ISSN 1346-2601 (Print)
ISSN 2436-5408 (Online) 2024 年 3 月 11 日公開

Applicability of digitization experience of the Kyoto City Archaeological Museum (KCAM) to MENA museums at risk: tackling preparedness and post-response

Mohamed Soliman (PhD) Archaeological Architecture (MoTA),
JSPS Researcher (DMUCH), and Visiting Researcher (ARC), Ritsumeikan University
E-mail msoliman8@yahoo.com
Mikiharu Takeuchi (PhD candidate, DMUCH, Ritsumeikan University)
Naoyo Sekihiro (Archaeological Director, Kyoto City Archaeological Research Institute)
Keiji Yano (Professor, College of Letters, Ritsumeikan University)

要旨

京都市考古学博物館（KCAM）におけるデジタル化は、COVID-19 の発生時に、備えと災害後の対応のための簡素で効果的な方法として写真測量技術を導入が試みられている。中東および北アフリカ（MENA）地域の博物館は、武力紛争や地震などの自然災害および人為的災害によって引き起こされるさまざまな危機にさらされている。

KCAM では、SfM/MVS を生成するために、フォトスキャン技術が採用され、その簡略化されたツールと処理が他の技術（例：UAV や TLS など）と比較された。その結果、本研究では、文化資源のデジタル化における写真測量の利点を説明し、他の技術と比較して、危険にさらされている MENA の博物館への適用可能性について議論する。

Abstract

Digitizing collections held at the Kyoto City Archaeological Museum (KCAM) highlights the value of photogrammetry technique during COVID-19 outbreak as a simplified effective method for preparedness and post-disaster response, potentially applicable for MENA region museums exposed to several types of crisis triggered by natural and man-made disaster, e.g. armed conflict and earthquakes.

A PhotoScan technique is adopted to generate SfM/MVS for KCAM, while its simplified tools and processing are demonstrated compared with other techniques (such as UAVs and TLS). Consequently, this study discusses the advantages of photogrammetry for digitizing cultural resources at KCAM and its applicability to museums at risk in MENA, in comparison with other technologies.

Keywords: MENA, KCAM, Covid-19, photogrammetry, 3D model, SFM/MVS

Introduction

In a time of natural and man-made disasters, digital humanities technology came to be in demand globally for preserving and developing cultural heritage. In recent years, numerous studies have been conducted in the field of architectural surveys thanks to the improvement and optimization of new technologies, which have greatly extended the range of applications even towards some more fully situated in the field of engineering. The standardized use of infographics technologies has revolutionized pathways for the restitution of artifacts.[1]

A few years ago, the world faced a tragic cultural disaster that drew attention to the technology of 3D recording space and the technology of restoring it to a virtual form. The fire at Notre Dame Cathedral in Paris in April 2019 made the world aware of the necessity of 3D laser measurement data and panoramic images of Notre Dame Cathedral left behind by the late art historian Andrew Talon.

The Kyoto City Archaeological Museum (KCAM) locked down in response to the state of emergency declared by the Japanese government due to the outbreak of the COVID-19 pandemic (Figure 1). KCAM became inaccessible. Scholars were deprived of the ability to access study material, and tourist mobility and tourism economy were negatively affected.

Fig. 1 Kyoto City Archaeological Museum (KCAM)

In the same perspective, Middle East and North Africa (MENA) museums are exposed to several types of crises, including armed conflict and seismic hazards. Governmental and global association reports describe the consequences of such disasters. These exposures brought massive destruction and looting, including structural collapse at some museums and the smashing of valuable objects.

Adopting a photogrammetry technique to digitize the KCAM collection tackled this problem in many ways. Simplification is adopted in the utilized photogrammetry technique to be merged in preparedness or post-disaster phases as a quick response in museums at risk. Technically, photogrammetry is an appropriate method that facilitates the mission of museum staff. The utilized tools and processing software are obtainable and easily manipulated. SfM/MVS photogrammetry has received increasing attention due to its convenience, broadening the range of its applications into archaeology and anthropology. Because the accuracy of SfM/MVS depends on photography, one important issue is that incorrect or low-density point clouds are found in 3D models due to poor overlapping between images. A systematic way of taking photographs solves these problems, though it has not been well established and the accuracy has not been examined either, with some exceptions.[2] Agisoft was used for the photogrammetric designation of points. This program uses still images of stationary objects to generate point clouds, 3D models and orthophoto maps. Agisoft is widely used in aviation and engineering photogrammetry, computer animations, and remote sensing. With the ability to export processed data to a variety of formats, it is therefore compatible with graphical programs (such as AutoCAD) or GIS analysis software (such as ArcGIS). These programs also have similar hardware and functionality requirements.[3]

However, digitizing the KCAM collections is a constructive attempt for a foreign scholar to deal with Japanese museums in terms of dealing with official procedure and investigating Japanese cultural heritage.

The aim of this study is to discuss how digital technology can be an effective means of protecting museum cultural resources from the risks of various natural and man-made disasters. As a case study, the results of digitizing exhibits using simple photogrammetric techniques at the Kyoto City Archaeological Museum, which was forced to close down during the COVID-19 disaster, will be presented. It is then suggested that the attempt could be useful for other museums exposed to disaster risks in the Middle East and North Africa region (MENA), for the preservation of museum collections, for the use of researchers and tourists, and for the protection of cultural heritage.

1. Demonstration of crisis typology in museums at risk

Disasters do not respect national boundaries. Therefore, an international standard communication platform for severity is vital to have agreement among countries. The impact of a disaster in a region, if not managed properly, can produce political and social instability, and affect international security and relations.[4]

In the face of the COVID-19 pandemic, culture was experiencing an unprecedented crisis and museums were paying a heavy price. The first impacts of the closure of museums included the drop in attendance. It was rightly assumed that all closed museums would experience such a decrease, but this also affected institutions that remained open or have since reopened their doors, due to the drastic drop in international tourism. According to the World Tourism Organization (UNWTO), destinations worldwide experienced one billion fewer international arrivals in 2020 than in the previous year, an overall decrease of 74% compared to 2019.[5]

As a result, COVID-19 outbreak consequences highlighted the necessity to create a 3D database for KCAM. The reason behind this was tackling the decline in accessibility to KCAM during COVID-19 resurgence and making the database available to stakeholders and scholars. Despite disaster patterns being different, conveying 3D model methodology and means is beneficial to MENA museums (Table 1).

Table 1 Disaster categorization and assessment in MENA

Country	Date	Disaster type	Exposure	Vulnerability
Egypt	-January 28, 2011 -August 14, 2013 -January 24, 2014	Arab Spring Vandalism	-Explosion -Deformation -Looting	-Smuggling -Absence of awareness
Syria	Since March, 2011	Civil war	-Explosion -Demolishing -looting	-Absence of official guarding
	April 27, 2023	Earthquake		
Iraq	March, 2003	USA invasion	-Explosion -Demolishing -looting	-Leakage of official guarding -Smuggling
	February, 2015	Vandalism		
Yemen	July, 2015	Civil war	-Explosion -looting	-Demolishing
Türkiye	April 27, 2023	Earthquake	Severe destruction	-Demolishing
Sudan	June 2, 2023	Civil war	-Explosion -looting	-Accidental damage. -Official difficulty to guard collections.
Morocco	September 8, 2023	Earthquake	Severe destruction	-Demolishing
Libya	Since February, 2011	-Civil war -Vandalism	-Deformation -Looting	-Leakage of official guarding. -Flooding -Coastal subsidence
	September 12, 2023	Daniel Cyclone	Severe destruction	

Natural and man-made hazards color MENA history, causing deep changes in topography and urbanism. Recent disasters recall the historical cost in lives and assets, to which the cultural heritage properties are exposed. The MENA region has been exposed to man-made disasters in the form of political changes that destroyed and looted uncountable museum's collections.

The instability and violence that Libya experienced in recent years have put its cultural heritage under tremendous stress and high risk since the Arab Spring in 2011. The threat of systematic damage to cultural heritage sites is of great concern. The losses endured are leading to the historical impoverishment of a country with an exceptionally rich cultural heritage. The slow but steady disappearance of Libya's cultural witnesses of the past has rendered evident the need for immediate action that will help protect them. Museums, auction houses, art dealers, and collectors are encouraged not to acquire or sell such objects without having carefully and thoroughly researched all the relevant documentation concerning their provenance.[6]

The Egyptian Ministry of State for Antiquities informed UNESCO of the looting of the Mallawi National Museum on August 14, 2013. The damage caused by the looters is catastrophic. Most of the artifacts have been stolen, destroyed, or burned. Around one thousand cultural objects, dating from the beginning of Egyptian history to the Islamic period, have disappeared (coins, jewels, statues, etc.).[7]

In February 2003, almost exactly three years later, the Iraq National Museum was forced to close its doors and look for new places for its collections. The impact this time was more devastating. The shattered public order in the aftermath of the war brought waves of theft and pillaging. In an unchecked frenzy of cultural theft, looters who pillaged government buildings and businesses after the fall of Baghdad also targeted the museum, stealing and destroying artifacts, some going back 7,000 years. Much of the looting occurred on Thursday, 10 April. The museum guards stood by as hordes broke into the museum with wheelbarrows and carts and stole priceless statues, bowls, and clay tablets, etc., leaving its galleries empty except for shattered glass display cases and cracked pottery bowls that littered the floors.[8]

In June 2014, just as the Mosul Cultural Museum in Iraq prepared to reopen after years of renovation, ISIS captured the city; in February 2015, the group published video of the museum's destruction. In addition to missing artifacts, some 25,000 volumes from the museum library had been burned and the buildings themselves had suffered considerable damage, most notably an 18-foot-long hole in the floor of the Assyrian Hall, caused by a bomb. In minutes, ISIS had wrought destruction that would take years to repair.[9]

A violent conflict erupted in Yemen causing terrible human suffering and loss of life. Yemeni cultural heritage sites are heavily affected, mostly through collateral damage. However, the intentional destruction of ancient tombs was reported to have occurred, for the first time, in Hadramout, in July 2015.[10]

Since the beginning of the Syrian civil war in March 2011, museums have been subjected to vandalism, looting, bombing, and destruction. With the deteriorating security in many cities and towns, many museums have been robbed or looted, while others have been bombed.

A joint report by German and Syrian organizations has documented severe damage to Syria's historical heritage and antiquities. The long-term damage inflicted on Syrian museums is worse than that of Iraqi museums, whose cultural and historical riches were severely damaged during the 2003 US invasion, and later, during the rule of ISIL, also known as ISIS.[11]

However, most of the damage to museums has occurred in the north-western region of the country, where there have been incidences of looting of valuable cultural property, and many works of art are currently unaccounted for. Many museums, including the Raqqa Museum and Citadel of Jaabar, the Museum of Folklore in Aleppo, and the Maarrat Museum have also had their infrastructure damaged as a result of being caught in the middle of armed conflict.[12]

Sudan's rich cultural heritage is at risk of irreparable damage from the conflict raging for more than a month since June 2023 as museums lack adequate protection from looters and vandalism.

The Arab Spring protests broke out in 2011 and caused political instability. In the latest troubling development, the Rapid Support Forces (RSF) fighters seized control of the Sudan National Museum in the capital, Khartoum, on June 2, 2023. The location of the museum — in close proximity to the Sudanese Armed Forces (SAF)'s Khartoum headquarters — made it at once vulnerable to accidental damage and difficult for officials to guard its collections.
The entry of SAF fighters into the Sudan National Museum happened just days after a building in Omdurman, northwest of Khartoum, housing archives that included priceless documents chronicling Sudan's colonial past, was ravaged by fire and looters. Experts fear artifacts spanning Sudan's 6,000-year history could face a similar fate to Syria's antiquities.[13]

Several ancient heritage sites in Türkiye and Syria are believed to be at risk following the devastating earthquakes in the region on February 6, 2023, according to an initial survey by UNESCO.[14]

In Türkiye, the majority of state museums seem to have suffered no relevant damage, while sites as Gaziantep Castle have been heavily impacted.[15] Artifacts inside the Syrian National Museum in Aleppo are also believed to have been damaged.[16]

The earthquake that struck Morocco late on September 8, 2023 dealt serious damage not only to residential houses and infrastructure, but also to the country's iconic museums and mosques. The earthquake also destroyed objects of material heritage. For example, the collection of the Dar Si Said Museum of pottery and carpets, located in a palace built in the second half of the 19th century, lost some of its valuable objects. A large portion of the museum's pottery collection was damaged, including many showpieces.[17]

2. Suitability of photogrammetry (SFM–MVS) technique compared to other 3D scanning methods to digitize museums at risk

The standardized use of infographics technologies has revolutionized pathways for the restitution of artifacts; however, new and important issues continue to be encountered related to the standards to be followed and the reliability and compatibility of the implemented procedures and methodologies. One speaks in this sense, therefore, of a *virtual replica* and of a three-dimensional modelling, overcoming the physical and spatio-temporal limits, decontextualizing it from the environment that surrounds it: the object is studied from each segment that composes it to its historical - functional peculiarities.[18]

Structure-from-motion (SfM) is a photogrammetric technique used to generate a 3D point cloud from a collection of overlapping 2D images. The SfM process starts with feature detection, which involves identifying unique features on an image and matching homologous features (e.g., key points) across overlapping images to generate image correspondences. Given a set of corresponding features, 3D coordinates of matched features (e.g., a sparse point cloud) can be generated using an iterative bundle adjustment (BA). The BA is a least-squares optimization that simultaneously estimates the 3D positions of a scene and camera poses. The camera's intrinsic parameters can be included as an unknown in the BA (e.g., a self-calibrating BA). Following the BA, a multi-view stereo (MVS) algorithm is then used to generate additional points to create a dense point cloud; the entire workflow is referred to as SfM-MVS.[19]

Overall, archaeologists have found SfM to produce more accurate and precise models than time-consuming traditional methods such as plan drawing. As SfM is a relatively new method to the archaeological sciences, the accuracy and error of SfM models will likely remain case-specific until a better understanding of these issues in archaeological applications can be developed.[20]

A point cloud, as raw data to generate 3D models, is acquired using several technical methods. Terrestrial Laser Scanner (TLS) is attracting increasing interest as a revolutionary technology. The ranging system is the core component of a TLS, and uses a laser ranger to measure the distance from the scanner to an object. The working principle is that the scanner emits a laser beam to the preset scanned area by changing the deflection angle in vertical and horizontal directions. As the laser beam hits a reflective surface in its path, it returns to the receiver. By using different methods of range measurement, the distance (S) between the scanner and the object can be calculated. Finally, according to the azimuthal (horizontal) and elevation (vertical) angles (a, b) of the light, the reflecting point position (Xp, Yp, Zp) can be determined based on the instrument coordinate system.[21]

UAV (unmanned aerial vehicles) are widely used in photogrammetric surveying for the representation of cultural heritage. The UAV can control the mission area via its sensors and can transfer data by using wireless communication. Based on various working environments of the UAVs, each route should be generated dynamically. Hence, the path smoothing method can produce a feasible path in real-time.[22]

Despite such simplifications, there are countless safety issues; in fact, regulations and laws have been drawn up and passed worldwide that restrict the areas of use. In some countries, such as Syria, Morocco, and Iraq, the use of UAVs is even banned. This issue raises important questions for the protection and preservation of the cultural heritage contained in these countries.[23]

Regardless of the efficiency of these methods, they are inappropriate to acquire data from museums' collections, whether for preparedness or post-disaster response. This is because of the diminutive scale of the artifacts that require flexible techniques to rotate inside closed/narrow spaces in museums rather than large-scale methods usable in open spaces. Special handling sensitivity is required to acquire data from fractioned objects during post-disaster response. Subsequently, the seamless processing of the acquired data of objects that should be isolated from the surrounding environment decreases distortion, scattered data, and saves time consumption. On the other hand, adopting a photogrammetry technique simplifies these very specialized techniques for museum staff (e.g., curators and conservators). Taking into consideration the potential for a post-disaster loss of power, the required photogrammetric tools are a camera or smartphone for capturing photos, a turntable to carry the objects, and an adjustable light source. In comparison to high-cost/large-scale methods (e.g., UAV and TLS), the availability of such uncomplicated low-cost tools and simple installation strengthens the objective of a museum staff to digitize and safeguard the objects and interact with the post-disaster situation.

3. Values and exposures of the designated objects in KCAM

The Kyoto City Archaeological Research Institute was established in 1976, and has accumulated many achievements in excavation, investigation, and research. Based on the results, the purpose is to display and publicize the results to spread awareness. The KCAM was opened in November 1979. Through the exhibits, visitors experience the lifestyle and culture of the past, and use this space as a place to think about our important mission in passing on buried cultural heritage to the future.[24]

On the 1st floor, two themed special exhibitions are held every year, and a planned exhibition in collaboration with a university in Kyoto once a year, while “newsflash” displays and planned exhibitions are staged as well. The 2nd floor houses the permanent collection, with panel explanations of the transition in ceramics used during the Heian period, some 1,000 pieces of archaeological material Paleolithic and Edo era, as well as merchandise from trade with China and Korea, and artifacts excavated from the Heian Imperial Palace and dwellings of the Jomon period. In addition, the museum also has a “hands on” corner where visitors can actually handle large pieces of pottery and roof tiles.[25]

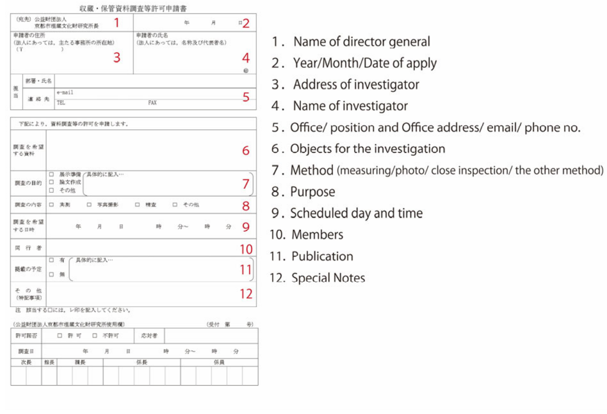

Fig. 2 Interpretation of the required application form that should be submitted to KCAM

3-1. Artistic attributes, historical values and criteria suitability

A glazed water pitcher and vessel stand with the miniature are two unique objects from KCAM selected to implement a prototype photogrammetry technique. The two objects were selected based on specific criteria, which are compatible with the characteristics of MENA museums’ collections, namely; 1) the utilized technical process, 2) vulnerability of objects of pottery to breaking, 3) simplicity and complexity of the decorative patterns, 4) the regular dimensions are suitable to modelling, 5) similarity of the simple classic design of KCAM building to many MENA museums. The two objects inside a wall showcase were inaccessible to visitors; during COVID-19, not even 2D images and on-site information were sufficient. Japan, as a country exposed to natural disaster and a pioneer in disaster management, can inspire the MENA region with the required processes to deal with similar cases. Moreover, implementing photogrammetry technique at KCAM facilitates merging it to disaster risk reduction (DRR) plans.

The fragments of an ash glazed water pitcher were found in the ancient pit of Kitashirakawahaiji temple, in Daido-cho, Sakyo Ward, Kyoto City (Figure 3). The water pitcher was found in one of the pits with haji-dishes, deep Sue ware bowls, and green glazed wares. The water pitcher is dated between the second half of the 8th century and the beginning of the 9th century. This pitcher is made in ash glazed pottery and is roughly 30.7 cm in height. The manufacturing technique of ash glazed pottery was developed in the 9th century (Heian era), which is characterized by burning in high temperature using plant ash.

The vessel stand with miniatures was discovered in Tatsumi round tomb mound No.1, located in Yamagoe Tatsumi-cho in Ukyo Ward, Kyoto City (Figure 4). The vessel is of a type usually used to offer water for Buddhist statues or confession ceremonies (Fusatsue). Styles of pitchers are divided into four types. This object belongs to the Senzan style and is considered older. The vessel is attributed to Sue ware burned in high-decreasing temperature with the reduced state. The manufacturing technique was transferred from the Korean peninsula in the early 5th century. It is characterized by thin and hard fabric, smooth and unglazed texture, and is roughly 45 cm in height. Such vessel stands were mainly used for funeral rituals and decorating burial chambers. The miniatures on the rim of the bowl are called "children" because the stand is identified as the "parent" object.

Fig. 3 Ash glazed water pitcher from Kitashirakawahaiji-temple

Fig. 4 Vessel stand with miniatures (Sue ware) from Tatsumi round tomb No.1

4. Compatibility of the operated tools for data acquisition

Digitizing museums at risk requires a quick-systematic response. Considering a simplification of concept, photogrammetry technique meets the demands of museum staff and scholars, in terms of availability and simplifying installation of the utilized tools. Moreover, the need for 3D Scanning instruments is inseparable from the needs that are so fast and effective in costs and the increasing need for measuring the accuracy of a small-sized manufacturing component. As a result of the many needs of these small-sized components, a careful and accurate method is needed.[26]

Accordingly, the utilized tools were combined to incorporate a system, which consists of control unit (e.g., PC, tablet, smartphone: android/ IOS), photographic camera, light source, and turntable table (Figure 5).

Stabilizing the camera on the appropriate parameters by a tripod is essential to take accurate shots on three levels, regularly. Setting up a software on the control unit compatible with the camera is required to capture photos remotely. In the case of KCAM, NIKON WIRELESS MOBILE UTILITY software was compatible with a NIKON D5500 (60mm) camera, which is available on Windows Store, IOS, and Android systems. NIKON software was installed on Oppo 2020 A5 smart phone as a control unit via Google Play.

Fig. 5 Installation of utilized tools for photogrammetry data acquisition

The lighting environment should be appropriate to the material texture and parameters of the object. A multi-spectral light ring was installed on a tripod to isolate the targeted object from the lighting environment inside KCAM. The light ring helped to eliminate shading and reflections in order to scan the real texture of the object only. In addition, a photo studio box was used to enhance isolation of the water pitcher, which possesses a glazing reflection effect in the color tones.

The vulnerability of objects made of fragile materials such as glass, pottery, and stone requires a steady stand to put the object upon. A turntable divided into twenty-four segments is dedicated to carrying the object. One controls the capturing position by turning the turntable counterclockwise.

In light of the above, photo-scanning the object's features requires taking a counterclockwise orbital parameter. Accordingly, data acquisition was run as follows: 1) calibrate the camera and light unit at the appropriate angle to meet the required parameters. The camera was installed at an oblique angle on each parameter, which was 45° in the upper, 85° in the middle, and 45° in the lower, 2) capturing photos by a control unit, which was a smartphone in the KCAM case, connected with the camera via offline Wi-Fi, 3) a turntable divided into twenty-four segments was utilized to rotate the object 360 degrees counterclockwise, remotely. Each capture was taken simultaneously while aligning with the twenty-four segments, which guarantees a high density of tie points and avoids gaping.

Nevertheless, segmental processing is a concept to guide regular positioning of the object and to identify the start and end points. Moreover, the capturing count and parameters are variable, based on the span of each parameter, and the shape and dimensions of the object. For instance, twelve images were sufficient to cover the water pitcher's tapered top, while the Sue ware object needed four, due to its multi-curvature and ornamentation.

5. Agisoft–Metashape processing and analysis workflow

With consistency to simplifying the digitization of museums at risk, the acquired data processed and analyzed.

5–1. Fundamental processing workflow guidance

Two well-known commercial software options for SfM are PhotoScan (v.1.4) by AgiSoft and AutoDesk ReCap Photo (v.2018). At this time, PhotoScan has been replaced with MetaShape (v.1.5) through a free upgrade for professional and standard licensed users. The main differences between the programs are how GPU and processing power are allocated and the ability of MetaShape to classify identified points into object-classes.

The fundamental algorithm and user-preference settings remain consistent between the two software versions. Due to different design parameters between programs, an individual's experience could, and does, change depending on which software they select. It is important to consider the cost of the license, the intuition of the graphic user interface (GUI), accessibility to rendering parameters, and the overall user experience for a non-specialist.[27]

PhotoScan (now MetaShape) creates excellent models; is easily available to users and can be extremely cost-effective when users are affiliated with an institution to allow for educational licensing. The pros of PhotoScan include an intuitive GUI, which allows novice users more than adequate control in creating models, given their system has sufficient memory. There is a significant amount of advanced user control also present for increasing camera optimization (if using a reference system), editing masks, and the points clouds themselves, as well as working with multiple "chunks" of a single project.[28]

In this regard, six regular phases of Agisoft-Metashape process the PhotoScanned data. The processing workflow phases are activated gradually, one-by-one (Figure 6).

The phases begin with adding the acquired photos, whether separated or as a folder to a new project. Once the photos are added by Align Photo order, they are then processed: ordering and combining the photos according to the assigned 360° levels based on a 40,000 key point limit and a 10,000 tie point limit (Figure 7). Afterwards, the Build Dense Cloud phase is activated, which extracts point clouds from the aligned photos (Figure 8).

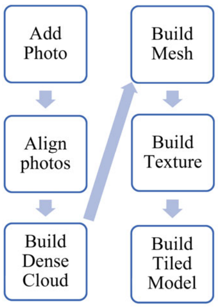

Fig. 6 Agisot-metashape processing workflow

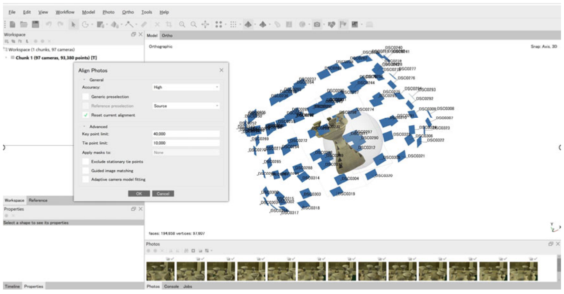

Fig. 7 Align Photo

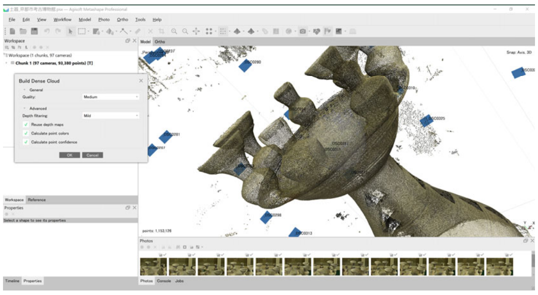

Fig. 8 Build Dense Cloud

The subsequent three phases (Build Mesh, Build Texture, and Build Tied Model) finalize the point cloud data and generate a real 3D model. The Build Mesh order converts the point cloud to a network (Figure 9), which is a skeleton compatible with the Build Texture of the object (Figure 10). Eventually, the last phase of Build Tied Model process leads to building the 3D model using the Dense Cloud order as source data with an accuracy of 0.0006 metric pixels size and 250 tile size (Figure 11).

Despite of the simplicity of Agisoft-metashape workflow, occasionally leakage photos aren't aligned, because of insufficiency of tie points. Therefore, creating masks is an effective solution to realign the photos. Subsequently, the Intelligent Scissors tool is used to crop the object shape in each scattered photo (Figure 12). Afterwards, selecting the cropped photos and exporting it as masks leads to alignment of all the photos. However, Intelligence Scissors is also effective for disposing of the scattered point cloud, which has been collected during data acquisition.

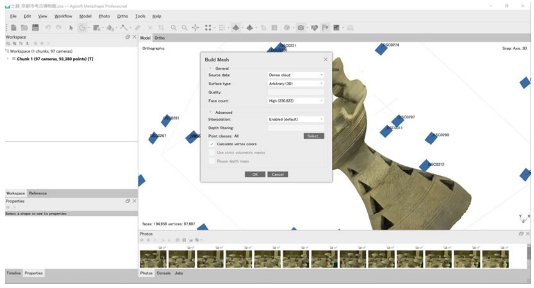

Fig. 9 Build Mesh

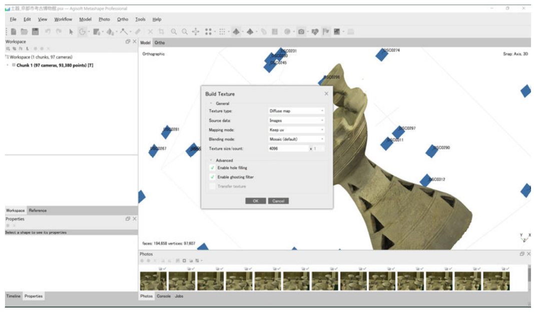

Fig. 10 Build Texture

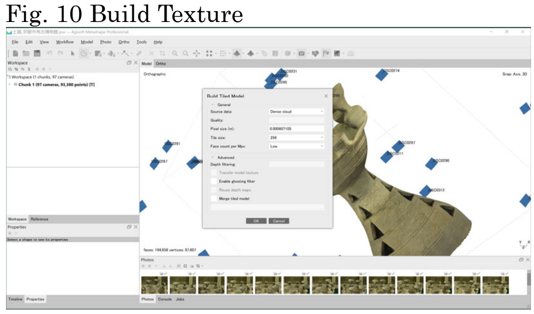

Fig. 11 Build Tiled Model

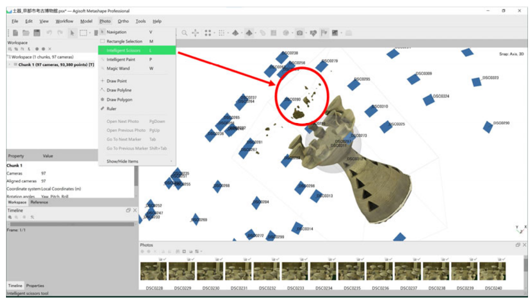

Fig. 12 Cropping using Intelligent Scissors

Table 2 Comparison between processing parameters of water pitcher and Sue ware objects

Processing phase / Main parameter / Common sub-parameter / Water Pitcher sub-parameter

Processing Phases	Detailed data		water pitcher	Sue ware
General	Cameras		73	97
	Aligned cameras		73	97
	Coordinate system		Local Coordinates (m)	
	Rotation angles		Yaw, Pitch, Roll	
Point Cloud	Points		10,991 of 14,477	93,380 of 105,472
	RMS reprojection error		0.206881 (0.864395pix)	0.169097 (0.357774 pix)
	Max reprojection error		0.627883 (20.6651pix)	0.508934 (14.0519 pix)
	Mean key point size		4.10527 pix	1.92759 pix
	Point colors		3 bands, uint8	3 bands, uint8
	Key points		No	No
	Average tie point multiplicity		2.84693	3.0715
	Alignment parameters	Accuracy	Highest	Highest
		Generic preselection	No	Yes
		Reference preselection	No	No
		Key point limit	40,000	40,000
		Key point limit per Mpx	40,000	
		Tie point limit	10,000	4,000
		Filter points by mask	Yes	
		Mask tie points	No	
		Exclude stationary tie points	No	No
		Guided image matching	No	No
		Adaptive camera model fitting	No	No
		Matching time	1 minutes 18 seconds	37 seconds
		Matching memory usage	30.97 MB	314.25 MB
		Alignment time	25 seconds	58 seconds
		Alignment memory usage	17.93 MB	51.18 MB
	Date created		2022:07:18 08:55:34	2022:07:13 07:02:17
	Software version		1.7.4.13028	1.7.4.13028
	File size		953.71 KB	7.39 MB
Depth Maps	Count		73	97
	Depth maps generation parameters	Quality	Ultra-High	Medium
		Filtering mode	Mild	Mild
		Max neighbors	40	
		Processing time	2 minutes 46 seconds	21 seconds
		Memory usage	502.24 MB	
	Date created		2022:07:18 03:17:51	
	Software version		1.7.4.13028	
	File size		52.57 MB	13.82 MB
Dense Point Cloud	Points		3,780,721	1,153,126
	Point colors		3 bands, uint8	3 bands, uint8
	Depth maps generation parameters	Quality	Ultra-High	Medium
		Filtering mode	Mild	Mild
		Processing time		21 seconds
		Memory usage	2.08 GB	
	Dense cloud generation parameters	Processing time	3 minutes 15 seconds	16 seconds
		Memory usage	2.08 GB	
	Date created		2022:07:18 03:21:07	2022:07:13 07:04:54
	Software version		1.7.4.13028	1.7.4.13028
	File size		54.34 MB	14.78 MB
Model	Faces		665,786	194,658
	Vertices		334,143	97,607

	Vertex colors		3 bands, uint8	3 bands, uint8
	Texture		4,096 x 4,096, 4 bands, uint8	4,096 x 4,096, 4 bands, uint8
	Depth maps generation parameters	Quality	Ultra-High	Medium
		Filtering mode	Mild	Mild
		Max neighbors	40	
		Processing time	2 minutes 46 seconds	21 seconds
		Memory usage	502.24 MB	
	Reconstruction parameters	Surface type	Arbitrary	Arbitrary
		Source data	Dense cloud	Dense cloud
		Interpolation	Enabled	Enabled
		Strict volumetric masks	No	No
		Processing time	2 minutes 37 seconds	40 seconds
		Memory usage	2.12 GB	854.21 MB
	Texturing parameters	Mapping mode	Generic	Generic
		Blending mode	Mosaic	Mosaic
		Texture size	4,096	4,096
		Enable hole filling	Yes	No
		Enable ghosting filter	Yes	Yes
		UV mapping time	1 minutes 16 seconds	58 seconds
		UV mapping memory usage	1.65 GB	273.73 MB
		Blending time	21 second	11 seconds
		Blending memory usage	600.43 MB	629.33 MB
		Blending GPU memory usage	497.60 MB	
	Date created		2022:07:18 03:24:23	2022:07:13 07:17:55
	Software version		1.7.4.13028	1.7.4.13028
	File size		43.22 MB	28.49 MB
Tiled Model	Texture			3 bands, uint8
	Depth maps generation parameters	Quality		Medium
		Filtering mode		Mild
		Processing time		21 seconds
	Reconstruction parameters	Source data		Dense cloud
		Tile size		256
		Face count		Low
		Enable ghosting filter		No
		Processing time		1 minutes 8 seconds
		Memory usage		1.38 GB
	Date created		2022:07:18 08:55:34	2022:07:13 07:37:33
	Software version		1.7.4.13028	
	File size		43.22 MB	10.49 MB
System	Software name		Agisoft Metashape Professional	
	Software version		1.7.4 build 13028	
	OS		Windows 64 bit	
	RAM		15.71 GB	
	CPU		Intel(R) Core (TM) i7-8750H CPU @ 2.20GHz	
	GPU(s)		NVIDIA GeForce GTX 1050 Ti with Max-Q Design	

Survey Data expressed the camera location overlap and relevant data that are varied, depending on the sufficiency of photos to adequately capture an object's shape. Therefore, relevant details were mentioned, including the count of the taken photos, camera positions, and extracted tie points that are used to align the photos, as well as projection and reprojection errors. The camera setting is outlined: namely, the model (NIKON D5500), resolution of the camera, focal length, and pixel size in micrometer (14.814.8 μm) or {14.8 μm = (14.8/10,000mm)} (0.00148×0.00148 cm), which generates the high-resolution model (Table 3).

Based on the survey data, **Camera Calibration** data describe the coefficient and correlation matrix, and image residual for the camera. Despite coordination being less necessary for KCAM objects than for architectural heritage, the **Digital Elevation Model (DEM)** was generated by default and referenced to metric coordinates, which is convertible to the WGS84 datum.

NIKON D5500 (60mm)
97 images

Type	Resolution	Focal Length	Pixel Size
Frame	**1620 x 1080**	**60 mm**	**14.8 x 14.8 µm**

	Value	Error	F	Cx	Cy	K1	K2	K3	P1	P2
F	4213.7	0.63	1.00	0.07	-0.75	-0.27	0.22	-0.19	0.06	-0.47
Cx	5.60381	0.81		1.00	-0.06	-0.04	0.04	-0.05	0.95	0.02
Cy	3.9147	1.3			1.00	0.16	-0.15	0.14	-0.06	0.58
K1	-0.0204664	0.0019				1.00	-0.95	0.87	-0.04	0.04
K2	0.354909	0.087					1.00	-0.98	0.05	-0.03
K3	-3.39683	1.2						1.00	-0.06	0.01
P1	-0.000130991	7.9e-05							1.00	0.03
P2	0.000646289	5.5e-05								1.00

Table 3 Calibration coefficients and correlation matrix in processing Sue ware

5-2. Interpretational analysis

Agisoft-Metashape's exported report concludes the processing and analysis workflow. The report comprises specific details on the attributes of the photos taken on the exact date and time the report was generated. (Table 2).

The report summarized the **Processing Parameters** that delineates all phases in specific detail. Consequently, the information began with properties and calibration of the utilized camera followed by the six processing phases. The PC operating system and the software are described as well.

The generated 3D model is exported to several domains, according to the outlined objectives, where PDF format is appropriate for reports and simple use, while other formats such as LAS and LAZ are much more suitable for producing virtual reality, for instance. However, Agisoft supports point cloud export in the following formats: Wavefront OBJ, Stanford PLY, XYZ text file format, ASPRS, LAS, LAZ, ASTM E57, U3D, potree, Agisoft OC3, Topcon CL3, and PDF.

In this regard, the provided information reflects the diversity in processing of the two objects in the KCAM collection (water pitcher and Sue ware). Camera positions and capturing count for the water pitcher are fewer than for the Sue ware item, due to dimensional diversity. Processing synchronization is proportionate, based on the artistic and manufacturing characteristics of the objects and the data acquisition parameter. Processing the water pitcher (1 min 18 s) took longer than the Sue ware object (37 s), due to leakage of tie points in the scattered photos of the water pitcher, which required more editing. The alignment time necessary for the Sue ware object (58 s) was proportional to the count of camera positions (97), which was higher than for the water pitcher (25 s), which needed73 camera positions (Table 2).

Measurement is essential in documenting museums' collections. PhotoScan doesn't provide such relevant automated parameters. So, measuring the object requires an absolute reference scale. A measurement scale should be set beside the object during the data acquisition phase, to serve as a reference to measure desired distances. Alternatively, an automated measuring scale could be generated by identifying the distance between two visible points on the object.

6. Discussion: Significance of digitizing KCAM and applicability to MENA museums at risk

Outcomes of digitizing objects in the KCAM collections emphasized the benefits of PhotoScan techniques during the COVID-19 outbreak and suggest its applicability to other museums at risk.

The essential message of KCAM is to create a place to think about the heritage of archaeological properties for the future. Therefore, 3D modelling is an effective method to achieve the fulfilment of this duty.

Interviews with KCAM staff concluded that COVID-19 revealed the privilege of digitizing the collection in the current storage environment for creating digital databases at the time of disaster and publicizing them on the KCAM website. Digitizing the designated objects of KCAM, namely an ash glazed water pitcher from Kitashirakawahaiji-temple, and vessel stands with miniatures (Sue ware) from Tatsumi round tomb No. 1, allows traditional and valuable artifacts of the Kofun era and the Heian era in Kyoto City to survive. Inaccessibility to the collections during the COVID-19 state of emergency disabled KCAM staff and scholars to check the objects. The asymmetrical and elaborate design of the water pitcher and the Sue ware object were not easily recognizable and not appropriate for hands-on display. Therefore, photogrammetry technique generates 360 degrees visibility for both objects, which provides detailed texture, especially the multidimensional shape and previous restoration diagnosis. Moreover, generating 3D model documentation will allow displaying the valuable objects outside KCAM, safely. Eventually, formation of the objects by 3D printers will also be essential to KCAM future and its social commitments. For instance, the Kansai University Museum adopted 3D printing as a method to showcase the outcome of combining real object and replica in one museum scenario.[29]

Conclusion

Outcomes of this contribution will be aggregated to create a digital database and virtual museum for KCAM at the time of crisis, which introduces and publicizes Kyoto's cultural heritage. In addition, dissemination of the adopted methodology and means is fruitful to other museums vulnerable to the same or resemblance risk, especially in the Middle East and North Africa (MENA) region. Accordingly, the outbreak of the COVID-19 pandemic emphasized the importance of generating an interactive database using photogrammetry in museums that allow stakeholders, scholars, as well as tourists to engage with KCAM's collection, considering the exceptional global restrictions that impacted human communications, behavior, and mobility. Furthermore, the benefits of this technique extend to preserve the cultural heritage of countries at risk, wheather those exposed to armed conflicts or vandalism such as Iraq, Syria, Yemen, and Sudan or those exposed to natural disasters such as earthquakes that struck Türkiye, Syria and Morocco. Creating a 3D digital database for museums supports the efforts of anti-smuggling and the illegal trading of antiquities for example that took place in Egypt as a consequence of the January 2011 revolution. Regrettably, Egyptian museums were exposed to several attacks, including an attempt to loot the Egyptian Museum in Cairo on January 28, 2011, the looting of the Mallawi Museum in August, 2013, and the severe damage in the Museum of Islamic Art that was affected by the Cairo Security Directorate explosion in January, 2014.

Consequently, discussion around adopting photogrammetry technique for selected objects of KCAM demonstrates the applicability of generating 3D models for MENA museum collections exposed to natural disaster and armed conflict. In addition, the workflow is outlined as a guidance to explain the technical background of photogrammetry/photo-scanning (SfM-MVS) and its advantages compared to other 3D scanning methods, such as TLS and UAV. Moreover, clarification of setting the equipment and parameters up according to different targets for scholars and professional, who wish to adopt a similar approach for other museums. Subsequently, simplification of the tools that were once expensive became now available at a low price, and systems that require specialized knowledge are becoming easier to use in the form of applications.

In view of the above; applying photogrammetry technique at KCAM emphasizes the importance of digitizing the museum’s collections in the time of crisis, as a fruitful prototype for the museum itself and abroad.

Acknowledgment

The authors greatly acknowledge the International Joint Digital Achieving Center for Japanese Art and Culture (ARC-iJAC) and the Japan Society for the Promotion of Science (JSPS) for supporting this contribution, which comes out within the first author as JSPS international researcher, Visiting Researcher at Ritsumeikan University and principle investigator of research project “Qait’bay Citadel (1477-1479): Visualizing the Main Coastal Fortification of Medieval Alexandria, Egypt” , and International Research Fellow of Japan Society for the Promotion of Science of Postdoctoral Fellowships for Research in Japan.

Gratitude is extended to Prof. Masakazu Yamamoto, Director of the Kyoto City Archaeological Museum to facilitates and support the mission of the teamwork.

［Notes］

1) Barbato [2015], p. 361
2) Kaneda et.al. [2015], p. 1
3) Barbasiewicz et.al. [2018], p. 2
4) Jithamala H et.al. [2022], p. 1534
5) UNESCO. [2021], p. 16
6) ICOM. [2015], p. 3

7) UNESCO. [2013]
8) Ghaidan *et.al.* [2003], p. 99
9) Aetnet. [2021]
10) UNESCO. [2021]
11) Aljazeera. [2020]
12) UNESCO. [2023]
13) Arab News-Japan. [2023]
14) Adams. [2023]
15) ICOM. [2023]
16) Adams. [2023]
17) Russian News Agency. [2023]
18) Barbato et.al. [2015], p. 361
19) Benjamin U et.al. [2020], p. 2
20) Christine A et.al. [2020], p. 4
21) Chao Wu et.al. [2020], p. 2
22) Goudarzi et.al. [2015], p. 6
23) Pepe et.al. [2022], p. 14
24) KCAM. [2011]
25) Kyoto Museums. [2011]
26) Mahfudz et. al. [2020], p. 1
27) Christine A et. al. [2020], p. 2
28) Christine A et. al. [2020], p. 9
29) Sakaguchi et.al. [2022], p. 42

[References]

Adrianna Barbasiewicz, Tadeusz Widerski, and Karol Daliga. The analysis of the accuracy of spatial models using photogrammetric software: Agisoft Photoscan and Pix4D E3S Web of Conferences 26, 2018, pp. 1-5. https://doi.org/10.1051/e3sconf/20182600012

Aljazeera. Report documents severe damage to Syrian heritage and museums. June 8, 2020. https://www.aljazeera.com/features/2020/6/8/report-documents-severe-damage-to-syrian-heritage-and-museums (Accessed: Oct. 4, 2023)

Arab News-Japan: How conflict is jeopardizing Sudan's museums and Cultural heritage. June 6, 2023. https://www.arabnews.jp/en/middle-east/article_97002/ (Accessed: Oct. 4, 2023)

Artnet News. Six years Ago, ISIS Brutally Attack an Iraqi Museum. March 2, 2021. https://news.artnet.com/art-world/iraq-mosul-museum-destruction-restoration-efforts-1948306 (Accessed: Oct. 3, 2023)

Barbato, Davide. A Possible Method for 3D Photo Scanning Speed Survey: The Case Study of the Bridge of Saint Angelo above Auso. Hand book of Research on Emerging Digital Tools for Architectural Surveying, Modelling, and Representation, IGI Global, vol. I, 2015, pp. 361-381. https://doi.org/10.4018/978-1-4666-8379-2.ch012

Benjamin U. Meinen, Derek T. Robinson. Mapping erosion and deposition in an agricultural landscape: Optimization of UAV image acquisition schemes for SfM-MVS. Remote Sensing of Environment, 239. 2020, pp.1-10. https://doi.org/10.1016/j.rse.2020.111666)

Christine A. Jones, Elizabeth Church Photogrammetry is for everyone: Structure-from-motion software user experiences in archaeology Journal of Archaeological Science: Reports. Report 30, 2020, pp. 1-10. https://doi.org/10.1016/j.jasrep.2020.102261

Chao Wu, Yongbo Yuan, Yang Tang and Boquan Tian. Application of Terrestrial Laser Scanning (TLS) in the Architecture, Engineering and Construction (AEC) Industry. Sensors. Vol. 22. 2022, pp. 1-32. https://doi.org/10.3390/s22010265

Geraldine Kendal Adams: Fears for ancient sites in Türkiye and Syria after devastating earthquakes. Museums Association. 10 February, 2023 https://www.museumsassociation.org/museums-journal/news/2023/02/fears-for-ancient-sites-in-turkiye-and-syria-after-devastating-earthquakes/

ICOM: -Emergency Red List of Libyan Cultural Objects at Risk, Paris, 2015, 8p. https://icom.museum/en/ressource/emergency-red-list-of-libyan-cultural-objects-at-risk/) (Accessed: Oct. 4, 2023)
-Turkey and Syria earthquake – Statement February 23, 2023. https://cimcim.mini.icom.museum/turkey-and-syria-earthquake/ (Accessed: Oct. 3, 2023)

Jithamala H, Caldera S. C. Wirasinghe. A universal severity classification for natural disasters. Natural Hazards, Springer Nature. 2022, p. 111:1533–1573 https://doi.org/10.1007/s11069-021-05106-9

Kaneda A, Nakagawa T, Tamura K, Noshita K, Nakao H. A proposal of a new automated method for SfM/MVS 3D reconstruction through comparisons of 3D data by SfM/MVS and handheld laser scanners. PLoS ONE 17 (7): e0270660. 2022. https://doi.org/10.1371/journal.pone.0270660

Kyoto City Archaeological Museum website (KCAM). 2011. https://www.kyoto-arc.or.jp/museum/sisetsu.html (Accessed: Oct. 5, 2023)

Kazumi Sakaguchi et.al. (2022) Construction of A 3D Digital Archive of Flintlock Guns and The Development of Digital Content for Exhibition. Naniwa Osaka Study, issue. 4, pp. 39-50.Vol. doi/10.32286/00026338

Kyoto Museum. Exploring Museums in Kyoto. Kyoto City Archaeological Museum. 2011 https://www.kyoto-museums.jp/en/museum/north/3923/

(Accessed: Oct. 4, 2023)

Mahfudz Al Huda et.al. Investigation the Effects of Cutting Parameters on Geometric Accuracy of Machining Marine Propeller using 3D Photo-scanning Technique, WTATM, Vol. 15, 2022, pp. 1-10. http://dx.doi.org/10.37394/232011.2020.15.1

Massimiliano Pepe, Vincenzo Saverio Alfio and Domenica Costantino. UAV Platforms and the SfM/MVS Approach in the 3D Surveys and Modelling: A Review in the Cultural Heritage Field. Applied Sciences. 2022, 36 p https://doi.org/10.3390/app122412886)

Russian News Agency. Morocco's historical mosques, museums sustain serious damage during earthquake 10 September, 2023 https://tass.com/emergencies/1672187

Shidrokh Goudarzi, Nazri Kama, Mohammad Hossein Anisi, Sherali Zeadally, Shahid Mumtaz. Data collection using unmanned aerial vehicles for Internet of Things platforms. Computers and Electrical Engineering. Issue 15. 2019, pp. 1-15 https://doi.org/10.1016/j.compeleceng.2019.01.028

UNESCO. Museums around the world in the face of COVID-19. UNESCO. Paris, April 2021, 67p.

UNESCO: -Looting of the Mallawi National Museum in the Upper Egypt city of Minya. 21 August 2013 https://www.unesco.org/en/articles/warning-looting-mallawi-national-museum-upper-egypt-city-minya (Accessed: Oct. 2, 2023)
-Gallery: Heritage at Risk in Yemen. 2015. https://en.unesco.org/galleries/heritage-risk-yemen (Accessed: Oct. 3, 2023)
-Looting of museums and warehouses in Syria. April 27, 2023 https://www.unesco.org/en/node/66288 (Accessed: Oct. 4, 2023)

Ghaidan Usam, and Paolini Anna. A Short History of the Iraq National Museum. Museum International. Facing history: museums and heritage in conflict and post-conflict situations. Isabelle Vinson. Vol LV, n°3-4, Blackwell Publishing, December 2003, pp. 97-102 https://unesdoc.unesco.org/ark:/48223/pf0000133499