Digital Imaging of Artefacts: Developments in Methods and Aims

edited by

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Foreword

Jacob L. Dahl

In a recent article in *Scientific American*, David Pogue discusses the fight against 'file format rot' (D. Pogue, 'How to Fight Format Rot', *Scientific American*, November 1, 2017). Pogue begins his article with a story about how his own digital sheet-music files had fallen victim to file format rot and bases the remainder of the article around a discussion with staff from the Library of Congress, an institution where file format rot could have more serious consequences than for most of us. Unsurprisingly, the Library of Congress has been a leader in digitisation of collections for two decades. Somewhat offhandedly, Pogue mentions the dramatic increase in capture resolution over the past two decades. Consequently, the digitisation of the Library of Congress collections is never finished: the files have to be continuously re-formatted to prevent format rot, and the original documents have to be continuously re-imaged with new and improved technology. Although one of the ultimate goals of digitising heritage collections is to reduce handling, we should therefore not expect that one round of digitisation will ever be enough—rather we should expect to produce generations of images, documenting the objects in increasingly better quality, but also any change over time.

My own knowledge of cultural heritage imaging comes from years of imaging cuneiform tablets and cylinder seals, and the observations of this introduction are almost entirely derived from my work in this area over the past two decades, and from my association with the Cuneiform Digital Library Initiative (CDLI, https://cdli.ucla.edu). The CDLI is without question the world's leading online project for cuneiform studies, serving a catalogue with more than 330,000 records and large amounts of meta-data such as well-structured transcriptions of more than 100,000 of these ancient texts, as well as various generations and types of visual documentation. Like the Library of Congress, we have also experienced an almost exponential growth in the possible capture resolution concurrently with a reduced cost of storage, yet we have resisted the temptation to increase our general capture resolution (600 ppi, serving only 300 ppi images online). There are two particular reasons for this. Obviously, cuneiform studies are not as well funded as an institution such as Library of Congress and never will be: increasing capture resolution leads to an increase in capture time and costs. But more importantly, perhaps, all of our objects originate from countries in the Middle East where access to the Internet is still lagging behind that which can be expected on campuses in other parts of the world, and increased file size will therefore lead to reduced access to these objects in the countries of origin.

But there is another, more crucial, reason for continuing to image everything first with simple techniques and at a relatively low resolution. In order to get an overview of a cuneiform tablet collection (and some are very large, such as the British Museum with more than 100,000 tablets), speed is of the essence. Capturing most collections at the same resolution also makes data management an easier task. Consider having to recover data after any emergency if your core data consists of thousands of tiny JPEGs used to deliver a non-static image in tiles (the standard delivery method for Reflectance Transformation Imaging data, e.g. https://cdli.ucla.edu/?q=rti-images). An overview of collections also enables us to answer different research questions and to fully integrate the study of text and artefact. And in the end, any image is better than no image. We need only remind ourselves of the most recent destruction of cultural heritage in the Middle East to

conclude that whatever can be done to capture the form and content of cuneiform tablets and other artefacts should be done.

Insisting on such simple standards does not mean that we have neglected any investigation or use of other novel capture technologies. About 10 years ago, I enthusiastically joined an Oxford-Southampton collaborative project led by Graeme Earl to build and test several camera dome systems for Reflectance Transformation Imaging (RTI) and to increase use and awareness of these systems in Oxford, Southampton, and beyond. Following some initial difficulties, especially how to share the results of dome captures online, we eventually co-opted this technology to target specific objects within a given collection. We therefore decided on a pragmatic approach to capturing these endangered collections. We insist on initially imaging all collections with the same technique (flatbed scanners) and the same resolution to gain an overview of the collection and to be able to quickly present collections online. We then use this overview to identify those objects that we deem important to capture with specialist equipment. This choice is made on a number of criteria. Is the object unique? Is it a high-impact object? Is the text deciphered? Is the text difficult to read and/or the object deteriorating? Is the object sealed? Usually, about one-fifth of a collection needs special attention, whereas the other four fifths can be imaged using standard equipment.

Whereas we had thus overcome the problems of imaging seal impressions by using RTI, the physical seals themselves remained very difficult to digitize. The most common Mesopotamian seal found impressed on cuneiform tablets, and therefore of particular interest to us, is the cylinder seal. These tiny cylindrical seals, engraved in intaglio on stones with a great variety of visual grain, are notoriously difficult to image. In modern publications, they are traditionally rolled in plasticine or a similar product and a black-and-white photo of the impression is reproduced. The paper by Dahl et al. (pp. 47-72) describes in detail the work we have undertaken to capture a fuller representation of cylinder seals. This work has the potential to revolutionise the study of cylinder seals, and with it the study of ancient Near Eastern art and iconography, and of ancient Near Eastern administration. To date, no unifying catalogue of cylinder seals exists, and no-one knows how many seals there are in collections worldwide. Instead, individual collections, often with very idiosyncratic collecting histories, have been published with little regard to the implications for wider study of cylinder seals. Being in its infancy, imaging cylinder seals will therefore surely lead to generations of images, and the constant need to update formats to avert format rot. But that is not a problem, as we must expect technology to progress and new research questions to be asked.

Drs Kelley and Wood assembled an exciting group of scholars for what was first thought of as an informal gathering, but which quickly developed into an important, albeit brief, workshop on current trends in imaging of ancient artefacts. A healthy mix of historians, engineers, and curators contributed to the success of the workshop. It is my view that it is exactly when we are able to bring together specialists from different disciplines that we make progress in the digital humanities, as well as in traditional humanities disciplines. It is a testimony to this that all of the papers here engage with humanities research questions, while exploring new methods to answer them.

Acknowledgements

The workshop that forms the basis of this volume would not have been possible without the financial support of Wolfson College's Academic Research Fund and Digital Research Cluster. We are particularly indebted to Prof. David Robey of the Digital Research Cluster for his enthusiasm in the formative stages of the project. The editors also wish to thank the funding bodies whose support gave them the opportunity to organize the event and the time to work on the preparation and editing of the volume: the John Fell Fund made possible the work of *Seals and their Impressions in the Ancient Near East* research project (2016–2017) at the University of Oxford, and the Leverhulme Trust sponsored the British Museum and University of Oxford research project *Empires of Faith* (2013–2018).

Our warmest thanks go to all the contributors to the workshop and the volume for their dedication and energy in engaging in this venture and sharing their work and experiences, and to all those who came to the workshop and participated in the discussion, especially Elena Draghici-Vasilescu and Jamie Cameron.

We would like to extend special thanks for the encouragement and support of the principal investigators of *SIANE* and *Empires of Faith*, Profs Jacob Dahl and Jaś Elsner, respectively, as well as that of our colleagues at the British Museum and the University of Oxford. We are also grateful to the participation of Wolfson College's Ancient World Research Cluster in the workshop, and for their continuing fellowship and community. Particular thanks are due to Louise Gordon and the Wolfson College Events Office for facilitating such a productive event, and for being extremely flexible when faced with an ever-expanding number of participants.

We are grateful to David Davison and Ben Heaney at Archaeopress for the production of this book, and to all those who granted permission for images, which are crucial for a subject such as this. We would also like to thank J. D. Hill and the British Museum for their support in the publication of this volume. Finally, we would like to make an additional thank you to all the host institutions of the artefacts under study for supporting and making welcome the various projects represented in the following pages.

Kate Kelley & Rachel Wood, October 2018.

Contributors

Editors

Dr Kate Kelley received her Doctorate of Philosophy in Assyriology from the University of Oxford in 2018 and is a specialist in the socio-economic history of early Mesopotamia. She is a Postdoctoral Fellow at the University of British Columbia (2018–19), and formerly a Research Associate at the Oriental Institute, Oxford for the project Seals and Their Impressions in the Ancient Near East (2016–17). Kate has been working for the Cuneiform Digital Library Initiative since 2012, including digitizing cuneiform tablets in the Louvre, the National Museum of Scotland, and the Yale Babylonian Collection.

Dr Rachel K. L. Wood is Lecturer in Classical Archaeology at Corpus Christi College, Oxford and a Junior Research Fellow at Wolfson College, Oxford, specialising in the art and archaeology of ancient Iran. In her previous position as a postdoctoral researcher with the British Museum and University of Oxford project *Empires of Faith,* she was an assistant curator of the Ashmolean Museum's exhibition *Imagining the Divine: art and the rise of world religions* (October 2017–February 2018).

Contributors

Juan Aguilar received a BA in Assyriology and Religious Studies from Heidelberg University and a Master's degree in Anthropology of the Americas at the University of Bonn. During his training as an archaeologist, he has excavated in Germany, Syria and Iraq, and later specialised in excavation photography, photogrammetry and drone mapping, working for projects in Iraq, Mexico, and Nicaragua. In addition to his studies, he has been active as an independent filmmaker and has completed two feature-length documentary film projects, *A Better Road* on Tibetan nomad people, and *Scanning The End* on laser scanning an ancient Maya city, together with one fictional short film entitled *Override*. He is currently working on the 'Rock Art of Iraqi Kurdistan Project' by Heidelberg University.

Professor Jacob Dahl is a specialist of the pre-Classical cultures and languages of the Near East at Oxford University. He has written on early Babylonian socio-economic history, early Near Eastern writing systems, and Sumerian literature. He works on the decipherment of proto-Elamite, the last undeciphered writing system from the ancient Near East with a substantial number of sources (more than 1600 tablets divided between the Louvre Museum and the National Museum of Iran). As a co-PI of the Cuneiform Digital Library Initiative, Dahl seeks to document and safeguard Mesopotamia's contribution to our shared world history by making the ancient records available freely online.

Steven Dey founded ThinkSee3D Ltd, a professional 3D studio near Oxford specialising in applying 3D technologies to natural and cultural heritage projects for museums and university researchers. Steven has produced hundreds of 3D digital models (using photogrammetry, structured light scanning and CT) and replica 3D physical objects (using colour and high resolution 3D printing) for clients including the British Museum, National Museum Scotland, Birmingham Museums Trust, UCL and the Universities of Oxford, Birmingham, York and Cambridge. A physics graduate from the University of Warwick, Steven went on to invent a collaborative decision software tool (AWARD) that is a UK government standard and was used in the procurement of major venues at the 2012 Olympics.

Dr Alexander Geurds is Associate Professor and Senior Researcher in the School of Archaeology at the University of Oxford and Associate Professor in the Faculty of Archaeology at Leiden University. He also holds a position as Assistant Professor Adjunct at the University of Colorado (Boulder) and served as Academic Director of the Netherlands Research School for Archaeology ARCHON between 2015 and 2018. He has carried out fieldwork in the Netherlands, the Antilles, Mexico and Nicaragua. He is the founding editor of the book series 'The Early Americas: History and Culture'(Brill). He primarily works on the prehistory of Middle and South America, with broader research interests in monumental sculpture, technology, archaeological theory, the contemporary conditions of archaeological fieldwork and the history of archaeology.

Professor Haris Procopiou is Professor of Aegean Archaeology at the University of Paris 1, Panthéon-Sorbonne. She is attached to the National Centre of Scientific Research (CNRS) Laboratory "Archéologie et Sciences de l'Antiquité" (ArScAn, UMR 7041). A specialist in ground stone tools, prehistoric agricultural techniques, and lapidary technologies, she applies use wear and residues analysis. Her recent studies and publications focus on tactile and visual perception of archaeological surfaces and on the role of senses and emotions during craft production. She participates in several archaeological fields in Greece and the Near East and in ethnographic studies in Morocco and Tunisia. She has directed two projects on lapidary crafts and technological transfers in the eastern Mediterranean supported by the French National Agency of Research (ANR). She has directed ethnoarchaeological field studies in Greece and India as also campaigns of experimental archaeology.

Hendrik Hameeuw is a Researcher at the Royal Museums of Art and History in Brussels and a faculty member at the University of Leuven (KU Leuven). He specializes in the application of imaging methods for Ancient Near Eastern artefacts, such as multi-light reflectance, SfM (Structure from Motion) photogrammetry and multispectral imaging.

Dr Jonathon S. Hare is a lecturer in Computer Science at the University of Southampton. He holds a BEng degree in Aerospace Engineering and Ph.D. in Computer Science. His research interests lie in the area of multimedia data mining, analysis and retrieval, with a particular focus on large-scale multimodal approaches. This research area is at the convergence of machine learning and computer vision, but also encompasses other modalities of data. The long-term goal of his research is to innovate techniques that can allow machines to understand the information conveyed by multimedia data and use that information for fulfil the information needs of humans.

David Howell is Head of Heritage Science at Bodleian Libraries. His current research applies imaging and analytical techniques to heritage objects. After a position as Head of Conservation Research for Royal Historic Palaces, he moved to the Bodleian to take up a role as Head of Conservation and Collection Care from 2005 until 2012. In his current role he oversaw the financing and conservation of the Gough Map of Great Britain and the Selden Map of China. David is a Trustee of Icon and The National Heritage Science Forum, and is an accredited conservator.

Professor Jeremy Johns is Director of the Khalili Research Centre and Professor of the Art & Archaeology of the Islamic Mediterranean at the University of Oxford. He is principally interested in the relationship between Islam and Christianity in the medieval Mediterranean as it is manifested in material and visual culture. His research has focused upon the archaeology of the transition from late antiquity to early Islam in the Levant and, especially, upon the archaeology, history, and art history of Sicily under Islamic and Norman rule, from the Muslims' conquest of the island in the 9th century to the destruction of the Islamic community of Sicily by Frederick II in the 13th century. He is also the

co-investigator in a project on the reconstruction of the early Islamic rock crystal, 9-12th century AD (supported by Ranros Universal SA).

Professor Kirk Martinez is a specialist in Electronics and Computer Science at the University of Southampton. His imaging and image processing research includes the VASARI and MARC projects on high resolution colorimetric imaging. In the EU Viseum project a new system was designed to allow web browsers to view high resolution images (which became IIPimage). He founded the VIPS image processing library and has developed ten RTI imaging systems. He is also active in wireless environmental sensor networks.

Fiona McKendrick received a BA in Archaeology and Anthropology from the University of Oxford and now works at the Ashmolean Museum, Oxford, managing and distributing images and 3D models of museum objects, and integrating the technology into digital collections online, education, and public engagement. Previously, she served as the Education and Outreach Officer for the Institute for Digital Archaeology and has carried out fieldwork in the UK, Italy, and Canada. Her research interests include museum technology, digital archaeology, digitization, and heritage visualisation as an interpretive lens.

Dr Elise Morero is a postdoctoral researcher at the Khalili Research Centre for the Art and Material Culture of the Middle East (University of Oxford). As an archaeologist, specialising in the analysis and reconstruction of ancient manufacturing techniques, her research focuses on lapidary craftsmanship, using a multidisciplinary approach (archaeological and ethnoarchaeological data, experimental reconstruction of ancient techniques, traceological and tribological analyses). Her work integrates diverse periods and regions from the stone vase industry in the eastern Mediterranean world during the Bronze Age (3rd - 2nd millenniums BC) to to the Mughal jade industry (17-18th century AD). She is co-investigator of the project on the reconstruction of the early Islamic rock crystal vessel production, 9-12th centuries AD (supported by Ranros Universal SA), and for a research program on the reuse of hard-stone spolia in Sicily under the Norman and Hohenstaufen rulers, 12-13th century AD (supported by the Gerda Henkel Stiftung and the John Fell Fund).

Dr Alison Pollard is the Principal Investigator of a multispectral imaging and 3D scanning project on the Greek and Roman sculptures and inscriptions of the Arundel Collection in the Ashmolean Museum in Oxford. She was Project Curator for the redevelopment of the Arundel Collection and Randolph Sculpture Gallery, and is now Assistant Curator in the Department of Antiquities at the Ashmolean. Alison is Lecturer in Classical Archaeology at St John's College, Oxford, specialising in the art and archaeology of ancient Greece and Rome.

Dr Roberto Vargiolu is a researcher in tribology at the Laboratoire de Tribologie et de Dynamique des Systèmes of the École Centrale de Lyon (University of Lyon, CNRS). Specialising in methods of wear process analysis applied to humanities, especially archaeology and the history of technology, he is co-investigator of many international multidisciplinary projects in collaboration with archaeologists, historians, and museums such as the British Museum and the Louvre. He is also committed to the development of educational projects inspired by his scientific research projects. He has thus produced comic books and public performances for children explaining the multidisciplinary of scientific research, the role of tribology and ancient technology.

Dr David Young completed his PhD in geophysics at Cambridge University. As Research Associate at Edinburgh University (1980-85), he worked on human visual perception and motor control. At Sussex University (1985-2010), he taught many areas of computer science, while researching computer vision and artificial intelligence, concentrating on image motion and retinal image representations. He has continued working on digital image analysis at Southampton University, looking at time-lapse imagery of rivers for flow monitoring and deep learning applied to aerial imagery.

Professor Hassan Zahouani teaches mechanics and tribology of surfaces at the École National d'Ingénieurs in Saint-Étienne. He is director of the Centre of Bioengineering and the research team Mechanics of Materials and Processes at the Laboratoire de Tribologie et de Dynamique des Systèmes of the École Centrale de Lyon (University of Lyon, CNRS). He is also President of the French Society of Bioengineering and Imaging. Beside bioengineering, his research has mainly focused on analyses of use-wear mechanisms and the development of new methods of surface analysis, employed in several international multi-partners and multidisciplinary projects in co-direction with archaeologists and museums. He is at the originator of eight patents concerning the engineering of human skin and is President of the humanitarian association *Treatment of the Eyes and Skin* for the rural population in Morocco.

Contents

Introduction

Kate Kelley and Rachel K. L. Wood

This volume brings together new lines of research across a range of disciplines from participants in a workshop held at Wolfson College, Oxford, on 23rd May 2017. In light of rapid technological developments in digital imaging, the aim in gathering these contributions together is to inform specialist and general readers about some of the ways in which imaging technologies are transforming the study and presentation of archaeological and cultural artefacts. The periods, materials, geography, and research questions under discussion therefore are varied, but the contributions are united in shared interests concerning how technological development can encourage new types of research and public engagement.

Over eight chapters, various imaging methods are introduced and their capabilities explored. A key feature of this volume is the diversity of specialists involved, including archaeologists, art historians, conservators, curators, computer scientists, imaging technicians, and heritage outreach specialists. It aims to offer an exchange of ideas between groups working across the sciences and humanities, and joins the ranks of other volumes, conferences, and special journal editions that recognise the 'urgency of providing a common ground, where technology may meet humanities' (Stanco, Battiato, and Gallo 2011). Bridging these gaps is perhaps easier said than done, but we hope this collection will contribute fresh and up-to-date perspectives to a growing inter-disciplinary dialogue.

The aims of cultural heritage imaging projects can generally be divided into three groups: outreach, preservation/conservation, and historical or archaeological research—each of which is touched upon in this volume. A particular focus is put on research: digital imaging of material culture is a key component of the digital humanities, which broadens the scope and nature of 'traditional' humanities research questions by applying digital information technologies to the presentation, organisation, and mining of data. This includes both textually encoded data and, increasingly, visual data. In some ways, the study of uninscribed artefacts with imaging technologies has lagged behind that of archaeological landscapes and inscribed objects, although interest in artefact imaging is quickly growing in momentum.[1]

Not only 'how?', but 'why?' is an important question when it comes to the digital imaging of cultural heritage. When we have the ability to use new imaging techniques, in what situations should they be used? What are the aims and intentions in using particular imaging technologies? Popular and academic debate about, for example, 3D reconstructions of the arch of Palmyra, have emerged, often focusing on ethical and political issues (Clammer 2016; Harrowell 2016; Munawar 2017; Newhard 2015). Consequently, there are growing efforts to present applications of technology with more explicit comment on their significance and theoretical implications (Hermann 2016; Huggett 2015; Warwick, Terras, and Nyhan 2012), themes that are also brought out in this volume.

The following chapters explore applications of developing technologies in artefact imaging and the impact of those technologies upon the study and presentation of material culture. Technologies include photogrammetry, hyperspectral and multispectral imaging, reflectance transformation imaging (polynomial texture mapping), structured light scanning, portable light microscope, and 3D

[1] At least two other important recent conferences have presented a broader focus on imaging of cultural heritage, from objects to landscapes: '3D Imaging in Cultural Heritage' (The British Museum, 9–10th November 2017) and 'Digital Cultural Heritage' (The Final Conference of the Marie Skłodowska-Curie Initial Training Network for Digital Cultural Heritage, Olimje, Slovenia, 23rd– 25th May 2017). Both events demonstrate the interest, relevance, and advances made in recent work on the digital imaging of artefacts.

printing, among others. In the first chapter, Steven Dey provides perspectives from a 3D digital professional, describing various 3D imaging technologies and strategies in relation to artefacts, including photogrammetry, structured light scanning, CT and micro-CT scanning, and the potential applications of these methods for research and especially in public engagement and museum contexts. David Howell uses hyperspectral imaging to discover colour and lost polychromy on different types of artefacts and reflects on the future potential for new applications of these methods.

Three contributions to this volume discuss imaging of small objects including ancient seals, engraved gems, and coins. The contribution from the *Seals and their Impressions in the Ancient Near East* research team (Jacob Dahl, Jonathon Hare, Kate Kelley, Kirk Martinez, and David Young) discusses their project to develop and test a new system capable of imaging large numbers of ancient Near Eastern cylinder seals. Their work diverges from the majority of 3D imaging efforts by aiming to capture an entire corpus (of c. 50,000 objects) rather than select items. Elise Morero, Hara Procopiou, Jeremy Johns, Roberto Vargiolu, and Hassan Zahouani use a digital microscope and interferometry to identify tool traces that can assist in the study of lapidary craftsmanship, presenting aspects of their work on early Islamic rock crystal vessels and Mughal hard stone production. Hendrik Hameeuw explores technical difficulties in reconstructing the surface shape and appearance of stone seals and metal coins using photometric stereo (PS), challenging researchers to produce the most accurate images possible for each unique cultural heritage object.

Moving from the miniature to the monumental, a series of free-standing sculptures are discussed by Alexander Geurds, Juan Aguilar, and Fiona McKendrick, who take us to a small family-run museum in Nicaragua. They use photogrammetry as a means to create digital immersive virtual environments and augmented reality for understanding prehistoric statuary in its original landscape and assisting in its presentation to the contemporary public. In Oxford's Ashmolean Museum, Alison Pollard uses multi-spectral imaging on Roman marble sculpture from the Arundel collection to investigate polychromy, ancient and modern restorations, the carving process, and ancient and modern display, demonstrating how digital imaging can contribute to object biographies and the history of museum collections. In the final chapter, Rachel Wood documents the process of 3D imaging and printing of a high-impact, but materially challenging, object within the time constraints of planning a temporary exhibition, providing the viewpoint of a classical archaeologist making their first engagement with digital imaging.

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