoon tea	
15:20-15:40	*178. Indigenous Data Sovereignty: A Critical Consideration of UNDRIP's Implications for Canadian Archaeology* *Lindsay M Montgomery (University of Toronto)**
15:40-16:00	*137. Converting Geographic Facts into Geospatial Data: FAIR and CAREful Approaches to Creating and Disseminating Open Geodata in Western and Central Asian Archaeology* *Michael T Fisher (Max Planck Institute of Geoanthropology)*; Bijan Rouhani (University of Oxford)*

S22: The Ethics of Open Data	
16:00-16:20	*182. Persistent Identifiers to Promote the Contextual Integrity of CAREfully FAIR Data in Archaeology* *Eric C Kansa (Open Context)**
16:20-16:40	*177. Engaging with Practitioners: FAIR and CARE Training for Archaeologists and Cultural Heritage Professionals* *Leigh A Lieberman (Open Context)**
16:40-17:00	*121. Advancing FAIR and CARE Practices Across Networked Communities* *Sarah Kansa (Open Context)*; Melissa Cradic (Open Context)*
17:00-17:40	*Discussion*

37. FAIR & CARE in Southern South America: Examining Archaeological Data in Córdoba Province, Argentina

Andrés D. Izeta (IDACOR. CONICET & Universidad Nacional de Córdoba); Roxana Cattaneo (IDACOR. CONICET & Universidad Nacional de Córdoba)*

In recent years, the international scientific community has been advancing the idea of how to analyze and share academic knowledge in line with the principles of open science. This presentation focuses on characterizing the state of affairs in Córdoba's archaeology and its adherence to the FAIR (Findable, Accessible, Interoperable, Reusable) and CARE (Collective Benefit, Authority to Control, Responsibility, Ethics) principles for Indigenous Data Governance. These principles were created to advance the legal assumptions underlying collective and individual data rights, particularly in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP).

We analyze three dimensions related to regional archaeological research and its curation and dissemination: spatial interpretation, temporal interpretation, and communication. The spatial dimension reveals a challenge in geolocating archaeological sites due to concerns about their protection and the lack of precise information. In terms of the temporal dimension, current historical-cultural models are insufficient, and the scarcity of radiocarbon dating complicates the construction of precise chronologies. To address these challenges, all of this data is now publicly available at The Suquía Institutional Repository. This database was developed as a digital platform for the preservation and dissemination of cultural heritage in Argentina. It includes a diverse range of cultural material, such as documents, photographs, maps, newspapers, videos, and audio recordings. This digitization of cultural heritage is essential to guarantee the conservation and accessibility of documented material associated with archaeological investigations. In addition, the Suquia Repository serves as a valuable resource for indigenous communities, environmentalists, researchers, scholars, and students seeking to research or learn about Argentina's cultural heritage. By making cultural heritage materials freely available to the public, the Suquia Repository seeks to promote a more informed and educated society by ensuring access to knowledge. As a result, it stands as a nationwide example of how institutions foster this type of initiative.

Regarding the third aspect, data communication, and storage infrastructure, the region has a tradition of archaeological publications and a growing interest in open-source systems to ensure open access to data. Institutional repositories and university-based journals using systems like PKP's Open Journal System, which follows the Diamond Open Access model (papers published, distributed, and preserved with no fees to either readers or authors), are the norm. Editorial and content quality are regulated through their inclusion in national and international indexes and databases.

These efforts align with the principles of FAIR and CARE, but from an academic perspective. In addition, local indigenous communities are still seeking collective identification and political re-articulation. Therefore, discussions regarding issues of data sovereignty and governance, as well as other ethical considerations in data management, are not immediate concerns. Especially when compared to historical requests for ancestral territories and the return of ancestors' remains.

In summary, Córdoba's academic archaeology is consciously or unconsciously moving towards the adoption of FAIR and CARE principles, but faces challenges such as site protection, improving chronologies, and implementing open-source systems for open data access. On the other hand, we have initiated dialogues with indigenous communities to listen to their perspectives on ethical concerns related to archaeological data. Peer data governance and digital data sovereignty are the challenges that academic communities, committed to open science and respecting both ethics and Indigenous knowledge, must address together with Indigenous peoples.

184. A FAIR-er Archaeological Archive? Experiments in Decolonial Intervention

*Anne H Chen (Bard College)**

Post-colonially-informed critiques of recent years have made clear early archaeology's problematic entanglements with colonialism. (1) Increasingly well-documented are downstream impacts of such entanglements, including cultural heritage ownership and data sovereignty debates, perspectival biases, archival silences, and inequities in physical accessibility of displaced collections. Less reflected upon, especially in Mediterranean archaeology, are the mechanics of persisting intellectual access limitations and the resultant perspectival-marginalizations that descend from colonial power imbalances at the time of excavation. This paper argues that the FAIR data movement in archaeology, and the development of inherently multilingual, lower-technical-barrier platforms like Wikidata, present opportunities for developing ethically-informed interventions in legacy archives related to Classical 'Big Digs' of the 19th and 20th centuries. It also reflects on what Mediterranean archaeologists might learn from the CARE principles and critical debates on the ethics of indigenous cultural heritage data management.

The paper draws on the work of the International (Digital) Dura-Europos Archive (IDEA), an ongoing project funded by the National Endowment for the Humanities.(2) It calls attention to important but little commented upon ripple effects (language of metadata/scholarship composition; site name bias; scholarship silos) that mark both the analog and digital archaeological information landscapes in the wake of blockbuster foreign-run excavations from the dawn of the discipline. Citing outreach work among local stakeholder communities, it explicitly ties those persistent biases to global inequities in access to certain kinds of knowledge. It then turns to reflecting on the utility of the FAIR-compliant and multilingual Wikidata platform for work across languages, disciplines, and borders toward active remediation of persisting inequities, biases, and entrenched hierarchies of knowledge of the sort that are often rooted in early archaeology. The paper closes with a final reflection on how Mediterraean archaeology might learn from the CARE principles for indigenous data.

References

1. Meskell, Lynn. 2020. "Imperialism, Internationalism, and Archaeology in the Un/Making of the Middle East." American Anthropologist 122 (3): 554–67. https://doi.org/10.1111/aman.13413.

2. www.duraeuroposarchive.org

182. Persistent Identifiers to Promote the Contextual Integrity of CAREfully FAIR Data in Archaeology

*Eric C Kansa (Open Context)**

Archaeologists generate vast amounts of data in the form of databases, media files, spreadsheets, GIS files, reports, articles, and other literature. Our colleagues have made tremendous strides to help our discipline cope with the preservation challenges and making sense of this information through developing vitally needed institutional repository services, semantic standards and technologies, and more recently, machine-learning and AI augmented workflows.

However, despite years of advocacy and data management investments, much archaeological information is still poorly curated, scattered, incompatible, and haphazardly preserved. Journal publications, books, and reports rarely cross reference digital data. Similarly, physical specimens curated and stored in various repository and museum collections often lack clear linkages to information in publications or digital datasets.

Thus, archaeological information is typically fragmentary and scattered piecemeal across many types of media, platforms, and institutional contexts. Not only does this siloing harm understanding, but it also undermines our capacity to achieve our ethical goals and obligations. For example, key information such as "was this vessel from a burial context?" that may inform curation, repatriation, or restitution requirements may be hidden away in some other disconnected information source.

Because of these needs, this paper explores information management strategies to reduce fragmentation of archaeological information. We present recent collaborations between Open Context and the larger iSamples project to develop persistent identifier services that support connections between physical specimens and information derived from those specimens. By maintaining associations between physical things, their provienance, their collection and documentation histories, and their use in research communications, these persistent IDs can promote better scientific (the FAIR principles) and ethical (the CARE principles) data management practices. By improving support of information provenance, we hope to better reflect and respect how archaeological information relates to communities and their norms, expectations, and interests.

57. Reimagining Archaeological Data Management Workflows through the Lens of Reuse

*Holly Wright (University of York)**

The Archaeology Data Service (ADS) is a CoreTrustSeal accredited archive for digital archaeological data, and a world leader in the development of best practice and standards development in this domain, but the advent of the FAIR Principles and their application by the ADS has led to changes in the way we think about how we manage our own data workflows. In particular, the idea that all four principles require equal engagement. While the ADS has worked hard to ensure the data we hold is Findable, Accessible and Interoperable, FAIR has shown us we need to better understand both how our data is Reused, and how to better engage with broader user communities to ensure we can respond to their needs.

The ADS is working to meet this challenge in a range of ways, but particularly through participation as partners in Transforming Data Reuse in Archaeology (TETRARCHs). This three year project, funded under the CHANSE ERA-NET Co-fund programme (which has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement no 101004509), is experimenting with new approaches to collecting archaeological data and using that data for storytelling in ways that are meaningful for diverse audiences. This experimentation is also looking at new approaches to how to better communicate the value of cultural heritage to people who may not see its value, and better support data creators in communicating the value of their work more directly, as a counterbalance to the ways this information is often misused both socially and politically.

To do so, TETRARCHs is creating new workflows for collecting and managing archaeology and heritage data. This includes examining how archaeological processes in the field, the lab and the archive can be changed to support storytelling with the data, and these workflows are being developed in partnership with an interdisciplinary team of archaeological specialists, data scientists and museum practitioners, alongside three key audiences: domain experts, creative practitioners, and memory institutions. TETRARCHs is experimenting with archaeological data collection at three different scales as well: landscapes, single sites, and individual objects, using four increasingly common technologies for data capture: airborne LiDAR, 3D scanning, digital field drawing and photography. Once the workflows are complete, TETRARCHs will test them by supporting people who work in creative fields to develop new stories and other imaginative works using archaeological data.

These new workflows have implications for how this data is managed by archives such as ADS. What changes would be necessary for our workflows to accommodate a much broader understanding of reuse, as defined and developed by the TETRARCHs Project? Do these workflows conflict with the way we must work in order to preserve our accreditation? What aspects could be easily incorporated into our workflows, and what aspects would require longer-term changes to our way of working? How do we balance the time and effort necessary to make these changes with the demands of a busy archive? How does engaging with a project like TETRARCHs help the ADS meet its mission? How replicable and useful are these changes across the archaeological data management domain? This paper will explore these questions and present the results of the ADS partnership in TETRARCHs thus far. It also represents an opportunity for CAA members to give feedback on the progress and direction of this work, as TETRARCHs moves towards its final year

19. When Paradata Becomes a Paradox? Limits and Extents of Process Pransparency in Archaeological Documentation

*Isto Huvila (Uppsala University)**

Studies of data documentation and reuse point to the need of documenting not only the whatness of data but also the processes and practices of how it came into being. Data can be truly open and FAIR only if it is known how it came into being, has been (re)shaped and used during its lifetime. Such process information is conventionally termed in archaeological literature as paradata (Huvila 2022). At the same time with underlining the need of more openness, there is extensive evidence in the literature of how radical transparency can also backfire and how it is frequently at odds with other equally central ethical and practical principles and legislation. The risk of unwelcome repercussions is especially apparent with paradata, which is often available in personal notes and commentaries and requires understanding and identifying actors who participated in data making and processing. A part of the problem is that as research shows, demands for exhaustive openness can paradoxically lead to reduced transparency when data creators and data creating communities feel necessary to mitigate actual and potential problems of increased disclosure. In the end, however, many of the typical objections against transparency do not necessarily imply that it needs to be abandoned as a goal but rather to consider what forms could be achievable and how (Elliott 2022).

This presentation discusses the limits and extents of process transparency drawing on on-going research in the research project CAPTURE (www.uu.se/en/research/capture). The findings point to that there can be, in different senses, problematic types of paradata and controversial kinds of openness and transparency depending on the frame of reference from which they are approached. Aligning the different views and landing on paradata that would be both FAIR'ful and CARE'ful might not be impossible but requires mitigation through architectural rather than disruptive forms of innovation (Henderson and Clark 1990) that seek to make not only paradata but its guiding principles interoperable with each other in both technical and social senses.

References

Elliott, Kevin C. 2022. "A Taxonomy of Transparency in Science." Canadian Journal of Philosophy 52 (3): 342–55. https://doi.org/10.1017/can.2020.21.

Henderson, Rebecca M., and Kim B. Clark. 1990. "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms." Administrative Science Quarterly 35 (1): 9–30. https://doi.org/10.2307/2393549.

Huvila, Isto. 2022. "Improving the Usefulness of Research Data with Better Paradata." Open Information Science 6 (1): 28–48. https://doi.org/10.1515/opis-2022-0129.

165. Moving from FAIR to CARE: Why Understanding Archaeological Data Reuse is Critical to Developing Ethical Practice

Kristy-Lee Seaton (University of York);*

What expectations do we have for the reuse of archaeological data? Several authors suggest there are few good examples of digital data reuse (Huggett 2018a; Faniel et al. 2018; Lodwick 2019b; Kansa, Kansa and Arbuckle 2014; Kansa and Kansa 2018; Cook et al. 2018; Garstki 2022), but what constitutes reuse? The EU has spent more than a decade investing in aggregating heritage data and making it more interoperable. However, there needs to be more investment in understanding if and how that data is being reused. As a result, the next challenge is how to maximise archaeological data for reuse (Richards et al. 2021). Saving European Archaeology from the Digital Dark Ages (SEADDA) was a recently completed EU-funded COST Action that explored different stages of the data management lifecycle with an aim to build capacity by sharing best practices. One of the SEADDA working groups looked specifically at the use and reuse of archaeological data and how it might be measured qualitatively. However, the lack of prior best practice work in this area meant they struggled to find a practical approach. The results were useful but primarily showed the amount of baseline work still needed to begin understanding the topic. This has led to more focused research using data held by the Archaeology Data Service (ADS), which demonstrated that archaeological data is being reused, just not in the way that we expected, and to reassess our expectations regarding data reuse and a better understanding of what constitutes good data reuse.

How should we address ethical issues related to data reuse? We first need to understand what data reuse looks like. Data deposition with the ADS is limited to UK-related archaeological research, geographically or through researcher affiliation. Therefore, it is understood that this research on data reuse is limited to a reasonably well-funded, Europe-focused research environment. But we have to start somewhere, and it needs to be from a place of understanding how we are actually reusing data, not just how we think it is being reused. This paper will present a comprehensive analysis of the available evidence of the reuse of archaeological data held by ADS, providing the quantitative data that has been lacking in the current critiques of our practice.

This evidence will include citation analysis using Digital Object Identifiers (DOIs) but will also go beyond this traditional form of understanding to find evidence of the reuse of ADS data in unpublished fieldwork reports (grey literature) and datasets which lack traditional citation. The results of this research will show how data is actually being used, which contradicts how reuse is perceived. With a solid understanding of what is happening with reuse, we can move from FAIR to CARE, and we can look critically at a narrow archive like ADS and begin the conversation about the ethics of what such an archive holds and how they operate.

References

Cook, K., Çakirlar, C., Goddard, T., DeMith, R.C., Wells, J. (2018). Teaching Open Science: Published Data and Digital Literacy in Archaeology Classrooms. Advances in Archaeological Practice, 6 (2), pp.144–156. [Online]. Available at: doi:10.1017/aap.2018.5.

Faniel, I. M., Austin, A., Kansa, E., Kansa, S.W., France, P., Jacobs, J., Boytner, R., Yakel, E. (2018). Beyond the Archive: Bridging Data Creation and Reuse in Archaeology. Advances in Archaeological Practice, 6 (2), pp.105–116. [Online]. Available at: doi:10.1017/aap.2018.2.

Garstki, K. (2022). Teaching for Data Reuse and Working toward Digital Literacy in Archaeology. Advances in Archaeological Practice, 10 (2), Cambridge University Press., pp.177–186. [Online]. Available at: doi:10.1017/aap.2022.3.

Huggett, J. (2018a). Reuse remix recycle: Repurposing archaeological digital data. Advances in Archaeological Practice, 6 (2), pp.93–104. [Online]. Available at: doi:10.1017/aap.2018.1.

Kansa, E. C., Kansa, S. W. and Arbuckle, B. (2014). Publishing and Pushing: Mixing Models for Communicating Research Data in Archaeology. International Journal of Digital Curation, 9 (1), pp.57–70. [Online]. Available at: doi:10.2218/ijdc.v9i1.301.

Kansa, S. W. and Kansa, E. C. (2018). Data beyond the archive in digital archaeology: an introduction to the special section. Advances in Archaeological Practice, 6 (02), pp.89–92. [Online]. Available at: doi:10.1017/aap.2018.7.

Lodwick, L. (2019). Sowing the seeds of future research: data sharing, citation and reuse in archaeobotany. Open Quaternary, 5 (7), pp.1–15. [Online]. Available at: doi:10.5334/oq.62.

Richards, J. D. et al. (2021). Digital Archiving in Archaeology: The State of the Art. Introduction. Internet Archaeology, (58), University of York. [Online]. Available at: doi:10.11141/ia.58.23.

177. Engaging with Practitioners: FAIR and CARE Training for Archaeologists and Cultural Heritage Professionals

*Leigh A Lieberman (Open Context)**

Although the curation, communication, and interpretation of research data have assumed greater prominence across the humanities and social sciences, these disciplines still lack adequate support and expertise to fully realize new opportunities afforded by data (Yakel et al. 2019). The problem is particularly acute in archaeology, a discipline that often relies on destructive research methods—namely excavation—and often requires the coordination and collaboration of data collection and analysis between researchers with very different disciplinary specializations (Faniel and Connaway 2018). Archaeological teams generally have little formal training in managing data, which can unfortunately lead to bespoke data creation, archiving, and sharing practices that make curation and reuse more difficult and expensive (Edwards et al. 2011; Kansa, S. W. et al. 2020).

Data management cannot be regarded as a simple compliance or technical issue. Data involve significant ethical concerns, including issues around cross-cultural intellectual property, protection of sensitive data, and equitable recognition of contributors, many of whom work in conditions of precarity or face structural discrimination in hyper-competitive academic contexts. For example, representatives of indigenous communities need self-determination and recognition in the governance of the data and media relevant to their histories and heritages. Similarly, although the disclosure of site location data can invite looting and vandalism, without carefully considered public information sharing, it can be difficult to mobilize and coordinate protection of historical landscapes (Kansa, E. C.

et al. 2018). Finally, new forms of digital scholarly communications can offer greater recognition for contributions of students, specialists, and other contributors in collaborative archaeological research projects. However, as demonstrated by some of the dysfunctions of social media (e.g.: trolling, doxing, gendered and racial abuse, etc.), exposure can be dangerous. Without editorial and administrative controls, online scholarship, including data sharing, can perversely reinforce structural inequalities.

For archaeological data to be meaningfully preserved and used in intellectually rigorous ways, they must be integrated into all aspects of archaeological practice, including ethics, publishing, outreach, and teaching. For this reason, The Alexandria Archive Institute/ Open Context (AAI/OC) leads several parallel professional development programs around data and digital literacy for archaeologists and cultural heritage professionals. This paper outlines two of these programs: Networking Archaeological Data and Communities, funded by the United States National Endowment for the Humanities; and Digging Up Data, designed in partnership with the American Society of Overseas Research. These programs notably target the growing number of early career researchers, faculty, librarians, support staff, and public archaeologists, both those who are members of and those who work with underserved communities. Because these kinds of practitioners often do not have access to critical training resources through their own institutions, The AAI/OC's programs aim to cultivate a more accessible network of colleagues and develop a more equitable cache of resources around archaeological data literacy. In this way, these programs provide mentorship and support so that participants can develop skills that are critically important for success in archaeology and the cultural heritage sector, ensuring that their efforts aim toward bridging FAIR and CARE from the very beginning of any research or resource management project.

References

Edwards, P. N., M. S. Mayernik, A. L. Batcheller, G. C. Bowker, and C. L. Borgman (2011) "Science friction: Data, metadata, and collaboration." Social Studies of Science, 41(5), 667–690. https://doi.org/10.1177/0306312711413314.

Faniel, I. M., and L. S. Connaway (2018) "Librarians' Perspectives on the Factors Influencing Research Data Management Programs."College & Research Libraries Journal, 79 (1). https://doi.org/10.5860/crl.79.1.100.

Kansa, E. C., S. W. Kansa, J. J. Wells, S. J. Yerka, K. N. Myers, R. C. DeMuth, T. G. Bissett, and D. G. Anderson (2018) The Digital Index of North American Archaeology: Networking Government Data to Navigate an Uncertain Future for the Past. Antiquity, 92(362), 490–506. https://doi.org/10.15184/aqy.2018.32.

Kansa, S. W., L. Atici, E. C. Kansa, and R. M. Meadow (2020) "Archaeological Analysis in the Information Age: Guidelines for Maximizing the Reach, Comprehensiveness, and Longevity of Data." Advances in Archaeological Practice, 8(1), 40–52. https://doi.org/10.1017/aap.2019.36.

Yakel, E., I. M. Faniel, and Z. J. Maiorana (2019) "Virtuous and vicious circles in the data life-cycle." Information Research, 24(2). http://informationr.net/ir/24-2/paper821.html.

137. Converting Geographic Facts into Geospatial Data: FAIR and CAREful Approaches to Creating and Disseminating Open Geodata in Western and Central Asian Archaeology

Michael T Fisher (Max Planck Institute of Geoanthropology); Bijan Rouhani (University of Oxford)*

Open-access geographical resources such as satellite imagery mosaic services now provide an unprecedented quantity and resolution of readily available information about the planet's natural and modified surface. Archaeologists can freely use these resources to remotely identify, assess, monitor, and analyze the remains of the past visible over nearly every region on Earth. While field-based research forces archaeologists to engage with local communities and adhere to national and international legal frameworks for scientific activity, digital methods such as satellite imagery interpretation allow researchers to bypass–wittingly or unwittingly–both of these standard barriers to unethical practices (1). Moreover, they enable exploitation of local landscape imagery for purposes potentially detrimental to the people who live there. Thus, it is imperative for archaeologists to adopt robust ethical frameworks such as the UN Declaration on the Rights of Indigenous Peoples (UNDRIP), independent from laws that may or may not govern remote-sensing activity over a given foreign nation.

The FAIR open-data standard (Findable, Accessible, Interoperable, & Reusable) provides conceptual guidance for technical sharing and sustainability of data. The CARE data principles (Collective benefit, Authority to control, Responsibility, & Ethics) go further to help researchers consider and balance the impact that their data collection and management practices have on indigenous communities and promote inclusive strategies. Implementing both, however, demands contextualization, cooperation, planning, and, sometimes, compromise. Transregional landscape investigations and other large-scale remote-sensing projects can create dilemmas in contextualization and therefore require even greater attention to CAREfully developing data structures, collection methods, and dissemination channels.

This paper examines the issue of GIS and data sovereignty from the perspectives of two different scalar contexts. It looks at the Endangered Archaeology in the Middle East & North Africa (EAMENA) project and the Mongolian Archaeology Project: Surveying the Steppes (MAPSS). Where EAMENA interprets open-access geographic resources such as Google Earth and other freely available satellite imagery in order to generate archaeological GIS data across twenty countries that span parts of two continents, MAPSS applies similar approaches but confines them within a single nation-state. By highlighting and comparing the challenges and solutions that arise within each project, this paper considers if a national- or transregional-scale is ethically preferable for Big Data remote-sensing in archaeology, and how developing an ethical framework based on guidelines such as UNDRIP and UNESCO's Recommendation on the Ethics of Artificial Intelligence (2) might apply differently according to each project's scope.

While EAMENA realizes the challenges of a transregional approach when multiple nations are involved, each with independently developed data needs, MAPSS highlights both the benefits of and limitations imposed by working within modern national boundaries. Potential for instances of local misgiving exists at both scales, yet can manifest differently. 'Classical Humanitarian' creeds such as 'do no harm' are important touchstones; however, when conducting research in multiple heterogeneous regions comprising highly variable communities, simple but important questions arise such as 'to whom?', as different groups may benefit or suffer from the same methods. This issue can apply across or within national boundaries, and so we argue that adopting clearly defined theoretical principles can form an ethical baseline for remote-sensing archaeological investigation, regardless of scale and context. In order to build a conceptual underpinning, we draw on postcolonial theory, particularly Symmetrical Archaeology (3), and Resilience Humanitarianism, as means for interpreting the integration of FAIR and CARE principles for the praxis of archaeological GIS at different scales in Western and Central Asia.

References

[1] Fisher, M.T., Fradley, M. Flohr, P. Rouhani, B. & Simi. F. 2021. "Ethical considerations for remote sensing and open data in relation to the endangered archaeology in the Middle East and North Africa project". Archaeological Prospection,

28, 279-292.

[2] UNESCO Recommendation on the Ethics of Artificial Intelligence. 2021. https://www.unesco.org/en/articles/recommendation-ethics-artificial-intelligence

[3] Shanks, M. 2007. Symmetrical Archaeology. World Archaeology 39(4), 589-596.

121. Advancing FAIR and CARE Practices Across Networked Communities

Sarah Kansa (Open Context); Melissa Cradic (Open Context)*

Context

This paper presents two current projects concerned with advancing FAIR and CARE practices in cultural heritage, both of which are run under the auspices of Alexandria Archive Institute/Open Context. The first is “Past Global Change Research Coordination Network”, part of the FAIR Open Science initiative of the National Science Foundation (USA). This interdisciplinary network brings together archaeologists, cultural heritage and museum professionals, and paleoecologists. The second, “Advancing FAIR+CARE in Cultural Heritage,” is a National Leadership Grant supported by the Institute of Museum and Library Sciences (USA) which networks a broad cohort of archaeologists across domains of cultural heritage, academic research, museums, and Tribal Preservation Officers.

These projects aim to reconcile the apparent social and technical contradictions between CARE (highly contextual, socially embedded) and FAIR (fungible, open) principles in archaeology, cultural heritage, and biodiversity communities. The FAIR (Findable, Accessible, Interoperable, and Reusable) Data Principles (Wilkinson et al. 2016) codify fundamental requirements for data intended to serve public needs in science and government. While the FAIR principles focus on eliminating barriers to open data, the CARE (Collective benefit, Authority to control, Responsibility, and Ethics) Principles for Indigenous Data Governance (Carroll et al. 2020) emphasize the need to respect complex social and cultural needs and expectations around data documenting the histories, landscapes, and cultures of Indigenous and other descendant communities. These projects research and develop data management practices to navigate these two very different visions for data.

Both projects leverage networks of diverse participants to devise tangible outcomes to expand awareness of FAIR and CARE practices and encourage their adoption. By providing clear ethical good practice guidance and digital data governance models integrating FAIR and CARE practices, these projects aim to improve the overall quantity and quality of reusable data while reducing risks of harm and encouraging meaningful participation and benefits-sharing with Indigenous nations and other descendant communities.

Argument

Digital data collected at enormous expense are continually, rapidly, and permanently being lost due to hardware failures, media degradation, software obsolescence, and inadequate documentation. Much of what is not yet lost, is not discoverable or accessible and will ultimately be lost unless data governance practices change dramatically. This problem is not new, but tragically, it is not noticeably improving—to the detriment of research, public education, and cultural heritage conservation. We will discuss how these two projects are working to change this discouraging trajectory by developing protocols, data governance processes, and good practice guidance to implement FAIR and CARE data governance principles together within the discipline of archaeology and cultural heritage, as well as on an interdisciplinary level across biodiversity practitioners.

These projects bring together networks of individuals to help develop, disseminate, and promote ethical good practice guidance and digital data governance models integrating FAIR and CARE practices. We will discuss some of the opportunities and challenges in working with diverse network participants, who bring different perspectives and needs around data access.

Implications

By integrating FAIR and CARE across a variety of domains of archaeological and heritage practice and between various disciplines, these projects highlight that excellence in data curation is not, and cannot be, a program to alienate digital data from stakeholders solely for the benefit of narrow technocratic interests. Open Science and Open Government practices that promote excellence and transparency can and should be adapted to support continued inclusion of stakeholder perspectives and interests in cultural heritage data. By demonstrating how FAIR and CARE practices work synergistically, these projects highlight how data curation and reuse is not only relevant but central to the ethical conduct of research, instruction, and communication.

References:

Carroll, S.R., I. Garba, O.L. Figueroa-Rodríguez, J. Holbrook, R. Lovett, S. Materechera, M. Parsons, K. Raseroka, D. Rodriguez-Lonebear, R. Rowe, R. Sara, J.D. Walker, J. Anderson, and M. Hudson

2020 The CARE Principles for Indigenous Data Governance. Data Science Journal 19(1): 43. DOI: http://doi.org/10.5334/dsj-2020-043

Wilkinson, M., M. Dumontier, I. Aalbersberg, et al. 2016 The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data 3, 160018. https://doi.org/10.1038/sdata.2016.18

178. Indigenous Data Sovereignty: A Critical Consideration of UNDRIP's Implications for Canadian Archaeology

*Lindsay M Montgomery (University of Toronto)**

The United Nations Declaration of the Rights of Indigenous Peoples (UNDRIP), originally signed in 2007, has received increasing attention within academic and public policy spheres over the past five years. For instance, in April of 2021, the Society for American Archaeology (SAA) passed a motion (147-38.6D) asserting the Board of Directors support for UNDRIP. The SAA's commitment to UNDRIP reflects the professional organizations' broader efforts since 2020 to decolonize the profession and prioritize social justice, equity, and diversity. Two months later, UNDRIP received Royal Assent within Canada's parliament, compelling the federal government to create an action plan to address systemic racism and historic injustices in consultation with First Nations, Métis, and Inuit peoples. This newly acquired legal weight is part of the Canadian government's response to the recommendations of the 2015 Truth and Reconciliation Commission's 94 Calls to Action and the Missing and Murdered Indigenous Women and Girls Calls for Justice report in 2017. In adopting UNDRIP, professional organizations and nation-states agree to recognize the inherent sovereignty of Indigenous peoples and their right to self-determination over their territories and resources as well as the right to free, prior, and informed consent on matters related to Indigenous life and lands.

Within UNDRIP there are several articles that pertain specifically to archaeological praxis, including Article 8.1 (freedom from forced assimilation), Article 11.1 (right to protect and develop cultural traditions), Article 12.1 (right to religious traditions and ceremonies), and Article 31.1 (the right to control, protect, and develop cultural heritage including biocultural remains) (UNDRIP Act: 10-13). These articles position Indigenous peoples as the primary rights holders over archaeological sites and cultural landscapes as well as the traditional knowledge associated with these places. This repositioning of First Nations, Métis, and Inuit communities vis-a-vie archaeological and historical sites will entail a significant shift in current models of ethical praxis like those laid by the Society for American Archaeology (SAA 1996). UNDRIP, particularly Articles 11.1 and 31.1, requires archaeologists to acknowledge Indigenous place-based authority by following "co-stewardship" (McAnany et al. 2022: 16) or "clientage" models (Blakley 2020: S191) of heritage management which create an ethical obligation to listen and comply with the expressed interests and goals of Indigenous communities. However, as the abstract for this session contends, there remains a significant gap between the spirit of UNDRIP and operationalizing these principles within ongoing settler colonial contexts, like Canada. In dialogue with emerging discussions around the implementation of UNDRIP in North America, this paper considers how institutional practices within Canadian cultural heritage management currently constrain Indigenous sovereignty and rights.

The first case study examines current archaeological labeling practices in the province of Ontario, which provides only two possible designations for sites, "Aboriginal" and "Euro-Canadian". These reporting structures reinforce a binary distinction between pre-European contact "Aboriginal" places and post-contact "Euro-Candian" settlements. As a result of these database categories, Indigenous occupations during the nineteenth and early twentieth century are systematically under-represented in the ministerial database, and Tribal communities are rarely asked to consult on these sites (Beaudin 2016). In creating the false impression that Indigenous occupation ended with the coalescence of the Canadian nation-state in 1867, such reporting practices and database structures significantly undermined Indigenous rights to control and protect their cultural patrimony.

The second case study explores how permitting procedures within Ontario maintain the privileged position of primarily non-Indigenous archaeologists in the documentation and management of First Nations, Métis, and Inuit sites and landscapes. Current practices undermine Indigenous sovereignty in three ways: (1) by maintaining the Ministry's control over who is eligible to conduct archaeological research on Indigenous cultural remains, (2) by creating a reporting obligation to the provincial government rather than Tribal Nations, and (3) by designating the license holder as the primary steward of all artifacts and associated records produced through fieldwork. These structures are in direct contradiction to the right of free, prior, and informed consent under UNDRIP and significantly impinge on the ability of Native communities to exercise control over their cultural heritage and knowledge derived from its study. Ultimately, through an examination of archaeological databases and policy practices, I identify pathways through which archaeologists working in Canada as well as more globally might actualize the principles of UNDRIP both in spirit and in practice.

References:

Beaudoin, Matthew A. 2016. Archaeologists Colonizing Canada: The Effects of Unquestioned Categories. Archaeologies 12 (1): 7-37.

Blakely, Michael L. 2020. Archaeology under the Blinding Light of Race Current Anthropology 61 (22): S141-S339.

McAnany, Patricia A., George Nicholas, Dorothy Lippert, Michael Wilcox, Larry J. Zimmerman, Lindsay M. Montgomery, Randall McGuire, Patricia Ayala Rocabado, Margaret Conkey, and Chip Colwell. 2022. Reading the Fine Print: What You Should Know About UNDRIP. The SAA

Archaeological Record: 14-17.

Society for American Archaeology. 1996. Principles of Archaeological Ethics. https://www.saa.org/career-practice/ethics-in-professional-archaeology

United Nations Declaration on the Rights of Indigenous Peoples. Resolution adopted by the General Assembly on 13 September 2007. Sixty-First Session, Supplement No. 53 (A/61/53), part one, chap. III, sect. A.

S23: Advances in Computational Archaeology

Thursday 11th April, 10:20–14:20, 260-073 OGGB4

Lisa Fischer
Jeffrey Glover

Do you have a computational archaeology topic or project to present outside of the scope of one of the existing sessions? Are you engaged in cutting-edge research on geophysics, data management, visualization techniques, semantic web, or another digital archaeology topic that you would like to share? This general session is open to standard papers and posters that may not be a perfect match for any of the current topical sessions. Papers accepted into this session for the final program will be grouped thematically, as practical, to create related blocks of papers.

For the ease of the review process, please select the most closely related topical session as your primary choice when uploading in the CMT submission system. Then you may mark "Advances in Computational Archaeology" as the secondary option if you feel that your paper may not be a strong fit for the primary one chosen.

S23: Advances in Computational Archaeology	
10:20-10:40	*44. Analysis of Sensory Impression Factor Structures of Jomon Kaen Potteries through a Semantic Differential Method Experiment Utilizing 3D Models on Microsoft HoloLens* *Haruhiro Fujita (Niigata University of International and Information Studies)*; Toru Miyao (Niigata Prefectural Historical Museum); Simon Kaner (University of East Anglia); Hiroyuki Sasaki (Niigata University of International and Information Studies); Yew Kuwang Hooi (University of Technology Petronas)*
10:40-11:00	*155. Reconstructing Regional Geographic Variations in the Rate of the Bantu Expansion* *Alexes Mes (University of Cambridge)**
11:00-11:20	*70. The Relationship between Mandibular Morphology, Population History and Diet in the Mesolithic–Neolithic Transition in Westernmost Iberia* *Ricardo Miguel Godinho (ICArEHB)**
11:20-11:40	*103. Modelling the Cognitive Effect of Material Culture in Periods of Demographic Changes* *Lizzie Scholtus (Christian Albrecht Universität zu Kiel)*; Bruno Vindrola (Christian Albrecht Universität zu Kiel)*
11:40-12:00	*159. Repeated Names among Judahite “Private” Jar-handle Impressions: A Quantitative Approach* *Eythan Levy (Bern University)**

155. Reconstructing Regional Geographic Variations in the Rate of the Bantu Expansion

*Alexes Mes (University of Cambridge)**

In just a few thousand years, Bantu languages proliferated over more than 9 million square kilometers to become the largest language group in Africa today. Major economic and cultural changes took place across sub-Saharan Africa during this time, with the dispersal associated with a 'bantu cultural package' consisting – wholly, or in part, at various times – of a more sedentary lifestyle, thick-walled pottery, iron metallurgy, cattle-keeping and crop cultivation.

Behind all large-scale human dispersals, such as the spread of the Neolithic in Europe, lies a body of literature seeking to categorise this movement as demic migration vs. acculturation. The same debate surrounding the Bantu expansion sees supporters predominately for demic diffusion, cultural diffusion, or combinations thereof. In addition, there is support for the hypothesis that in the later stages of the Bantu spread, language and farming dispersed simultaneously through a demic expansion. Framing dispersal debates in this way is not always helpful. It rigorously restricts to only two ways of movement: the migration of the social group as a self-contained entity, or the borrowing of ideas by local populations without any population admixture. The reality in any human migration is far more complex: the units of migration (individuals, families, communities), as well as the localised tempo and direction of dispersal shifted frequently. Agency for social action needs to be afforded to both the incumbents in a given area and the migrants – both having an equal ability to be influenced by the other to adopt appropriate cultural traits [Robb and Miracle].

It is the localised migration dynamics that this paper aims to examine through the archaeological record: understanding the Bantu expansion as a series of regional and complex movements, focusing on variations in the tempo of dispersal and arrival times of Bantu-speaking people within smaller geographic areas. This is done in a Bayesian framework: calculating regional arrival times using hierarchical phase models and movement rates using Gaussian Process Quantile Regression (GPQR) and Automatic Relevance Determination (ARD).

Regression analyses have a long history in archaeology: beginning with the pioneering work of Edmonson in the 1960s who used the earliest occurrences of pottery, copper and maize to determine the rate of diffusion of neolithic conditions globally. The idea was built on by Ammerman and Cavalli-Sforza in 1971, who used a linear regression on 14C dates to determine the rate of the neolithic expansion in Europe. Subsequently, mathematical models have been proposed to analyse archaeological transitions and classify the driving mode behind spreads. The calculated rate from regression analyses on radiocarbon dates is compared to predicted rates determined from either a demic diffusion model or cultural diffusion model, from which the calculated spread is classified as being driven by one of these mechanisms. From this point, there have been several refinements to mathematically model archaeological transitions. However, there are major limitations to these types of analyses: (i) the analysis is dependent on the spatial scale, how one selects local sample sizes and defines a nominated origin (from which the distance and there from speed is calculated), (ii) the method uses mean calibrated dates and does not take measurement uncertainty into account, (iii) typically the use of linear regression yields single dispersal rates, which dramatically gener alises movement dynamics. The method can be adapted but it remains difficult to determine if the variations in calculated dispersal rates are genuine and not caused by measurement uncertainty, calibration error, or sample size.

In the first part of this paper, I calculate the dispersal rate of the Bantu spread using a Bayesian quantile re gression, which mitigates some of the limitations facing ordinary linear regression. Focusing on the 90th and 99th percentiles is used to specifically examine the distribution of the earliest arrival dates. Using MCMC sampling, a Gaussian process adaption which allows for localised variation in the dispersal rate is explored. Here the parameter which controls the extent of the spatial autocorrelation between two sites is based purely on great-arc distances. There are, however, other factors which influence how sites are related to other another, and distance can be extended to include ecological, as well as geographical, measures. Automatic Relevance Determination [Williams and Rasmussen], a method which hasn't yet been widely applied in Archaeology, provides this framework and is implemented here for the Bantu case study. Computational intensity, and how this can restrict approaches to large archaeological datasets is briefly discussed.

The second part of this paper focuses on hierarchical phase modeling. While perhaps not having as long established a history as regression-based analyses in archaeology, Bayesian phase model analyses of radiocarbon dates have been used in several different studies: typically in stratigraphic contexts to accurately and precisely chronologically delineate cultural phases, estimate the arrival of cultural traits or crops, or to model migration arrival times. A core advantage of Bayesian phase models is that they are able to take measurement uncertainty into account when determining estimated arrival times. Limitations include: (i) the calculations are sensitive to how the spatial regions are defined, and (ii) uneven sampling leads to some sites contributing multiple dates and the interdependence of these dates biases the arrival time estimation.

The arrival times of the Bantu in geographic regions are examined using a Bayesian phase model, where a hierarchical structure is introduced to account for the bias introduced by sample interdependence. This frame work is then built on by considering if and how certain factors – such as temperature, rainfall, geography and river-networks – resulted in varied frictions to the Bantu dispersal and quantifying to what extent these potential drivers explain the observed differences in the dispersal process. In terms of our case-study, one example of these potential drivers could be rainfall-induced environmental changes: either Bantu speakers made use of the drier corridors through the rainforest at ~ 4000BP and ~ 2500BP (which eventually merged into the Sangha River Interval) and the unfamiliar habitats encountered altered the route and pace of dispersal; or the Bantu people initially migrated through the interior of the rainforest before the drier conditions were in effect (~ 4400BP), proving they overcame – rather than were directed by – ecological conditions [Koile et al.].

The results from these two approaches are presented in order to build a more detailed description of the localised dynamics of the Bantu expansion. Throughout, biases which influence the data – such as uneven spatial and temporal sampling density – are acknowledged and measurement uncertainty (the error on the calibration curve and the sample's 14C age error) is accounted for in all models.

References

Koile, E., et al. "Phylogeographic analysis of the Bantu language expansion supports a rainforest route". Proceed ings of the National Academy of Sciences 119, no. 32 (Aug. 2022).

Robb, John, and Preston Miracle. "Beyond migration versus acculturation: new models for the spread of agricul ture". In Proceedings-British Academy, 144:99. Oxford University Press Inc., 2007.

Williams, C.I., and C.E. Rasmussen. Gaussian processes for machine learning. Vol. 2. 3. MIT press Cambridge, MA, 2006.

159. Repeated Names among Judahite “Private” Jar-handle Impressions: A Quantitative Approach

*Eythan Levy (Bern University)**

This paper deals with repeated names among the so-called Judahite “private” jar-handle impressions, a widely distributed type of stamps attested on jar handles found all over Judah (southern Levant) in the Iron IIB period (8th century BCE) (Vaughn 1999: 81-167). These stamps usually bear a personal name followed by a patronym. Over 80 years ago, David Diringer noted that this corpus contains an unusually large amount of repeated names, and concluded that “it is quite possible, if not very probable, that the same family is concerned”, a family he interpreted as “a species of “dynasty” of potters” (Diringer 1941: 89). Since then, this pattern of repeated name has never been studied in depth by other researchers.

Yet, this is exactly the kind of problem that lends itself to a quantitative analysis. We propose a statistical approach to this problem based on three steps: (1) we define three metrics to quantify the phenomenon of repeated names, (2) we compare the value of these metrics in our corpus and in a contemporary corpus of names and patronyms occurring on stamp seals and bullae (clay sealings), (3) we show that, with a high probability, the pattern of repeated names among the stamped handles cannot be due to mere chance.

We then examine the corpus more in depth, to characterize the precise pattern of repeated names. We show that most of the repetitions are due to pairs of names occurring as a personal name on one stamp, and as a patronym on another stamp. We show that the statistical significance of this pattern is extremely high, and conclude that it most probably points to genealogical relations between the stamp bearers, thus vindicating Diringer’s informal intuitions in quantitative way. We also propose an updated genealogical tree of the stamp bearers.

Our analysis is based on a simple random sampling procedure implemented in the Python programming language. This study opens the way for further future analyses of names occurring on stamps (in the southern Levant or elsewhere) in order to better assess the relations between a set of persons mentioned in a given epigraphic corpus.

References:

Diringer, David (1941). On Ancient Hebrew Inscriptions Discovered at Tell ed-Duweir (Lachisch). Palestine Exploration Quarterly 73: 38–56, 89–109

Vaughn, Andrew G. (1999). Theology, History, and Archaeology in the Chronicler’s Account of Hezekiah. Atlanta, GA: Scholars Press

44. Analysis of Sensory Impression Factor Structures of Jomon Kaen Potteries through a Semantic Differential Method Experiment Utilizing 3D Models on Microsoft HoloLens

Haruhiro Fujita (Niigata University of International and Information Studies); Toru Miyao (Niigata Prefectural Historical Museum); Simon Kaner (University of East Anglia); Hiroyuki Sasaki (Niigata University of International and Information Studies); Yew Kuwang Hooi (University of Technology Petronas)*

Archaeologist and anthropologist Kobayashi Tatsuo (1996) suggested spatial cognitive differences between Jomon people and modern people. He proposed a house as a “rather holy container space,” perceived as such by the

Jomon people [1].

Ishii (2010) proposed anthropological hypotheses regarding the spatial recognition of ancient Jomon people, defining cultural space during the Jomon period. He made comprehensive improvements to a hypothesis by Kobayashi Tatsuo on the spatial cognition of Jomon people. Ishii focused on the "container nature" of space and studied the structure of spatial recognition and the symbolism of human-made spaces in the Jomon period, including "houses," "villages," and "monuments," as well as earthenware spaces [2].

In the further development of the hypotheses mentioned above, Ishii suggested that Jomon potteries represent micro spaces reflecting the sensibilities and sensory impressions of pottery makers. The authors conducted an experimental survey involving the viewing of local doll 3D models using Microsoft HoloLens, focusing on the interests and impressions of those experienced with the "virtual museum" [3]. In modern times, some Jomon pottery is perceived as formative art crafts, microcosms rather than archaeological artifacts, by museum visitors. Therefore, it is of interest to study the sensory impressions of modern people on Jomon pottery, including Kaen types.

3D modeling of Jomon potteries and Sue wares was conducted using an optical scanner (Creaform, Go!SCAN 3D) with VXelements software, and OBJ files were exported. Then, the Blender CG software was used to resize the 3D models for transport to Microsoft HoloLens.

An experiment on the sensory impressions of nine potteries, including the Kaen and close types, was conducted using the Semantic Differential Method. Sixteen adjectives were measured with 73 testers, and the results were analyzed through Factor Analysis and Analysis of Variance.

The 16 adjectives were as follows:

- Beautiful - Ugly
- Pleasant -Unpleasant
- Likable - Repugnant
- Light - Heavy
- Cheerful - Gloomy
- Lively - Quiet
- Dynamic - Static
- Gay - Sober
- Excited - Calm
- Soft - Hard
- Strong - Weak
- Soft - Hard
- Smooth - Rough
- Blunt - Sharp
- Relaxed - Tense
- Delicate - Rugged

Each adjective was assigned a five-scale selection, ranging from "very applicable" to "strong non-applicable." A Google Forms site was created as a questionnaire input interface for the testers.

The results showed that two Tochikura and one Umataka (Kaen) pottery had significantly higher scores for the first factor of "activity" and the second factor of "good-looking" than other Jomon potteries and the Sue ware. On the contrary, the third factor, "surface smoothness," of these two Tochikura and one Umataka (Kaen) pottery showed significantly lower scores than others. The scores of these nine potteries exhibited symmetric patterns between the first factor of "activity" and the third factor of "surface smoothness." The study provided basic evidence of sensory impression characteristics for Tochikura and Umataka (Kaen) potteries, which are chronologically and geographically close; they showed significant sensory impressions of stronger "activity" and "good-looking," and higher "surface roughness."

References

[1] Kobayashi Tatsuo. 1996. “The World of the Jomon People.” Asahi Sosho. Asahi Newspaper.

[2] Ishii Takumi. 2010. “Spatial Recognition and Manufacturing in the Jomon Period.” Research Bulletin of Kokugakuin Traditional Culture Research Center, Vol. 2, 59-70.

[3] Fujita Haruhiro, Kubota Kazuyuki, and Kawano Kazutaka. 2018. “Demonstrative Experiments of Local Doll Hologram Displays by Microsoft HoloLens - For the Virtual Museum.” Tofu-Seisei, Bulletin of Kyushu National Museum, 2017, Vol. 13, 47-62.

100. Estimating Carrying Capacity Across Time and Cultures: A Diachronic Approach

*Laurenz Hillmann (ROOTS)**

The characteristics of demographic development within historical societies have long been a subject of debate, often attributed to either environmental or social factors. This talk introduces a new project that will investigate a novel approach to estimating carrying capacity (CC) on a large scale and compare it to the subsequent change within archaeological cultures. It will employ a diachronic perspective covering the period from 10,000 B.C.E to 1000 A.C.E across Europe and parts of Asia. The primary objective is to construct a comprehensive database by integrating environmental and archaeological proxy data, which will serve as the foundation for creating a raster-based CC map. This map will facilitate a quantitative analysis of the interplay between CC and variations among archaeological cultures. The geographic scope of this research extends from Western and Central Europe to the Russian border, encompassing the Middle East, Turkey, and the Fertile Crescent region.

Carrying capacity, initially introduced by Thomas Malthus in (1798), posits that population growth is constrained by available food resources, ultimately reaching a state of equilibrium. Among others, the concept has also been further developed by Ester Boserup, with population pressure as one of the driving forces within community development (Boserup 1975). In archaeology, CC gained traction during the era of New Archaeology in the 1970s and ‘80s. However, it soon became apparent that ecological and demographic theories and methods did not seamlessly translate to archaeological contexts, leading some scholars to question the utility of the concept (Hayden 1975). With the advent of digital tools such as GIS, SRTM, R, and expanded datasets related to soil fertility, climate, and precipitation, the concept of CC has experienced a revival. Several small- and regional-scale studies utilizing multi-proxy data have been conducted, shedding light on the concept’s theoretical implications in various scientific projects, even those not explicitly focused on CC. However, available research has been fragmented, limited to specific periods and locations, and challenging to relate to one another. However, the concept of CC offers a promising avenue for understanding the complex interplay between environmental and societal influences on human development.

As the project is in its initial stages, we would like to shift the attention towards the fundamental aspects that are essential. This includes the possibility of different datasets and types, as well as different approaches to modelling the possible CC. The aim of this research is to collect and synthesize a wide variety of information, combining environmental with archaeological data, such as site distributions, C14 dates, and subsistence strategies, to examine CC over time. An optimal balance between complexity and interpretability must be found by careful consideration of methods, proxies, and variables. In conclusion, this talk aims to initiate a dialogue on potential directions and potential challenges in the study of CC within archaeological contexts. The emphasis is placed on seeking feedback and collaboration to advance this approach further.

References

Boserup, Ester. 1975. “The Impact of Population Growth on Agricultural Output.” Q. J. Econ. 89 (2): 257–70. https://doi.org/10.2307/1884430.

Hayden, Brian. 1975. “The Carrying Capacity Dilemma: An Alternate Approach.” Mem. Soc. Am. Archaeol. 30:11–21. https://doi.org/10.1017/S0081130000003737.

Malthus, Thomas Robert. 1798. An Essay on the Principle of Population: As It Affects the Future Improvement of Society with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers. London.

103. Modelling the Cognitive Effect of Material Culture in Periods of Demographic Changes

Lizzie Scholtus (Christian Albrecht Universität zu Kiel); Bruno Vindrola (Christian Albrecht Universität zu Kiel)*

Underwater environments contain a wealth of cultural heritage that is inaccessible to most scholars and public due to difficult access conditions. The harsh marine environment accelerates decay and cultural heritage digital preservation helps maintains the link with our material history. Digital preservation in underwater contexts is hard – light attenuation due to refraction and reflection of the dense water environment prevent faithful portrayal of underwater objects and is constrained by depth. Photogrammetric 3D model reconstruction of underwater artefacts from 2D images by traditional techniques leads to suboptimal results sometimes due to variable turbidity of the water rich in particles and plankton.

Here, we investigate how to reconstruct faithful photogrammetric models of underwater heritage from images suffering multiple degradations (poor visibility, lack of contrast and colour shift), made possible thanks to recent advances in computer vision. We present a workflow combining state of the art techniques for constructing photorealistic 3D models of colour-corrected underwater artefacts.

We present a workflow starting with a pre-processing step for the colour correction of images, followed by the reconstruction of the dense point cloud of the scene. A 3D rasterisation based on gaussian splatting then leads to realistic visual rendering of submerged wrecks. The modular separation of the pre-processing step provides flexibility with respect to the target environments enhancing the information entropy of the obtained images to produce high-quality dense point cloud reconstructions of historical wrecks (WWII era planes) submerged at different depths and in waters of vastly diverse turbidity in the Pacific.

70. The Relationship between Mandibular Morphology, Population History and Diet in the Mesolithic–Neolithic Transition in Westernmost Iberia

*Ricardo Miguel Godinho (ICArEHB)**

Introduction

The agro-pastoralist mode of subsistence was first developed in the near-east at ~10000 years before the common era (BCE). This transition from hunting-gathering to farming and animal husbandry involved profound social, cultural and economic changes that impacted, e.g., settlement strategies, material culture and diet. This, in turn, also impacted the health and morphology of the populations involved, as demonstrated in multiple previous studies focusing on diverse regions that transitioned from one mode of subsistence to the other. Indeed, changes in diet in the Iberian Peninsula have been documented using, e.g., stable isotopes and dental wear. Moreover, aDNA studies have also shown that this transition in Iberia involved meaningful changes in population structure that mainly reflect replacement of previously existing local Mesolithic populations by incoming migrating groups (despite some level of admixture) that reached Iberia via the northern Mediterranean by no later than 5500 BCE. Considering such changes in diet and population history, it is expectable that this transition involved significant changes in mandibular morphology because it responds to both factors. Nevertheless, this topic has not been explored adequately yet. Considering the relationship between mandible form and these two variables, we hypothesize that Iberian Mesolithic and southern Levantine Chalcolithic specimens are significantly different from each other and also from the other groups, and that post-Mesolithic Iberian specimens are morphologically intermediate between the two previous extreme groups.

Materials and Methods

We sampled 100+ mandibles from the Iberian Mesolithic to the Chalcolithic, and from the Chalcolithic southern Levant. Including the latter specimens allows examining the relationship between Iberians and the populations from the region where agro-pastoralism first originated. To examine the relationship between mandibular form and other variables of interest we used a combination of conventional and virtual anthropology methods. Specifically, standard palaeobiological data was collected first, including dental wear magnitude according to the ordinal scale of B. H. Smith (1984). Specimens were then digitized using Computer Tomography (CT) or surface scanning. This allowed ensuing virtual reconstruction of fragmented and/or incomplete specimens and then morphological analyses using Geometric Morphometrics (GM). We then used several statistical approaches to assess if there are significant differences between groups and if hypothetical morphological differences are related most likely to population history or diet.

Results

Iberian Mesolithic and southern Levant Chalcolithic populations are significantly different in shape (but not in size) from every group. Iberian post Mesolithic groups are significantly different from the two previous extreme groups but not among one another (again, in shape but not in size). When examining the first two Principal Components (PCs), we find that Mesolithic Iberians appear morphologically more gracile than Chalcolithic Levantines and that post-Mesolithic Iberians are morphologically intermediate between the two previous extreme groups. Dental wear was most severe in the Iberian Mesolithic, followed by the southern Levantine Chalcolithic and then the Iberian Neolithic – Chalcolithic samples. Little relationship was found between dental wear magnitude and mandibular shape.

Discussion

Our results, showing significant differences between Mesolithic Iberians, Chalcolithic Levantines and post-Mesolithic groups (but not among post-Mesolithic Iberians, which are morphologically intermediate between the two extreme previous groups), are consistent with aDNA studies showing that the Mesolithic-Neolithic transition in Iberia involved population replacement (and some degree of population admixture). Further, despite heavier wear, Mesolithic Iberians appear more gracile than Chalcolithic Levantines (and also post-Mesolithic Iberians). This, together with the little relationship found between mandibular shape and dental wear, suggests the Iberian mandibular morphological changes arising in the transition from Mesolithic foraging to Neolithic – Chalcolithic agro-pastoralism were mainly driven by population history and possibly, but to a lesser extent, by feeding mechanics.

43. Image Restorations of Sundial-shaped stones of Oyu Stone Circle Site by CycleGANs

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The Oyu Stone Circles were constructed at a ritual site on a terrace along the Oyu River in Kazuno City, Akita, Japan, around 2000 B.C. The Oyu Stone Circles consist of two stone circles, namely Manza and Nonakado. These circles are comprised of arrangements of river stones, forming a double ring, each with a sundial-shaped stone arrangement.

The ritual site was first discovered in 1931, and excavation surveys were conducted in 1951 and 1952. It was designated as a national special historic site in 1956 and registered as a World Heritage site in 2021.

In contrast to the stone circles at the nearby Isedotai ritual site in Kitaakita City, approximately 40 km west of the Oyu Stone Circles, where the monuments were constructed using a variety of stones from various types of mother rocks, the Oyu Stone Circles were formed by selectively using a specific rock type. The primary material (more than 60%) is quartz diorite [1], sourced from the middle streams of the Oyu River and the Akutani River, a tributary of the Oyu River.

Most of the stones in the Oyu Stone Circles, including the sundial-shaped stones, were exposed to sunlight and rain after excavation. learning. CycleGANs guarantee that swapped colors and textures can be reverted back to the original colors and textures, rather than just style conversions found in other GANs. Since we have obtained research results indicating that CycleGANs are particularly effective for faded objects, we attempted to apply them to weathered stone artifacts as well.

Thus, CycleGANs were applied to represent the original color and textures of the sundial-shaped stones while preserving the geometries of the original stone surfaces. The CycleGANs transfer river stone color and textures onto weathered stone images, as well as transfer the weathered stone color and textures onto the river stone images.

Apart from the Adversarial Loss function, which is the primary algorithm of the Generative Adversarial Network (GAN), the CycleGANs have two Cycle Loss functions, as well as the Identical Loss function, to ensure that the transformed images revert back to the original images[2].

A total of 14 trials were conducted by modifying the learning rates of the generators and discriminators of CycleGANs, as shown in Table 1. The restoration results were evaluated by analyzing the loss curves of the two generators and discriminators, as well as visually identifying differences in color and textures.

The combination of 5.0E-03 for the generators and 1.0E-03 for the discriminators resulted in the best restoration in terms of loss curve convergence (see Loss curves) and visual identification (see Figure outputs and D1.0E-03_G5.0E-03). This was observed in the experiment “oyu_cyclegan_test_run_12” in Table 1, which utilized river stone images with two background colors: beige and white.

The issue remains that there is no direct evidence indicating whether the combination of background colors in river stone images had a direct effect on the restoration or not. This is

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Most of the stones in the Oyu Stone Circles, including the sundial-shaped stones, were exposed to sunlight and rain after excavation. The upper surfaces and the northern directional faces have suffered from black biological damage, making it difficult to identify their original color and textures.

The archaeological significance of restoring the color and texture of the Oyu's sundial-shaped stones is to examine the possibility that the Jomon people in Oyu had a specific color and texture preference. This is achieved by representing the original color and textures of the mother rocks of those weathered sundial-shaped stones using a deep learning methodology.

The research team succeeded in restoring images of faded cultural properties, such as gold sutras on dark blue papers, using CycleGANs (Cycle Generative Adversarial Networks), a type of deep learning. CycleGANs guarantee that swapped colors and textures can be reverted back to the original colors and textures, rather than just style conversions found in other GANs. Since we have obtained research results indicating that CycleGANs are particularly effective for faded objects, we attempted to apply them to weathered stone artifacts as well.

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The issue remains that there is no direct evidence indicating whether the combination of background colors in river stone images had a direct effect on the restoration or not. This is a common challenge in explaining results using generative models.

References

[1] Yukio Fujimoto, 2021. “Earth Science of the Jomon Stone Circles Distributed in Northern Akita Prefecture, Northeast Japan”. Proceedings of the Geological Society of Japan 128th Academic Conference. T5-O-1.

[2] Jakub Langr and Vladimir Bok, 2019. “GANs in Action: Deep Learning with Generative Adversarial Networks”. Chapter 9, CycleGAN.

Python Codes

The Python source code for CycleGANs was referenced as follows:

https://github.com/junyanz/pytorch-CycleGAN-and-pix2pix

The analyses were conducted using a modified Python code as follows:

https://github.com/arch-inform-kaken-group/pytorch-CycleGAN-with-Hydra-and-MLflow