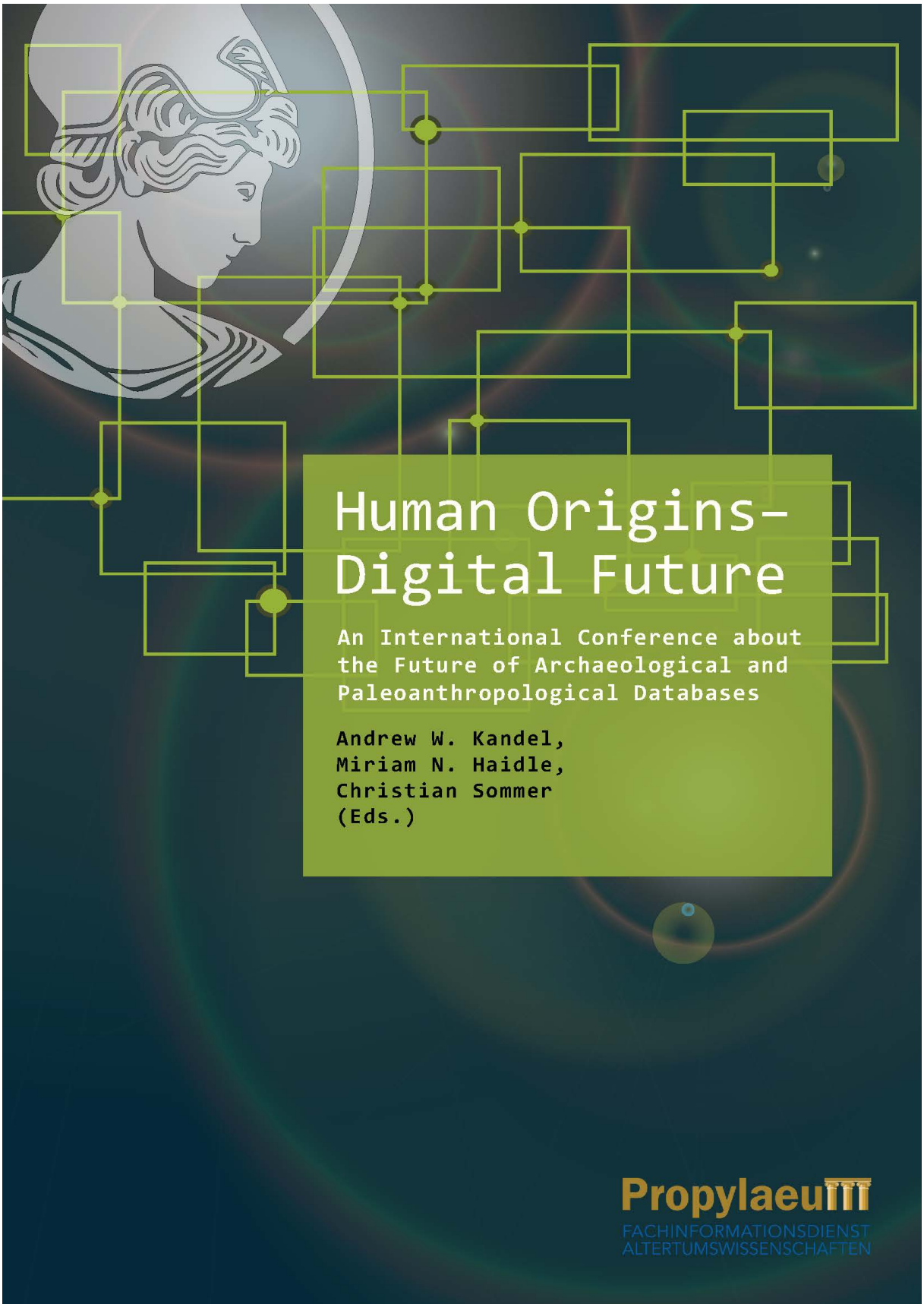

Human Origins–Digital Future

An International Conference about the Future of Archaeological and Paleoanthropological Databases

Andrew W. Kandel,
Miriam N. Haidle,
Christian Sommer
(Eds.)

Propylaeum
FACHINFORMATIONSDIENST ALTERTUMSWISSENSCHAFTEN

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ROCEEH Perspectives 1

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THE ROLE OF CULTURE IN EARLY EXPANSIONS OF HUMANS

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TÜBINGEN

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Miriam N. Haidle

Christian Sommer

VOLUME ABSTRACT

Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases

Editors
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Keywords: big data, databases, FAIR principles, archaeology, paleoanthropology

This eBook presents the proceedings of an online conference entitled, "Human Origins – Digital Future" which took place from 27-31 July 2020. The main aim of the conference was to discuss integrative aspects and approaches for developing, using and securing large scientific databases in the future, specifically in the context of archaeological and paleoanthropological research. The conference focused on how databases with novel information technology can be used to gain new knowledge by linking, retrieving and analyzing archaeological, paleoanthropological, paleobiological and geographical information. In addition to addressing fundamental questions of digitization and open science, the conference examined approaches using innovative methods. Given the digital nature of the conference, we designed the format of this publication to employ multimedia and interactive features. Therefore, this volume brings together the abstracts of the talks, each containing a link that allows the reader to view the video as presented at the conference. In addition, the volume closes with a round-table discussion that can be accessed through links to interviews about selected topics related to the future of databases.

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A. W. Kandel, M. N. Haidle, & C. Sommer (2022*). Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (p. 2). Propylaeum, Heidelberg.
DOI: https://doi.org/10.11588/propylaeum.882.c13429

PREFACE

Volker Hochschild

PREFACE

Volker Hochschild

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The Role of Culture in Early Expansions of Humans (ROCEEH), Heidelberg Academy of Sciences and Humanities, Hölderlinstr. 12, 72074 Tübingen, Germany

This digital publication brings together presentations held at the Human Origins – Digital Future (HODiF 2020) conference, which was organized by The Role of Culture in Early Expansions of Humans (ROCEEH) under the sponsorship of the Heidelberg Academy of Sciences and Humanities. With teams in Frankfurt and Tübingen, this long-term project has created a comprehensive database containing information about archaeology, paleoanthropology, paleontology, paleobotany and paleogeography to study the prehistory of the hominins who migrated out of Africa into Eurasia. We call our web-based tool the ROCEEH Out of Africa Database (ROAD). Originally, we planned the HODiF 2020 conference to take place at the Senckenberg Research Institute in Frankfurt from 27–31 July 2020, but had to transform the event into an online format because of the CoVID-19 pandemic. Although we were at first unsure about the digital format, the conference turned out to be a success; the interpersonal contact it fostered during the pandemic was greatly appreciated. We scheduled the conference for two hours each weekday during the Middle European afternoons, enabling participants from as far as Japan and the USA to join at convenient times.

Today, challenges for all databases include the increasing amount of digital data available, web-based accessibility, the ability to maintain data beyond the period of project funding, and long-term storage. For these reasons, we split the conference into sessions about Databases, Methods, Applications, Products and Perspectives. I will not list examples of the papers given here, but instead focus on the major outcomes we gained from the conference. There was overall agreement about the importance of implementing the FAIR principles, which state that data should be findable, accessible, interoperable and reusable. In addition to the ROAD archaeological database there are numerous globally recognized examples of archaeological, paleontological and paleoecological databases and search portals such as ARIADNEplus, NEOTOMA, NQMDB, PaleoCore, Throughput, and many more. These databases face similar problems of uncertainty in their future concerning longevity and ontologies. From a methodological perspective, reverse engineering, data mining and machine learning approaches showed their tremendous potential for applications in archaeology. Finally, the "linked open data" approach seemed to be one of the most promising future directions in terms of finding and facilitating shared access to archaeological data.

Hochschild, V. (2022). Preface. In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (pp. 4-5). Propylaeum, Heidelberg. DOI: https://doi.org/10.11588/propylaeum.882.c13430

Another major success of the conference was the strengthening of collaborations. In addition to further bilateral meetings, I hope that ROCEEH will organize a follow-up conference so we can all meet in person in the future. Sadly, Eric Grimm from the University of Minnesota passed away during the preparation of this edition, so we keep him in our memory. Finally, I would like to thank Maria Malina for the faultless technical support during the week, Miriam Haidle for summarizing the results daily in Mind Maps, as well as Angela Bruch, Christine Hertler, Claudia Groth, Zara Kanaeva, Andrew Kandel, Christian Sommer and Michael Bolus for session chairing and organization.

I hope you will enjoy hearing these papers covering a wide range of very interesting topics.

Volker Hochschild

July 2022

INTRODUCTION

Miriam N. Haidle

Andrew W. Kandel

Christian Sommer

Mind Map – CONFERENCE OVERVIEW

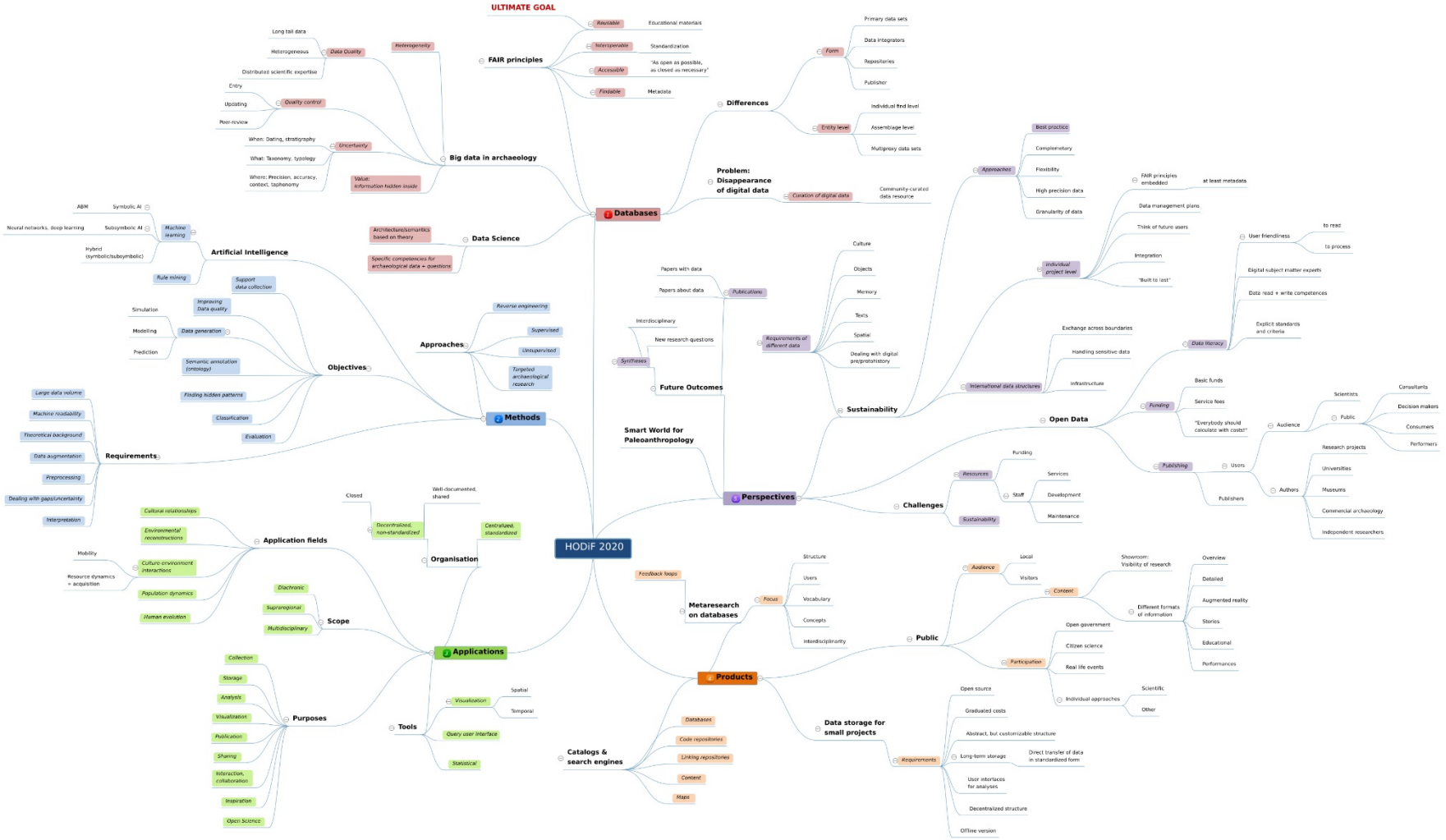

Figure 1: Mind-map drawn using the collaboration platform Nextcloud showing the results of all five sessions: Databases, Methods, Applications, Products and Perspectives, each day in a different color. The Mind-map of each session is presented in greater detail at the beginning of each chapter (see Figs. 2-6).

INTRODUCTION

Overview of the Conference: Human Origins – Digital Future

Andrew W. Kandel[1], Miriam N. Haidle[2] & Christian Sommer[1,3]

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This volume presents the results of the conference, "Human Origins – Digital Future", organized by The Role of Culture in Early Expansions of Humans (ROCEEH), and examines current trends in the dynamic field of data management and research. The main aim of the conference was to discuss integrative aspects and approaches for developing, using, and securing large scientific databases in the future, specifically in the context of archaeological and paleoanthropological research. The conference focused on how databases with novel information technology can be used to gain new knowledge by linking, retrieving, and analyzing archaeological, paleoanthropological, paleobiological and geographical information. In addition to addressing fundamental questions of digitalization and open science, the conference examined approaches using innovative methods.

Due to the COVID-19 pandemic, the conference took place virtually over one week as a series of short, mainly prerecorded talks and interviews, daily summaries, and discussions (Haidle et al. 2020). To document the lectures and secure the results for an interdisciplinary public, we decided to present the proceedings of this event in a multi-media format.

The chapters in this volume follow the overall structure of the conference, which was organized into five main sessions about Databases, Methods, Applications, Products and Perspectives. Each chapter starts with a Mind Map created with the productivity platform Nextcloud. The first Mind Map outlines the entire conference (Fig. 1), while the Mind Maps in the following chapters (Figs. 2–6) summarize the main ideas presented in the individual sessions. Each session began with a recap of the previous day presented by Miriam Haidle using the Mind Maps as guides. As a result, those who could not attend the previous day could quickly review the essence of the talks. We hope you will also find these graphics insightful.

Within the five main chapters, the authors present their abstracts with keywords and references. Yet, it is the videos of the talks themselves which represent the heart of this volume. They provide a flavor of the broad spectrum of ideas presented. We hope you will enjoy watching and learning from them, and perhaps you will be inspired.

Kandel, A. W., Haidle, M. N., & Sommer, C. (2022). Introduction. In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (pp. 9-15). Propylaeum, Heidelberg. DOI: https://doi.org/10.11588/propylaeum.882.c13431.

Since the beginning of the discipline, the science of archaeology has dealt with vast amounts and diverse types of data, which are in turn connected to other datasets. Examples include the three-dimensional location of a find within a site, the stratigraphical association with other finds, catalogs of similar finds or decoration styles from a specific period and area, to name only a few. The associations of data are used for relative dating, interpreting technologies, functions, and numerous other processes, understanding distributions within and between communities, connections, and thresholds. With growing inclusion of additional scientific studies such as botanical and faunal analyses, absolute dating, geoarchaeological and, increasingly, genetic analyses, the amount and diversity of data has expanded enormously. The potential of digital databases in gathering and combining information has given an additional push to the propensity of archaeologists to acquire ever more data.

Thus, databases have become ubiquitous in archaeology. They range from a few variables to huge datasets, from simple lists to complex relational databases; they can comprise one artifact category of a layer at a site, or cover numerous types spanning millions of years and several continents. Every project works with at least one database. Data compilation takes a large segment of a researcher's time. Nonetheless, data are often treated as bucket finds, or even as backdirt. Unlike the more sexy finds, data are nothing to show off and thus receive limited care. At the end of a project, most of the data collected, including even newly created records, vanishes within inaccessible storage mediums and locked files, or through outdated program standards. Despite the widespread use of data, many questions remain unresolved about the development and growth of databases in archaeology, their analytical function, interoperability, and sustainability.

Databases

The first chapter highlights differences among prehistoric databases, which are heterogeneous with regard to data quality, degree of quality control, and frequency of maintenance. Uncertainties such as the imprecision of data concerning chronology, spatial location, and terminology, all impede our ability to interconnect. Databases differ in their level of granularity. Digital data tend to have a short lifespan because projects end, and the software they use may be proprietary or become outdated. Networking problems can hinder the implementation of comprehensive, large-scale evaluations and syntheses, which belong in the realm of Big Data. Following the FAIR principles – Findable, Accessible, Interoperable and Reusable – can help researchers to overcome these issues. The establishment of "prehistoric data science" is another necessary foundation to integrate elements of computer science with subject-specific competencies for archaeological, paleoanthropological, and environmental themes, among others. This makes sense because the architecture and semantics of a database are based on theoretical assumptions and specific questions arising within a scientific discipline.

The session begins with **Eric Grimm & John W. Williams** who introduce a community-curated data resource, the NEOTOMA Paleoecology Database. Based on a centralized IT-platform, shared standards, ontology and terminology, NEOTOMA provides a long-term and low-cost archive for paleobiological data and allows users to analyze multi-proxy data.

In contrast, **Andrew Kandel & the ROCEEH Team** present the ROCEEH Out of Africa Database (ROAD), which represents an integrator of multidisciplinary data about human evolution managed by one group. The talk details the different levels of decisions and actions taken to create, maintain, and implement such a diverse database as ROAD.

Franco Niccolucci describes ARIADNEplus as an example of an infrastructure that offers a very broad overview. ARIADNE provides access to archaeological datasets from excavation reports and assemblages of finds through research databases, for example, from the Archaeological Data Service (ADS) or ROAD. While he stresses the variety and diversity of archaeological data contained in ARIADNE, it can still cause problems in the application of techniques making use of Big Data. In the future, he suggests developing a specific data-centric research methodology for archaeology. **Christopher Nicholson** focuses on the Digital Archaeological Record (tDAR) as another large online repository of archaeological data, serving as a digital curator of data. Digitization can at least partially help overcome the destruction caused by excavation, but the application of the FAIR principles is necessary to hinder the fading of digital resources. Finally, **Jesús Rodríguez** highlights how different levels of uncertainty can be a major problem for archaeological and paleontological databases such as the Neogene-Quaternary Mammals Database (NQMDB). Although the collection of data seems like a neutral process, theory-driven decisions have to be made to create the architecture and semantics required of a database.

Methods

Chapter II focuses on methods which are applied to databases that make a dataset more valuable by deriving knowledge from raw information. Quantitative methods are useful in the whole workflow from data collection, quality assessment, linking databases to the analysis and interpretation of data. **Juan A. Barceló** presents the concept of reverse engineering, which aims to understand the functionality and genesis of an object by reconstructing it. Applied to archaeology, this makes it possible to reconstruct the social actions of earlier societies on the basis of the archaeological record. With the help of several examples, he points out that this reconstruction goes beyond the pure 3D recording of objects, but that human behavior can be described by functional analysis and mathematical models. **Christian Sommer** refers to quantitative methods resulting from the availability of archaeological Big Data, such as the ROAD database. Using two methods from the field of machine learning, he illustrates how the boundaries of the human niche can be inferred from site distributions and environmental data. Furthermore, he shows how the functional relationships between lithic tools can be explored using a frequent pattern algorithm borrowed from the online marketing industry.

Alice J. Williams demonstrates how targeted agent-based models can be applied to real-world archaeological data to test conceptual models. In her example, she discusses Carneiro's circumscription theory, on the basis of which she simulates the formation of social complexity within the context of geographic barriers. This approach allows her not only to highlight research gaps, but also to facilitate debates rooted in profound and logical scenarios, even where data are missing. **Christian Willmes** draws attention to how geodata can facilitate the analysis of human-environment interaction. He describes how paleo-geospatial data can be made available to the public through a web platform and web services, and how these data can be exploited through GIS analyses to provide insights into the interface between humans

and the environment. Finally, he highlights the PaleoMaps concept, a framework designed to overcome the lack of interoperability of heterogeneous scientific data and enable broad exchange.

Applications

In the third chapter, we examine the ways in which research databases are currently used by archaeologists, paleoanthropologists and paleoclimate scientists. Such applications are varied and often connected with other tools, such as Geographic Information Systems (GIS) and Agent Based Models (ABM), to extract further information from existing datasets. These papers examine new considerations for databases, with several focused specifically on ROAD, while others consider paleoenvironmental data, questions about human behavior, and population dynamics.

Some of the speakers look at how archaeologists develop and use databases for different purposes. **Ewa Dutkiewicz** presents examples of databases of Paleolithic art. While these databases attempt to provide a structure for data that were previously considered unstructurable, such data are difficult to quantify digitally. She speaks about her own database, SignBase which details geometric signs on mobile objects and mentions an international project which catalogs representations of animals in European parietal and mobile art. **Shannon McPherron** asks whether a decentralized, non-standardized approach to data sharing in archaeology serves us well. He notes how methodologies in data collection and analysis have often been individualized in the past. However, new technologies for data collection and sharing may overcome some previous limitations. In the end, he argues that a variety of methods and techniques allows for a more robust understanding of the past. **Denné Reed** presents a database called Paleo Core, a platform for integrating data in paleoanthropology. Paleo Core hosts almost a dozen active research projects and includes details about more than 85,000 specimens. This integrative data management system promotes digital workflows from the start of a project up through the curation of the artifacts in museum collections.

Several talks focus on the varied uses of ROCEEH's own database, ROAD. **Rimtautas Dapschauskas & the ROCEEH Team** introduce a study that examined questions about the large-scale development of cultural behavior in human evolution. Using ROAD, his team conducted analyses of assemblages containing the red pigment ochre in Africa during the Middle Stone Age. They determined that ochre use accelerates across Africa and becomes habitual starting about 140,000 years ago. **Christine Hertler & the ROCEEH Team** discuss the development of an application in ROAD called the MapModule. This integrated GIS allows registered users to visualize the distribution of archaeological, human, faunal and plant finds stored in ROAD and also connects to external databases which contain further details about paleoecology and mammals (e.g., NEOTOMA and NQMDB). The user can also use different map backgrounds (e.g. sea level, glaciation, vegetation, biome, temperature, precipitation, and others.)

Ericson Hölzchen & the ROCEEH Team detail their experiments in simulating Neanderthal mobility (NeMo) in a virtual environment using data from ROAD in ABMs. Their models can be used to compare differences in mobility patterns between regions, quantify differences in mobility patterns during different climatic events, or differentiate subsistence strategies and raw material procurement. **Zara Kanaeva & the ROCEEH Team** demonstrate the usefulness of a new tool, the ROAD Summary Data Sheet. These PDFs can be generated automatically for any locality stored in ROAD and provide details about the site, its location, stratigraphy, dating and assemblages as well as its bibliography. Such a summary is useful for the general public interested in learning more about our human heritage and scientists who want to get an overview on the find assemblages of specific sites.

Some speakers discuss how to integrate paleoenvironmental data into questions about human behavior and population dynamics. **Ana Mateos** and her team examine the trophic resources available to humans during a warm period, MIS 11, in Europe. Using variables such as net primary productivity and ungulate carrying capacity as proxies for the abundance of plant and animal resources, they match the presence of sites with paleoenvironment to better frame the requirements established by human paleoecology. **Mika Puspaningrum** and her team aim to reconstruct the topography, hydrology, climatic patterns, and vegetation cover of the Eastern part of Java, including Sangiran, about one million years ago. They use ABM to reconstruct a background model and simulate how hominins behaved and interacted with their environment. **Manuel Will** and his team explore the evolution of human brain and body size during the Pleistocene using paleoenvironmental and paleoanthropological datasets within a quantitative statistical framework. They determine that temperature predicts body size across all human taxa – likely a direct effect of climate on human physiology. On the other hand, net primary productivity and long-term variability in mean annual precipitation work well to predict brain size in archaic hominins, but not modern humans. Multiple interacting causal mechanisms likely underlie the evolution of these key biological characteristics of humans. **Andreas Zimmermann & Isabell Schmidt** study prehistoric population dynamics and presented the geostatistical upscaling procedure named the "Cologne Protocol" which provides a consistent approach to estimate population size and density. By interpolating between estimates with a logistic equation, they model long-term population dynamics across many cultural periods in Europe. Future directions include extending the spatial dimension using regression analysis and expanding the temporal framework in conjunction with data stored in ROAD to model site distribution.

Products

The fourth chapter surveys products from and for databases. Products are aimed to reach a range of stakeholders, from field archaeologists and interdisciplinary research teams to the general public. Products include catalogs and search engines, linking of code, repositories and even researchers, as well as the communication of results. External, centralized storage options represent an important product, especially relevant for smaller projects. To provide a long-term perspective, open source approaches and standardized structures are fundamental, while the development of user interfaces for analysis is desirable. Finally, research focusing on databases and their use can in turn serve as a product, which may act retroactively on a database itself.

Wolfgang Börner introduces Wien Kulturgut as part of a digital platform for open government. It integrates data from five governmental departments to provide information on architecture, town history, art works in public space, historical maps, and archaeology. With an internet and an intranet version it aims at decision-makers as well as the local public and even tourists. The METAhub project at Frankfurt presented by **Liane Giemsch & Tanja Neumann** connects material remains in museums with performance art using digital formats. A content hub provides open information to the interested public; a planned immersive app will enrich localities with augmented reality; and discursive events such as the participative discovery of collections integrate the urban community as active partners.

Yasuhisa Kondo reports about interdisciplinary challenges and in-project action research in the Cultural History of PaleoAsia project. A meta-analysis of the database revealed distinctions in terminology and working habits between the disciplines involved. Pointing to differences in working cultures, such an approach is the foundation of efforts for more interdisciplinarity. Introducing Spacialist, **Matthias Lang & colleagues** retrace the development of a virtual open-source research environment for humanities with a strong spatial component. They show the possibilities of such an endeavor especially for small projects as well as the pitfalls such as underestimated costs and workload.

Perspectives

Chapter V ventures into the future of archaeological databases. In four interviews, influential people in scientific database management share their thoughts on the future development of databases and report the lessons learned. Viewed together, they paint a picture of diverse, interconnected databases that integrate varied stakeholders from the public, private, and scientific sectors and are openly and permanently available. However, they also address the current challenges, such as funding and institutionalization, which still need to be resolved. **Sarah Whitcher Kansa** informs about Open Context, a data publishing platform where archaeological objects can be registered with high granularity following the principle “one URL per pot sherd.” The service accompanies the data of authors on its way from digitization and the creation of metadata, to annotation and publication as linked data in a permanent repository. In addition, users receive advice on important but not necessarily popular topics such as data preparation and digital ownership. **Peter McKeague** calls for the development of a unified Spatial Data Infrastructure based on existing national and international geodata standards, similar to the European Commission’s INSPIRE Directive – and extending them with thematic conventions from the field of archaeology. Such a data structure allows transnational data exchange, also via already existing geodata portals, and helps make data sustainably usable and save them from fossilization.

Julian Richards provides insight into what made the Archaeology Data Service one of the most influential data providers: The Open Archival Information System as a structural basis; free accessibility of the data for everyone; and finally, free and expert advice to keep the level of data quality high. For future development, he counts on the collaboration of like-minded people to advance the FAIR principles and establish a global network of research data.

Dieta Svoboda-Baas of the Heidelberg Academy of Sciences and Humanities reports from the perspective of a research institution that supports the life cycle of data in new projects in all aspects, conceptually, structurally and financially. However, she also talks about the challenge of catching up with the preservation of digital data in existing projects, some of which have been running for many decades. She sees the future in overcoming isolated solutions through standardization and mentions the German National Research Data Infrastructure (NFDI) as a possible solution.

Closing remarks

Finally, in three appendices, we provide links to databases and other resources discussed during the conference, and list of the speakers and registered participants of the conference. In summary, we hope that this digital book helps to keep your memories of the conference alive. It was a challenge to conduct the event online during the beginning of the pandemic, but we felt it was a rewarding experience for all those involved. We greatly appreciate the interaction we had with all of our colleagues in attendance, and thank everyone for the lively discussions that ensued. We again draw your attention to a review of the conference published shortly thereafter (Haidle et al. 2020).

ACKNOWLEDGMENT

ROCEEH is located at the Senckenberg Research Institute in Frankfurt and the University of Tübingen. This long-term research project is promoted by the Joint Science Conference of the Federal Government and the state governments of the Federal Republic of Germany within the framework of the Academies' Programme. Funding comes from the Federal Ministry of Education, Science and Research and the states of Baden-Wurttemberg (Ministry of Science, Research and the Arts) and Hesse (Ministry of Science and the Arts). With additional support from the *Senckenberg Gesellschaft für Naturforschung*, the conference "Human Origins – Digital Future" took place online from July 27–31, 2020 with 113 registered participants from 19 countries ranging from the Far East to the American West. Invited researchers presented their findings in English in a series of 15 lectures, 11 poster presentations and four interviews. We are grateful to all contributors to the conference as well as to the Propylaeum team of the Heidelberg University Publishing that made this innovative publication possible.

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Haidle, M.N., Bolus, M., Bruch, A.A., Hertler, C., Hochschild, V., Kanaeva, Z., Sommer, C., Kandel, A.W. (2020). Human Origins – Digital Future, an International Conference about the Future of Archaeological and Paleoanthropological Databases. *Evolutionary Anthropology, 29*, 289–292. https://pubmed.ncbi.nlm.nih.gov/33179353/

CHAPTER I

Session 1

DATABASES

Chair: Volker Hochschild

Eric Grimm

Andrew W. Kandel

Franco Niccolucci

Christopher Nicholson

Jesús Rodríguez

Mind Map – DATABASES

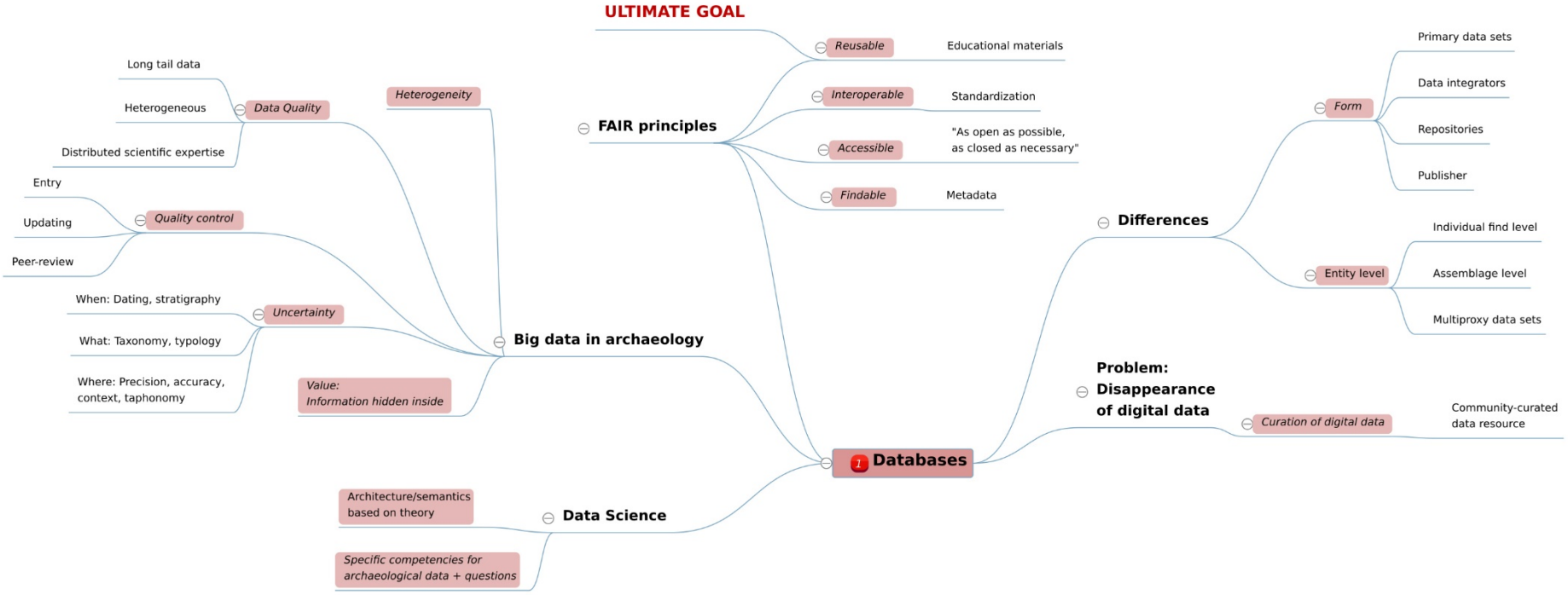

Figure 2: Mind map of session 1 - Databases. Issues included the problem of the disappearance of data, differences in data formats, general questions about how to integrate with the data sciences, the use of big data in archaeology, and how to apply the FAIR principles with the ultimate goal of making data reusable.

The Neotoma Paleoecology Database: Shared Standards, Community Curation, and Active Reanalysis of Paleo Data

Eric C. Grimm[1] & John W. Williams[2]

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In Memoriam

Very sadly, Eric Grimm passed away as we were working on this volume. Therefore, we are unable to include his video in this publication. From the early days of ROCEEH, Eric played a crucial role in developing a steady connection between the Neotoma Paleobiology Database and ROAD. With the implementation of APIs connecting Neotoma and the ROAD Map Module, a link was established which enables ROAD users to connect directly to the paleobiological and archaeological data of Neotoma. We are and always will be grateful for Eric's generous support and will remember him as an exceptionally helpful and kind person. We also add a few links to articles that speak of his life's work and hope you will read these remembrances in his honor:

https://www.tandfonline.com/doi/full/10.1080/01916122.2020.1870281

https://link.springer.com/article/10.1007/s00334-021-00828-z

https://epdweblog.org/2020/11/17/passing-of-eric-grimm/

https://ecologyofthepast.info/2020/11/16/eric-grimm-rip/

https://www.amqua.org/in-memory-of-eric-grimm.html

Keywords: Databases, paleoecology, paleobotany, paleoflora, paleofauna

The Neotoma Paleoecology Database is a community-curated data resource that supports interdisciplinary paleoenvironmental and global change research. Neotoma standardizes data structure and metadata across different data types, which facilitates common tool development and lowers data management costs. Neotoma makes paleoecological data openly available and offers a high-quality, curated resource.

Neotoma comprises virtual constituent databases for different types of data or for different regions. The constituent databases appoint data stewards, who are trained to validate and upload data and to help ensure high quality and completeness of data and metadata.

Grimm, E. C., & Williams, J. W. (2022). The Neotoma Paleoecology Database: Shared Standards, Community Curation, and Active Reanalysis of Paleo Data. In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (pp. 19-20). Propylaeum, Heidelberg. DOI: https://doi.org/10.11588/propylaeum.882.c13706

Neotoma is living database that can be corrected or updated with additional data or metadata. Thus, two aspects of data curation are (1) initial validation and upload and (2) continued data maintenance. Other than correcting errors in original data submissions, examples of data updates include addition of new radiocarbon dates or new age models, which may be based on new radiocarbon dates, new radiocarbon calibration curves, or new age modeling techniques. An important example of new radiocarbon dates are the many new AMS dates that have been obtained on purified collagen from vertebrate specimens already in Neotoma. Various research projects have added many new age models developed with Bayesian methods or with other methods that provide estimates of the error in interpolated ages. Neotoma attempts to store sufficient metadata to replicate these age models.

Neotoma's distributed scientific governance model is flexible and scalable, with many open pathways for participation by new members, data contributors, stewards, and research communities. The Neotoma data model supports, or can be extended to support, any kind of paleoecological or paleoenvironmental data from sedimentary archives.

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A Beginner's Guide to the ROCEEH Out of Africa Database

Andrew W. Kandel & the ROCEEH Team

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Watch the Video

Keywords: databases, big data, digital heritage, archaeology, paleoanthropology

In 2009, ROCEEH began integrating archaeological, paleoanthropological, paleontological and paleobotanical information into the ROCEEH Out of Africa Database (ROAD). As of June 2020, the team has compiled information on more than 1800 localities in Africa and Eurasia. ROAD now contains over 11,000 assemblages dated between about three million and 20,000 years before present. In this talk, I will present some of the achievements that ROAD has made over the last 12 years. In keeping with the framework of this conference, I refer each point to one of the five sessions of the conference, namely S1 (Databases), S2 (Methods), S3 (Applications), S4 (Products), and S5 (Perspectives). In some cases, I draw attention to other members of ROCEEH who will present further details about our work during the conference.

One of ROAD's main functions is to preserve our human past as a resource for digital heritage in the future (Perspectives). It also serves as an educational tool in prehistory and the Quaternary sciences (Products). As part of our outreach, we sponsor workshops to acquaint users directly with the database and its many functions (Products). Furthermore, ROAD is a research tool with which a user can explore ideas and formulate hypotheses about human migration (Applications). Outputs from ROAD can be further tested using advanced techniques such as agent-based modeling (E. Hölzchen–Applications) and machine learning (C. Sommer–Methods).

While this talk provides a brief overview of the basic logical structure and semantics of ROAD (Databases), it will focus mainly on what the database can do. I will mention the benefits ROAD offers its users, such as querying data, visualizing results with the Map Module (C. Hertler–Applications), and conducting time series analysis with the Time Slice Tool (Methods). I will introduce the Summary Data Sheet, which provides an overview of each locality entered in ROAD (Z. Kanaeva–Applications) and show how data and maps from other large databases can be linked to ROAD. I will also discuss some ongoing research projects which collaborate using the data from ROAD (Applications). In sum, I hope to demonstrate how this database works as a powerful tool for researchers and the public alike.

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A Data-Centric Archaeological Research Methodology: Opportunities and Risks

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Watch the Video

Keywords: ARIADNEplus, archaeological data sharing, big data in archaeology, grand challenges, semantics

It is nowadays commonplace to consider the use and re-use of digital data as one of the pillars of archaeological research. The deposit of research data and the creation of aggregators such as ARIADNEplus in Europe and tDAR in the USA make available and searchable online very large catalogues of archaeological datasets – the former has now reached about two million items. Large thematic databases, also available on-line, as ROAD on human evolution with its more than 10,000 records, provide rich information on specific domains. Nevertheless, the information provided by these sources is still human-readable only, after a machine-made selection based on criteria defined by humans. The temptation of using more sophisticated technology is strong, but it must be cautiously analyzed. Counting the data made available by such sources adds up to big numbers, but it is uncertain if they may be considered Big Data. Some argue that the blind application of Big Data techniques such as artificial intelligence or deep learning, so effective in many other fields, may lead to unpredictable and possibly misleading results when applied to archaeological data. On this regard there are enthusiastic but uncritical supporters as well as scholars expressing doubts that are not completely unjustified.

The lecture will discuss with examples why analyzing the impact of digital data on the archaeological research methodology cannot be avoided or further postponed, and which are the concerns that at present still limit an effective use of advanced digital technology to automatically process, extract and combine them to produce new knowledge, mostly based on machine actions where humans intervene only to use the results. This will hopefully pave the way to a critical and informed use of technology which is the foundation for a data-centric archaeological research methodology.

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Niccolucci, F. (2022). A Data-centric Archaeological Research Methodology: Opportunities and Risks. In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (p. 22). Propylaeum, Heidelberg.
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Challenges of Archiving Complex Archaeological Datasets for Reuse: An Example from the American Southwest

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Watch the Video

Keywords: digital archaeology, digital repositories, FAIR principles, Mimbres pottery, American Southwest

As datasets are "born digital" in both field and lab settings, archaeologists need to learn more about, and implement, plans for how their information will be 1) stored and cataloged in databases for analysis, 2) archived and preserved, and 3) reused by future generations. Creating data management plans at the onset of a project, which account for these issues, allows datasets to adhere to the FAIR Principles (Findable, Accessible, Interoperable, and Reusable) in science. Abiding by these principles allows complex archaeological datasets to be properly archived and ultimately shared with a broader audience, especially when that information is deposited in a trusted repository. In this talk, I discuss these principles and provide an example of a complex dataset that meets these guidelines; the Mimbres Pottery Images Database. This dataset – archived in the repository tDAR (the Digital Archaeological Record) – contains images and data from over 9,000 Mimbres vessels from the American Southwest. A newly created tool in tDAR permits users to query the database and view a subset of the pottery images with associated metadata. The records returned in a given query is partially based on security clearance granted by the Project Investigator. Different levels of accessibility protect private collections and culturally sensitive information, while at the same time enables sharing the resource with a broader audience; thus, embodying the FAIR Principles.

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The Specific Problems of Palaeontological Databases and How NQMDB Deals with Them

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Watch the Video

Keywords: uncertainty, taxonomy, chronostratigraphy, database structure

The Neogene-Quaternary Mammals Database (NQMDB), hosted at CENIEH and accessible through ROAD, records information on mammalian species from the Neogene and Quaternary of Europe. As in many other databases focused on paleontological data, lists of fossil taxa by site and stratigraphic unit constitute the core of the database. Moreover, to be useful for researchers, paleontological databases should link the fossil occurrences to information on chronology. Thus, occurrence of a taxon at a place at a moment in time constitute the minimum information that should be recorded in a paleontological database. However, out of this three variables, only the spatial location of the site where the fossils where found is known with certainty, and sometimes even this is not true. The two major problems that any paleontological database should deal with are the uncertainty on the taxonomic identity of fossils and the uncertainty in their age. Given the fragmentary nature of the fossil record, it is frequent for different specialists to sustain different opinions about the taxonomic identity of a single fossil. Even worst, different taxonomists usually support alternative hypotheses about the phylogeny of a group, which produce different taxonomic classifications. The uncertainty about the age of a fossil is created by the existence of different dating methods, their accuracy and their reliability. Biostratigraphy is usually a highly reliable method, but it is very inaccurate. The accuracy of radiometric dating methods is variable, as well as their reliability. The challenge for any paleontological database is to record and organize all these uncertainties but, at the same time, be capable of providing data susceptible of being analyzed by researchers.

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CHAPTER II

Session 2

METHODS

Chairs: Ericson Hölzchen & Christian Sommer

Juan Antonio Barcelo

Christian Sommer

Alice Williams

Christian Willmes

Mind Map – METHODS

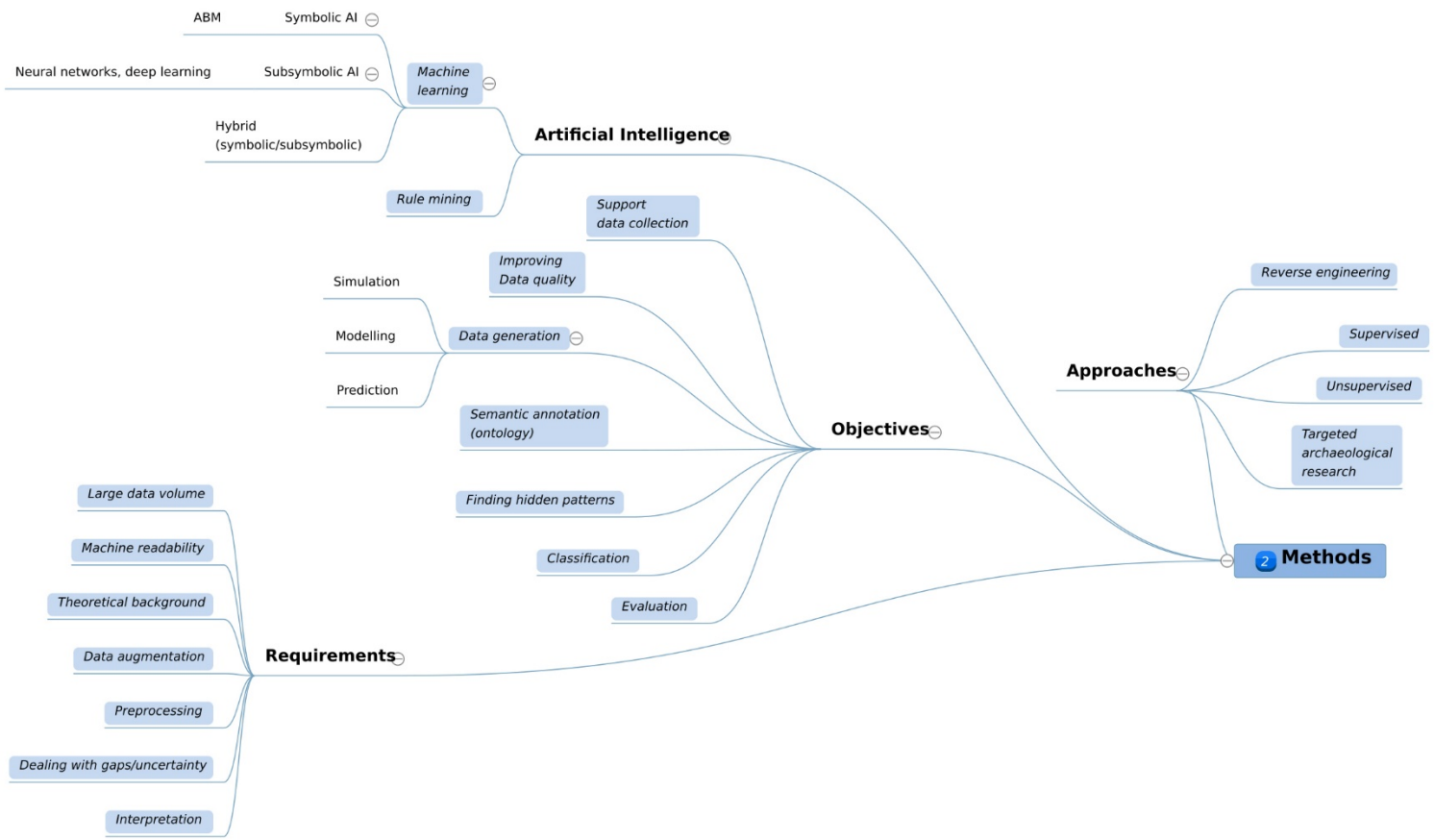

Figure 3: Mind map of session 2 - Methods. This session addressed different approaches and varying objectives of databases, with a further look at the requirements necessary and a view to what artificial intelligence can offer.

Solving Archaeological Inverse Problems – A Reverse Engineering Approach

Juan A. Barceló

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Keywords: archaeology, inverse problems, reverse engineering, shape analysis, finite element method, 3D modeling

Reverse engineering has been defined as the study of a sample of a product, device or machine, to discover how it functions or was made. The goal is to find the functional principles that make it work. It may be simply measuring all the parts and analyzing the materials, to be able to reproduce it. The underlying idea seems to be if you learn how to make it, you know how it works. That means that if you can reconstruct the process by which the object was created, you will understand why it has that specific shape, and size, why it is made of this material, why its surface has those visual or tactile properties, etc.

Archaeology is a form of reverse engineering for the social sciences. It seems the best way to approach the classical archaeological problem, formally: reconstructing the cause – social action – based on an observation of the effects – the archaeological record.

In most current applications of the reverse engineering approach in archaeology, it seems reduced to digitalization: how to reconstruct the original surface based on a sample of 3D points acquired through photogrammetry or laser scans. However, as the very idea of reverse bioengineering brings about, reverse engineering is not restricted to digital imaging or shape analysis. In biological systems, reverse engineering has been invoked to understand how living beings have evolved, that is, the task of inferring adaptive function from structure. In this paper I consider this approach in functional analysis of different kinds of archaeological items, from buildings to bones, from pottery and instruments to territories. It presents different ways to express mathematically human behavior, making emphasis on inverse kinematics methods and different variations of the finite analysis method.

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New Perspectives for Data Exploration in ROAD

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Keywords: Data mining, machine learning, digital humanities, GIS, spatial analysis

Since 2009, the ROCEEH project has accumulated information on more than 20,000 assemblages in the ROCEEH Out of Africa Database (ROAD) from the fields of archaeology, paleoanthropology, paleontology, paleobotany as well as geographical information with landscape reconstructions and its diverse elements. Linked over space and time, these data allow a broader picture of the deep human past to be drawn. In parallel to the development of ROAD, Artificial Intelligence (AI) analytical methods such as machine learning and data mining have become increasingly efficient and user-friendly in recent years. Supplementary to 'classic' analyses commonly used in the database (A. Kandel–Databases) and modelling approaches (C. Hertler–Applications), we will draw attention to further analytical methods, providing new opportunities to confirm existing hypotheses and discover patterns in the data that lead to the formulation of new hypotheses.

One example highlighted in this presentation investigates spatial human-environment interactions through the use of unsupervised classification to categorize archaeological sites by paleo-ecological conditions, and furthermore, predict potential habits through supervised classification. The derived suitability maps help to identify overlapping habitats, and thus potential migration corridors, as well as environmental barriers that help to understand (dis-) continuities in the Paleolithic record.

Another example focuses on methods to discover patterns of co-occurrence or obstruction of cultural items in archaeological assemblages. Association rule mining (Agrawal et al. 1993, 1996) is widely used in online marketing and applied to ROAD, offering the possibility to explore relations between e.g. the combination of lithic tools and site types on a quantitative basis. This allows us to identify potentially meaningful relationships between objects in large datasets.

While these methods allow us to gain new insights into prehistoric life from the perspective of quantitative data, the specific characteristics of archaeological data, such as incompleteness and biases, must also be taken into account.

Sommer, C., Hochschild, V., & the ROCEEH Team (2022). New Perspectives for Data Exploration in ROAD. In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (pp. 30-31). Propylaeum, Heidelberg.
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How Well Does the Circumscription Theory Explain the Formation of Complex Societies? Using Agent-Based Models to Evaluate Archaeological Theories against Existing Archaeological Data

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Keywords: agent-based modelling, cultural evolution, social complexity

How and why human societies began to form and sustain increasing levels of social complexity are heavily debated questions in archaeological research. Every region has unique trajectories of societal change but whether there are shared features between regions is a contentious issue. Similar factors relating to an increase social complexity are relatively easy to identify, such as the presence of warfare, organizational and agricultural intensification, charismatic leaders, or circumscribing barriers to population movement. It is much more difficult to objectively assess the influence of each of those factors and their general applicability across different societies and regions. The discussion on Carneiro's circumscription theory exemplifies this point. Multiple examples can be cited in either support or rejection of the importance of geographical, resource, or social barriers to population movement on the formation of social complexity. To resolve this debate, I developed agent-based models based on the assumptions of Carneiro's circumscription theory. These models allowed me to clarify the explicit and implicit assumptions of the theory and explore the range of conditions under which the theory is supported in abstract landscapes. To test the real-world applicability of the circumscription theory, I parameterized the models based on archaeological and environmental data from specific regions. The results from these experiments allow the precise quantification of the effects of circumscribing conditions on the formation of social complexity, and importantly, precisely highlight the gaps in archaeological research that need to be filled to firmly support or reject the circumscription theory. This research therefore shows the benefits of using agent-based models to move archaeological debates beyond stalemates, even when the data are limited.

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PaleoMaps – Creating, Collecting and Compiling Geospatial Paleoenvironment Data for Culture-Environment-Interaction Modeling Applications

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Watch the Video

Keywords: Paleoenvironment, GIS Data, data modelling, data publication

In the frame of the Collaborative Research Centre 806 (CRC 806), a German Research Foundation (DFG) funded interdisciplinary and inter-institutional research project, investigating human environment interaction (HEI) during the last 250,000 years, which was established in 2009 and is funded until 2021, considerable experience, competence and knowledge in integrating and managing data, information, and knowledge on HEI research was acquired and developed.

In this talk first the data management platform and repository CRC806-Database will be presented, that was developed for the CRC 806 as a central data archive, and data publication platform. It is shown, how the heterogeneous data that was produced and acquired by the project members, are organized in a web based platform.

This will be followed by the introduction of some example HEI modelling applications conducted within the CRC 806. These applications include for example Species Distribution Modelling (SDM), Least Cost Paths (LCP) and Site Catchment Analyses (SCA), Population Density Estimates, and more, which represents the state of the art in HEI modelling. One particular ingredient for almost any quantitative (and also for some qualitative) HEI modelling applications are computerized representations of well-defined paleoenvironments (Willmes et al. 2020).

Currently, this kind of data is published abundantly in the scientific record, but in very heterogeneous forms and formats. From implicit textual descriptions of huge regions to most detailed 3D models of small sites. From temporal categories of geological ages to exact and granular dates in time. By first investigating the state of the art in this field, data availability and accessibility, and looking at some exemplary geospatial paleoenvironment reconstructions in recent human-environment interaction modelling applications. The lack of a framework for sharing paleoenvironmental models or maps in the context of HEI modelling is addressed and discussed. This will be followed by a discussion and critique of state of the art approaches, leading to the definition and explanation of the PaleoMaps approach (Willmes et al. 2017), that seeks to address the before identified shortcomings of existing approaches.

Willmes, C. (2022). PaleoMaps – Creating, Collecting and Compiling Geospatial Paleoenvironment Data for Culture-Environment-Interaction Modeling Applications. In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (pp. 34-35). Propylaeum, Heidelberg. DOI: https://doi.org/10.11588/propylaeum.882.c13439

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CHAPTER III

Session 3

APPLICATIONS

Chair: Andrew W. Kandel

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Ewa Dutkiewicz

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Mind Map – APPLICATIONS

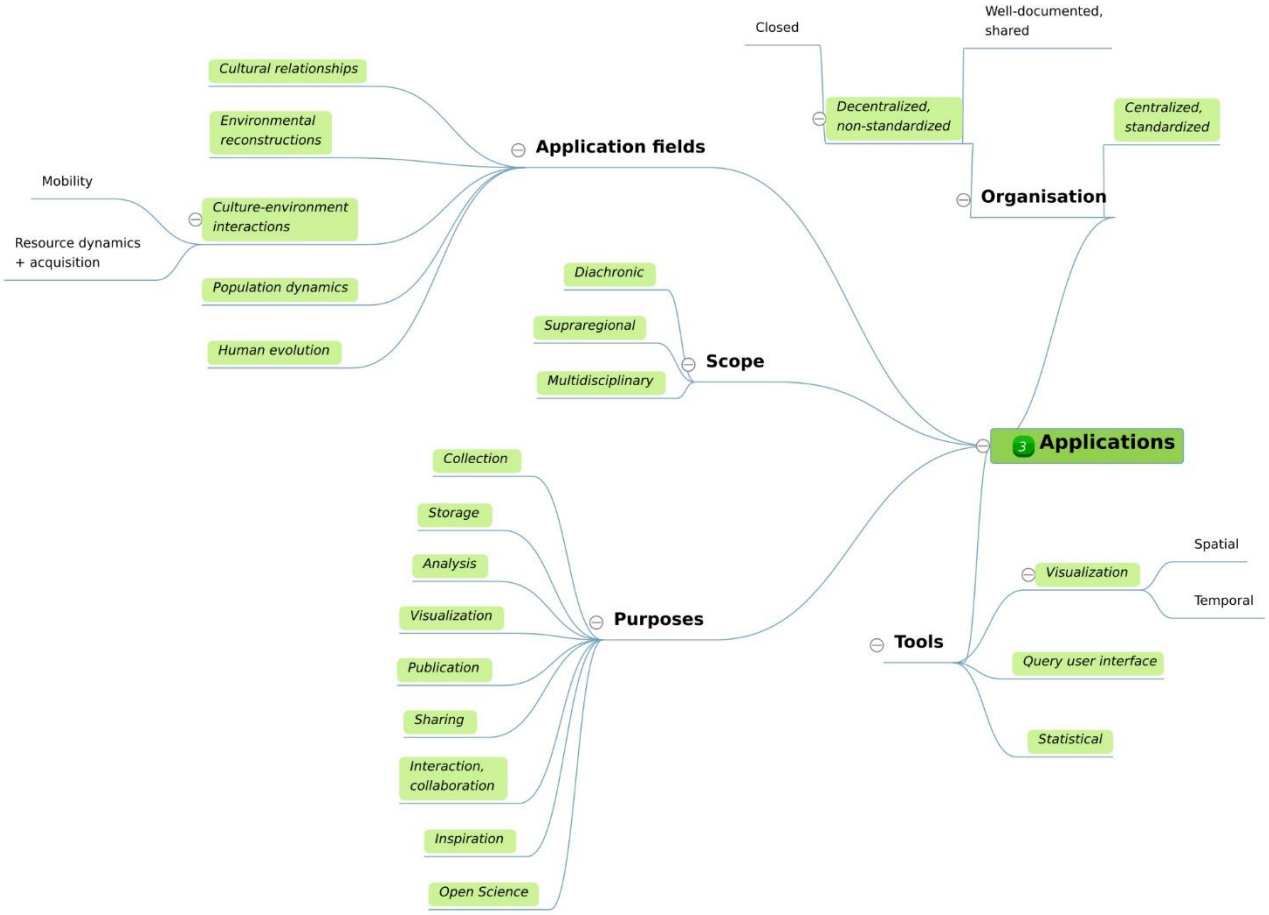

Figure 4: Mind map of session 3 - Applications. This session examined some of the purposes of databases as well as their scope. In addition, it looked at tools available, organizational structures and fields in which data can be applied.

Using a Georelational Spatial Information System to Examine Questions about the Large-Scale Development of Cultural Behavior in Human Evolution: The Example of Ochre in the African Middle Stone Age

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Keywords: ochre, Middle Stone Age, time averaging, finite mixture distribution

Archaeological databases should not be an end in themselves. Rather, they provide tools for addressing research questions based on large volumes of data that cannot be examined using conventional methods. In particular, large-scale archaeological meta-analyses about the long term development of cultural behavior during the Pleistocene are best approached with geo-relational spatial information systems such as the ROCEEH Out of Africa Database (ROAD). In our poster presentation we report the results of a project about ochre use during the African Middle Stone Age. We assessed data from 100 different archaeological sites and entered them into ROAD. The published data from each locality was evaluated based on the character and quality of the ochre artifacts reported, the nature of the excavation, the stratigraphy of the site, and the reliability of its dating. To overcome problems associated with variable data inherent in our age model, we employed the statistical concept of *time averaging* by developing an analytical tool called "time slice". This tool tallies the numbers of localities and assemblages which meet certain criteria as specified in a predefined query. It also allows the user to slide the analytical window across the scope of analysis at a given time interval. We wrote two queries for this analysis, one that generated a list of African localities containing assemblages of ochre, and another for stone artifacts. This method enabled us to identify three distinct chronological phases of ochre use between 500,000 and 40,000 years ago.

However, with regard to statements about the evolution of cultural behavior, data mining can only be the first step. In the next step, the results must be subjected to an interpretation process that is not based on the data themselves. For this purpose we integrated our results with findings about ritualized behavior from primatology, the cognitive sciences, and anthropology.

Dapschauskas, R., Göden, M., Sommer, C., & Kandel, A. W. (2022). Using a Georelational Spatial Information System to Examine Questions about the Large-scale Development of Cultural Behavior in Human Evolution: The Example of Ochre in the African Middle Stone Age. In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (pp.39-40). Propylaeum, Heidelberg. DOI: https://doi.org/10.11588/propylaeum.882.c13440

This allowed us to offer some well-founded conclusions about the evolution of ritual behavior during a critical phase as *Homo sapiens* developed into a socially complex bio-cultural species, not fundamentally different from contemporary humans.

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Structuring the Unstructured: Databases for Paleolithic Art

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Keywords: Paleolithic art, signs, animal and human depictions, quantitative linguistics, UPGMA tree

Studies on Paleolithic art always face the problem of subjectivity. Artistic expressions are difficult to describe, are often multilayered or contradictory. They arise from a creative process, have no or not always clear practical functions and are ambiguous. But the situation is not hopeless. Works of art have parameters that can be determined and described using database technology. It is possible to differentiate between e.g. mobile and parietal art, determine the production technique or the used material (Dutkiewicz et al. 2020; Dutkiewicz 2021a). However, determining the topics and relationships between them remains the greatest difficulty. Even if figurative representations are supposed to be easy to understand, it does not necessarily mean that, for example, a horse only represents one horse. Depending on the cultural context, a lot of information can be conveyed using the representation of a horse. Although the taxonomic determination is clear in most cases, the meaning remains obscure (Sauvet 1994; Sauvet et al. 2018). Does the representation of a mammoth in the form of an ivory statuettes from the Aurignacian around 40,000 years ago have the same meaning as the 15,000 years old drawings on cave walls at Grotte de Rouffignac (Conard et al. 2007, 2015; Plassard and Bosinski 1999)? Another point, especially when it comes to rock art, is to understand which pictures belong together. It has been proven that the caves have been visited repeatedly and that figures have been added at different times (e.g., Lorblanchet 2000; Clottes 2001; Pettitt and Pike 2007). If we get a temporal resolution at all, what does that tell us about the scenes we supposedly recognize? Another difficulty lies in the so-called signs. These are usually geometric, abstract motifs that often accompany the figurative representations, but in many cases also stand alone. These signs are difficult to read because what is reflected in them is not immediately apparent (Sauvet 1993; Dutkiewicz 2021a). It could be, for example, as Henri Breuil (1952) and others have suggested, shortened representations of real objects. It could be fixed symbols, which, similar to characters, bear certain information (e.g., Marshack 1991). It could be notations and counts or just decorative elements.

Dutkiewicz, E. (2022). Structuring the Unstructured: Databases for Paleolithic Art. In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (pp. 41-42). Propylaeum, Heidelberg.
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Here, I present some examples of current projects that have set themselves the task of structurally considering all aspects of Paleolithic art. Supra-regional and diachronic analyzes are intended to show connections and differences in the course of the Upper Paleolithic, which lasted several 10,000 years. On one hand, the project SignBase (Dutkiewicz et al. 2020), which deals with geometric signs on mobile objects, and on the other hand, a recently launched international project, which deals with animal representations in parietal and mobile art in Central and Western Europe (Dutkiewicz 2021b).

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The Map Module for the ROAD Database

Christine Hertler & the ROCEEH Team

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Watch the Video

Keywords: ROAD MapModule, archaeology, hominins, paleoenvironment, web-based GIS interface

ROAD makes use of a variety of tools to visualize data, among them the Map Module. The Map Module represents a handy way to display the geographical and temporal distribution of query results on a map. The Map Module offers a variety of services. First, it represents a simple way for anyone to check whether specific datasets are available in ROAD. In addition, registered users may apply the Map Module as a quick and simple way to display data on maps. The Map Module allows a user to select among a variety of maps, for instance displaying modern topography and climate as well as reconstructions of past climate and ecosystems – depending on specific research questions.

Finally, the Map Module serves as a link to other databases in order to search for additional data that are not stored in ROAD, thus avoiding redundancy in the efforts required in data collection. The Map Module provides a map interface in which query results from multiple databases can be joined and displayed. This can be achieved either graphically on the map or as a series of tables, which can be downloaded and subjected to further analysis, modeling or simulation. Applications in the Map Module are continuously updated and further developed. This poster introduces you to the main features of the Map Module and welcomes ideas for further development.

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NeMo – An Agent-Based Model for Simulating Neanderthal Mobility

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Watch the Video

Keywords: agent-based model, Neanderthals, mobility, topography, subsistence

The Neanderthals existed for several thousand years until they mysteriously disappeared at around 30ka, leaving only rare traces modern human genes as well as in the archaeological and fossil record. The spatio-temporal patterning we may deduce from these remains are the accumulated result of small-scale decisions from Neanderthal groups. Therefore, understanding these spatio-temporal patterns would require to understand how the Neanderthals moved across the landscape. Moreover, a simulation approach would allow to apply an experimental context with which behavioral models could be tested.

For this purpose, we developed Neanderthal Mobility ("NeMo"), an agent-based model for simulating the movement of Neanderthal agents on a virtual landscape. The agent-based model incorporates GIS spatial data, locality data retrieved from the ROCEEH Out of Africa Database (ROAD) and behavioral models for hunter gatherer subsistence.

The environment of the agent-based model represents the geographic extent of France and adjacent regions which bear a lot of Neanderthal sites. The agents move, build residential- and logistical camps and forage for resources to fill up their energy storage. As outputs, we quantify the frequency, duration and distances of residential- and logistical camps in a given time period.

NeMo serves as a basis for the investigation of further possible analyses, e.g. to (i) compare the differences in mobility patterns between regions or clustering between regions; (ii) quantify the differences in mobility patterns between cold and warm phases; or even (iii) incorporate additional features, such as differentiated subsistence strategies and raw material procurement.

NeMo exemplifies, how locality data retrieved from ROAD is used in conjunction with behavioral models to simulate the mobility of the Neanderthals. Furthermore, NeMo may act as a template how to simulate early hominin subsistence on the basis of topographic data.

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ROAD Summary Data Sheet – A Publication and Data Sharing Tool

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Watch the Video

Keywords: databases, database applications, database tools, archaeology, pdf

ROAD stands for the ROCEEH Out of Africa Database and contains archaeological and paleobiological data. It is a relational database with more than 50 tables. The information comes from publications written in English, German, French and several other languages. ROAD contains data for more than 1800 localities and 11,000 assemblages (as of June, 2020). The ROAD user interface has some visualization and querying tools, so a user who wishes to conduct for example quality control, can comfortably check selected parts of the database for the correctness of the data entered. Despite the convenience a user gains from these tools, he still needs to understand the structure of ROAD (tables and relations between the tables) in order to query all information for one selected locality. To gather all information for one locality stored in ROAD, a user would have to query about 50 tables.

To make the information stored in ROAD more easily accessible to scientists and the general public ROAD provides a tool for generating a datasheet summarizing each locality in the form of a PDF. This summary is a publication and can be used for scientific communication and education, data sharing and data control. The summary contains the essential part of the locality data including coordinates, layers, profiles, ages, assemblages and publication sources of the selected locality. The summary is published under a Creative Commons license (CC BY-SA 4.0).

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Matching Datasets and Palaeoenvironment to Frame Human Palaeoecology in Europe around MIS 11

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Watch the Video

Keywords: primary production, carrying capacity, hominins, Middle Pleistocene

The availability of trophic resources is one of the main factors that constraints the distribution and survival of any species, including hominins. Like any other organism, human beings aim always to adopt the most efficient feeding strategy for their given environmental conditions, under the limits of their own physiological constraints. Thus, in order to understand the survival strategies of ancient hunter-gatherer societies, we should look at the availability of trophic resources in their environment. We focus our attention on MIS 11, a key period for human biological and cultural evolution in Europe. In this period, the pre-existing populations progressively acquired the Neandertal anatomical characteristics, complex hunting activities were generalized, and the Prepared Core Technology (PCT) started to be widespread. Here we compiled information on the distribution of archaeological sites across Europe during MIS 11 from several datasets (NQMDB, ROAD and other sources), and analyzed the pattern of distributions of hominins in Western Europe with two proxies of resource availability. Net Primary Production (NPP) and Ungulate Carrying Capacity (CC_U) for MIS 11 were obtained from interpolated paleoclimate maps as proxies for the abundance of plant and animal resources.

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Is a Decentralized, Non-Standardized Approach to Data Sharing in Archaeology Good Enough?

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Keywords: data sharing, archaeology, open science

For decades there have been numerous efforts to design and build data standards and databases for the central storage, management and analysis of archaeological data. The success of these systems, as measured by participation and by research output, is varied. Mainly it seems that participation in these efforts is correlated with statutory requirements, and that in the absence of such enforcement mechanisms archaeologists continue to go their own way in terms of what they record and how (if) they share it. The good news is that in the meantime, significant technological advances have brought the ability of individual researchers to very effectively publish their data, and there appears to be an upcoming generation of archaeologists that are exploiting these new tools to good advantage. Here, I consider some of the benefits and drawbacks to this decentralized and non-standardized approach to data sharing, and I provide some practical examples. I conclude that in fact this approach may be better suited to much of research in archaeology.

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McPherron, S. P. (2022). Is a Decentralized, Non-standardized Approach to Data Sharing in Archaeology Good Enough? In A. W. Kandel, M. N. Haidle, & C. Sommer (Eds.), *Human Origins – Digital Future: An International Conference about the Future of Archaeological and Paleoanthropological Databases* (p. 50). Propylaeum, Heidelberg.
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Living in Sangiran

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Watch the Video

Keywords: Sangiran, Pleistocene hominin, paleoenvironmental reconstruction, paleotopography, paleoclimate, paleovegetation

Among many fossil-bearing localities in Java, Indonesia, Sangiran is the best-studied locality for hominid fossils. The stratigraphic sections in Sangiran hold a record of hominin occupation since at least 1.3 million years ago. The fossil and archaeological records in Sangiran includes hominid fossils, vertebrate and invertebrate fossils, pollen and other microfossils as well as artifacts throughout the stratigraphic section. Therefore, this site represents a unique window to study the early life of humans in Indonesia. As a follow up of fossil findings, paleoenvironmental aspects related to hominin occupation also have been long-studied in Sangiran. However, each study only focused on a certain proxies to reconstruct some environmental aspects in a limited area, covering hundreds of thousand years of interval. As a result, these studies did not give a comprehensive environmental background where hominin lived. Therefore, a reconstruction of a wider span of living area inhabited and exploited by a group (or more) of hominins in a scale of their lifetime is needed as a background to understand their behavior and interaction through modeling and simulation.

In this study we focused to reconstruct the topography, hydrology, climatic/seasonal pattern and vegetation cover of Eastern part of Java, including Sangiran, at one million years ago. The result and implication will be discussed during the presentation. This reconstruction will later be used as a background to model and simulate hominin behavior and interaction with their environment by using agent based modelling (ABM).

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Paleo Core – A Platform for Data Integration in Paleoanthropology

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Watch the Video

Keywords: data integration; data standards, open science, data sharing, vertebrate paleontology, Paleolithic archaeology, sedimentary geology

Paleoanthropology is transitioning from individual, project-focused initiatives to broader platform-focused initiatives that integrate data across multiple sources in order to address bigger-picture questions regarding human origins.

Initiated in 2012 with funding from the US National Science Foundation, Paleo Core hosts data from ten (and growing) active research projects with over 85,000 fossils, artifacts and geological samples and the ability to store geospatial locations for each item. Data from these collections is mapped to a standard data structure, which promotes data sharing, common best-practices for data acquisition and greater overall collaboration between formerly siloed research teams.

Paleo Core features a website and online platform for collecting, managing, and analyzing paleoanthropological specimen data. The Paleo Core platform hosts tools to facilitate digital data collection in the field and to import these data into a central repository online. The online platform provides a web-based collaborative interface that allows research teams to manage biological, geological and archaeological collections effectively. It features a comprehensive conceptual model based on existing international data standards that foster data integration across projects. This integration is the keystone supporting linked-data and global search and query across research projects that choose to share and integrate their data.

Paleo Core is designed as a data management platform for researchers at the initial and intermediate stages of the data lifecycle, from data collection, analysis, and publication up to accession in museum collection management systems. By providing the crucial infrastructure for digital data management at the acquisition and analysis phase, Paleo Core helps stem the tide of legacy analog data and promotes fully digital workflows from start to finish.

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Combining Paleoenvironmental and Paleoanthropological Datasets to Understand Human Brain and Body Size Evolution

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Watch the Video

Keywords: human evolution, body size, brain size, climate change, paleoanthropology

Body and brain size are essential biological parameters of hominins. While recent research has clarified taxonomic and temporal trends within the human lineage, the causal mechanisms for these changes remain contentious, including environmental change, but also demographic, social, dietary and technological factors. Here we test the influence of environmental factors on the evolution of body and brain size in the genus *Homo* over the last one million years by formalized hypotheses in a quantitative statistical framework. To this end, we for the first time combine a large fossil dataset (n=208) including spatial coordinates with a global climate model emulator that provides environmental variables for each space-time combination of individual fossils. Our results show different patterns of correspondence between modelled environmental variables and body and brain size evolution in *Homo*. Temperature predicted body size according to Bergmann's rule across all studied *Homo* taxa, likely a direct effect of climate on human physiology. On the other hand, net primary productivity and long-term variability in mean annual precipitation were good predictors of brain size in archaic but not modern humans. These environmental variables likely worked more indirectly in their effects, affecting cognitive abilities and extinction probabilities. While environmental challenges faced by hominins over their lifetime had some influence on body and brain size evolution in Middle Pleistocene *Homo*, Neanderthals and *Homo sapiens*, they explain only a part of the observed temporal patterns. Multiple interacting causal mechanisms at different time and on different taxa likely underlie the evolution of these key biological characteristics of *Homo* in the Pleistocene. Quantitative modelling with machine learning methods based on further interdisciplinary combination of large databases, for example from archaeology, will be key to further our understanding on brain and body size evolution within the genus *Homo*.

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Prehistoric Population Dynamics – Extended

Andreas Zimmermann & Isabell Schmidt

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Watch the Video

Keywords: Demography in Prehistory, Cologne Protocol, density-based upscaling, population estimates, Lower Paleolithic

During the last two decades, methodologically interconnected projects at the University of Cologne investigated population dynamics of Prehistoric Societies. The so-called Cologne Protocol provides a consistent approach to estimate absolute population sizes as well as densities. Periods under consideration cover the Late Pleistocene (at Pan European scale, CRC 806 Project E1) and Holocene (for central Europe, LUCIFS). Altogether, estimates are currently available for 14 time-slices covering the last 40,000 years. Modelling of long-term population dynamics has been accomplished by interpolating between the obtained estimates using a logistic equation.

The presentation will introduce the modelled long-term dynamics at the European scale and discuss future directions for extending its spatial and temporal framework. From our currently ongoing work, we present two potential pathways: Firstly, extending the spatial dimension, we draw from existing maps on cultural units and transfer estimates of the Cologne Protocol via regression analysis. Secondly, focusing on a temporal extension into earlier periods of human prehistory, we include georeferenced data from the ROCEEH Out of Africa Database (ROAD) on site occurrence and distribution. By applying the geostatistical upscaling procedure of the Cologne Protocol and data transfer from well-studied areas, our aim is to refine existing models on global prehistoric population dynamics.

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CHAPTER IV

Session 4

PRODUCTS

Chair: Christine Hertler

Wolfgang Börner

Liane Giemsch

Yasuhisa Kondo

Matthias Lang

Mind Map – PRODUCTS

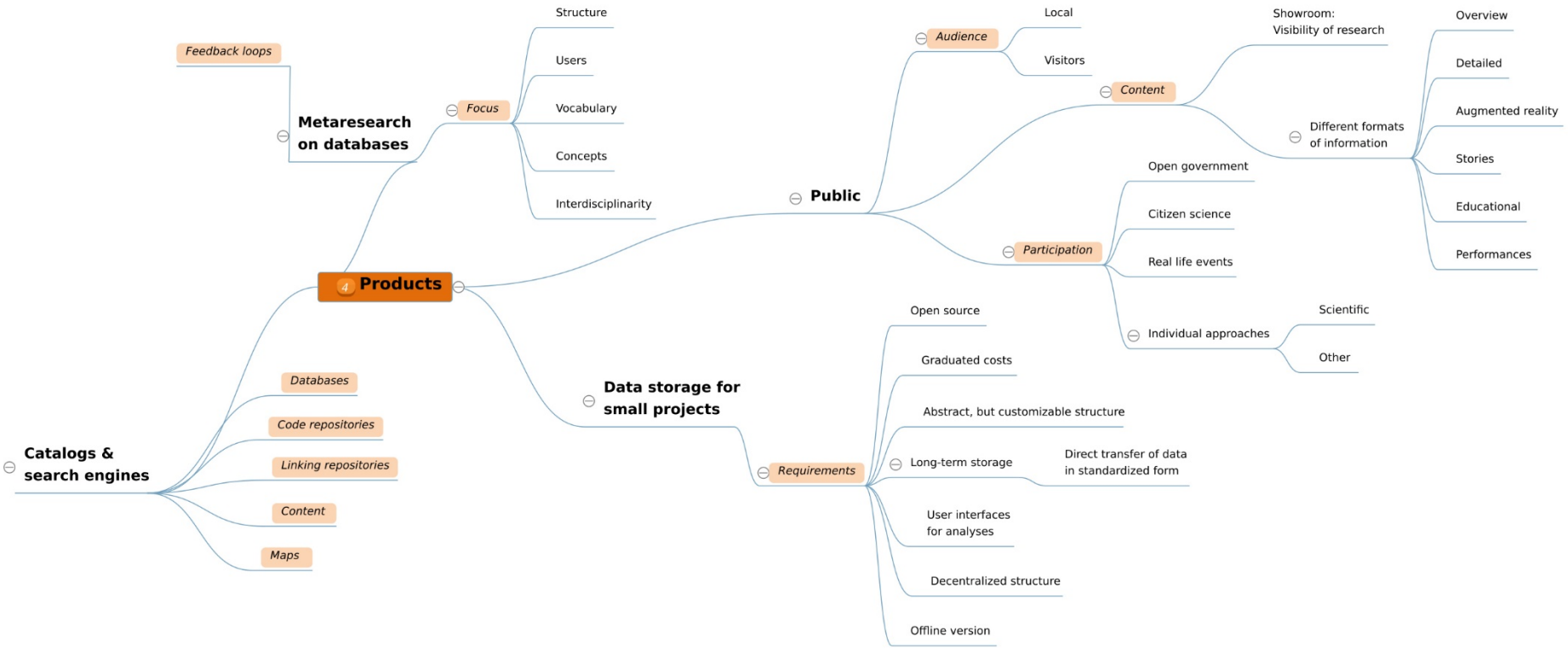

Figure 5: Mind map of session 4 - Products. This session gave an overview on catalogs of data, search engines, data storage for small projects, and meta-research carried out on databases themselves. It also discussed how the pubic interacts with data.

Wien Kulturgut: Web Portal for the Contribution of Archaeological Data from the Paleolithic until Today

Wolfgang Börner

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Watch the Video

Keywords: Vienna, Wien Kulturgut, web application, GIS

When did the first humans appear in the Vienna Basin? The city of Vienna has been closely connected with relics of the Ice Age for several centuries. In the year 1546 bones of a mammoth were interpreted as bones of Gog and Magog, the biblical giants. Those remains were fnd during the construction of the north tower of St. Stephen's Cathedral in 1443 and labelled with AEIOU. This stands for either *Austriae est imperare orbi universe* [Austria is destined to rule the world] or *Austria erit in orbe ultima* [Austria will be the last (surviving) in the world], which was the motto of Emperor Friedrich III. There is reason to believe that the territory of Vienna was also important for Ice Age hunting and gathering societies, as was the surrounding area of Lower Austria and the Danube region. It can be assumed that geographically prominent places such as the Wiener Pforte represented typical landmarks for Ice Age groups.

In December 2000, the Web Portal Wien Kulturgut [Vienna cultural assets] (formerly known as Wiener Kulturgüterkataster [Vienna cultural asset register]) went online. Since this time technology has changed, and new content has been uploaded. Since its start the Web Portal was highly accepted by both the citizens of Vienna and tourists alike. Vienna's cultural heritage Web Portal is the digital city map of Viennese culture and provides access to essential characteristics of the city's identity. Many maps show the cultural-historical trajectory and plot the development of urban planning from the early times until the present. The web portal offers everyone who is interested access to digitally recorded cultural heritage, which is stored and researched at various locations in Vienna. More than 4000 digitally available archaeological resources can be searched and filtered according to different criteria. In my talk I present the Web Portal as an analytical tool together with the Vienna Archaeological Geographic Information System (VAGIS).

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METAhub Frankfurt – A Database as Link Between Museum Cultures and Performative Art

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Watch the Video

Keywords: Frankfurt am Main, Kaiserpfalz Franconofurd, Börneplatz Synagoge, Jew's Lane Frankfurt, digital curating, digital artistic production, location based services, geotagging, open source

METAhub Frankfurt is based on a new form of cooperation between museum curators, documentaries and dramaturges on the one hand and coders and artists on the other. With METAhub Frankfurt, the Jewish Museum and the Archaeological Museum Frankfurt are developing a digital application that brings together parts of their collections, makes them available in narrative form and enables users to experience them in their former place as augmented reality. In an initial development phase, the early modern Judengasse, the Börneplatz synagogue and the early medieval imperial palace Franconofurd can be experienced digitally. In total, both museums have around 5,000 objects related to these locations. These include archaeological finds, ceremonial and everyday objects as well as numerous documents that can be used to reconstruct and tell stories. The Künstlerhaus Mousonturm and the NODE Forum are now inviting artists to create performative interventions in the urban space with the digitized cultural goods, providing contact with coders who further develop the application and the reusable data, and providing expertise in the participatory development socio-political issues.

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Interdisciplinary Challenges of the Cultural History of PaleoAsia Project and its Database Development: Lessons Learnt

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Watch the Video

Keywords: interdisciplinarity, in-project action research, conceptual boundaries and transformation, co-author network

The Cultural History of PaleoAsia is a Japan-funded large-scale research project aimed at understanding the distinct patterns in the formation of modern human cultures across Asia. More than 50 researchers, including archaeologists, cultural anthropologists, mathematical biologists, and paleoenvironmental scientists, have collaborated for this project. A team of the project is developing an archaeological site database to compile information on excavation, radiometric dating, lithic industry, and bibliographical reference. When this database was shared with natural scientists for joint research, the team found it difficult to share the key concepts such as culture, environment, and technology with them. Therefore, along with developing the database, the team is trying to span conceptual boundaries among the different domains involved. This invited talk shares the team's experience as lessons learnt and discusses how we can overcome such an interdisciplinary challenge.

To tackle this issue, the team applied lexical analysis, network graphs, and questionnaire surveys. First, a lexical analysis of the full text of the project's conference proceedings, annual reports, and website revealed that the term 'culture' was used in the context of materials (e.g. lithic culture, ceramic culture, etc.), geography (e.g. cultural zones), temporality (e.g. Aurignacian culture) and dynamics (e.g. cultural ecology). Second, the progress of interdisciplinary co-authorship was monitored through a network graph analysis of the conference proceedings; the number of co-authors was high in the archaeology groups and low in the cultural anthropology group. Third, a questionnaire survey revealed that cultural anthropologists prefer single authorship in comparison to other researchers. Regarding the fundamental concept of culture, 70% of the archaeologists chose 'behavior'. Among cultural anthropologists and mathematical biologists, there was no poll for 'materials', while the numbers for 'behavior' and 'information' were almost equal. Based on this evidence, the team is facilitating scholarly communication among researchers with different values and thoughts for better collaboration.

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Spacialist – A Virtual Research Environment for the Spatial Humanities

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Keywords: Virtual Research Environment, database, open-source, GIS, thesaurus

Many archaeological research projects generate data and tools that are abandoned after the project funding ends. Moreover, research data handling and the deployed tools are often highly specific for single projects. This practice leads to solutions that are incompatible with other tools, projects and infrastructures, and they often do not rely on accepted standards.

To close this gap, the project Spacialist was tasked to create a modular virtual research environment that offers an integrated, web-based user interface to record, browse, analyze, and visualize all spatial, graphical, textual and statistical data from archaeological or cultural heritage research projects. To address the highly heterogeneous requirements of such projects, Spacialist is developed as a software platform that is instantiated, customized and deployed for each research project. Spacialist uses project-specific controlled vocabularies based on the SKOS-XML standard, thus facilitating data analysis and interoperability with other projects and infrastructures.

The project is now beyond its development phase and is used by a number of projects in productive operation. In our presentation we will first present the functionalities and architecture of the software and then discuss in detail the experiences made so far. Special attention will be paid to the problem of sustainable further development and maintenance of Spacialist.

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CHAPTER V

Session 5

PERSPECTIVES

Chair: Volker Hochschild

Interviews with:

Sarah W. Kansa

Peter McKeague

Julian Richards

Dieta Svoboda-Baas

Mind Map – PERSPECTIVES

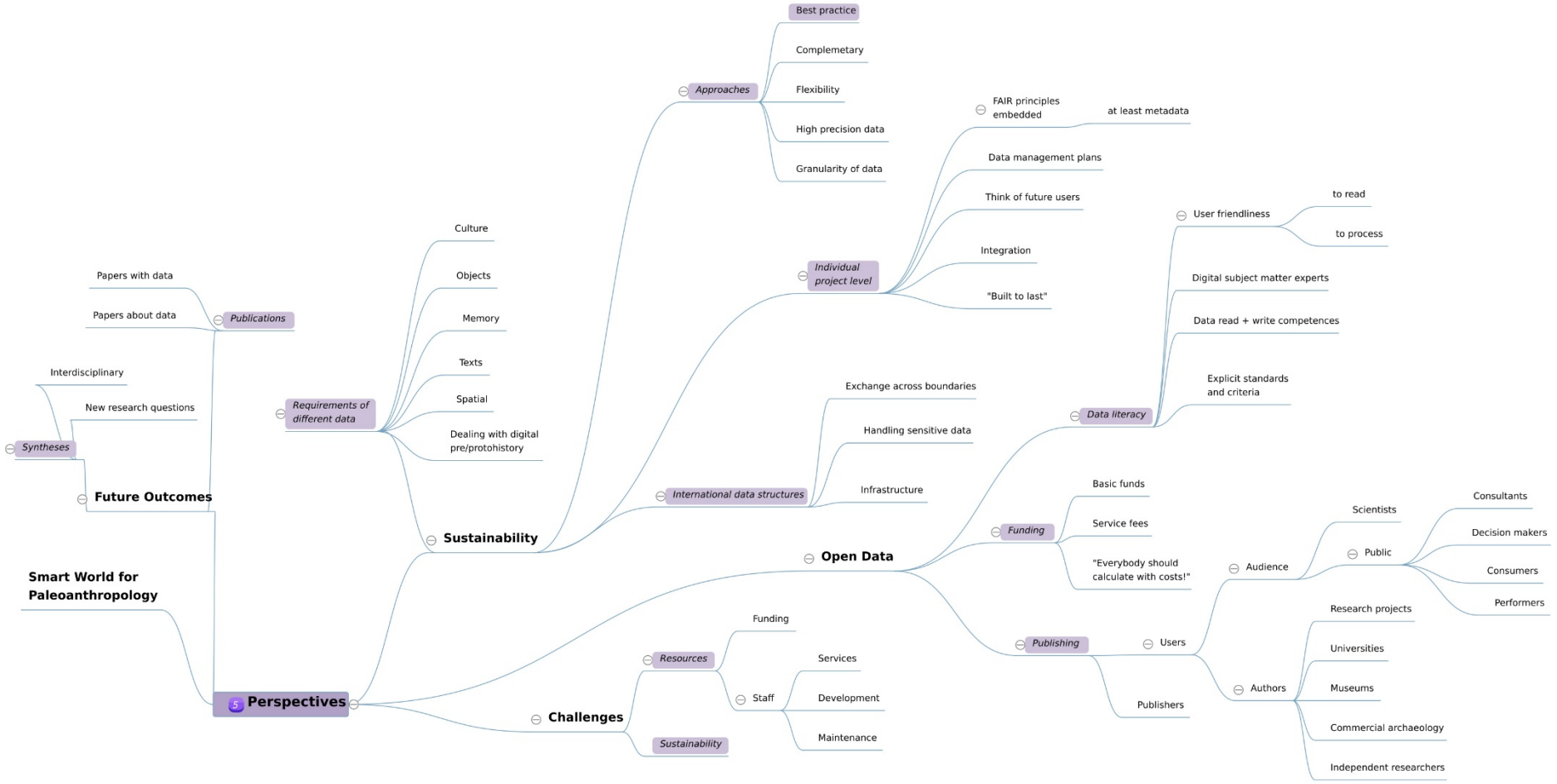

Figure 6: Mind map of session 5 - Perspectives. This session looked to the future of databases, with discussions about sustainability, open data, and smart world for paleoanthropology. The session also aimed to confront challenges and potential outcomes that the future has in store for us.

Sustaining Open Data: Lessons from Open Context

Sarah Whitcher Kansa
(Interview conducted by Andrew W. Kandel)

Executive Director, The Alexandria Archive Institute & Executive Editor,
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Watch the Video

Keywords: digital archaeology, data publishing, linked open data, data literacy

In this interview, Sarah Whitcher Kansa, Executive Editor of Open Context, discusses the development of Open Context and aspects of its approach to data publishing. Open Context's granular approach to data means that each item resolves to its own unique URL and is linkable to related data from across the Web. This "one URL per pot sherd" facilitates research by allowing people to cite specific items in a database and recognizes the individual contributions of authors who described or analyzed specific items. Recognizing there is not a one-size-fits-all solution to data archiving and dissemination in archaeology, Open Context has taken a bottom-up approach, developing new functionality to meet the demands of data authors over time. Open Context's team works with data authors to clean and decode their data and add descriptive information about the intellectual context of the data creation. This additional work, along with annotating datasets to facilitate linked open data, ensures that data are more intelligible and useful to future users. Kansa also discusses the importance of supporting innovation and exploration in the growing ecosystem of data sharing and archiving, highlighting how the success of related programs benefit Open Context. She concludes by discussing the benefits of broadening the community of people who engage with datasets through improved data literacy and storytelling.

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Mapping Our Heritage: Towards a Sustainable Future for Digital Spatial Information and Technologies in European Archaeological Heritage Management

Peter McKeague
(Interview conducted by Volker Hochschild & Christian Sommer)

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Watch the Video

Keywords: spatial data infrastructures, digital archaeological data, heritage management, INSPIRE

Archaeological record systems routinely record the position of sites and find spots from information reported from fieldwork or research. A simple point distribution map, with hyperlinks to related data, is sufficient for many web browsers (where the accuracy of location may be generalized to protect the precise archaeological location) and general distribution maps. However, spatial data also describes the extents and relationships between sites, features and objects in a geographic context. This is data derived from fieldwork and research. Modern surveying technologies enable archaeologists to produce highly accurate records of their fieldwork but the potential reuse of that data is often not realized beyond the immediate research objectives. Even where the project archive is accessible, most researchers will typically access this data as raster images within printed reports or pdfs rather than reuse the vector data. Reuse of data is therefore highly inefficient.

Development of a thematic Spatial Data Infrastructure (SDI) for archaeological data, modelled on established international and national SDIs, would realize the potential of spatial data fossilized in project reports and buried in archives (McKeague et al. 2017, 2019). By developing consistent mapping conventions archaeologists can present a coherent view of the archaeological landscape that can be easily understood by a range of users from researcher to the general public.

The Infrastructure for Spatial Information in Europe Directive (INSPIRE) Directive (European Parliament 2007) serves as a model. Developed as a response to transnational challenges, including pollution and flooding, INSPIRE has broken down national, regional and institutional barriers to sharing a range of spatial datasets across public agencies to support environmental policies and activities that may have an impact on the environment.

The INSPIRE SDI established the framework and rules for efficient data management and promotes data sharing as View and Download services via the INSPIRE Geoportal and national portals.

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The INSPIRE SDI established the framework and rules for efficient data management and promotes data sharing as View and Download services via the INSPIRE Geoportal and national portals.

INSPIRE requires public bodies responsible for the legal designation of archaeological sites to publish key data under the Protected Sites theme. However, there is no equivalent framework addressing the wealth of primary data from archaeological fieldwork.

Consequently, data is fragmented across organizations, stored in inappropriate formats, obstructing easy reuse and aggregation. In calling for a thematic SDI for primary data

- Archaeologists will create an environment in which spatial data from archaeological research is shared openly, maximizing its contribution to the study and stewardship of the past, and engages positively with the broader geospatial environment.

- To develop a sustainable approach to collecting and sharing spatial data from archaeological research that increases efficiency within our discipline, and releases the full potential of that data to the broader geospatial environment.

Data should be collected once and maintained at a level where this can be done most effectively (Infrastructure) in accordance with the FAIR Data principles coupled with capacity building within the profession (McKeague et al. 2020).

Without legislation, funding and hosts, realizing the potential of spatial data remains challenging, but it is being addressed through research initiatives. The SEADDA Cost Action recognizes the fragility of the wider digital resource whilst the ARIADNEplus Digital Infrastructure enables access to a range of data from multiple partners in Europe and beyond. It should be possible to develop the spatial element of that infrastructure to realize the potential of the spatial data we create.

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The FAIR Principles in Archaeology

Julian D. Richards
(Interview conducted by Christian Sommer & Volker Hochschild)

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Keywords: FAIR principles, digital humanities, heritage management, data infrastructures

Prof. Dr. Julian Richards is the director of the Archaeology Data Service (ADS) and since 2013 has been involved in the ARIADNE network. Begun in 1996, ADS is the oldest ongoing public undertaking dedicated to the management of data from the arts and humanities in the UK, and therefore plays a global pioneering role. It constitutes an accredited go-to place for scientists as well as public and private users. It offers expertise in the fields of archaeology and heritage data management, with the added possibility of depositing data in its repository. Richards, who has been with the ADS from the beginning and has served as its director for some 20 years, attributes this success to three forward-thinking services. First, the ADS offers long-term digital preservation based on a structure following the Open Archival Information System (OAIS), which started as an Open Standard, and is now an ISO-certified, highly compatible Reference Model. Second, the data are made freely available through the internet; and third, the ADS provides free and high quality advice and best-practice guides on standards, data management, and the likes. This shows how the ADS anticipated developments at an early stage, which were later formalized within the framework of the FAIR principles (findable, accessible, interoperable, reusable).

Richards emphasizes that FAIR-compliant data that are collected, shared, and reused help to improve science. He even advocates making research data FAIR by default. To further this development, Richards and representatives from repositories, data publishers, aggregators, and contractors came together in February 2020 in Tempe, Arizona to form the FAIR network. This group plans to organize workshops sponsored by the US National Science Foundation to address the implementation of FAIR principles in archaeology and their implications for all stakeholders, from funding bodies to field archaeologists.

For the future, Richards anticipates an increasing acceptance of FAIR principles, not only as a necessity, but also as a commitment made by researchers. Furthermore, a greater willingness on the part of funding bodies to routinely assume costs and an automated evaluation of data quality will be desirable, so that a global network of research data can eventually be established.

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Research Data Infrastructure – Securing Long-term Storage and Use

Dieta Svoboda-Baas
(Interview conducted by Miriam N. Haidle)

Heidelberger Akademie der Wissenschaften, Karlstr. 4, 69117 Heidelberg, Germany

Watch the Video

Keywords: Data management, interoperability, long-term archiving, data life cycle

Large projects conceived in the last decade are generally aware of the entire life cycle of data. Digital infrastructure departments of hosting institutions help to organize how projects deal with data, from the initial stages of planning the projects and onwards, including financial resources and staff positions. Older projects – many of which have run for several years or even decades – are problematic with regard to establishing organization of the data, finding adequate storage in repositories, and gaining financial support. This latter case includes many research projects run by the Academies Programme of the Union of the German Academies of Scienes and Humanities. Here, Dieta Svoboda-Baas reports her experience with the projects of the Heidelberg Academy of Sciences and Humanities as she attempts to avoid isolated approaches through standardized solutions. Examples of solutions include several initiatives for the National Research Data Infrastructures (NFDI) in Germany, as well as the need for growing data literacy combined with disciplinary expertise.

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SUGGESTED LINK
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APPENDIX A

Digital Resources

Table 1: List of digital resources discussed during conference in alphabetical order

Archaeology Data Service	https://archaeologydataservice.ac.uk/
ArchData	https://github.com/davidcrowland/archdata
ARIADNEplus	https://ariadne-infrastructure.eu/ and http://portal.ariadne-infrastructure.eu/
FAIR Principles	https://www.go-fair.org/fair-principles/
INSPIRE Geoportal	https://inspire-geoportal.ec.europa.eu/
METAhub	https://metahubfrankfurt.de/
Neotoma	https://www.neotomadb.org/
NFDI4Culture	https://nfdi4culture.de/
NFDI4Memory	https://4memory.de/
NFDI4Objects	https://www.nfdi4objects.net/
NQMDB – Neogene Quaternary Mammals Database	hosted at CENIEH https://www.cenieh.es/en and accessible through the ROAD MapModule (https://www.roceeh.uni-tuebingen.de/roadweb/map_modul/index.html)
One Archaeology	Manifesto https://doi.org/10.3390/info11040222
Open Context	https://opencontext.org/
PaleoAsia DB	internal project database – project website: http://paleoasia.jp/en/
Paleo Core	https://paleocore.org/
PaleoMaps	internal project database – project website: www.sfb806.de, see also https://crc806db.uni-koeln.de/maps/
PeriodO	https://perio.do/en/
ROAD	https://www.roceeh.uni-tuebingen.de/roadweb/
SignBase	https://www.signbase.org/
Spacialist / eSciences Tübingen	Information about Spatialist can be found on: https://www.forschungsdaten.info/fdm-im-deutschsprachigen-raum/deutschland/baden-wuerttemberg/vfu-projekte-in-baden-wuerttemberg/spacialist/ and downloaded from: https://uni-tuebingen.de/forschung/forschungsinfrastruktur/digital-humanities-center/
tDAR (the Digital Archaeological Record)	https://www.tdar.org/
Text+	https://www.text-plus.org/
Throughput database	http://throughputdb.com/ and https://throughput-ec.github.io/
Wien Kulturgut	https://www.wien.gv.at/kultur/kulturgut/

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