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Digital Archiving of Cultural Properties Based on Advanced ICT and Utilization of the Archived Data

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Digital Archiving of Cultural Properties Based on Advanced ICT and Utilization of the Archived Data

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Editor's Introduction

This book presents the contents of the fifth anniversary International Symposium of Asia Japan research at Ritsumeikan University, Session 1 held on February 22, 2021, entitled this data archiving of cultural properties based on advanced ICT and utilization of the archived data. The theme of this session is digitalized archiving of cultural heritage and its applications. We discuss, for example, how to archive cultural heritage objects, access the study archive data, utilize the Data Archive data for researchers and for the public. It contains five lecturers on this state-of -the-art research project.

We will begin with Professor Feener. He is a professor at Kyoto University and belongs to the Center for Southeast Asian Studies. Discussing the integration of digital heritage documentation and online archive building, his chapter explains the work of creating an online cultural heritage database with the Maritime Asia Heritage Survey (MAHS) project.

The second chapter is by Dr. Fadjar I. Thufail, a Senior researcher at the Indonesian Institute of Sciences (LIPI), and he presents his research from Indonesia, Jakarta, entitled "Sea as Method: Borobudur and the Ontology of the Maritime World," in which he introduces some new ways of the of utilizing this archive of data.

The third chapter is from one of the earlier-career researchers at Ritsumeikan University, Dr. Yuting Song. She is an expert in databasing. Her title is "Linking Ukiyo-e Records across Languages: An Application of Cross-Language Record Linkage Techniques to Digital Cultural Collections." She will present her new schemes for a language-matching database, which will be useful for our cultural heritage, database.

The fourth chapter is from researcher Itao Pan, a doctoral student at the Graduate School of Information Science and Engineering, Ritsumeikan University. Her chapter is entitled "Fused 3D Transparent Visualization for Large-scale Cultural Heritage Using Deep Learning-based Monocular Reconstruction." She will describe the visualization of the history archive, the Borobudur Temple of Indonesia, designated as a UNESCO World Cultural Heritage.

The final chapter is by Welte Li, a doctoral student at Ritsumeikan University. She is doing research on the archiving of the Gion festival, one of the biggest traditional festivals in Japan and the title of her talk is on the creation of collision visualization data using a laser scan point cross for safe designing of the route of the parade, which has many advantages over traditional processes in route planning.

We hope that readers will enjoy the various innovative uses of data visualization described in this book.

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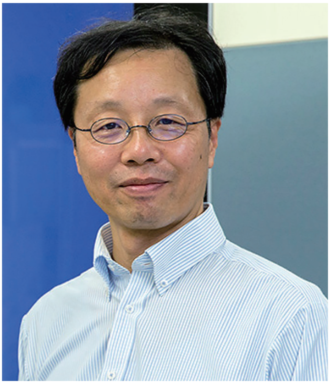
Contributors

Prof. Satoshi TANAKA



Editor

Satoshi Tanaka is a professor at the College of Information Science and Engineering, Ritsumeikan University, Japan. He also serves as the vice director of the Asia-Japan Research Institute, Ritsumeikan University. He earned his Ph.D. in theoretical physics from Waseda University, Japan, in 1987. Following positions as an assistant professor, senior lecturer, and associate professor at Waseda University and Fukui University, he assumed the role of professor at Ritsumeikan University in 2002. His current research focuses on computer visualization of complex 3D shapes, including 3D scanned cultural heritage objects, internal structures of the human body, and fluid simulation results. He has held leadership positions such as vice president of the Visualization Society of Japan (VSJ), president of the Japan Society for Simulation Technology (JSST), and president of ASIASIM (Federation of Asia Simulation Societies). Currently, he serves as a cooperation member of the Japan Science Council. He has been honored with best paper awards at the Asia Simulation Conference (2012 and 2022), the Journal of Advanced Simulation in Science and Engineering in 2014, among others.

Prof. R. Michael FEENER

Chapter 1. The Integration of Digital Heritage Documentation and Online Archive Building

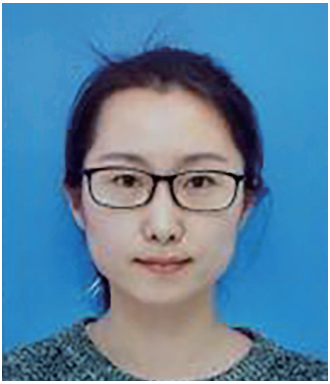
R. Michael Feener is a Professor of Cross-Regional Studies at the Center for Southeast Asian Studies at Kyoto University, and an Associate Member of the History Faculty at the University of Oxford. He was formerly the Research Leader of the Religion and Globalisation Research Cluster at the Asia Research Institute, Associate Professor in the Department of History at the National University of Singapore, and the Sultan of Oman Fellow at the Oxford Centre for Islamic Studies. He has also taught at Reed College and the University of California, Riverside, and held visiting professor positions and research fellowships at the Universidad de Macau, Harvard, Kyoto University, École des Hautes Études en Sciences Sociales (Paris), the University of Copenhagen, The Doris Duke Foundation for Islamic Art (Honolulu), and the International Institute for Asian Studies (IIAS) in Leiden, the Netherlands. He received his Ph.D. in Religious Studies from Boston University in 1999 and has published extensively in the fields of Islamic studies and Southeast Asian history, as well as on digital humanities, post-disaster reconstruction, religion, and development. He is currently PI and Director of the Maritime Asia Heritage Survey, which works to digitally document endangered archaeological and historic sites in the Maldives, Indonesia, and Thailand: <https://maritimeasiaheritage.cseas.kyoto-u.ac.jp>.

Dr. Fadjar I. THUFAIL

Chapter 2. Sea as Method: Borobudur and the Ontology of the Maritime World

Dr. Fadjar I. Thufail is a Senior Researcher and currently the Head of the Research Center for Area Studies of the Indonesian National Research and Innovation Agency (BRIN). He received his Ph.D. in Social Anthropology from the Department of Anthropology at the University of Wisconsin-Madison. His interests include science, technology, society studies, digital humanities, heritage infrastructure, multispecies ethnography, and Japan Studies. At BRIN, he leads the More-than-Human Lab Program and has initiated collaborations on digital humanities research focusing on the study of the digital infrastructure of cultural heritage in Indonesia and Japan.

Dr. Yuting SONG



Chapter 3. Linking Ukiyo-e Records across Languages: An Application of Cross-Language Record Linkage Techniques to Digital Cultural Collections

Dr. Yuting Song is a Scientist at the Agency for Science, Technology and Research (A*STAR) in Singapore. Before joining A*STAR, she was a Specially Appointed Assistant Professor at the College of Information Science and Engineering, Ritsumeikan University. She received her Ph.D. in Information Science and Engineering from Ritsumeikan University. Her research focuses range across natural language processing, cross-lingual information processing, digital libraries, and digital humanities. She is particularly interested in the potential of applying text and language processing technologies to the digital library and digital humanities domains to enhance accessibility, understanding, and utilization of vast collections of digital data.

Dr. Jiao PAN

Chapter 4. Fused 3D Transparent Visualization for Large-Scale Cultural Heritage Using Deep Learning-Based Monocular Reconstruction

Jiao Pan majors in Information Science and Engineering, with a keen focus on deep learning-based image processing and the 3D digitalization of historical artifacts. She earned her Ph.D. from the Graduate School of Information Science and Engineering at Ritsumeikan University in 2022. Following this, she held a position as a JSPS Postdoctoral Fellow until May 2023. Since July 2023, she has been serving as a lecturer at the University of Science and Technology Beijing. Among her notable publications are “3D Reconstruction of Borobudur Reliefs from 2D Monocular Photographs Based on Soft-Edge Enhanced Deep Learning,” *ISPRS Journal of Photogrammetry and Remote Sensing* (January 2022, Issue 183, Pages 439–450), and “Integrated High-Definition Visualization of Digital Archives for Borobudur Temple,” *Remote Sensing* (December 2021, Vol. 13, Issue 24, Page 5024).

Dr. Weite LI

Chapter 5. Collision Visualization of a Laser-Scanned Point Cloud: The Revival of a Traditional Procession Route

Weite Li completed his Ph.D. at the Graduate School of Information Science and Engineering, Ritsumeikan University. He is currently a Lecturer at the School of Artificial Intelligence, Chongqing Technology and Business University, China, and a Visiting Researcher at the Asia-Japan Research Institute, Ritsumeikan University. His research focuses on the reconstruction, visualization, and application of deep learning for 3D point clouds. Recently, his primary research efforts have been concentrated on utilizing deep learning techniques to process laser-scanned point clouds, aiming to achieve higher-quality visualization of 3D point cloud scenes. In his publication titled "Deep Learning-Based Point Upsampling for Edge Enhancement of 3D-Scanned Data and Its Application to Transparent Visualization," *Remote Sensing* (June 2021, Vol. 13, Issue 13, Page 2526), he proposed an upsampling network specifically designed for edge regions in large-scale laser-scanned point cloud data. This approach, combined with translucent visualization techniques, enhances the overall quality of visualization effects. Building on this work, he is currently investigating methods to complete the shape of incomplete areas within point clouds, particularly addressing large-scale laser-scanned data from the real world.

Chapter 1
The Integration of Digital Heritage Documentation and Online Archive Building

R. Michael FEENER

In this essay, I would like to address the issue of how the collection of raw data in the field can be combined with digital assets produced in a lab to create an integrated multi-media archive. In other words, how can the coordination of primary field documentation and digital processing work together in a coordinated way to construct something new that is more than just the sum of its parts? By way of illustration, I will introduce some of the more concrete aspects of the work that my team and I have been doing on the Maritime Asia Heritage Survey[1] both in our Digital Heritage Documentation Lab at Kyoto University, and in the field with our Survey Teams in the Maldives, Indonesia, and Thailand.

Over recent decades, the rush to digitize just about everything has both responded to, and in turn inspired further technological innovations that are transforming practices of scholarship across a wide range of fields. Work in new modes that digital technology affords has produced a massive amount of new documentation of diverse kinds of source material, from photographs and audio-video recordings to text scans, geospatial information, and 3D models. While the digital revolution was initially traumatic for some of the more established

1 The MAHS online archive is open-access at: <https://maritimeasiaheritage.cseas.kyoto-u.ac.jp>

Our project is financially supported by Arcadia, who share our firm commitment to open access publication of data: <https://www.arcadiafund.org.uk/promoting-open-access>

academic disciplines, particularly for the Humanities, after an initial rush to the ramparts around the turn of the twenty-first century, more scholars have been turning towards some more reflective critical engagement with what new media might mean for the interpretation of cultural phenomena.

Critical reflection on the epistemological implications of dealing with digitized culture prompts critical explanations of the new media ecology in which our work is now embedded. Well beyond the challenges of digital literacy and the development of small-scale techno fixes, we need to grapple on a conceptual level with new ways of conceiving of the very work of scholarly interpretation of Big Data and "born-digital artefacts."[2] As Jerome McGann remarks in conceptualizing what he calls a new republic of letters: "As we proceed to digitize our print and manuscript objects, and hence our engagements with those objects become primarily digital engagements, the living culture that created and sustains them itself also becomes an object" (McGann 2014).

The early rush to digitize the archives was pursued in relation to work done in the field of scanning literary texts — first primarily those in Roman script via OCR work on printed texts and subsequently of manuscripts in a wider variety of languages. In the course of such developments, some scholars of philology have come to recognize the particular strengths that their traditions of scholarship might be brought to bear on grappling with some of the new issues that arise alongside these new ways of seeing, reading and knowing.

Some historical perspective can then be helpful to try to frame our experience of the current moment. Consider, for example, how the very the form of a Codex, a book stitched between covers, helped to shape the formation of the humanities in the Western academic tradition that

2 These are particularly fast-moving conversations, often adjusting on the fly to both technological advances and academic fads.

has now come to assert a global influence — or how scholarly journal articles played a similarly formative role in the development of the modern sciences. Then we might begin to ask ourselves new questions about what kinds of scholarly work as well as digital formats and informatics structure — such as those of online multimedia archives — might facilitate. What new fields of scholarly interpretation might be born out of our engagement with these new media? And, how will specific modes of access and representation frame new histories of material culture?

In this brief chapter, I would like to try to open up some lines of discussion with particular reference to the work of my colleagues and I on the Maritime Asia Heritage Survey (MAHS), both in our Digital Heritage Documentation Lab at the Kyoto University Center for Southeast Asian Studies (CSEAS) and in our fieldwork in Indonesia, Thailand, and the Maldives.

The Maritime Asia Heritage Survey (MAHS)

The Maritime Asia Heritage Survey works to discover, inventory, and digitally document critically endangered heritage sites and object collections in coastal and riparian contexts across southern Asia to create an open-access digital archive of this material. Based upon a pilot study in the Maldives (Feener et al. 2021a), the MAHS has expanded operations across several counties along the Maritime Silk Road.

The MAHS pursues its aims of both producing new forms of digital documentation and facilitating open access and secure long-term preservation. Our integrated project design encompasses primary field documentation in multiple countries, digital archive construction, and metadata management, in addition to the production of new digital assets by the MAHS Lab. In what follows, I present a structured overview of our project. A primary selection criterion for field documentation sites is the relative severity of environmental and human threats to tangible cultural heritage.

Concept, Scope, and Schedule

Many of the coastal communities and riparian regions of maritime Southern Asia are at the front lines of climate change. Parts of the coast of Aceh, Indonesia have been suffering from dramatically increased risk of coastal erosion and flooding exacerbated by rapid subsidence following the 2004 earthquake and Indian Ocean tsunami. This has exacerbated the impending loss of areas that were historically part of the Aceh Sultanate in the sixteenth and seventeenth centuries, including major burial grounds, mosque complexes and other sites that are now either underwater or quickly going under.

IMAGE 1
Damage to an old Muslim cemetery in Aceh, Indonesia
Source: Author

Other complex examples are myriad across the region, but some of the most drastic threats confront the low-lying islands of the Maldives, where accelerating coastal erosion and rising sea levels endanger the long-term inhabitability of the entire nation:

Threats to the material heritage of the country are, however, not limited to environmental factors. In 2012, vandals stormed the National Museum in Male, severely damaging rare surviving artefacts from the country's pre-Islamic past.[3]

IMAGE 2
Vandalism at the National Museum of the Maldives
Source: Author

In this "100% Muslim" nation, moreover, many Islamic heritage sites also routinely suffer intentional destruction by human hands – especially older cemeteries and shrine mausolea (*ziyaaraiyy*), which were traditionally centers of ritual observance that are condemned by currently dominant reformist interpretations of Islam.

3 For a brief overview of the history of Islam in the Maldives, see: (Feener 2021).

IMAGE 3
Traditional Muslim shrine mausoleum in the Maldives
Source: MAHS

Given the nature of the dire, compound threats facing the Maldives, the MAHS is undertaking a systematic survey of every island in each atoll. Starting in the pilot phase of the project in the Maldives, we began a systematic survey of every island in the Maldives — the first-ever undertaking of its kind — which is expected to be completed by the end of 2025.

IMAGE 4
Field Documentation of an historic Muslim cemetery lost to coastal erosion in the Maldives
Source: MAHS

As work progresses on that front, the MAHS has also expanded to deploy new field teams to use the same systematic field survey methodology and data collection protocols in other countries, with ongoing operations in Indonesia and Thailand.

IMAGE 5
Terrestrial LiDAR scanning of a ruined mosque in the Maldives
Source: MAHS

Working with local governments and communities on every inhabited island and using aerial LiDAR and systematic field walking on the many more uninhabited islands, the Field Team documents any surviving pre-modern material traces of inhabitation from wells, cowrie deposits and ceramic scatters to ruins of Buddhist temple sites, mosques, and vernacular domestic structures.

In other countries where we work, our field survey documentation is selective, rather than comprehensive. In Indonesia, our work focuses on the eastern islands of the archipelago, which have historically received far less archaeological attention than have Java and Sumatra.

IMAGE 6
MAHS field documentation of a rock art site in eastern Indonesia
Source: MAHS

We work in consultation with the Indonesian Directorate General of Culture at the national level. In such a large and diverse country, it is not possible to document all historic and archaeological sites, and so the MAHS works with local government agencies and local communities to determine priority sites and objects for documentation. The selection process thus involves consideration of multiple factors, including significance to the local community, the existence of previous documentation, and the severity of threats facing a particular site or collection. Our methodology attempts to document the local significance of particular sites by incorporating the video recording of oral history interviews to complement our empirical data collection in the field. With written consent for publication, those videos are uploaded to our project's YouTube channel for maximum accessibility and archived for long-term preservation.

Project Teams

To record this wide range of field data, the MAHS deploys full-time teams in each country where we work. Each MAHS Field Team is comprised of seven full-time members, including a Country Coordinator, Field Survey Leader, Archaeologist, Architect, Surveyor, Photographer, and Data Wrangler.

IMAGE 7
MAHS Field Team recording an abandoned village in the Maldives
Source: MAHS

As most of the areas that we work in have limited capacity and access to some of the technologies needed to produce high-quality digital heritage assets, the Maritime Asian Heritage Survey provides the resources to help local field teams and invests significantly in capacity building. The aim is to establish solid foundations upon which future work can be conducted to make the open-ended expansion of this digital archive possible.

During the pilot phase of our work in the Maldives, we were challenged at first by the lack of experienced field documentation personnel. We were, however, able to second an officer from the Department of Heritage to help identify and train other Maldivian candidates. We also recruited field staff first in Aceh, Indonesia — where my colleagues and I had done some previous work — and brought a number of the most talented local partners we had there to begin training a cadre of Maldivians in field survey team methodology. When the pandemic hit, our colleagues from Indonesia went back home to Indonesia, but those in the Maldives stayed in place. Their two groups then came to form the cores of the two national teams that currently work in each country. The field teams are trained in the technical operation of both traditional survey equipment and newer digital technologies, including both terrestrial and aerial LiDAR. All of these tools are then used according to the standardized project methodology.

Field Survey Methodology

In the Maldives, only about 200 islands of the over 1200 islands of the country are currently inhabited, but some of them were previously inhabited. What our survey team does on a lot of these uninhabited islands, is to anchor offshore, wade the equipment to the beach, and set up a point to deploy the drone to capture data that can be used to produce an orthophoto map. We then proceed to systematically field-walk the island from the beach to the interior with bush knives and GPS units in hand to identify and mark potential sites. Once we find a site, we are then able to set up and follow data collection protocols.

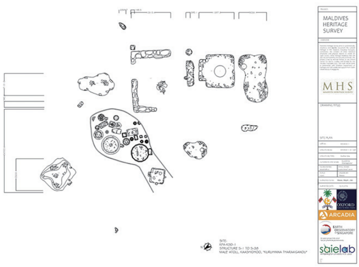


IMAGE 8
Aerial photo and CAD site plan for a ruined Buddhist monastery in the Maldives
Source: MAHS

On the inhabited islands of the Maldives, we have developed a productive method of engagement with local communities, starting upon our arrival with a formal meeting with the Island Council to both explain our work and to learn from the local community about any sites that they would like to prioritize for heritage documentation. This then becomes another major component of our site selection in addition to the ground proofing of sites listed on the modest registry of the Maldives Department of Heritage and new discoveries made in the course of fieldwalking by the MAHS Maldives Field Team. In the course of our work, we also document local collections held by Island Councils and individuals who consent to have manuscripts or other objects recorded and made open-access available online as part of the digital archive. Texts are systematically photographed and processed for IIIF deep zoom and published via a Universal Viewer plug-in on the MAHS website.

Each day, the work of the MAHS Field Teams produces a multimedia batch of information, which is loaded up to the cloud from the field teams by our data Wrangler. This is sent to Kyoto University, where we have established a digital heritage documentation lab at the Center for Southeast Asian Studies. There, the MAHS has a team including staff specializing in database construction and management, photogrammetry, CAD, GIS, LiDAR visualization, documentation editing, and other aspects of data processing.

Given the diverse forms of material recorded by the Field Teams and the range of digital assets created and curated by the MAHS Digital Lab in Kyoto, our dataset extends considerably beyond the established parameters of a traditional archeological survey. We have thus had to confront new challenges of how to organize, present, share, and store this diverse multi-media assembly. Each component must furthermore be integrated and conceptualized in relation to one another in ways that would not be possible within a traditional archaeological monograph publication format.

Our digital archive is designed to be integrated with multimedia digital assets and connected metadata in ways that facilitate dynamic search results and focus on cross-referencing in ways that can support practical usage, as well as the formulation and exploration of new research questions. We also create contextualizing reference materials that can help users coming to the website with tools for interpreting the dataset. This includes an annotated timeline that we have constructed out of local source material, a virtual library, where we have negotiated for open access rights to important pieces of scholarship on the country or sites where we work and make those publications easily available in one place — thus providing resources for contextualizing our dataset and supporting new research on related topics. Our most ambitious work of creating new reference materials for contextualizing the MAHS dataset has been the production of an illustrated glossary of Maldivian material culture that provides vernacular Dhivehi names and English-language glosses for different ornamental motifs, architectural features, and a wide range of traditional objects.

Data Structure, Access, and Long-term Preservation[4]

The multimedia records, digital heritage assets, and reference materials of the MAHS online archive are anchored in a database that is built on the Arches platform. Arches is an open-source software package that was first developed by the Getty Conservation Institute and the World Monuments Fund. This GIS-referenced database

4 The following section draws upon and summarizes a longer discussion of this topic that has been previously published as: Feener, Ishikawa, and Daly. “Big Data in the Humanities” (Feener et. al. 2021b).

architecture uses a customizable resource graph framework that opens up rich possibilities for thinking about how the pieces of data relate to each other. The MAHS has developed its Arches instance customized with record types that can accommodate a full range of materials ranging from individual pottery sherds to complex 3D structural models that have been produced through a combination of laser LiDAR and photogrammetry. Our Arches instance, furthermore, not only structures records collected by our own Field Teams, but also provides a framework for the incorporation of data from pre-existing datasets into the MAHS online archive. There is a tremendous wealth of documentation of archaeological and historical sites in the region already out there that has been collected by governments, museums, academic researchers, and community-based heritage organizations over recent decades. These datasets contain relevant, but previously unpublished material on heritage sites, structures, or collections of objects from all across the region. However, much data of this type has been largely unknown and/or unavailable beyond rather limited circles. To address this, the MAHS works closely with diverse stakeholders who are willing to join us in publishing their materials as open-access data available via the online archive.

To date, we have been working with a range of partners ranging from large governmental bodies such as the Indonesian Directorate General of Culture to international academic research projects and small, specialized local museum collections. However, much of the data that has been shared with us by various partners is idiosyncratically structured and/ or difficult to access, and each must be accessed and searched separately — making the work of comparison and connections frustratingly difficult if, that is, the information is even publicly available. The MAHS thus works with the owners of such datasets to standardize, integrate, and even translate their material into a searchable format that can be integrated into our online archive. In this way, a number of previously unconnected datasets can now be seen simultaneously alongside each other, mapped using GIS, and linked to a host of multimedia digital heritage assets. Our entire online archive is open access via our Arches database with larger files for associated point clouds, 3D models, and videos materials that are made easily accessible on our SketchFab, YouTube, and OpenHeritage3D accounts.

In addition to ensuring open-access to all of our data, the MAHS also provides for the long-term stable preservation of this digital archive. To ensure the long-term future accessibility of these digital assets, all our metadata is consistently formatted, and each batch deposit includes an accumulative README file containing a detailed asset inventory. In addition information is provided on general rights for reuse, contact information for project administration, and a recommended citation so that those people or those other datasets that have contributed to ours can get properly acknowledged when anybody uses their data.

We save our files both in the current application formats and also export them into the most widely used and durable file types available for various kinds of data at the moment of deposit. The university libraries and systems of both Kyoto and Oxford provide secure digital repositories of our complete dataset on two different continents to ensure long-term survivability. The latter is under the rubric of the Oxford Research Archive, which assigns a permanent DOI for data deposits for a project and provides long-term curation in the Bodleian Library's long-term archival digital storage. These redundancies are designed to ensure the maximum longevity and utility of the digital archive for future generations.

Conclusion

The Maritime Asia Heritage Survey is amassing a large amount of data from diverse sources in the course of our work and working to make sure that it is both archived for long-term preservation and made freely accessible online. Although the primary source material is of a kind that might be traditionally associated with fields like history and archaeology, we also devote considerable critical thought toward issues related to the kinds of digital assets we create and how the material we generate through our work might be preserved, transmitted, used, and possibly transformed in new directions in the future.

Scholars have long considered how their writings might be read and interpreted by posterity. Today, however, we find ourselves thrust into new kinds of consideration of our scholarly obligations to both the past that we endeavor to preserve, and to the future accessibility of what we are producing. Consideration of these kinds of questions raises a host of issues about the nature of archive building in the 21st century that go beyond earlier discussions of simply digitizing sources. Earlier conversations on digital humanities focused on issues arising from the work of scanning the archive in ways that tended to cast the situation as one of having a stable body of material that just had to be moved into a new media. Then, as Big Data Sets entered into consideration, a host of new issues involved with archiving the digital came to the fore. These include the structuring of a multimedia digital archive that incorporates existing digital records, scanned paper documents, primary archaeological field survey data, and a growing number of new digital assets that we create in our own lab and the implications carried by the recording of material culture into such virtual forms. It is not simply a matter of the migration of a traditional type of repository of cultural artifacts onto a new digital platform. Rather, our work today is more about shaping a different kind of archive that allows for new forms of engagement by diverse users today while also recognizing that there might be a whole other range of unexpected usage of our digital archive in the future.

The consideration of such questions by the MAHS reflects emerging trends across interdisciplinary engagements involving digital resource creation and the exploration of new frontiers in the humanities in a stimulating new collection of studies that appeared last year on cutting-edge intersections of historical geography, GIS science, and textual analysis. Charles Travis, Francis Ludlow, and Ferenc Gyuris, for example, aim to “conceive of new ontologies and epistemologies to understand the dynamics of human and environmental phenomena in the past, the present, and our possible speculative futures.” (Travis, Ludlow, and Gyuris 2020, xii). More sustained critical attention to the conceptual dimensions of new forms of digital archive can thus help us to do considerably more than just make additional material more widely available. For while pursuing such work, we must also be open to the exploration of questions about what forms of knowing might be enabled or hindered by the kinds of resource records and digital assets that our field and lab teams generate, and the potential usages for the archive which we are assembling out of that material, including those afforded by AI. This also needs to include a forthright acknowledgement that, almost inevitably, there will be unintended usage of our data in the future along trajectories that we are not yet able to imagine.

In closing, we would also like to emphasize that the work of constructing a complex multimedia archive of diverse digital heritage assets entails complex institutional as well as intellectual considerations. Beyond the first-order issues of obtaining project funding, recruitment, and logistics, a project such as this can also pose significant challenges to the traditional University structures of our respective institutions.

We see this, for example, in issues involving the relative positions of computer technicians and traditional academics in the structures of university facilities and departments, as well as in the still unexplored areas of developing mechanisms for assessing the quality of digital assets that might be similar to the old guild-based model of peer review that is central to both editorial authority and performance evaluations in academia today. In addition, a project such as ours must draw on the support of the university and its resources and potentially drive changes to other parts of the university system, including the IT office, Media Center, and Library. There are a tremendous number of issues involved in supporting a project of the scope of the MAHS, but to date, there has been little cross-institutional discussion of these issues. More will certainly be needed as big data projects in the humanities continue to develop in new directions in the future.

Our work on the MAHS aims to enable utilitarian access to data for use by government agencies, heritage management professionals and local communities. Beyond that, however, the overarching goal of our work is something bigger: to assemble, to preserve, and to freely share a body of empirical material that can be dynamically engaged with by anyone looking for resources to help them explore an open-ended range of questions in new ways. This essay has been an attempt to present the ways in which we have sought to facilitate this in the design and implementation of the MAHS in the hope of generating further constructive conversations.

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Chapter 2
Sea as Method: Borobudur and the Ontology of the Maritime World

Fadjar I. THUFAIL

Instead of going into detail by elaborating on the data and statistics, I will start by giving you an overview of conceptual issues that we can reflect on while doing digitalization work. This is important in order to explain this project not only in terms of the technical context, but also in terms of how it can shed light on some new questions, new challenges from an engineering point of view, and also from a scientific perspective.

I will begin with a brief introduction to why maritime studies are important for Indonesia by turning to the work of Professor Adrian. B. Lapian. Next, I will briefly elaborate on what I mean by "sea as method" and how it might be relevant as a way of reflecting on areas studies work, not only in terms of reflecting on the technical aspects of the project, but also on some broader conceptual issues that are related the notion of the theoretical framing of what we usually call area studies. I will describe two important sites, Borobudur and the Punjulharjo Boat, to show how materials found at the archaeological sites and digitization networks could help us to illustrate the "sea-as-method" approach. Finally, I will conclude by visiting this conceptual point and some other thoughts on how, in particular, a project can benefit from the "sea as method" using a project that we have been working on collaboratively with Ritsumeikan University on digitizing Borobudur and also the upcoming digitizing projects and ways of reflecting on the wider issues of my maritime work in Indonesia.

Indonesia has many islands and comprises a large body of seawater, not to mention thousands of river systems that also connect the hinterland to the coastal area. However, when one pays close attention to scholarly literature concerning Indonesia, the majority of researchers only talk about the history and the politics of agricultural land-based communities. This does not mean that there are no studies on maritime ecology communities, but most of them talk about agricultural land-based communities. In fact, when the US instituted area studies in the 1960s and 70s, the Indonesian studies focused largely on the cultures of people who live in Java, Sumatra, and Bali hinterlands, and Indonesian studies were primarily identical to the study of peasants and land-based cultures.

This situation drove the late Adrian B. Lapian (1929–2011) to challenge the status quo, and he succeeded in shifting the focus from the land to the sea. He thought that Indonesian history has basically been about the people within the interior. People are more familiar with ethnic diversity in Sumatra or the Kalimantan jungle than with the ethnic groups found along the coastal areas of the Indonesian archipelago, not to mention the ethnic groups who live entirely on the sea, such as the Sama-Bajau people. To fill in the lack of the studies of maritime communities, Lapian (2001) wrote a very important dissertation titled "Orang laut, bajak laut, raja laut: sejarah kawasan laut Sulawesi abad XI" ("Sea Nomads, Pirates, Sea Kings: Regional History Sulawesi Sea in the Eleventh Century") that has now become a classic in maritime historical studies in Indonesia. His dissertation was published later in Indonesian with the same title. It is a critical historical work. Lapian spoke Dutch, Spanish, and Portuguese languages, a rare capability among Indonesian historians, and having access to the primary archival sources allowed him time to pay more critical attention to the politics and the circumstances that served the Dutch, Spanish and Portuguese archival records, as the three major actors plying maritime trade in the 15th to 19th centuries in Southeast Asian waters.

Lapian suggests that the European sources used the denigrating term “pirates” to refer to the people who attacked European ships and disturbed the trade routes and shipping activities. Lapian argues that the maritime activities in the Indonesian sea took place actually long before the Europeans came. There were three social groups who were engaged in maritime network activities before that period. Those were the real pirates, the sea nomads, and later on, the maritime kingdom, political units who possessed significant naval powers. One of the major points Lapian highlights is that when we rely on European sources to study maritime power, we risk overlooking the so called “indigenous” maritime activities and materials that might be less interesting to the Europeans. We have neglected too many of those activities and materials regarding the daily life of the people, since long before the Europeans came seeking for spices and other traded goods.

Much of the project that we currently engage in is about trying to recover these indigenous materials and activities that might be less interesting to Europeans, but that actually became a central part of the daily life of people living in the Indonesian archipelago.

Sea as Method

Let me briefly explain what I mean by “Sea as Method.” Adrian Lapian states that we should imagine the sea as a system, and he proposed the concept of *systim laut* (sea system) to discuss the maritime world that is the Sulu Sea, as a sea system, which is the precursor to the expression “Sea as Method.” This chapter proposes a different kind of approach, what I call the topological approach to study the sea or the maritime world. What we understand as the maritime world actually consists of three major material components: the people, the material cultures, and the ecologies. Although we can argue that these components can form any landscape, in this case they comprise the dynamics and flexible relations that exist throughout the conduits of waterways and marine ecologies. So, when the people, the material cultures, and the ecology are assembled at one point in time, and at a particular location, what emerges is what I call the ontology of the maritime world.

I should also emphasize that what I take as an ontology is different from the philosophical notion of ontology, because the assembling and the network in my concept of ontology are always in a dynamic relationship, which is different from the notion of philosophical ontology, which is always regards ontology as something that is fixed and continuous throughout time. The ontology of the maritime world indicates a more dynamic notion of assembling a network when we are talking about ontology. We could mention here how recent work in digital anthropology also talks of the so-called digital as having its own kind of ontology. This chapter will not discuss the point here, but it is important to see that this is actually one way that Lapian was referring to when he spoke of wrapping up the theoretical questions that can bridge the humanities, social science applications, and technological engineering approaches.

Topologies

What we perceive as the Sulu Sea, from Lapian's point of view, is a geographical entity that can be distinguished from, for example, the Indian Ocean or the Java Sea. His notion of a map of this area is very much embedded with the GIS that Professor Feener mentioned in Chapter 1. When we talk about the maps, we are talking about the particular boundaries of a certain region. However, we see it from a different angle. That is, we can see the sea as a water conduit that allows the processes of topological formations to take place. The waterways facilitate the networks through which the assembling and branching out of people, material culture, and ecologies happen. Hence, it is more interesting to focus on the sea as a topological conduit that facilitates the assembling and branching out of people, material culture, and marine ecologies, rather than discussing the city solely as a site for activities.

Let me now illustrate my conceptual points with two archaeological data, the Borobudur Relief, and the Punjulharjo Boat site.

Borobudur and the Ocean

Borobudur is a Buddhist temple dating from the ninth century AD and a World Heritage site. You might wonder what Borobudur has got to do with the maritime world as it is located far inland on the central plain of Java Island.

Figure 1. Borobudur World Heritage Buddhist Temple.
9th Century AD: Hindu Buddhist Period
Source: Author

However, the water conservation office has identified at least ten reliefs of ships and boats depicted on different parts of Borobudur. Reliefs of ships and boats are scattered around, and they have already found at least ten depictions of boats and ships on the reliefs.

Figure 2. Ship depicted on the Borobudur Relief
Source: Author

Figure 3. Ship depicted on the Borobudur Relief
Source: Author

Let me draw attention to Figures 2 and 3. These are the most important and iconic depictions of ships on the Borobudur temple. If you carefully examine the pictures of the ships, you will see that these are most probably ocean-going ships.

If you look carefully, you can see the ships have outriggers. From this, we can conclude that these are not Chinese, Arab, or Indian ships, but locally built ships that commonly ply the Southeast Asian seas. Outrigger ships are the typical style of shipbuilding that is common in the Pacific or Southeast Asia. Thus, when you see this kind of outrigger ship depicted on the Borobudur reliefs, you can be sure that the people who built this temple in the ninth century AD were already familiar with the local technology of boat or shipbuilding, prior to the arrival of Chinese junks or European ships. This is an important historical fact that we should pay more attention to. One of the projects that we do when visualizing the Borobudur 3D model, is to focus on this kind of aspect, to see to what extent this kind of technology was actually already available during the construction of the temple.

In addition to the outrigger, the Borobudur ship in Figures 2 and 3 also uses fore and aft rigging, and this is another shipbuilding technique that is common in Southeast Asia. Figure 3 shows a full-scale reproduction of such a ship. It was constructed in 2002 by As'ad Abdullah, a master shipbuilder from Kangean Island, of East Java province. It was reconstructed in the shape of the Borobudur ship by traditional methods using the wood and bamboo materials commonly found in Southeast Asia.

Figure 4. The working reconstruction of the Borobudur ship
Source: Author

In 2003, this reconstructed ship then sailed from Jakarta to Accra, Ghana, to prove the seaworthiness of the design, and eventually, it arrived safely in Accra in 2004. This experiment successfully proved that in the Borobudur time, local people had the necessary knowledge to build long-distance, ocean-going ships. In Figure 5, you can see a digital reconstruction of the ship made by the Borobudur Preservation Office. There are some differences in details, but as you can see, they are trying to reconstruct the two major components depicted in the relief: the outrigger and the rigging system.

Figure 5. The digital reconstruction created by the Borobudur Preservation Office
Source: Author

This case is interesting because the actual reconstructed boat was made before the digital reconstruction, and usually it would be the other way round.

Figure 6. Boat with double outriggers from Palau, the Philippines.
Source: <https://www.flickr.com/photos/kartlasarn/23836007653/>

Figure 6 gives you an idea of what other examples of outrigger boats look like in the Pacific region. This one is from the Philippines.

Figure 7. Punjulharjo boat
Source: Author

The Punjulharjo boat was found and excavated by the Jakarta archaeological office, and the site was found near the town of Raman on the northern coast of Central Java, quite a distance from the Borobudur. In terms of the archaeological material, it is really interesting, because remains of boats are rarely found in Indonesia due to the hot humid climate. The Punjulharjo boat was carbon dated from the seventh to eighth century AD, a little earlier than Borobudur, so it is from the time of the early Sriwijaya Buddhist Empire (7th–14th Century AD) period and Hindu-Buddhist Mataram Kingdom (8th–12th Century AD) but not very far separated from the time of the Borobudur temple. According to one of the archaeologists, it was probably left behind and not wrecked during a trip, which is probably why the condition of the boat was quite intact.

Figure 8 shows the Punjulharjo boat, which is definitely different from the Borobudur boat as it has no outrigger. Perhaps it comes from a different boat-building tradition than the other ship. This is an important distinction that I would like to emphasize, as later on when I discuss topology, this kind of technological aspect is very important.

Figure 8. The preserved skeleton of the Punjulharjo boat
Source: Author

This boat also shows the techniques that are also common in Southeast Asia, which are the application of a certain design and lashed-lug techniques where the lugs and planks are lashed together with coconut fiber roots. These techniques are also commonly found in the Indonesian waters and in some of the Southeast Asian coastal communities.

Figure 9. No-outrigger boat for river transportation on the Borobudur relief
Source: Author

However, as you can see in Figure 9, a boat with no outrigger can also be found on Borobudur relief this year. The scene around the boat looks like a forest, and the animals also suggest that the boat is on a river not the sea. Therefore, this relief, together with the ship relief, indicates that the artisans and the people who built the temple and made the relief were already familiar with different types and functions of water transportation, one with ocean-going technology and the other with inland river transportation technology. So here we have two different kinds of technology that we can learn more about from the digital reconstruction of the Borobudur relief.

Conclusion

After briefly discussing the Borobudur ship and the Punjulharjo boat as examples of material cultures that are related to the maritime world, I would now like to go back to the conceptual points that I raised earlier. The important question is: How do we talk about the ontology of the maritime world? This chapter proposes that we can understand ship or boat-building technology as an assemblage that comes together to constitute an ontological space of the maritime world. Shipbuilding technology is not just a technology; it consists of an assemblage of materials, designs, experts, knowledge, belief system, and the ecological components.

From the above, my argument on the Borobudur Relief and the Punjulharjo Boat shows that we can at least talk about two ontologies of the maritime world that were constituted by how the outrigger technology, the building technology, or the shape of these boats and ship designs, are shaping the topologies of the maritime networks. Thus, when we talk about these kinds of topological connections there is not only assembly, but also branching out, so we can have those networks in which one representation of the network comes in the form of an outrigger boat and the other one as the assemblage of a technology, and that later on produces this kind of non-outrigger shipbuilding technology. These are the two kinds of ontologies which appear by using the maritime world as a context instead of the land base or country-specific context of an area.

To conclude this chapter, let me briefly illustrate what I mean by the topological network, and how this topological network can illustrate the networks that emerged from the technological assemblage.

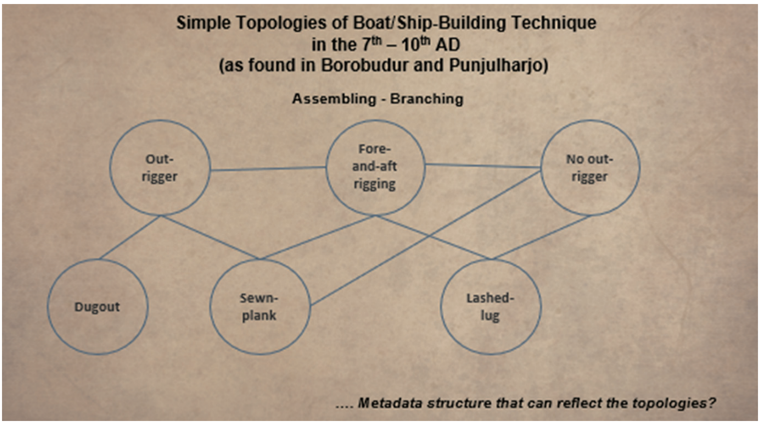

Figure 10. Simple Topologies of Boat/Ship-Building Technique in the 7th-10th AD
Source: Author

We should note that this deals only with the selected technological features of shipbuilding I mentioned earlier, which is the rigging and construction of the hull of the ship or the boat. There are many other technological features that can complicate the topological network such as the steering design, the stabilizing, and other social and cultural features, such as the composition of the crews and also the navigational technology.

I will close this chapter by returning to the central thread of this book: digital technology. I would like to propose an opening question. If we would like to create a digital database of the maritime world, such as the one Professor Feener has already been working on for quite some time, how can the structure of the database metadata reflect the complex topological networks? This question is important for me, because, as Professor Feener mentioned in the previous chapter, the most important part of this kind of new initiative is not only creating the database, but also reflecting on how the database could inform new conceptual and theoretical reflection, not only for the social science of humanities, but also in terms of technology, and computer science expertise.

Finally, regarding this digital ontology, we should all consider to what extent these techniques that we have been using into visualize components in Borobudur Relief, can also give more nuance to the complexity of this typological network that we have been describing in terms of our work on the maritime world?

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Chapter 3
Linking Ukiyo-e Records across Languages: An Application of Cross-Language Record Linkage Techniques to Digital Cultural Collections

Yuting SONG

The work described in this chapter was jointly done by Dr. Biligsaikhan Batjargal and Professor Akira Maeda at the College of Information Science and Engineering, Ritsumeikan University.

Ukiyo-e is well-known as a traditional Japanese art form and is one of the popular styles of the Edo period (1603–1868). Not only in Japan but also in many Western countries, there are many museums, libraries, and galleries that have digitized Ukiyo-e block prints. In different countries, digital cultural collections are described using metadata in different languages, and for example, digitized Ukiyo-e prints are found on the internet with metadata in Japanese, English, and Dutch.

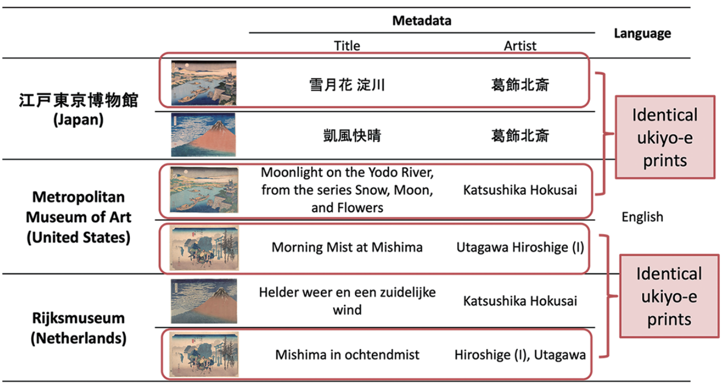

Figure 1. Digital versions with metadata in different languages
Source: Author

We can see that identical Ukiyo-e prints could be described in different languages like the examples in Figure 1. The metadata records refer to the same Ukiyo-e prints, but the metadata is in Japanese, English, and Dutch. The purpose of our work is to find the identical Ukiyo-e prints by using the textual metadata in different languages, for example, on the titles and artist names in Japanese and English as in Figure 2.

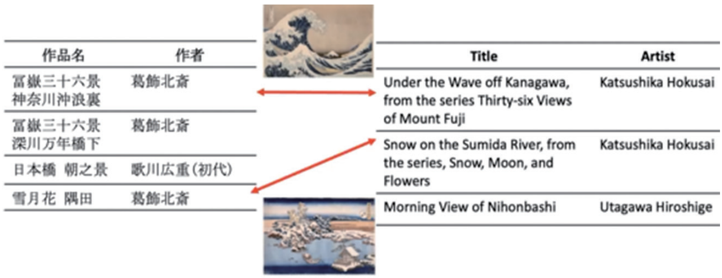

Figure 2. The examples of the identical Ukiyo-e metadata records from different digital collections in Japanese and English
Source: Author

This research could help people to search the Ukiyo-e prints, regardless of language and it could also help metadata creators enrich metadata in other languages.

Cross-language Record Linkage

Cross-language record linkage is used to identify record pairs that refer to the same real-world entities across data sources in different languages. Given the metadata records in different languages, the key step is to measure the similarities between metadata in the different languages, which is the across-language metadata similarity calculation. Then, based on these metadata similarities, the record pairs are classified into matches or non-matches by using a decision model.

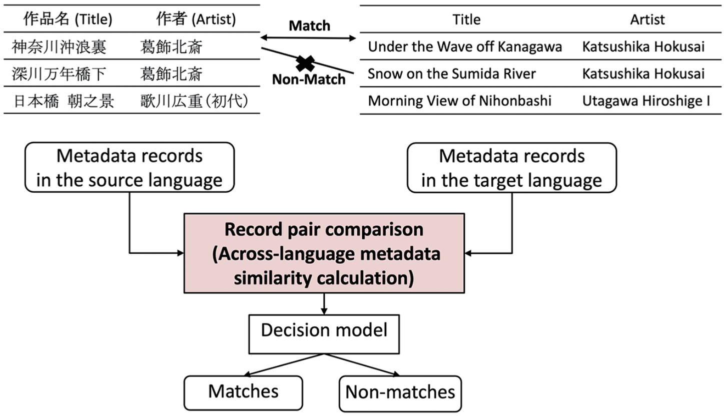

Figure 3. Calculating metadata similarities in different languages
Source: Author

The challenge of cross-language record linkage is how to calculate the metadata similarity in different languages. As shown in Figure 3, we deal with this problem from two directions. One is a translation-based method, which uses machine translation to overcome the language barriers, and the other is the method without translation. The metadata are translated from one language to the other using the translation-based method. As shown in Figure 4, the metadata are translated from Japanese to English by means of machine translation and then compared within the same language. For the second method, without using translation, we use bilingual word embeddings to represent words in metadata within one vector space, and then calculate metadata similarity.

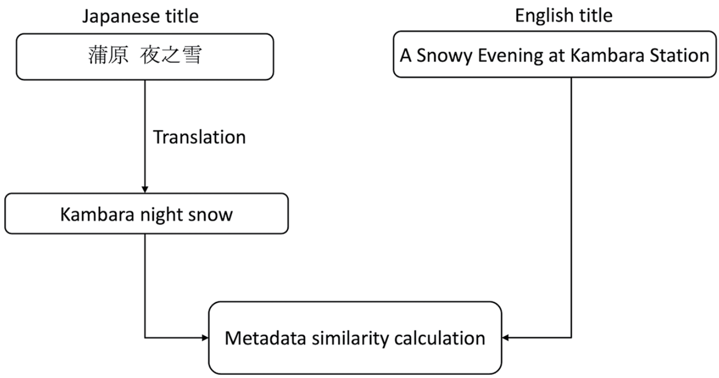

Figure 4. Metadata similarity calculation using translation-based method
Source: Author

Let me briefly explain word embedding and bilingual word embedding. Embeddings are the distributed vector representations of words, which are dense, low dimensional, and real value vectors. Usually, the dimension of the word vector is fixed, for example, 200 or 300. Figure 5 is an example of the word vector to represent the English word "storm."

- **The dimension of the vector is hundreds (eg. 200, 300)**
- **e.g. *vector* (storm) = [0.23, 0.44, -0.76, 0.33, 0.19, ...] dim = 200**

Figure 5. Vector for the word "storm"
Source: Author

One of the advantages of word embeddings is that semantically similar words are close in the vector space, and the semantic similarity between words can be calculated using this word vector.

In bilingual word embedding, the cross-lingual vector representations of words can be obtained by linear mapping between monolingual word embeddings.

Figure 6 shows a cross-lingual word embedding space. In this space, words such as the Japanese word "*sekai*" and its corresponding English word "world" have a closer distance represented by the close vectors.

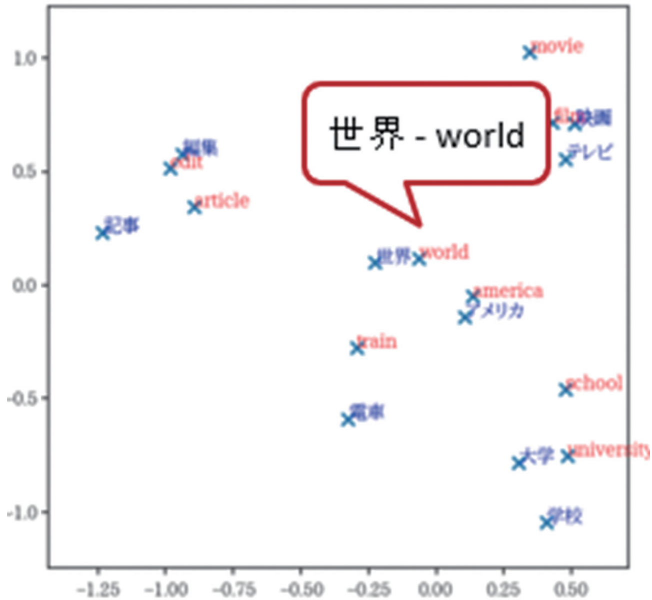

Figure 6. Words in different languages that are similar have close vectors.
Source: Author

Because bilingual word embeddings can capture the semantic meaning of words across languages, we use these vectors to represent the words in metadata, and then calculate the metadata similarities in different languages.

The process for calculating the similarity of Ukiyo-e titles using bilingual word embeddings involves the following steps. Firstly, we will represent all the words in the source and target languages using bilingual word embedding. For each word in the title in the source language, we calculate the cosine similarity with each word in the title in the target language, as shown in the equation at the bottom of Figure 7. At the same time, we also use the romanization of this word to calculate the cosine similarity with each word in the title in the target language. Accordingly, we use the maximum similarity score as the contribution of this word to the title similarity.

- For each word $w_i^{t_s}$ in the title in the source language
  - It is used to calculate the cosine similarity with each word $w_j^{t_T}$ in the title in the target language
  - The romanization of word $w_i^{t_s}$ is also used to calculate the cosine similarity with each word $w_j^{t_T}$ in the title in the target language
  - The maximum similarity score is used as the contribution of $w_i^{t_s}$ to the title similarity

$$S_{W2W-Mat}(t_s, t_T) = \sum_{i}^{N_{t_s}} max_{w_j^{t_T} \in t_T} \left[cosine\left(w_i^{t_s}, w_j^{t_T}\right), cosine\left(w_{r_i}^{t_s}, w_j^{t_T}\right)\right]$$

Figure 7. Metadata similarity calculation
Source: Author

Finally, the title similarity is calculated by using this formula and the sum of all the words that contribute to the title similarity. The example in Figure 8 shows the process of how our method calculates Ukiyo-e title similarity in Japanese and English. The arrows represent the similarity calculation between two-word vectors. Each word is used to calculate the cosine similarity with the word in the English title. The words in English titles are also represented by the bilingual word embedding. The red arrows represent the maximum similarities of Japanese words, which are the contributions of Japanese words to the title similarity calculation.

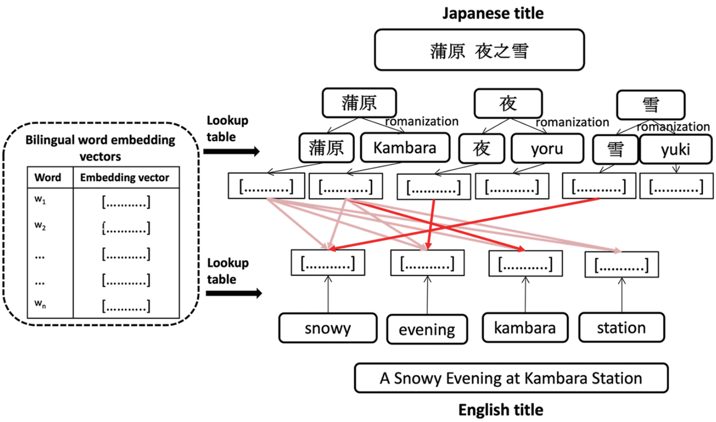

Figure 8. Example of title similarity calculation using bilingual word embeddings
Source: Author

Next, we did some experiments to find identical Ukiyo-e prints between databases in Japanese and English. We used the title of Ukiyo-e prints to evaluate our methods. To reduce the number of record pairs to be compared, we filtered the candidate record pairs by using the artists' names of Ukiyo-e prints. We collected 203 Japanese records from the Edo Tokyo Museum and 3,398 English records from the Metropolitan Museum of Art. Each Japanese Ukiyo-e metadata record has a corresponding English Ukiyo-e metadata record in this English data set, which means they referred to the identical prints that we wanted to find.

For the machine translation-based method, we translated Ukiyo-e titles from Japanese to English by using three well-known online machine translation systems: Microsoft Translator, Google Translate, and DeepL Translator. For the method without translation, we need to learn bilingual word embedding, which requires monolingual word embeddings and bilingual word pairs. To learn the monolingual word embeddings, we use Japanese and English Wikipedia articles and the Word2Vec toolkit. For the bilingual word pairs, we use 9000 common Japanese words and their English translations to learn the mapping between the Japanese word embedding space and English word embedding space. We followed the training setup in this paper [1].

The results for finding identical Ukiyo-e records are shown in Table 1.

Methods	MAP	Top-1 precision	Top-3 precision
MS	0.4949	0.3839	0.5663
Google	0.5750	0.4478	0.6522
DeepL	0.5114	0.3922	0.5862
BiWE-w2w	0.2698	0.2007	0.3002
BiWE-w2w+roma	0.5338	0.4660	0.5721

Table1. Experimental results

Among all the results, we can see that Google Translator obtained the best performance. Within the translation-based methods, we can see that the result is actually influenced by the different translation systems.

If we compare the method based on translation and the method without translation, although the result of the bilingual word embedding-based method is worse than that of the translation-based method, it is a promising result because it can be used for other low-resource language pairs where machine translation is not available.

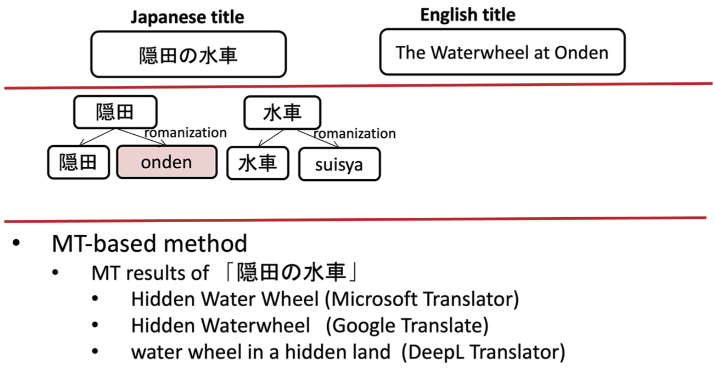

Figure 9. An example demonstrating that the bilingual word embedding-based method is better than the MT-based method
Source: Author

Figure 9 shows how using the romanization of Japanese words in the bilingual word embedding-based method contributes to the title similarity calculation. The corresponding Japanese word in this English title is romanized as “Oden,” but all the machine translation systems translated this word as “hidden” or “hidden land.” Thus, in this case, the machine translation result could not match its corresponding word in the English title.

We also would like to discuss the limitations of our approach. Because our method relies on the text for metadata, our methods failed in cases when the corresponding English title is an inadequate translation. For instance, as illustrated in Figure 10, these two identical Ukiyo-e prints’ the English title did not contain the first two Japanese words in the Japanese title. Our method failed in cases like this.

Figure 10. An example of the limitation of our approach
Source: Author

Conclusion

This chapter has introduced our method of metadata data similarity calculation in different languages and shown our method's ability to find the identical Ukiyo-e prints between Japanese and English databases. In the future, we will further improve the performance of this method by using other metadata fields. Currently, we only use the title and artist's name, but in the future, we want to use other metadata fields, such as the publication date. We also intend to apply our method to other languages, for example, between English and Dutch, and between Japanese and Dutch.

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Chapter 4
Fused 3D Transparent Visualization for Large-Scale Cultural Heritage Using Deep Learning-Based Monocular Reconstruction

Jiao PAN

Figure 1. Borobudur Temple
Source: Author

The visualization of digital archives is increasingly important in the preservation and also the analysis of cultural heritages. With 3D scanning technology, it is possible to efficiently acquire and preserve digital data of existent cultural heritages. For some cultural heritages that no longer exist, multiple image-based methods can also be used to reconstruct 3D models.

However, there are many cases where only one monocular photo remains for one cultural heritage. In this case, as 3D scanning and multiple image-based methods cannot be applied, the ability to reconstruct a 3D model from a single image is urgently required.

Figure 1 shows the Borobudur Temple, a UNESCO World Heritage site Feener introduced in Chapter 1. It is the largest Buddhist temple in the world. On the temple wall, there is the most complete collection of Buddhist reliefs in the world, containing more 1,400 panels of reliefs.

Each relief tells a different story, accurately illustrated by many objects. Based on different themes, these reliefs can be divided into five sections. One section is named the Karmavibangga, the Hidden Foot. Due to restoration work 200 years ago, almost the entire section of 160 panels of the Karmavibangga is buried under stones and is no longer visible to visitors except for four panels on the southeastern temple wall.

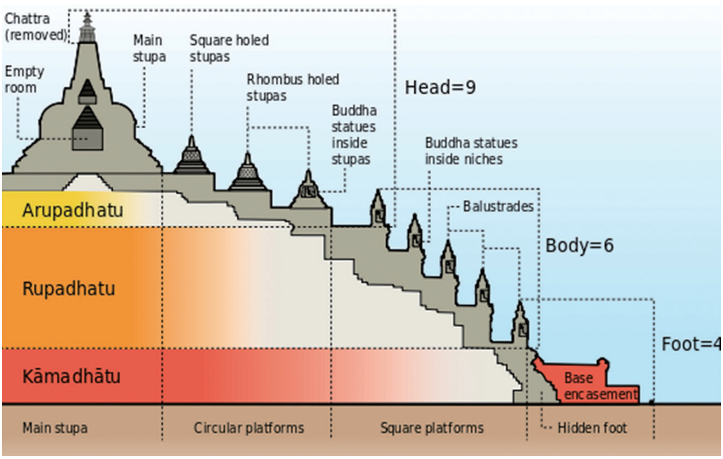


Figure 2. Section of Borobudur showing the hidden foot (in red)
Source: Autho

In Figure 2, the red box represents the southeast corner of the temple. Figure 3 is a photo of the corner, and you can see that only four remaining reliefs on the temple wall are visible, and all the other reliefs on the first level, which are shown in yellow, are covered by stones.

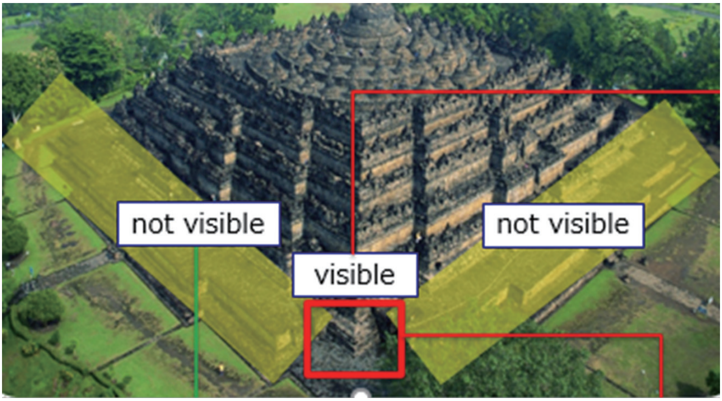


Figure 3. Exposed corner of the temple
Source: Author

To record the visible parts, we can simply use 3D photographic scanning and visualize the scanning data. However, we need to find another way to get the image of the buried parts, as only some grayscale photos taken in 1890 remain. Figure 4 shows one of these grayscale monocular photos and there is only one photo remaining for each panel.

Figure 4. 1890 photo of the buried relief
Source: Author

As these photos are the only remaining record, conventional digitizing by 3D laser or photo scanning multiple image-based methods cannot be applied in this case. So, we proposed using monocular depth estimation based on deep learning to reconstruct a 3D model directly from the old monocular photo. Fortunately, all the old photos taken in 1890 are still available.

Visualization Method

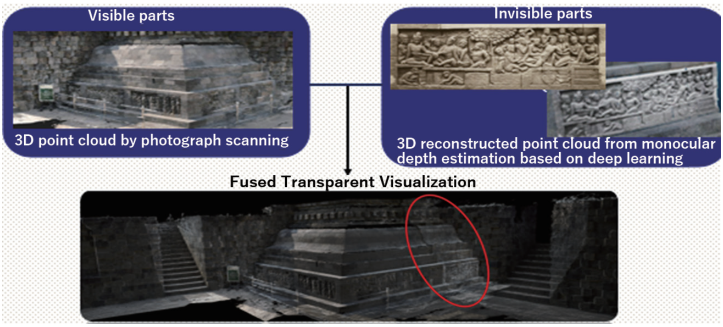


Figure 5. Flowchart of proposed visualization method
Source: Author

Figure 5 is a flowchart of our proposed method. For the visible parts, we use photograph scanning to obtain 3D point clouds. For the buried parts, which are not visible, we use deep learning to estimate the depth from the monocular photo and reconstruct it into point clouds. Then, we can fuse these two kinds of point clouds together and provide a transparent visualization for the entire Borobudur Temple.

This method is efficient and accurate for providing actual 3D visualization directly from a single monochrome photo of the image, especially for relief-type cultural heritages.

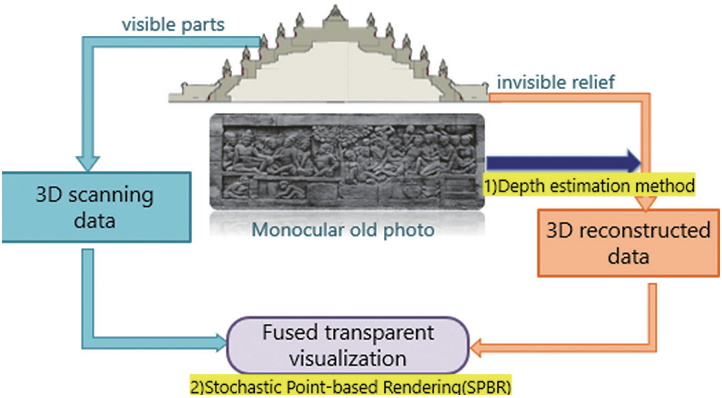


Figure 6. Fused 3D transparent visualization for Borobudur
Source: Author

Figure 6 shows an overview of the method we employed. To achieve this fused 3D transparent visualization, we mainly use two methods. The first one is the depth estimation method which is used to reconstruct the point clouds of the buried parts. The second one is the transparent visualization method, the Stochastic Point-based rendering (SPBR) that our lab developed.

When there is no extra information to use, we need to estimate depth by using deep learning to reconstruct the 3D model from a monocular 2D image. With this depth map, we can reconstruct the 3D shape of the reliefs because the value of each pixel in the depth map represents the depth distance between the point and the camera.

Deep Learning Method

Next, I will briefly introduce how deep learning works in our case by explaining how we get the estimated depth map from the monograph photo. It is a machine-learning method based on deep neural networks, which has become more and more popular in recent years. In computer science, it is named neural network because its structure is similar to the neurons in the human brain. Figure 7 shows a drawing of a basic neural network. It has input layers, which is what you have, and output layers, which is what you want to obtain.

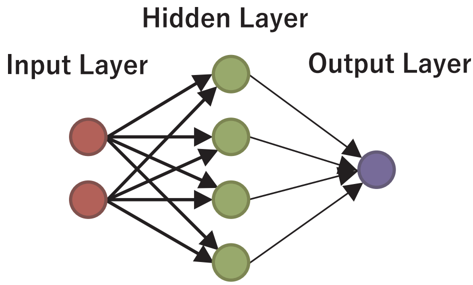


Figure 7. A simple artificial neural network
Source: Author

Moreover, the hidden layers are usually designed to be very deep and complicated, so that we can learn and solve difficult problems with them. In Figure 7, the hidden neural has only one layer, but it usually has hundreds or even thousands of layers. We use the monocular images as the input and the depth map as the output. In order to train the model, we need to tell the model direct answers to the questions; that is, we need to use ground truth of the old photos during the training process. In this step, we need a great number of relief pictures and the ground truth, which are the depth maps for the training set. First, we use photographic scanning to scan the visible parts and obtain our original data set, which is point cloud data of those visible four reliefs in Karmawibhangga. Next, we separate the information into pairs of images and depth maps, which is the label for our training. As the reliefs are large-scale, we cut the large images into patches and apply this augmentation method to them. While obtaining the individual scanning data, it is also necessary to reduce the effects of light conditions and noises, otherwise it will affect the results. Before our data is fed to the depth estimation network, median filter and batch normalization are applied to the data set to reduce the effect of different light conditions.

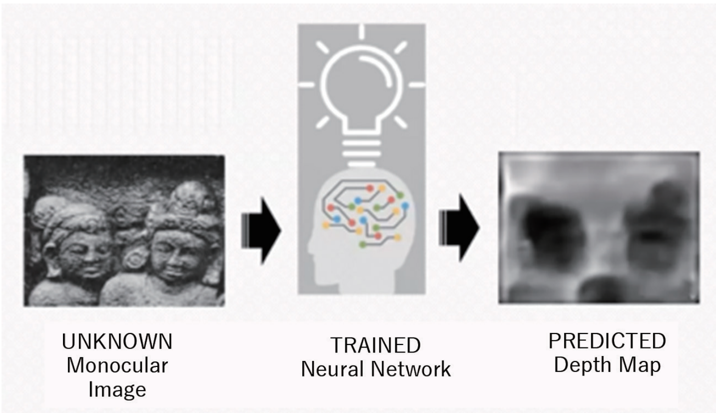


Figure 8. Completing the training process
Source: Author

When we have finished the training process, we can input the old photo of the hidden reliefs, which are totally unknown to the neural network. The training model will estimate the depth loss, and we can get an output depth map as in Figure 8.

Now, let me summarize the depth estimation method. To reconstruct the 3D model from a monocular photo, the most important difference between a 2D monocular photo and a 3D Point Cloud is that we do not have depth estimation in the photos, which is the value of the Z axis. In the first step, we apply a depth prediction neural network to map intensity to depth value. The network will provide us with a depth map where the value of each pixel contains the distance between the point and the camera. Once we obtain the depth map, point cloud data can be reconstructed by a linear transformation between the depth value and the Z axis. In Step 1, we need the relief data set to train the model because we apply a neural network. In our case, we use pairs of monocular photos and depth maps. We calculate the dataset from the scanning 3D points of the visible reliefs in Borobudur.

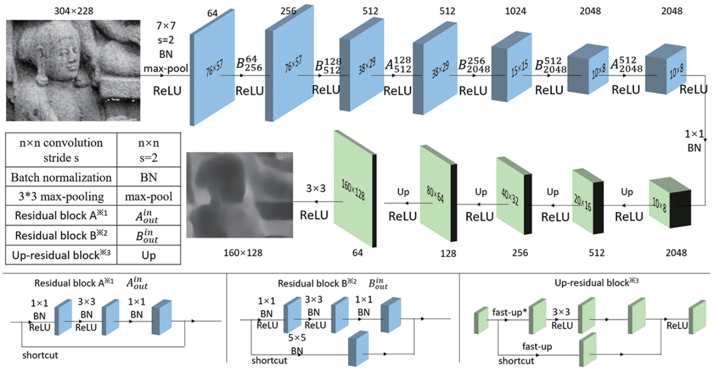


Figure 9. ResNet based depth estimation network
Source: Author

In our depth estimation network, we use more than 60 hidden layers based on a famous network named the ResNet. The blue blocks in Figure 9 are the encoders, which reduce the image resolution and extract the features, and they are based on ResNet. The green blocks represent the decoder. So, instead of the fully connected layers, we use the deconvolutional layers to recover the image resolution, and therefore, the outputs can be nearly half of the input. With this model, we can get a clear output depth map of the old photo.

For the evaluation, we made a quantitative comparison with our previous work. Figure 10 shows the qualitative results. The last column is the 3D error calculators over the reconstructed point cloud and the other is calculated over the depth maps. Significantly, the actual relief size is 0.15m, and our depth result is 0.089 centimeters. So, as we can see in the table, the accuracy of the proposal method is about 95%.

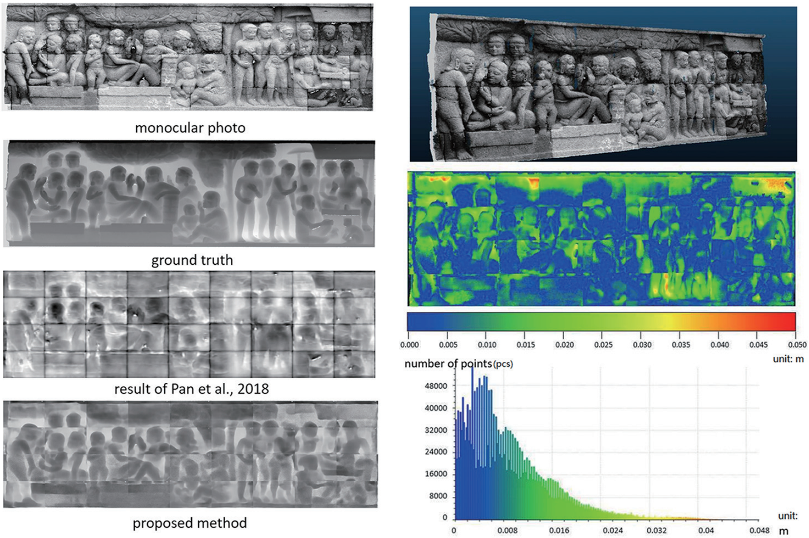
Over the depth map | Over the reconstructed point cloud

実験	Higher is better			Lower is better		
	α1	α2	α3	RMSE	RMSElog	C2C distance[2]
PAN et al[3]	0.25047	0.45433	0.60945	10.24803	0.41194	0.01498m
Ours	0.47939	0.77222	0.88119	10.07052	0.25000	0.00890m

The real relief size: 2.7m (length), 0.92m (height), 0.15m (depth)
The mean distance is approximately 0.008m (0.15cm).
The accuracy of our method is 95%. (0.008m/0.15m).

Figure 10. Quantitive Comparison Experiment
Source: Author

Figures 11 and 12 show the qualitative conversion results. Figure 10 shows the results of depth maps. The first row is the monocular photo, and the second is the ground truth. The last row is the result of the proposed method.



Figures 11and 12. Qualitative Comparison results
Source: Author

We can see the improvement here. On the right is the heatmap of the difference, which is calculated by C2C distance between the reconstructed data and the scanning data. As the color turns from blue to red, the error distance increases. Moreover, as the histography shows the error distance of almost all the points is lower than two centimeters.

After the reconstruction, we also applied a transparent visualization method known as Stochastic Point-based Rendering (SPBR) which our lab designs. It is a high-quality, see-through imaging mechanism for point cloud data. We have successfully applied it to many kinds of point cloud data, including cultural heritage. This method can achieve a transparent visualization result without any in-depth sorting, which means it does not suffer from large computation costs. This means that it is very suitable in our case because the scale of the point cloud of the entire Borobudur temple is exceptionally large.

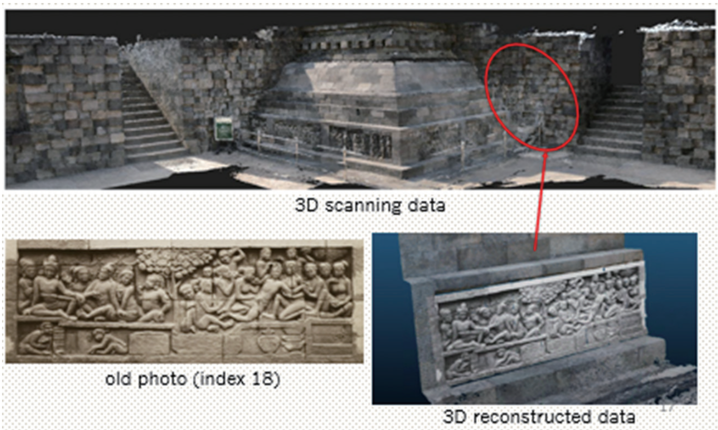


Figure 13. Fused Visualization Results
Source: Author

Figure 13 shows the visualization results by using SPBR. Here we use the 3D scanning data of the southeast temple corner and the reconstructed data of the old photo indexing number 18 as an example. The location of photo number 18 is behind the wall in the red ring and right next to the visible reliefs. The top picture shows the opaque visualization, and you cannot tell where the hidden relief is, but in the bottom picture we can look into the stones and figure out what the hidden relief looks like. When we zoom in you can see the details of the reliefs clearly.

Conclusion

In conclusion, this work provides an efficient method for fused transparent visualization of incomplete cultural heritages based on a monocular depth estimation neural network and stochastic point-based rendering. We applied our method to the Borobudur temple and visualized a corner as an example. The reconstruction accuracy achieved was 95% and the fused visualization and the field's transparent visualization provided us with promising results.

For future work, first we want to improve the reconstruction methods as we want to work on a larger dataset. We also want to design and use other models which are more suitable for the relief type data. Also, to improve the visualization results we are planning to apply edge-highlighting to the reliefs. Finally, we hope to complete the entire temple visualization.

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Chapter 5
Collision Visualization of a Laser-Scanned Point Cloud: The Revival of a Traditional Procession Route

Weite LI

Recent developments in laser scanning technology have enabled the capture of the three-dimensional shapes of real objects quickly and precisely. Until now, the application of the technology to cultural heritages has been mainly to record their standing 3D shapes. This technology, however, should also be useful for analyzing the dynamic behavior of 3D culture heritages. In fact, in industry, laser scanning data is often used for collision detection and the location of facilities in production plants. Such collision detection is also useful for preserving and analyzing intangible cultural heritages such as traditional festivals, and we contend that 3D laser scanning is suitable for making a high-definition survey as it is a fast and efficient way of collecting special data on the environment.

Conventionally, collision detection of laser-scanning objects is generally performed by transforming the laser-scanned point clouds into polygon meshes, and then collision detection is calculated using depth maps generated from the point clouds. However, it is difficult to eliminate the noise and error caused by the loss of shape. There are also many other problems in generating high-precision polygons with good aspect ratios, which affects the accuracy of the collision detection. To solve this problem, instead of transforming point cloud data into polygon meshes, we proposed a point cloud method for collision visualization.

The Gion Festival is one of the most famous festivals in Japan. The festival occurs annually in Kyoto city and spans the entire month of July. The highlight of the festival is the Yamahoko float procession, which consists of parades of festival floats in the middle of July. The Yamahoko float procession that accompanies the opening of the festival is called the *Saki Matsuri*, and the return procession is called the *Ato Matsuri*. The boat-shaped float called Ofunehoko, shown in Figure 1, is an important Yamahoko float in the final position in *Ato Matsuri* procession every year.

Figure 1. Ofunehoko Float in the procession
Source: Author

Figure 2 shows a partial map of the procession, and Sanjo Street and Teramachi Street, which are marked red, were once used as a part of the original procession routes, but are not included in the procession routes of the restricted *Ato Matsuri*. However, the Kyoto city government hopes to revive the original procession route. The reason why the original route has not been revived is that it is not known whether the Ofunehoko float is still capable of traveling through these streets safely.

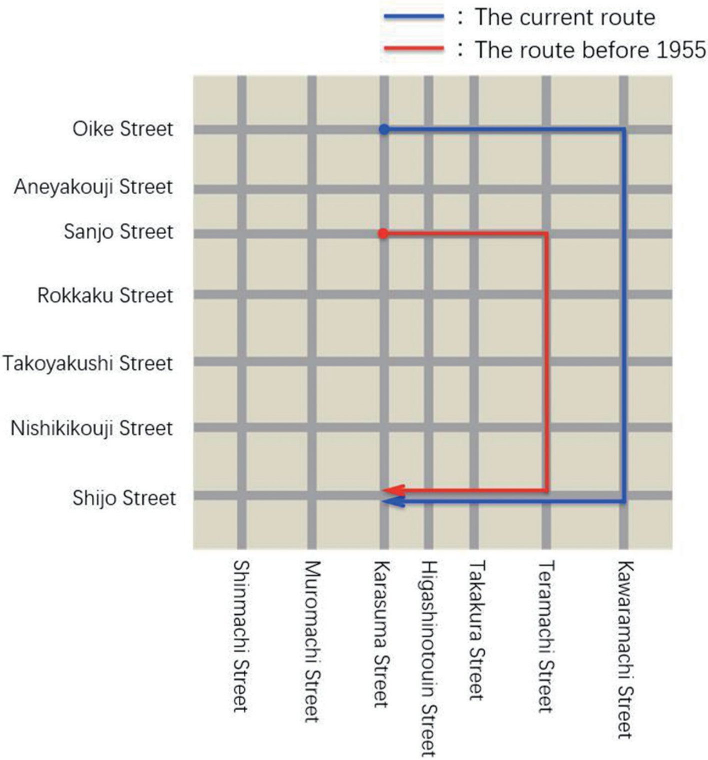

Figure 2. Partial map of the procession route
Source: Author

In fact, we do not know whether the Ofunehoko float can travel the streets without any collisions due to major changes in road conditions, such as newly built houses, power lines, and billboards.

In our work, we apply our method to analyze our simulation of the collision detection between our paradigm festival float and the street. We employed our computer simulation to detect collisions between the

Ofunehoko float and the original procession road in a virtual space for the road's revival at the Gion festival.

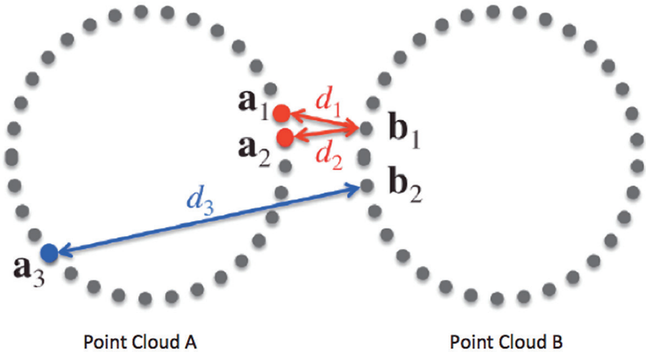

Figure 3. Collision Detection
Source Author

Methodology

First, for collision detection for the corner, an applied set (which I will explain later) of each point in the two given point clouds is determined by performing the nearest neighbor search of the points in K-d Tree binary trees. For each point in one point cloud, we search for and find its nearest neighbor point in the other point cloud. Next, we obtain the inter-point distance between these two points. As we can see here, consider two point clouds, A and B, and $a_i(x_i, y_i, z_i)$ is a point in point cloud A and $b_j(x_j, y_j, z_j)$ is the point in point cloud B, then the collision detection will be performed as follows. First, for point a_i in point cloud A, we perform a nearest label search and find its nearest label point b_j Then we can calculate the inter-points distance between these two points, a_i and b_j, based on this formula.

$$D = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$

Finally, we need to compare the inter-point distance with the threshold value, and if the distance is less than or equal to our threshold value ε (epsilon), we assign a proper collision area corner to a_i. However, if the distance is larger than ε and less than or equal to our proper known smallest distance $D_{\max}$, we will assign a proper high collision risk area corner to a_i. Here, we set the threshold value, ε.

Generally, the collision point is usually the point at which the inter-point distance is zero. However, because of the loss of laser scanning, there are very few points where the inter-point distance is completely zero, so an extremely small value ε, is set as the collision parameter. In the current work, ε is set to 1/100 or 1/500 of the bounding-box diameter of the scenes that consist of point clouds, as in Figure 4.

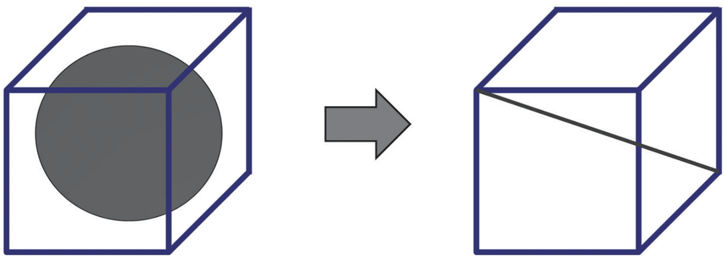

Figure 4. Determination of threshold. The accuracy is based on the length of the diagonal of the bounding box in the scene. Normally, for buildings, one-fifth of the diagonal length, about 20mm, is chosen as the threshold. For wires, one hundredth of the diagonal length, about 100mm, is usually chosen as the threshold.
Source: Author

When we consider carriages with extra wheels, the bigger value of 1/100 works better because the electric power lines are very thin, so sometimes the number of points is very small.

Next, we need to perform the transparent rendering because the conventional method cannot observe the inside and the outside simultaneously. So, in order to improve the visibility of the collision result, a precise, transparent rendering is required. The precise see-through imaging of collision point clouds can be executed with a correct depth view with interactive speed by using stochastic point-based transparent rendering (SPBR), which was proposed for dealing with large-scale laser scaling point clouds.

In our experiment, we planned to highlight collision point clouds and collision risk areas, so we used a color map and an opacity map. When executing the collision detection, we need the definitions of the collision area corner and high collision risk area corner as they must be avoided. We use the white color for the collision area and the rainbow colors for the high collision risk area. For the case that the inter-point distance is very close to ε for the minimal non-collision distance, the high collision risk corner becomes red over a proper large spreadsheet inter-point distance $D_{\max}$. The point corner is made blue, and we will designate it as a collision-free area.

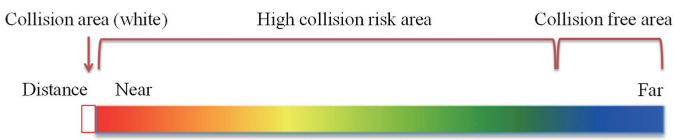

Figure 5. Opacity Map
Source: Author

Table 1. The opacity of the different areas of the rainbow.

Rainbow Color	Opacity
Blue	0.2
Blue – Light Blue	0.4
Green – Yellow	0.6
Orange – Red	0.8
White (Collision Lines)	0.9

Figure 5 shows an opacity map based on the color map. The collision area opacity is rated 0.2 to 0.9, depending on the level of collision risks. From the red to the orange area, the opacity is set to 0.8. From the yellow to the green, the opacity is set to 0.6. For the light blue, the opacity is 0.4. For the remaining blue areas which are far from the collision area, the opacity is 0.2. These opacities can be easily realized by the SPBR method.

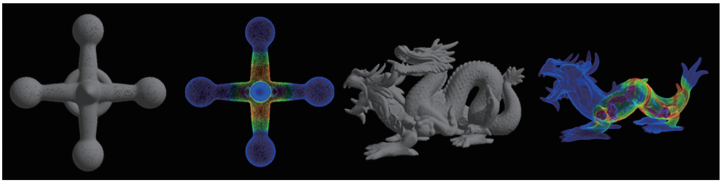

Figure 6. Result of the collision detection experimental. Left: Jack (2.5×10^5 points) and Torus (2.5×10^5 points). Right: Asian dragon (7.3×10^5 points) and Dragon (4.4×10^5 points). Source: Author

Figure 6 shows the collision detection results of our method on two sets of simple models, and the results are rendered using SPBR to visualize and analyze the collision hazard. From this result we can see that the collision area opacity and the high collision risk area opacity can also be realized within the framework of the rendering.

Next, we applied our visualization method to the collision detection simulation of the Ofunehoko float around its original procession roads of the Gion Festival. A point data model of the Ofunehoko float was moved in a virtual space constructed using the point cloud data of the street acquired by our mobile mapping system. The Ofunehoko model was constructed using CAD software. Then the collision potential of the street and the float was investigated and visualized by our method.

Figure 7 shows the cloud data of the laser scanning point of Sanjo Street, which is part of the original float procession route. It is narrow compared with the current route and contains many electrical wires, billboards, and other objects, which may collide with the festival float during the procession. This includes the road point cloud data, but in the collision-detection experiments, the road data was removed to avoid reporting the natural contact between the road and the float.

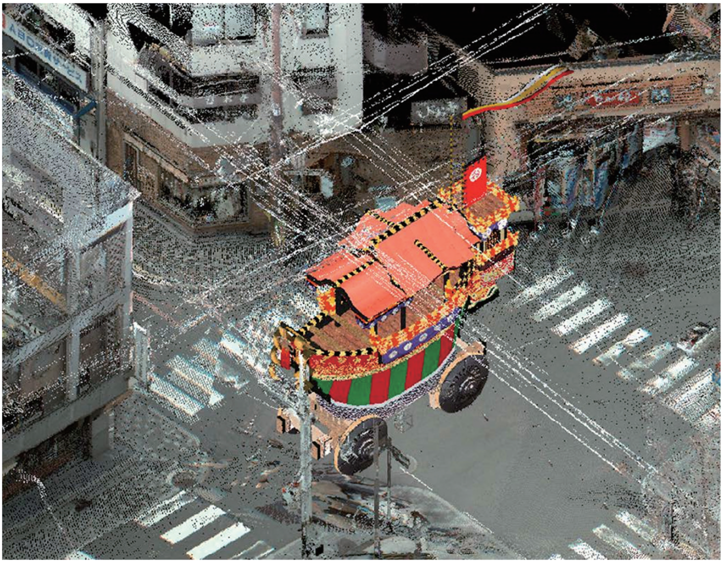

Figure 7. Point cloud of the Ofune-hoko float (9.7×10^6 points) placed in the scene of Sanjo Street. Source: Author

Figure 7 shows the result of placing the point cloud data of the Ofunehoko float in the crossing of the street. We can clearly foresee that the float will collide with the electric wires when moving in the street. Collisions with billboards and other objects are also expected when turning at a street intersection. Figure 8 shows an example of the proposed see-through virtual imaging of the collision points related to the collision and high collision-risk areas. The collision-free area is also visualized. Sanjo Street in the background of the Ofunehoko float is also visualized SSD using its original corners. As I explained, the opacity is the highest for the collision line and the opacity of the remaining areas is the lowest. This colored see-through view with the corrected depth view enables us to clearly observe collisions along with the whole float and the street.

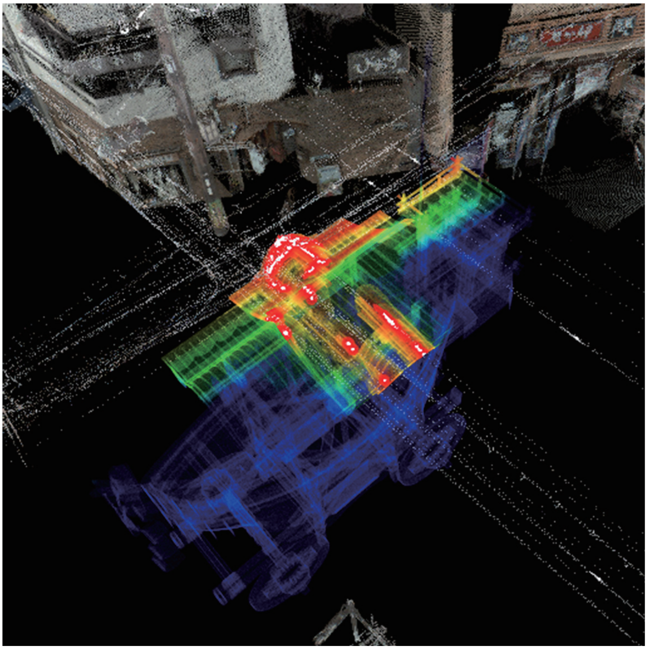

Figure 8. See-through visualization of the Ofunehoko float that collides with electric wires. The total number of points used for the visualization is 8.4×10^6, and the rendering speed is 16.19 fps. Source: Author

Figure 9 shows an image with see-through results in which only the collision areas of the Ofunehoko float are highlighted by the white coloring and the remaining parts of the float and the street are virtualized using the original colors. By giving high opacity to the collision areas, we can more clearly observe the areas.

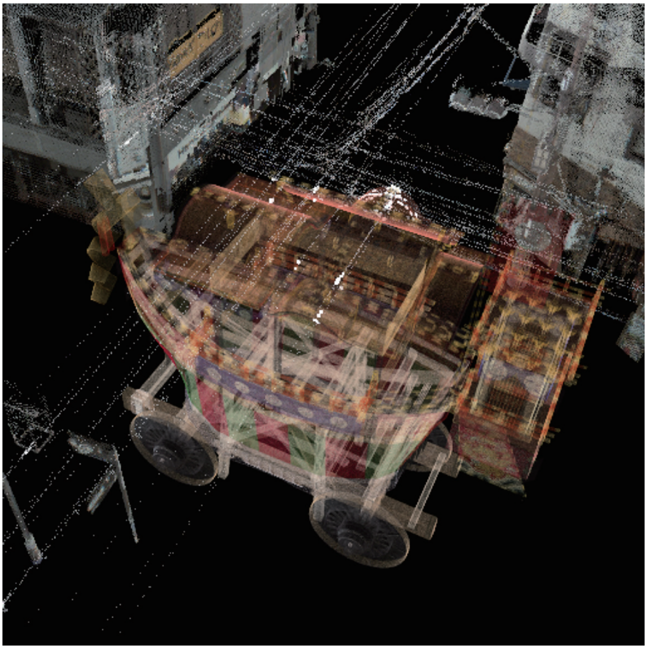

Figure 9. See-through collision visualization similar to Figure 8. Only collision areas of the Ofunehoko float are given the white highlight color.
Source: Author

Here, we consider another possible tuning of our color model to highlight collision regions. If the colliding objects are white or nearly white, it is not the best way to simply assign the color white to their collision areas. In such a case, we highlight the collision areas (white) together with narrow surrounding areas of very high collision risks (red). In this way, the white collision areas become apparent and are highlighted successfully (see Figure 10). Using areas of only very high collision risks is also helpful in keeping the original colors of the colliding objects as much as possible.

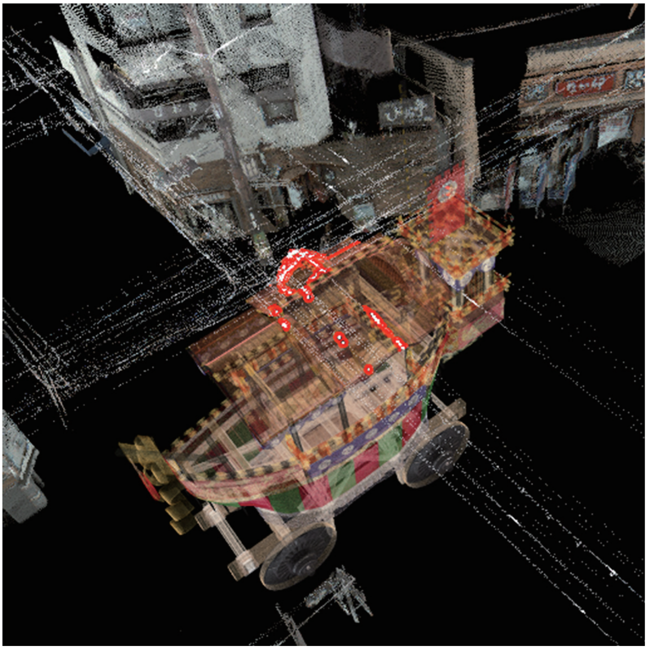

Figure 10. Highlighting collision areas (white) together with their surrounding narrow areas of very high collision risks (red).
Source: Author

It is also worth mentioning another application of our method in the industrial field. Recently, cloud data simulation has become popular for industry fields, because, in the construction process, it is difficult to determine whether a large crane can be safely placed in the construction space. In this case, we can perform the collision detection simulation with our point cloud data pairing to predict any dangerous obstacles.

Let me conclude this overview of our work by summarizing our process. Instead of transforming point cloud data into polygon meshes, we propose a point-cloud-based method for collision visualization and the collision points are highlighted with a corrected depth feel that can accurately predict collision points by SPBR.

In the future, we plan to execute our collision visualization through our real-time creation detection simulation. We hope that this technology will contribute to increased safety by helping event managers as well as construction managers to predict and avoid dangerous and potentially costly collision damage.

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