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Cultural Heritage and Science (CUHES)

Cultural Heritage and Science (CUHES) is an interdisciplinary academic, refereed journal for scholars and practitioners with a common interest in heritage.

Aims and scope

Provide a multidisciplinary scientific overview of existing resources and modern technologies useful for the study and repair of cultural heritage and other structures. The journal will include information on history, methodology, materials, survey, inspection, non-destructive testing, analysis, diagnosis, remedial measures, and strengthening techniques.

Preservation of the architectural heritage is considered a fundamental issue in the life of modern societies. In addition to their historical interest, cultural heritage buildings are valuable because they contribute significantly to the economy by providing key attractions in a context where tourism and leisure are major industries in the 3rd millennium. The need for preserving historical constructions is thus not only a cultural requirement, but also an economic and developmental demand.

Therefore, Cultural Heritage and Science (CUHES) cover the main aspects related to the study and repair of an existing historical artifact, including:

- ✓ Issues on the history of construction and architectural technology
- ✓ General criteria and methodology for study and intervention
- ✓ Historical and traditional building techniques
- ✓ Survey techniques
- ✓ Non-destructive testing, inspection, and monitoring
- ✓ Experimental results and laboratory testing
- ✓ Analytical and numerical approaches
- ✓ Innovative and traditional materials for repair and restoration
- ✓ Innovative strategies and techniques for repair and restoration
- ✓ General remedial measures
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- ✓ Seismic behavior and retrofitting
- ✓ Detailed and state-of-the-art case studies, including truly novel developments
- ✓ Cultural Heritage and Tourism
- ✓ Close-range photogrammetry applications for cultural heritage,
- ✓ Laser scanning applications for cultural heritage,
- ✓ 3D modeling applications for cultural heritage,
- ✓ UAV photogrammetry applications for cultural heritage
- ✓ Underwater photogrammetry applications for cultural heritage
- ✓ Virtual Reality and Augmented Reality applications for cultural heritage
- ✓ Remote Sensing applications for cultural heritage
- ✓ Archeologic studies
- ✓ Architecture studies
- ✓ History of Art studies
- ✓ Description of novel technologies that can assist in the understanding of cultural heritage.
- ✓ Development and application of statistical methods and algorithms for data analysis to further understanding of culturally significant objects.
- ✓ Computer sciences in cultural heritage

The main objective is to provide an overview of existing resources useful for the rigorous and scientifically based study of the state of ancient structures and to present state-of-the-art novel research in the field. The journal will publish review papers, research papers, and detailed case studies. Interdisciplinary contributions will be highly appreciated.

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The digital memory for the cultural heritage in the 21st century

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Keywords
Memory
Digital
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Abstract

The concept of memory has been redeveloped since the beginning of the 20th century. Social memory is directly related to the cultural heritage, which includes memory, and the protection and transfer of heritage. Technological applications that ensure sustainability of tangible and intangible cultural heritage in the 21st century are included in cultural institutions and internationally UNESCO projects. In this study, it was aimed to evaluate the concepts of memory, about the using in the international and historical documents of the cultural heritage. In the study, the concept of memory was focused in terms of cultural heritage, and the technological applications developed against the loss of information and documents of universal value were examined. The Memory of the World Register developed by UNESCO in 1997, is within the scope of documentary heritage. From Turkey, Observation and Earthquake Research Institute Kandilli Observatory Manuscripts, Hittite Tablets, Süleymaniye Library Ibn-i Sina Manuscripts Collection, Evliya Çelebi Travel Book, Kultepe Tablets, Divan-ü Lügâti't-Türk and Piri Reis's Map, Karatepe Tablets recorded in the list. As a result of the study, the importance of transferring information and documents that have universal value as a world heritage to digital media has been emphasized and the aspects of the using technology in culture have been evaluated.

1. Introduction

Memory actually tends to forget and remember, as well as relatively qualitatively, to misremember or reinterpret the past. It is in question that memory can mislead its owner, distort the common reality, as well as provide the opportunity to reinterpret events.

The concept of memory is used to express common values for societies, together with the word social or collective (common) with a general definition developed at the beginning of the 20th century. In the social sense, the concept of memory not only has the distinctive features of various countries in the world, but also points to the common characteristics of societies. The disturbation of the international community about cultural heritage preservation have also resulted in the popularization of the world heritage concept (Buyar & Unal 2022).

Today, when we think of the world as a large mansion, we know that objects from the past thrown into the attic determine your present and future situation. When we consider the world as our common residence, it becomes important to record the past rather than ignore it. It would be wise to take advantage of technological opportunities while doing this. In this context, international organizations are developing various projects on the conservation of world memory.

In this study it was aimed to evaluate the concepts of memory, about the using in the international and historical documents of the cultural heritage.

2. Method

2.1. Memory, collective memory and cultural heritage

According to Bergson, the concept of memory records everything that is perceived in detail in daily life in the form of images, appearances and memories in a chronological manner in the time process. Memory necessarily accumulates everything perceived according to utility or other criteria (Bergson 2007; Annepçioğlu &

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Kurt 2019). The culture is the whole of human knowledge, belief and behavior and all kinds of material ans spiritual creations that are parts of this whole (Usta & Gafar 2022). Culture depends on the passing on of learned knowledge between individuals, through teaching and copying. The duration of cultural memories depends not just on the amount of social learning but also on the fidelity of information transmission. The transmission indicates that the accuracy with which information passes between individuals (Laland & Rendell 2013). However, the concepts of memory and culture both have social and inter-communal meanings because they cover the past and provide cultural transfer.

The concept of memory can be used synonymously with the concept of memory, as well as by emphasizing the quality of storage and preservation, and by choosing the word memory. For example, according to Sancar, memory has become an interdisciplinary concept, a concept that can be evaluated within the scope of cultural heritage in the art and literature environment and includes cultural memory. Cultural memory is the organ of remembering non-daily events. And the cultural memory tends towards certain points in the past" (Sancar 2016, Ünay Selçuk 2018).

When the use of the concept of memory in various fields was investigated, the concepts of collective and social memory were developed by Aby Warburg in the early 20th century. Collective memory, which can be expressed in the form of collective memory, is formed by the permanence of values that are accepted as common in society. The content of memory and its organization, how long it will be preserved, are determined not by the capacity and orientation of the individual, but rather by external conditions, the conditions of the social and cultural framework (from Assman 2015 by Bayraktar 2017). These descriptions, which reveal the common and permanent characteristics of the society, are clarified with the concept of cultural heritage. Halbwachs developed the concept of "social frameworks of memory"; by facilitating and influencing the recollection of the individuals in it, society creates a space for individuals to make their memories permanent and to find them again (Halbwachs, 1925). In the field of cultural memory, which Assman classifies under the title of meaning transfer, traditions take place as a way of transferring and reviving cultural meaning. The concept is valid not only for monuments, temples, idols, but also for anything that transcends the boundaries of object memory, such as symbols, icons, representations that contain meaning, by translating the introverted time and identity sequence outward (from Assmann 2015 by Bayraktar 2017). Collective memory products consist of "transmitted by mutually recognized codes" in the definition of folklore and are passed on from generation to generation as "intangible cultural heritage" (Oğuz 2007). But nowadays it can be cultural assets can be seen to have tangible and intangible qualities at the same time.

Through the ages cultural transmission in societies provided by visual arts, monuments and architecture. Artists and architcts have carried out various studies and work on the concept of memory, with the subject of forgetfulness, which is experienced in the world due to the rapid transformation that took place with the Industrial Revolution. In today's world, where technological developments and social transformations took place after the industrial revolution, individuals and artists felt the need to connect to their memories. It is in question that artists consciously keep in their memories the events and subjects they feel and their connections with the past, protect them, and reflect this concept to their works and works whenever they want (Annepçioğlu & Kurt 2019).

The inclusion of the concept of memory in artistic life has raised awareness of memory culture from the individual to the society. In the academic literature written in Turkish and based on the studies in this field, it is seen that the word "memory" is generally preferred as the equivalent of the word memory in English. Although these two words are used synonymously, it is pointed out that the meanings of "protection and preservation" in the origin of the word memory do not correspond to memory and its derivatives (Bursalı 2017). Considering the social meaning of memory and the protection of cultural heritage, they are interrelated concepts. As the definition of cultural heritage expands, it has been observed that works, architectural monuments and documents of universal value have increased both in terms of numbers and content.

Cultural heritage determinated by UNESCO as the legacy of physical artefacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations (UNESCO, 2022).

In tangible culture, "preserved objects also validate memories; and the actuality of the object, as opposed to a reproduction or surrogate, draws people in and gives them a literal way of touching the past" (UNESCO, 2022). Tangible cultural heritage assets point to the timeless definition as they belong to the present time, future as well as the past.

Tangible culture are two important components in life of societies (Alyilmaz, 2010, Uysal 2013), The most important step to be taken in order to protect this culture as desired is the documentation of the Works in terms of national and universal culture (Kaya 2021, Alptekin 2019, Şasi 2019, Ahmet 2018). In terms of cultural heritage protection, preserving these assets and transmitting them to the future generations is critical (Kanun 2021, Alptekin 2019, Ulvi 2020, Yakar 2017). In the process of documenting cultural heritage, traditional techniques have left their place to digital techniques, as their efforts to acquire the right data in the shortest time have developed in technology in recent years (Yakar 2017).

2.2. The role of technology in preserving cultural memory

The most important step to be taken in order to protect these works as desired is the documentation of the works.

Technical applications for storing in memory, which are considered among the socially beneficial aspects of technology, are today accepted as a permanent solution worldwide. Private, foundation or state-affiliated cultural institutions, especially museums, carry out applications such as databases for long-term storage of works, objects, information and documents, and virtual collections on their websites. These applications provide up-to-date solutions and enable the transfer of tangible and intangible cultural assets as well as information and documents for the future in a permanent way.

In the 21st century, tangible cultural heritage values such as monuments, architectural structures, works of art that have survived from the past, and intangible cultural heritage values that can be summarized with various cultural transfers such as traditions and customs, oral culture, handicrafts, which may occur in the protection and storage conditions of the world heritage, can be transferred to digital memory if it is necessary.

Today, the cultural heritage, which transcends the borders of countries and is owned and responsible for the world, has been expanded to include tangible and intangible cultural assets with the definitions developed in the process. Social memory, which enables the creation of the original identity of societies, includes visible monuments and structures, as well as the values of the society such as art, craft, tradition, custom and ritual. This wide-ranging concept necessitates the delivery of more diverse and numerous documents in the field of application to the future.

Throughout the ages, the intellectual and cultural heritage of humanity has been preserved mostly in written forms such as manuscripts, books and magazines. Unlike other individual memories, these documents cover generations and centuries (van der Hoeven 1996). For this reason, it preserves a wide spectrum of human history from the classic to the popular.

Except that the tangible and intangible cultural heritage of the UNESCO World Heritage List, it is of great importance that significative documents are registered, preserved and shared in a universal context. In this way the concept of "documental sustainability" was put forward (Akyüz Levi 2021). It can support the evaluation transfer of cultural heritage with a holistic perspective. This approach is broad to encompass cultural heritage types and diverse societies.

With this purpose, in 1992, UNESCO defined the Memory of the World Program under the title of "Building Information Societies" as "protecting the documents and information that constitute the historical, cultural and social memory of humanity and which are in danger of disappearing due to various natural disasters, especially wars, or social reasons, as common values of humanity, and as one of the measures of protection, to ensure that it is shared in the digital environment". The main goal of the program was explained as "to facilitate the preservation of the documentary heritage of the earth with the most appropriate techniques, to assist in universal access to the documentary heritage, to raise awareness around the world about the existence and importance of the documentary heritage" (UNESCO World Memory Program, 1996). The Memory of the World Registry, which was created within the framework in question, contains the documentary heritages of almost every country and continent selected since 1997, with a variety of history, language and art. Documents reflecting social and political life from many countries of the world, international historical treaties, postcards, photographs, documentaries, motion pictures, festival or concert recordings constitute a large collection. The common point of documents belonging to different subjects, countries and cultures is that they have the characteristics of a periodical document heritage of humanity, they can be recorded digitally and they can be shared without any time and place limit. While the transfer of historical artifacts and documents to digital media helps to stop the effect of physical conditions on the temporality of time, the shareability of the digital document paves the way for international accessibility and research. From Turkey in 2001 Boğaziçi University Observation and Earthquake Research Institute Kandilli Observatory Manuscripts, Boğazköy Hittite Tablets, in 2003 İbn-i Sina Manuscripts Collection at the Istanbul Süleymaniye Library, 2013 Evliya Çelebi Travel Book, 2013 Kültepe Tablets, in 2017 Divan-ü Lügâti't-Türk and Piri Reis's Map, in the year 2022 Karatepe Tablets are recorded in the World Memory list. (UNESCO World Memory Program, 2022). Turkey with its rich cultural heritage, is on the list with a valuable collection from Assyrian tablets to Ottoman period manuscripts.

The collection was created by bringing together manuscripts and terracotta tablets, which are the first written texts in history, under the same title. Drawing attention to the importance of written and visual documents that have survived as a world heritage, the selection points to the shareable and usable nature of digital memory for large audiences. As it is known, applications such as photography and video used in documentation are technologies that can be used at the first stage in the preservation, storage and transmission of social memory. Today, storing documents in digital environment and providing accessibility has been accepted as a more common and reliable method. In the early years of the UNESCO Memory of the World Program, recordable CD and DVD technologies were used and their abilities in long-term preservation and storage were evaluated (Bradley 2006).

One advantage of the technological systems is that the sharing of digitalized intangible cultural heritage values on the online platforms of museums can support other researches, be accessible, introduce and increase social awareness (Ertürk 2020).

2.3. Problems encountered for digital memory

The fact that technological devices have a certain useful life, and that innovations in technology quickly disable the previous system or device can be counted among the negative qualities. Nowadays, systems that do not require external tools such as cloud volume and virtual memory are preferred because CD and DVD tools do not have long-term storage characteristics.

However, virtual storages such as the cloud can cause irreversible problems such as data loss that may occur due to threats such as copying or technical disruptions, basically shows that the use of traditional physical documentation and storage methods cannot be abandoned.

3. Discussion and conclusion

UNESCO World Memory Program, ensures that the intangible cultural heritage, which is actually an artifact value, can be considered together on the digital platform. Digital platforms have an introductory and interest-increasing sense as they make information storable as well as facilitating accesibility.

However, it is clear that any copy or reproduced document with a long-lasting nature cannot replace the original work or document. It can be foreseen that the problem can be solved in a multi-faceted way by eliminating the technical problems that digital technologies may be insufficient or creating insecurity, and simultaneously improving the long-term physical preservation conditions of documents.

It is considered as an important advantage that digital documentation and storage are easily accessible by the researcher and that physical documents that can be damaged by external factors can survive longer in the virtual environment.

The UNESCO Memory of the World Register, which is among the application examples of data storage, is important in terms of digitizing information and documents, bringing together the cultural data of societies from various subjects and periods, creating the common memory of the world and making it widely accessible.

Conflicts of interest

The authors declare no conflicts of interest.

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Three-dimensional modeling of the Kubbe-i Hasiye Shrine with terrestrial photogrammetric method

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Keywords
3D model
Photogrammetry
Cultural Heritage

Abstract

Natural and unnatural structures, which are the subject of our cultural heritage, are in constant danger of extinction as a result of both man-made destruction and natural events such as natural disasters, rains and strong winds. Therefore, it is necessary to take very good protection measures in order to keep cultural assets alive and transfer them to future generations. In the light of today's technology, different techniques have been developed to take these protection measures. One of these techniques is terrestrial photogrammetry technique. With this technique, all the details of the building are measured and a three-dimensional visual model of the building can be created thanks to the pictures of the building. Thus, by recording all the features of the building such as detail dimensions, shape, size, type of building material, necessary interventions can be made in case of any structural deterioration, modification and repair that may occur in the building. In this study, it is aimed to measure the Kubbe-i Hasiye tomb located in the center of Tillo district of Siirt province, photogrammetrically, and to make a three-dimensional modeling with the pictures taken of the tomb by making three-dimensional modeling. As a result of the measurements made on the model obtained as a result of the study, precision was obtained in the reference intervals determined and the amount of error was determined below 2 cm.

1. Introduction

Cultural and natural structures in any geography are like mirrors that reflect all the values they have such as the historical past, lifestyles, religious beliefs, national traditions and customs of the civilizations that have lived and are living in that geography. However, they witnessed all the events experienced by the civilizations that lived in that region (Uysal et al. 2013). Cultural and natural structures have always faced the danger of being damaged and destroyed due to natural and unnatural causes from past to present. As a matter of fact, it is seen that many buildings with a recent past have not survived and disappeared due to these reasons. The main reasons for this are the failure to take adequate measures to protect these structures and the failure to use scientific and technical methods to keep these cultural heritages alive. The first way to protect our historical artifacts that are the subject of cultural heritage is to document these works digitally as soon as possible (Kaya et al. 2021). In addition, the most important feature of the documentation to be made in order to transfer these works to future generations should be a sensitive documentation work (Yakar et al. 2009).

These structures of the world heritage have been exposed to both natural and unnatural human-induced effects. There are many different scientific methods for the preservation and survival of these structures. Photogrammetry, which is one of these methods, is a scientific method that allows these natural and unnatural structures to be modeled in three dimensions together with the pictures taken by allowing the measurement of all detail points (Yakar and Mohammed 2016). Thanks to the photogrammetry technique, digital documentation of

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Research Article

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cultural assets can be realized very quickly and reliably (Yakar and Yılmaz 2008).

In case of damage to historically important buildings, whose three-dimensional modeling is done with the photogrammetry method, repairs and restoration works can be carried out correctly and in accordance with the historical texture of the building, and at the same time, three-dimensional models of these structures can be produced when desired. Along with the developing technology, photogrammetric methods have also developed and started to use remotely controlled aerial vehicles such as laser measuring devices and Unmanned Aerial Vehicles that produce thousands of detail point information per second. This situation has led to the use of photogrammetry in many space (Yakar et al. 2005).

Terrestrial photogrammetry technique allows three-dimensional modeling of objects. In this technique, with the help of geodetic measurements and photographs of the objects to be modeled, a three-dimensional model is obtained by making drawings on special technical software in the digital environment. Three-dimensional position information of the object is obtained through this model (Şanlıoğlu et al. 2013). In terrestrial photogrammetry technique, photographs are made with cameras that provide images as single or double images. Usually, images are provided as double images from distances up to 25 m (Yılmaz et al. 2000).

In terrestrial photogrammetry, the reception center is above ground. Rays reflected from the object can be recorded both analog and digital. Thanks to the technological developments, terrestrial photogrammetry technique has started to be used in many fields, especially in industry. This technique is used in fields such as engineering applications, architecture, medicine, geological activities, as well as in studies such as the protection, restoration and digital recording of cultural assets (Yılmaz et al. 2000).

Terrestrial photogrammetry technique has been used for many years for archaeological measurements and documentation of cultural artifacts. With the technological developments in photogrammetry, this method has become a much more economical and useful method for the preservation and digital recording of cultural assets (Suveg and Vosselman 2000). With this technique, the real dimensions of the work being modeled can be determined geometrically and the geographical location of the work can be determined with the obtained three-dimensional model (Mırdan and Yakar 2017). In this photogrammetry technique, while modeling with traditional methods, objects such as ornaments, relief gilding, etc., cannot be adequately modeled. In this case, these problems can be solved by modern methods of terrestrial photogrammetry such as laser scanning or close-up photogrammetry (Ulvi et al. 2019).

2. Material and method

2.1. Kubbe-i Hasiye Shrine

The shrine is located on a dominant hill in the Fakirullah neighborhood of Tillo district, which is 9 km away from the city center of Siirt (Figure 1). The shrine is geographically located at latitude 37.9410041 and longitude 42.006942. Known to have been built in the last quarter of the 18th century for Zemzem-il Hassa (Hasiye), one of the female awliya descendants of His Holiness İsmail Fakirullah who lived in Tillo District, known as the land of saints, the shrine, which is known to have been built in the last quarter of the 18th century, has undergone restoration work over the years and has taken its present form. The shrine has dimensions of 10 x 12 m and a height of 4 m (Figure 2). It has a fine workmanship and a simple architecture. Just below the roof eaves, there are four small windows with patterns and embossments that allow light to enter, together with the extremely gentle and embossed patterns on all four sides of the building. At the same time, there is a small entrance gate 1.1 m long and 50 cm wide for those who enter by bowing respectfully. The Dome of the Annunciation shrine is in a structure where there is a constant density, which is visited by people not only for faith-based but also for recreational purposes, as it has a large garden and trees around the garden.

Figure 1. Study Area (URL1)

Figure 2. Kubbe-i Hasiye Shrine

2.2. Field Study

Spectra Cors GPS (Figure 3) and Gowin TKS-202 total station (Figure 4) measurement devices were used for field measurement, Nikon D5100 camera was used for taking photographs.

Before starting the measurement process in the field, the project area was visited and the points where the polygons to be established were determined and land reconnaissance was made. In addition, the photographs of the building were taken and a sketch was created by marking the measured points on the structure by taking the printout. Fixed points of the polygons were determined and benchmark sketches were arranged. A closed polygon network was formed by establishing five polygon points around the building in a way that they would see each other, and coordinated in the national system with the Cors GPS device (Figure 5 and 6). A total station device was installed on the measured polygon points and zero connection was made from the polygon to the polygon, and the error value was determined to be below 0.5 cm and the measurement was continued with the total station. Polygon points coordinated with Cors GPS measuring device were used as control points. In this way, three-dimensional coordinates of the structure were obtained by making measurements on the structure with the help of these points with the total station measuring device. Polygons P.2 and P.3 had to be installed closer to the structure, since there was a wooded part in the west and northwest of the building, causing problems during photographing and measurement.

The measurement process of the study took about half a day. The measurement process was completed by measuring the points marked on the sketch of the work. In addition, pictures were taken of the same surface of the building from three different angles in order to make balancing easily. The zoom setting of the camera is fixed during photo shooting. Attention was paid to take the photographs at an angle and to cover each other so that the overlapping can be done easily. In order for the shooting points of the photos not to be the same, the photo shooting process was carried out by relocating them.

2.3. Office Work

The measurement values obtained from the field were transferred to the computer environment and obtained in .ncn file format in Netcad 5.1 software and then converted into .txt format for evaluation in Photomodeler software. The parameters of the camera from which the photographs were taken were introduced in the Photomodeler (PM) software and the calibration process was carried out before proceeding to the drawing process. For the calibration process, the calibration paper was printed in A4 size from the output part of the PM software. In order for the calibration process to be performed correctly, 8-12 photos of the calibration paper should be taken. The printout was placed on a flat surface, and 10 photographs were taken by turning it clockwise. Care was taken to ensure that the camera was in a horizontal and vertical position during photographing. After the successful completion of the calibration process, the balancing process was also done successfully and the drawing process was started.

Figure 3. Cors GPS GNSS receiver (URL 2)

Figure 4. Total station (URL 3)

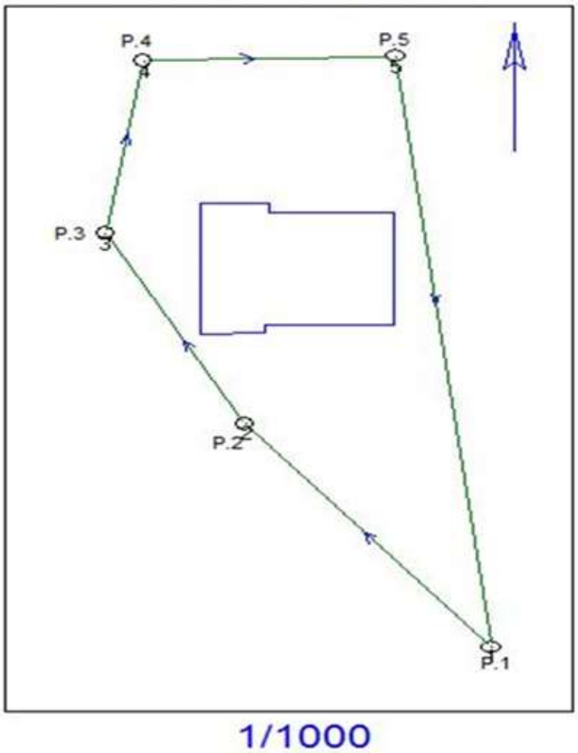

Figure 5. Polygon mesh

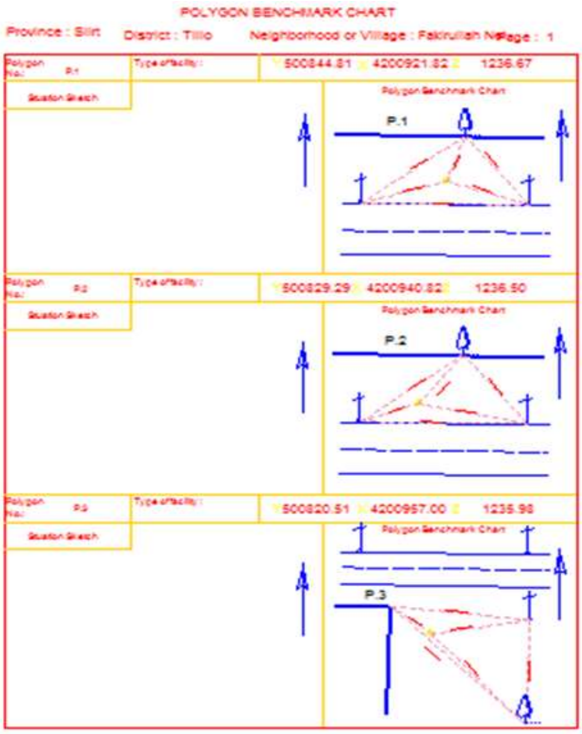

Figure 6. Polygon benchmark chart

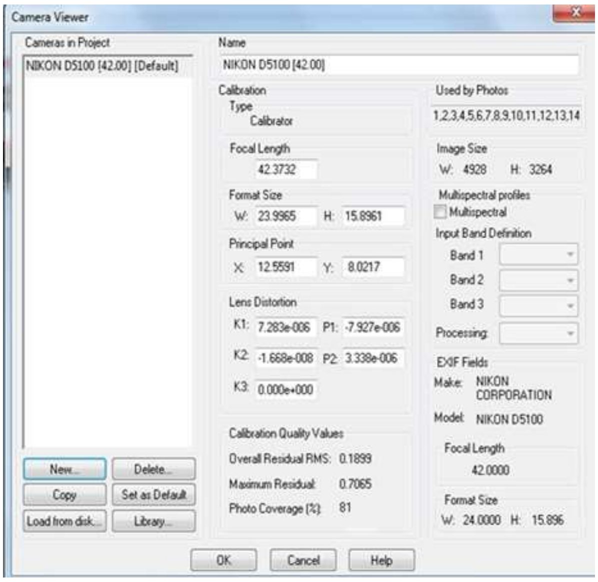

Figure 7. Calibration parameters

Figure 8. Camera (URL 4)

Table 1. D5100 Camera features (URL 5)

Sensor type	CMOS
Efficient pixel	16 MP
Focal length	18-55 mm
Screen width	3.0 inç
Weight	560 gr
Battery capacity	1030 mAh

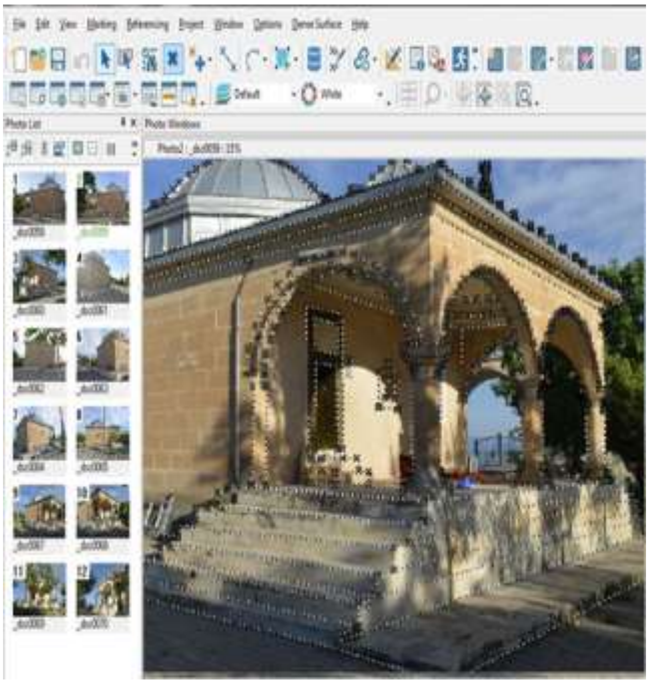

Figure 9. PM detail drawing

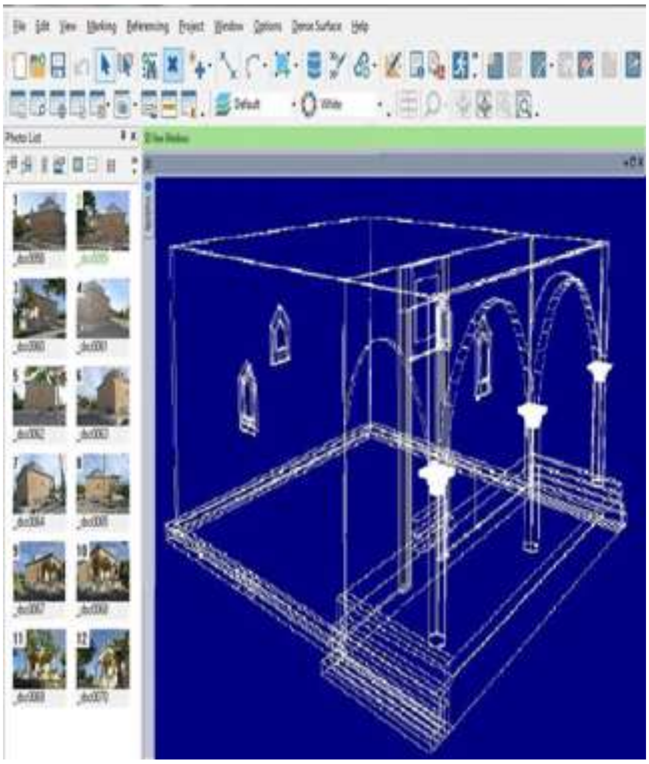

Figure 10. 3D drawing stage of the building

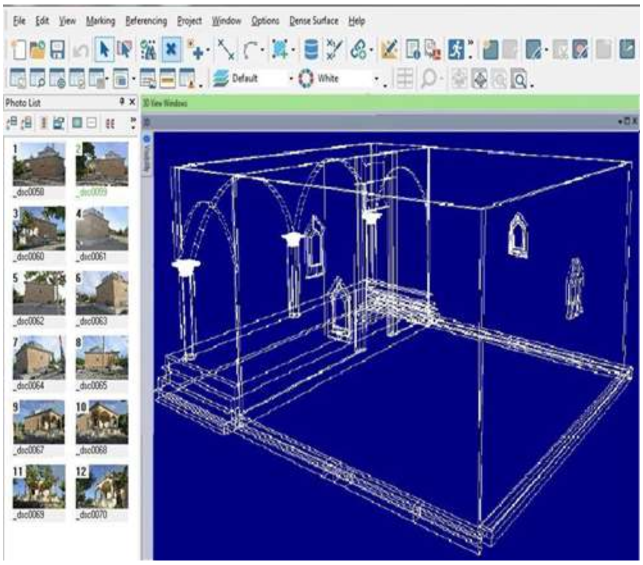

Figure 11. 3D drawing screenshot of structure

Figure 12. Textured of building

Figure 13. 3D view of the model

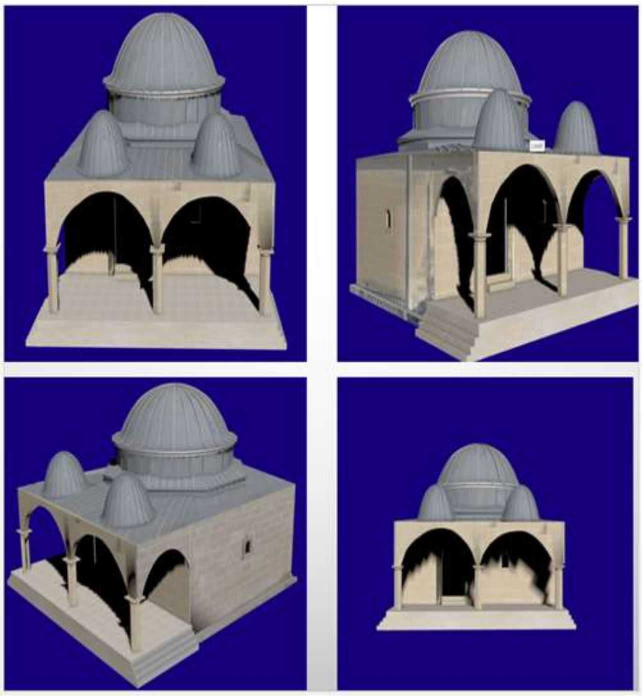

Figure 14. Screenshot of the model taken from different angles

Conclusion

Today, because historical buildings shed light on the past and are a bridge between the past and the future, the preservation and restoration methods of these works are of great importance as well as the preservation and restoration of historical buildings and artifacts. It provides an innovative participation in this field as a method with lower cost, less time and high sensitivity, with photogrammetric studies carried out by the discipline of surveying engineering, to the studies carried out by architects with survey studies and classical methods until now. One of the most important advantages of the photogrammetric method is that it enables historical buildings and artifacts to be recorded digitally and digitally in three dimensions. Since the method is based on sensitive measurements, extremely sensitive measurements can be made on the works, so in case of any restoration work or repair, the original dimensions of the work are taken into account. Miniatures of the works recorded in this way photogrammetrically can be produced using their numerical measurements or they can be opened to visit as an online museum in the digital environment.

Author contributions

Fatih Pulat Conceptualization, Methodology, Software **Murat Yakar:** Data curation, Writing-Original draft preparation, Software, Validation. **Ali Ulvi:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

There is no conflict of interest.

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3D modeling of historical artifacts with terrestrial photogrammetric method: Roman sarcophagus and tomb stele example

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Keywords
Terrestrial Photogrammetry
Historical Artifacts
Documentation
Cultural Heritage
3D Modeling

Abstract

Many societies, civilizations and states have lived on the lands of Anatolia, the cradle of cultures and civilizations, from the past to the present. Each of these civilizations and states has left many works. It is very important to protect the material and moral works left to us, and transfer them to the next generations. Documentation studies should be carried out for this purpose. There are many methods for performing documentation work. The most important of these methods is the studies in the field of photogrammetry. With the photogrammetry method, the objects are modeled in three dimensions (3D) and recorded in the computer environment, and these data can be used at any time for the repair or reconstruction of the work in case of any deformation. The concept of 3D is the concept that emerges by knowing the width, height and height dimensions of the objects. One of the methods that can be used to model objects in 3D is the terrestrial photogrammetry method. With the terrestrial photogrammetry method, after the necessary data are collected from the objects, a 3D model is obtained using various software in the computer environment. In the modeling phase, it is very important to find the appropriate software. In this study, it was aimed to model the sarcophagus and tomb stele from the Roman period in Aksaray Museum using two different software. Agisoft Metashape and Pix4d software were preferred for 3D modeling. The results obtained from the software was compared in terms of the number of photos and the number of point clouds used and location accuracy. It has been observed that the error values found by the square mean error method in Agisoft software are lower than in the Pix4d software. It was observed that the Pix4d software produced more point clouds while modeling. An equal number of photographs were used in modelling.

1. Introduction

Our cultural heritages are assets that bridge between the past and the future and shed light on the past (Yakar & Doğan, 2017). Protecting historical artifacts is everyone's common responsibility. Today, there is still not enough effort to protect our cultural heritage, and many assets were destroyed due to various disasters, neglect or indifference (Yakar & Kocaman, 2017). Therefore, it is very important to document and record these works. At this point, photogrammetry technique has been used frequently for years because it provides data and methods in a fast, efficient, economical and reliable way in archaeological measurements, documentation and 3D modeling applications of cultural heritage (Uslu & Uysal, 2017; Yakar & Yılmaz, 2008).

Many institutions are working to protect the existing historical monuments, to research the past, and to transfer them to future generations in a solid way. The most important places where historical artifacts are exhibited are museums (Güleç, 2007). There are many museums throughout Turkey. It is necessary to protect the works in museums and open spaces from possible harm. These damages can be natural or human factors. It is necessary to make good documentation of historical artifacts against possible damages (Kanun et al. 2021). All of these processes are called documentation. (Georgopulos & Ionnidis, 2004) described documentation of cultural heritage as "measurement, evaluation, recording and presentation processes necessary to determine the current situation, new size, shape and location of a historical or cultural structure in

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a three-dimensional space" (Yakar & Kocaman, 2017). There are various documentation methods used in documenting historical and cultural heritage (Böhler & Heinz, 1999). These methods are; classical manual documentation method, topographic methods, photogrammetric methods and scanning methods (Böhler & Heinz, 1999; Scherer, 2002; Yakar & Kocaman, 2017). The most important of these is the work done in the field of photogrammetry. Photogrammetry means drawing using light. It is to have information about the object and its environment by analyzing and interpreting the sent energy without touching the objects.

The history of photogrammetry dates back to ancient times (Yaşayan et al., 2011). The foundations of photogrammetry were laid with the first photograph taken. One of the most common uses of photogrammetry is the documentation of cultural heritage. Terrestrial photogrammetry method is a highly preferred method in this regard. With the development of digital technology, terrestrial photogrammetry has become more economical and more efficient. Three-dimensional solid models and textured images help to better recognize complex structures (Atkinson, 1996; Bozdoğan et al., 2022).

The advantages of terrestrial photogrammetry method are that the measurement time is short, the results can be reused at any time, and measurements of a distant object can be made (Duran, 2017). Three-dimensional models are obtained by evaluating the energy sent to the objects. Three-dimensional modeling is the modeling of a 3-dimensional object in digital environment (Oruç, 2021).

There are many historical and cultural monuments, including mosques and churches in the city of Aksaray, which was under the rule of Rome, the Seljuk State, many principalities and finally the Ottoman Empire. The software used in documentation is as important as documenting these works. In this study, necessary data were collected from historical artifacts of different sizes with the terrestrial photogrammetry method and these data were modeled in two different software, Agisoft and Pix4d. The results obtained from the software were evaluated in terms of the number of point clouds, the number of photographs and location accuracy.

2. Method

Photogrammetry technique, photographs of the object to be measured and its immediate surroundings or terrain are taken. Desired information can be obtained by measuring their images on the photograph, or these photographic images can be converted into maps or plan formats by using special hardware and software (Yaşayan et al, 2011).

The photogrammetric method applied when the reception center is a point on the ground is called terrestrial photogrammetry. In terrestrial photogrammetry, images obtained by analog or digital recording of electromagnetic rays reflected from objects are evaluated (Yakar & Mohammed, 2016). Terrestrial photogrammetry has been a preferred method for many years. Terrestrial photogrammetry has many applications. One of them is the documentation of cultural heritage and historical artifacts.

In practice, the modeling of the sarcophagus from the Roman period and the tomb stele from the Roman period in the Aksaray Museum were discussed. Aksaray Museum is located in the province of Aksaray Aksaray Museum first operated in the Zinciriye Madrasa in 1969, then moved to its reconstructed building.

The tomb stele used in modeling is located in the garden section of the museum. It was discovered in Musagi/Bozcayurt village. The work made of marble is 100 cm high and 33.5 cm wide. The upper part of the stele, which is in the form of a rectangular prism, is in the form of a saddle. It has a relief bust and 4 rows of inscriptions on it. The face is long and bearded. The forehead is wide. Hair not specified. The eyes are given in the form of almonds. It is surrounded by thick lines. The neck is thick. The body part is carved in low relief (Figure 1).

Figure 1. The tomb stele with three-dimensional modeling.

The sarcophagus is located in the garden section of the museum. Aksaray Ulu Mosque was found in front of the old fountain in 1973. It has dimensions of 153 * 100 * 40 cm. The white thick-grained marble Sarcophagus is rectangular in shape. The monolithic sarcophagus was built without a cover. The front and side faces of the sarcophagus are decorated, while the back is left plain without processing. An evacuation hole was opened on the front side of the sarcophagus in order to be used as an ablution trough at the back. There is calcification on the surface and abrasions especially on the bull heads and upper part. In the upper part, the discharge channel is located at the rear and on the short side on the right. Leaving the reverse side untreated indicates that the sarcophagus was placed against the wall in the necropolis or where it was used (Figure 2).

Necessary permissions were obtained from Aksaray Museum Directorate and Aksaray Provincial Culture and Tourism Directorate before the field studies.

2.1. Field Study

Topcon GPT 3007N Total Station instrument with reflectorless measurement feature was used to obtain the coordinates of the detail points in the field studies (Figure 3), (Table 1).

Figure 2. The sarcophagus with three-dimensional modeling work.

Figure 3. Topcon GPT 3007N Total Station

Table 1. Topcon GPT 3007N Total Station instrument features.

Field of view	1 ° 30
Min. Focal Distance	1,3 m (4,29 ft.)
Measuring Range	1,5 to 250m (5 to 820 ft.)
Measurement Screen	11 digits
Laser Class	Class 1 (for dismount measurement) Class 2 (Laser Mark On)
Battery	4400 mAH
Max working time	Including distance measurement: Approx. 5 hours Angle measurement only: Approx. 10 hours
Charging time	4 hours

Nikon D3500 camera was used to take pictures of the sarcophagus and tomb stele (Figure 4) (Table 2).

Figure 4. Nikon D3500 Camera

Table 2. Technical specifications of the camera

Sensor	24.2MP DX-Format CMOS Sensor
Image Processor	EXPEED 4
video recording	60 fps'de Full HD 1080p
Bluetooth Connection	SnapBridge
ISO	Native ISO 100-25600

Before starting the measurement works, first of all, 7 control points on the tomb stele and 12 control points on the sarcophagus were established with the help of easily distinguishable sign plates in order to determine the coordinate and location accuracy. Point 2 on the grave stele was not included in the analysis studies as it moved during the measurement (Figure 5 and 6).

Figure 5. Checkpoints located on the sarcophagus

Figure 6. Checkpoints on the tomb stele

While determining the points, care was taken to establish the control points homogeneously, taking into account the location, dimensions and shape of the object. Then, 2 polygon points were determined around the objects and random coordinates were given to them.

After the coordinates of the points, the photographs of both objects were taken in an overlay manner. All the data obtained were transferred to the computer environment and the modeling and analysis phase was started.

2.2. Office Work

Agisoft and Pix4d softwares were used for evaluation and 3D modeling for both historical artifacts.

2.2.1. 3D modelling with Agisoft

Agisoft is a software developed to obtain 3D models by using fixed images. The resulting result can be obtained in various formats to evaluate the products in different software (Çağlayan, 2020).

Initially, the photos were transferred to the software. 35 photographs were used for the tomb stele and 127 photographs were used for the sarcophagus. After the orientation process, it was started to mark the points. Afterwards, point clouds and 3D models were obtained by performing other steps (Figure 7, 8, and 9).

Figure 7. Solid model and tiled triangular model created in Agisoft software for the tomb stele.

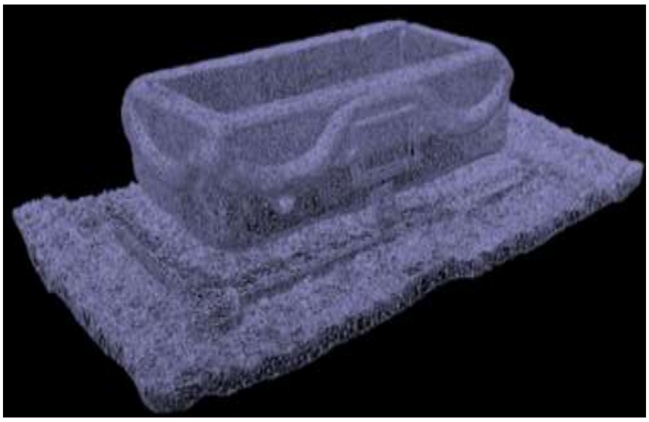

Figure 8. Triangle model for sarcophagus created in Agisoft software

2.2.2. 3D modelling with Pix4D

It is a package software group with various features that uses digital algorithms to model the earth and objects in 3D. It can perform various operations with RGB, NIR, JPG, TIFF and many similar image formats. After the processes, products in various formats can be obtained (Çağlayan, 2020).

The photos have been transferred to the software. 35 photographs were used to model the tomb stele and 127 photographs were used to model the sarcophagus. Detail points are automatically extracted from the photos. Reciprocal points matching has been performed. Afterwards, the balancing process was started. Other stages of the software were applied and point clouds and 3D models were created (Figure 10 and 11).

Figure 9. 3D model for the sarcophagus created in Agisoft software.

Figure 10. 3D model for the tomb stele obtained in Pix4d software

3. Results

The values obtained from the field and the modeling results were compared in terms of the number of point clouds, the accuracy of the coordinates and the ease of use of the software.

Both works were modeled in Agisoft and Pix4d programs. Different numbers of point clouds were obtained from each modeling. The numbers are given in "Table 3".

Figure 11. 3D model of the sarcophagus obtained in Pix4d software

Table 3. Number of point clouds in tomb stele and sarcophagus

	Tomb stele point cloud	Sarcophagus point cloud
Agisoft software	952.233	2.637.960
Pix4d software	2.613.369	8.136.240

The mean square errors of the points were calculated by using the coordinate values (X) obtained from the field and the coordinate values (L) obtained from the software. First, the differences of the coordinates were taken (Equation 1), then the mean square errors were found (Equation 2) using the differences (V) and measurement numbers (n), and finally the mean squared errors in the x, y, z directions (Equation 3) were calculated.

$$V = L - X \quad (1)$$

$$m = \pm\sqrt{\frac{[VV]}{n-1}} \quad (2)$$

$$m_{xyz} = \sqrt{m_x^2 + m_y^2 + m_z^2} \quad (3)$$

The coordinate differences of the tomb stele obtained from the field and Agisoft software are given in Table 4. Mean square errors are given in Table 5. Coordinate differences obtained from Pix4d software are given in Table 6. Mean square errors are given in Table 7.

Table 4. Coordinate differences of the tomb stele obtained from the land and Agisoft software

	Vi Differences (mm)			ViVi Differences (mm)2		
	Vx	**Vy**	**Vz**	**VxVx**	**VyVy**	**VzVz**
1	-1.7	3.4	-4.4	2.89	11.56	19.36
3	0.6	0	4.4	0.36	0	19.36
4	0.9	1.4	0.8	0.81	1.96	0.64
5	2.3	0.9	-2.7	5.29	0.81	7.29
6	-1.8	-1.8	-2.4	3.24	3.24	5.76
7	-0.4	-4.6	4.8	0.16	21.16	23.04

Table 5. Accuracy analysis results of the 3D model of the tomb stele for Agisoft software

	Vi Differences (mm)		
	Vx	**Vy**	**Vz**
Vmin	0.4	0	0.8
Vmax	2.3	4.6	4.8
Vavg	1.3	2.1	3.3
m	1.60	2.78	3.88
mxyz	±5.03		

Table 6. Coordinate differences of the tomb stele obtained from the field and Pix4d software.

	Vi Differences (mm)			ViVi Differences (mm)2		
	Vx	**Vy**	**Vz**	**VxVx**	**VyVy**	**VzVz**
1	-6	5	-5	36	25	25
3	-3	0	3	9	0	9
4	4	1	-1	16	1	1
5	4	3	-3	16	9	9
6	-6	-4	1	36	16	1
7	3	-5	9	9	25	81

Table 7. Accuracy analysis results of the 3D model of the tomb stele for Pix4d software.

	Vi Differences (mm)		
	Vx	**Vy**	**Vz**
Vmin	3	0	1
Vmax	6	5	9
Vavg	4.3	3	3.7
m	4.94	3.90	5.02
mxyz	±8.05		

The coordinate differences of the sarcophagus obtained from the field and Agisoft software are given in Table 8, mean-square errors in Table 9, coordinate differences obtained from Pix4d software in Table 10 and mean-square errors in Table 11.

Table 8. Coordinate differences obtained from the land of the sarcophagus and Agisoft software.

	Vi Differences (mm)			ViVi Differences (mm)2		
	Vx	**Vy**	**Vz**	**VxVx**	**VyVy**	**VzVz**
1	-0.3	0.6	0.2	0.09	0.36	0.04
2	-0.3	0.4	0.4	0.09	0.16	0.16
3	2.2	-0.9	-1.3	4.84	0.81	1.69
4	1.5	1.7	-0.9	2.25	2.89	0.81
5	-1.3	1	0.8	1.69	1	0.64
6	3.8	1	0.3	14.44	1	0.09
7	-0.8	1.3	0.1	0.64	1.69	0.01
8	-1.7	0.4	-1.2	2.89	0.16	1.44
9	1.9	1.5	2	3.61	2.25	4
10	1.9	-2.1	1.6	3.61	4.41	2.56
11	0.8	-2.5	1.7	0.64	6.25	2.89
12	-2	-1.3	1.4	4	1.69	1.96

Table 9. Accuracy analysis results of the 3D model of the sarcophagus for Agisoft software

	Vi Differences (mm)		
	Vx	**Vy**	**Vz**
Vmin	0.3	0.4	0.1
Vmax	3.8	2.5	1.7
Vort	1.5	1.2	1
m	.1.88	1.44	1.22
m_{xyz}	±2.66		

Table 10. Coordinate differences of the sarcophagus obtained from terrain and Pix4d software.

	Vi Differences (mm)			ViVi Differences (mm)2		
	Vx	**Vy**	**Vz**	**VxVx**	**VyVy**	**VzVz**
1	2	2	-1	4	4	1
2	4	4	3	16	16	9
3	-2	-1	2	4	1	4
4	2	2	-2	4	4	4
5	5	-2	1	25	4	1
6	-3	1	1	9	1	1
7	2	4	-4	4	16	16
8	3	-2	3	9	4	9
9	-4	-3	4	16	9	16
10	3	4	3	9	16	9
11	-3	-3	3	9	9	9
12	4	-3	1	16	9	1

Table 11. Accuracy analysis results of the sarcophagus 3D model for Pix4d software

	Vi Farklar (mm)		
	Vx	**Vy**	**Vz**
Vmin	2	1	1
Vmax	4	4	4
Vort	3.1	2.6	2.3
m	3.37	2.91	2.70
mxyz	±5.21		

The error amounts calculated in Agisoft and Pix4d software for both the sarcophagus and the tomb stele are given in Table 12.

Table 12. Error amounts measured in Agisoft and Pix4D softwares (mm)

	Lahit	Mezar steli
Agisoft	±2.66	±5.03
Pix4d	±5.21	±8.05

For both works, the number of point clouds obtained from the two software, the number of photographs used and the amount of errors are also compared in Table 13.

4. Conclusion

It is our duty to preserve our historical artifacts and pass them on to future generations. An important step for this is achieved with documentation. There are many methods for documentation work. One of the most widely used of these methods is terrestrial photogrammetry. It is a frequently preferred method especially for modeling medium-sized works.

Table 13. The number of tomb stele and sarcophagus point clouds found in Agisoft and Pix4d software, the number of photographs used and the amount of error.

		Tomb Stele	Sarcophagus
Number of point clouds	Agisoft	952 233	2637 960
	Pix4d	2613 369	8 136 240
Number of used photos	Agisoft	35	35
	Pix4d	127	127
Amount of error (mm)	Agisoft	±5.03	±2.66
	Pix4d	±8.05	±5.21

In this study, 3-dimensional modeling of the sarcophagus and tomb stele from the Roman period in the Aksaray museum in Aksaray province was carried out with the terrestrial photogrammetry method. Agisoft and Pix4d software were used for the modeling process. As a result of the evaluation studies, the number of point clouds, the accuracy of the coordinates and the usability of the software were compared. For this comparison, the mean square error method was preferred. The position accuracy of both objects was calculated at the mm level. It was determined that the position error of the tomb stele was ±5.03 mm when modeled using Agisoft software, and ±8.03 mm when modeled with Pix4d software. The position error of the sarcophagus was ±2.66 mm when evaluated with Agisoft software, and ±5.21 mm when evaluated with Pix4d software.

Looking at the results obtained, it was seen that the position error obtained from the Agisoft software was lower than the Pix4d software and more point clouds were obtained in the Pix4d software compared to the Agisoft software.

As a result, it has been seen that while Agisoft software stands out in precision for 3D documentation studies, Pix4d software's point cloud production feature is at the forefront.

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The production of line-drawing and 3D modeling of historical Mehmet Ali Bey Fountain with SFM approach

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Keywords
Cultural heritage
SFM
Line-drawing
Ortho-image
3D Modelling

Abstract

Historical and cultural artifacts provide information about ancient life, language, religion, literature, traditions and architecture. Documentation of cultural artifacts is of great importance in terms of protecting and transferring them to future generations. In recent years, Structure from Motion (SfM) can be used to generate dense point cloud, ortho-image, line-drawings, and 3D models in addition to the classical terrestrial photogrammetry methods. The fast documentation and archiving studies can be carried out by SfM approach using low-cost cameras with cost effective project budget. In this study, it is aimed to produce line-drawing, ortho-image, and 3D models of Mehmet Ali Bey Fountain by using SfM approach. The Mehmet Ali Bey Fountain is one of the registered historical structures in the "Monuments" class among registered immovable cultural assets throughout Turkey, located in the Abbasaga District of Besiktas/Istanbul from the Ottoman Sultan II. Mahmut period. The installation and measurement of the control points were conducted, and the image acquisition was performed with convergent image acquisition method. The 3D point cloud generation of Mehmet Ali Bey Fountain was performed after image orientation steps. The productions of 3D model, ortho-image, and line-drawing have been carried out successfully using the produced point cloud. In this study, all processes for the documentation of historical structure were carried out using "Agisoft Metashape Professional" and "Autocad" software. The analyzed measured distances between the GCPs and corresponding distances from 3D model (standard deviation of the differences is 0.5 cm) proved the success of the SfM method for documentation of registered historical artifacts and cultural heritage.

1. Introduction

The conservation of the cultural heritage is one of the most important topics for the countries since the historical artifacts and buildings are vulnerable to disasters, human actions, and tourism (Bakirman et al., 2020; Yastikli & Ozerdem, 2017). The documentation of cultural artifacts that have survived from the past to the present is a very essential task because of the high risk of deterioration of cultural heritage (Peña-Villasenín et al., 2018). Terrestrial laser scanning (TLS) is a preferred method for the documentation of cultural artifacts, but it is relatively expensive; often require time and expert knowledge for the operation (Themistocleous, 2016). Nowadays, Structure from Motion (SfM) is a popular technique for cultural heritage documentation and so, it is one of the most widely used methods in the obtaining of high resolution and high precision textured 3D point clouds as well as terrestrial laser scanners in the field of cultural heritage (Brandolini & Patrucco, 2019; Peña-Villasenín et al., 2018). The main advantages of SfM are the cost and time of execution. The SfM technique is very efficient for the conservation, monitoring, and restoration of historical and cultural artifacts because of the rapidity, easiness, completeness, and low price (Peña-Villasenín et al., 2018; To et al., 2015).

SfM method has been commonly used in cultural heritage studies for various purposes such as 3D modelling of archaeological artefacts, digitization of historical documents, monitoring of buildings, digital reconstruction of lost monuments and damaged archaeological sites, surveys of cultural and geo-heritage (Brandolini et al., 2020). To et al. (2015) proposed the archaeological documentation of the "One Pilla" pagoda located in Hanoi capital, Vietnam using

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structure from motion technique. Themistocleous (2016) employed SfM for the documentation of cultural heritage as a range imaging method to determine 3D landscape features from two dimensional (2D) image series obtained from video. Brandolini and Patrucco (2019)'s purpose is to assess a highly flexible and low-cost SfM procedure to digitize historical maps and documents using cost efficient commercial sensors. Brandolini et al. (2020) carried out SfM method in their study to document archaeological properties defined during surveys in the Sultanate of Oman. Bakirman et al. (2020) used SfM method to create 3D point cloud data of Otag-i Humayun, a historical building, with ultra-light drones (ULD) and a low-cost unmanned aerial vehicles (UAV).

In this study, an efficient approach based on SfM method was aimed to use for the producing line-drawing, ortho-image, and 3D models of Mehmet Ali Bey Fountain. For the objective of this study, installation and measurement of the ground control points were conducted, and the point cloud of Mehmet Ali Bey Fountain from the Ottoman Sultan II. Mahmut period was produced using the photographs taken with the convergent image acquisition method. The productions of 3D model, ortho-image and line-drawing have been carried out successfully using this produced point cloud. The results of this study indicate that a SfM methodology successfully supply the dense 3D point cloud, ortho-image, line-drawings, and 3D models of cultural artifacts for the documentation, restoration, and preservation studies.

2. Method

SfM is a method, using photos to compute 3D data of the targeted objects (Seitz, 2018). The SfM method uses numerous overlapping photos instead of a single stereo pair (Fig. 1). The improvements in the image-based 3D data-extraction algorithms, calibration techniques for non-metric cameras and computing hardware have contributed to the further development of SfM method (Peña-Villasenín et al., 2018). The SfM is applied in many commercial 3D modelling software such as Pix4D and Agisoft Photoscan Professional (PS) (Yastikli & Ozerdem, 2017).

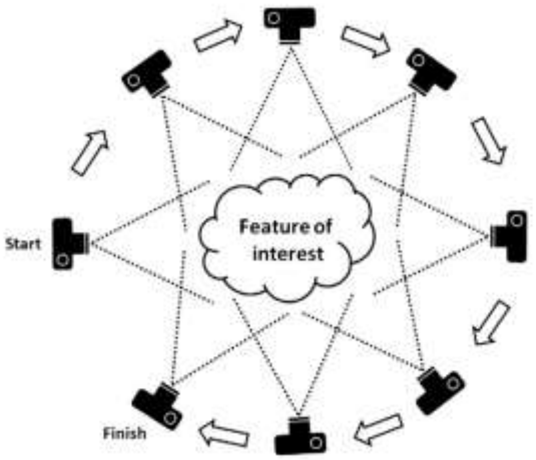


Figure 1. The SfM technique (Westoby et al., 2012)

In fact, structure from motion refers to only one stage of the SfM workflow (Smith et al., 2016). SfM technique, which is formed of a group of algorithms, is based on identifying common features and converting them into 3D information; accordingly, common features are defined and matched in all images (Lowe, 2004; Papakonstantinou et al., 2019). In other words, the epipolar geometry is estimated from 2D images using feature matching algorithms like scale-invariant feature transform (SIFT) (Brandolini & Patrucco, 2019). A sparse point cloud, unscaled 3D point cloud in arbitrary units, is generated by calculating the position of every point in 3D space, and the sparse point cloud is thickened to constitute a dense point cloud (Furukawa & Ponce, 2009; Papakonstantinou et al., 2019). The majority of the studies use Multi-View Stereo (MVS) algorithms to increase the point density after the producing sparse point cloud (Smith et al., 2016). The dense point cloud generation workflow with SfM technique is given in Fig. 2.

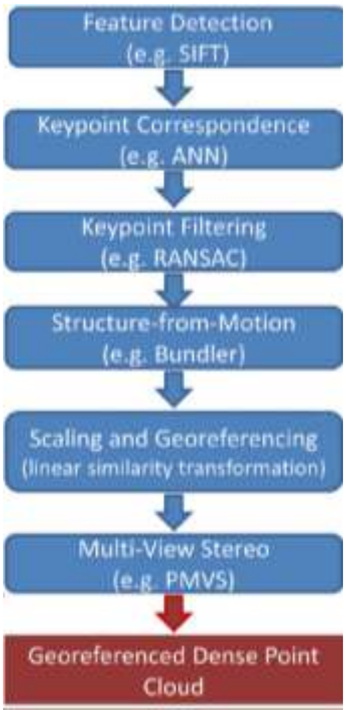


Figure 2. The workflow of the dense point cloud generation with SfM (Smith et al., 2016)

Unlike classical photogrammetry, SfM does not require the camera positions or 3D location of ground control points (GCPs) to enable scene triangulation and reconstruction (Westoby et al., 2012). In contrast, the SfM procedure use a iterative bundle adjustment based on matching features in multiple overlapping two dimensional (2D) images and estimates relative camera locations (Bakirman et al., 2020; Westoby et al., 2012). Small number of GCP is only needed in the transformation to absolute coordinate system from local image coordinate system. However, a large number of data is necessary for SfM technique to be able to reconstruct accurate dense point cloud and a good quality 3D model (Clini et al., 2016).

3. Study area and Dataset

Mehmet Ali Bey Fountain, which is one of the registered historical structures in the "Monuments" class among registered immovable cultural assets throughout Turkey, located in the Abbasaga District of Besiktas/Istanbul (Fig. 3). Mehmet Ali Bey Fountain was built in 1836 during the Ottoman Sultan II. Mahmut period by Mehmet Ali Bey. There are four different inscriptions and tugras on each side of the Mehmet Ali Bey Fountain, which is made of cut stones with a cube body.

(a)

(b)

Figure 3. The location of the fountain (City Map-2021) (a) and Mehmet Ali Bey Fountain (b)

The ground control points (GCPs) have been determined on the fountain in order to obtain the 3D model in local coordinate system. Horizontal, vertical, and diagonal distances between the GCPs were measured with a steel tape measure (see Fig 4.). A total of 181 photos were taken from near and far distances with the Canon EOS 1100D camera (see Table 1 for specifications) using the convergent image acquisition method for the production of the 3D dense point cloud using SfM technique. SfM procedure have been applied by using "Agisoft Metashape Professional" commercial software for production of the 3D dense point cloud, line-drawing, ortho-image, and 3D models of Mehmet Ali Bey Fountain.

Figure 4. The ground control points and distances between them

Table 1. Technical specifications of the used camera

Canon EOS 1100D	
Sensor Size	22.2 x 14.8 mm
Total Megapixels	12.60
Maximum Image Resolution	4272 x 2848
Weight	495 g
Dimensions	129.9 x 99.7 x 77.9
Pixel Density	3.71 MP/cm^2
Pixel Pitch	5.19 µm

4. Results

For the 3D model generation, first the camera calibration process has been performed by defining the focal length (c) and position of principal point (x_0, y_0), radial (K_1, K_2, K_3) and tangential (P_1, P_2) distortion parameters. The obtained photographs are aligned and tie points (166.612 points) have been generated to calculate the camera positions where each photograph was taken (Fig. 5). The determined ground control points are marked on all photos and the distance values between control points were identified by using the obtained measurement in the study area (Fig. 6).

Figure 5. Automatically calculated camera positions

Markers	X (m)	Y (m)	Z (m)	Accuracy (m)	Error (m)	Projections	Error (pix)
point 1	1005.850000	1000.000000	1000.000000	0.005000	0.020802	151	1.247
point 2	1000.000000	1000.000000	1000.000000	0.005000	0.024766	146	1.084
point 3	1005.850000	1000.000000	1001.700000	0.005000	0.021242	157	0.859
point 4	1000.000000	1000.000000	1001.700000	0.005000	0.022342	159	0.808
point 5	1005.850000	1005.630000	1000.000000	0.005000	0.028957	140	1.374
point 6	1005.850000	1005.630000	1001.700000	0.005000	0.023619	157	0.781
point 7	1000.000000	1005.550000	1000.000000	0.005000	0.015714	144	0.880
point 8	1000.000000	1005.550000	1001.700000	0.005000	0.020699	164	0.740

Figure 6. The point position errors of GCPs

A sparse point cloud is created using all matching points in all photos at first stage. An example of the matching points in two photos taken from different position is given Fig. 7. A dense point cloud including 49,828,870 points was obtained after the sparse point cloud generation (Fig 8a). The 3D solid model of the Mehmet Ali Bey fountain was obtained after mesh generation (Fig. 9).

Figure 7. The matching points in two photos

Figure 8. The dense point cloud of the Mehmet Ali Bey Fountain

Figure 9. The 3D model of the Mehmet Ali Bey Fountain

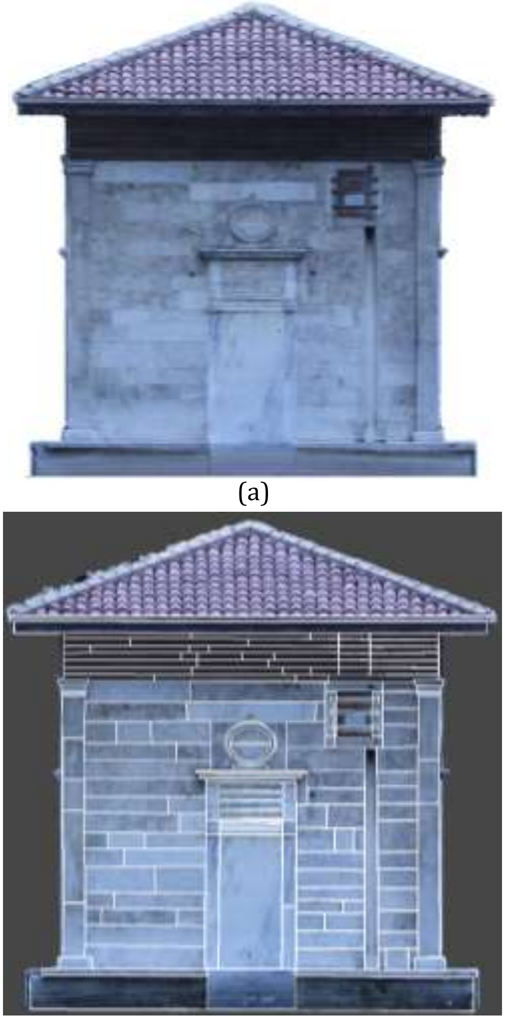
In order to test the accuracy of the created 3D model, the distances between the GCPs on the study area and the distances between GPSs on the 3D model were compared (see Table 2). When the difference in distances between the GCPs on the study area and the distances between GCPs on the 3D model are analyzed, the differences are between -0.5 cm and 1.3 cm, and standard deviation of the differences is 0.5 cm which is acceptable.

Table 2. The comparison of distances

Distances	Study area (m)	3D model (m)	Difference (m)	Error rate (%)
Point1_Point2	5,850	5,846	0,004	0,1
Point1_Point3	1,700	1,687	0,013	0,8
Point1_Point4	6,090	6,095	-0,005	-0,1
Point1_Point5	5,610	5,607	0,003	0,1
Point1_Point6	5,855	5,854	0,001	0,0
Point2_Point3	6,075	6,084	-0,009	-0,1
Point2_Point4	1,700	1,700	0,000	0,0
Point2_Point7	5,550	5,546	0,004	0,1
Point2_Point8	5,815	5,818	-0,003	-0,1
Point3_Point4	5,855	5,853	0,002	0,0
Point3_Point5	5,885	5,880	0,005	0,1
Point3_Point6	5,630	5,627	0,003	0,1
Point4_Point7	5,785	5,787	-0,002	0,0
Point4_Point8	5,550	5,551	-0,001	0,0
Point5_Point6	1,700	1,705	-0,005	-0,3
Point5_Point7	5,845	5,844	0,001	0,0
Point5_Point8	6,092	6,097	-0,005	-0,1
Point6_Point7	6,090	6,091	-0,001	0,0
Point6_Point8	5,860	5,859	0,001	0,0

After 3D model production, an ortho-image with a ground sample distance (GSD) of 2 mm was produced in TIFF format (Fig. 10a). All the details on one surface of the Mehmet Ali Bey fountain were drawn in stereo with anaglyph glasses, and the line-drawing of the fountain was obtained (Fig. 10b). The line-drawing of Mehmet Ali

Bey Fountain at the scale of 1/50, was obtained using "Autocad" software (see Fig. 11).



(a)

(b)

Figure 10. The ortho-image of the Mehmet Ali Bey Fountain (a) and the line-drawing overlapping the ortho-image (b)

Figure 11. The line-drawing of the Mehmet Ali Bey Fountain

5. Conclusion

In this study, line-drawing, ortho-image, and 3D models of historical Mehmet Ali Bey Fountain were successfully produced with the SfM method. When the distances between the GCPs on the study area and the distances between GCPs on the 3D model were compared, it has been seen that the standard deviation of the differences is 0.5 cm and accordingly, the error rate is within acceptable limits.

The results of this study indicate the potential of SfM method for production of the dense 3D point cloud, ortho-image, line-drawings, and 3D models of cultural artifacts for the cultural heritage. More GCPs can be selected on the fountain façade in order to obtain high accuracy, and the total stations can be used to measure more precise coordinates of GCPs. With this study, it will be possible to perform the restoration and reconstruction studies for Mehmet Ali Bey Fountain with the help of the information from the 3D model, ortho-image, and line-drawings in the possible future destruction or demolition due to natural disaster such as earthquake and flood.

Author contributions

Naci Yastikli: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing-Original Draft Preparation, Writing-Review and Editing, Visualization, Supervision.
Zehra Cetin: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing-Original Draft Preparation, Writing-Review and Editing, Visualization, Supervision
Erdal Asamaka: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing-Original Draft Preparation, Writing-Review and Editing, Visualization, Supervision

Conflicts of interest

The authors declare no conflicts of interest.

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3D modeling of historical theodolite with photogrammetric techniques and accuracy analysis

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3D Modelling
Digital Preservation
Digital Cultural Heritage
Theodolite

Abstract

As historical artifacts are the common heritage of all humanity, preserving historical artifacts is very important in keeping the cultural heritage alive and passing it on to generations. Creating scale models of these works and transferring them to digital media is a useful method for reproduction and documentation. In this study, an experiment on 3D modeling of historical artifacts exhibited in the Museum of Geomatics Engineering Department of Istanbul Technical University using photogrammetry and 3D scanning methods is presented. Theodolite (19th century) in the museum were modeled in 3D using photogrammetry and 3D scanning methods, and accuracy analysis was performed. For real values, length measurements were made with calipers over the models. According to the results obtained, the accuracy is 7.3 mm photogrammetric model and 1.3 mm for the 3D scanner model.

1. Introduction

Historical artifacts are the common cultural heritage of humanity, which sheds light from the past to the future and has a great importance in transferring thousands of years of knowledge and experience. It is the common duty of all humanity to transfer historical artifacts to future generations by preserving their originality. Our country is home to many historical artifacts as an achievement of its deep-rooted history. This heritage we have is a treasure that should be transmitted to future generations in a healthy way.

Historical artifacts wear out over time, become deformed and can undergo various changes by being damaged. It is of great importance to document historical artifacts in order to monitor these changes and to carry out restoration work in accordance with the original structure during possible restoration works.

High-accuracy 3D models are needed for detailed digitization and visualization of cultural heritage such as decorative and ritual objects, historical architectural details, wall paintings, stonework art, engravings, and archaeological finds (Duran and Aydar, 2012). Laser scanning method, which provides modeling opportunities by obtaining dense point cloud, is used to a significant extent in documentation studies.

Duran and Aydar (2012) used laser scanning and photogrammetry to reconstruct an antique measuring tool called the Nippur rod. As a result, high-accuracy models were created. A digital camera and a portable laser scanner for tiny items were employed in this investigation. McCarthy (2014) used the photogrammetric approach to model tombstones from the seventeenth century. The use of unmanned aerial vehicles (UAVs) in the documenting of historical objects is demonstrated by Bakirman et al. (2020). The models created with a very light UAV and a low-cost UAV were compared in the study. Sasi and Yakar (2018) used data from terrestrial and aerial photogrammetry to create a 3D model of the Hasbey Dar'ül Huffaz building in Konya. The investigation collected data with the use of an unmanned aerial aircraft. Photogrammetry and laser scanning were used to create 3D documentation of an Early Christian obelisk in the work by Lerma and Muir (2014). Photogrammetric and laser scanning were used to create 3D representations of a medieval castle by Bolognesi et al. (2014). Yakar et al. (2010) applied photogrammetric survey for documentation purposes of Cambazlı Church and mausoleum located in Cambazlı

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village of Silifke district of Mersin province. 3D model of Ivriz relief, which is located on Mount Aydos in the village of Ivriz, is generated using a photogrammetric technique by Sanlıoglu et al. (2013). In another study by Zeybek and Kaya (2020), damage analysis was carried out with the help of the photogrammetric technique.

In this study, the Theodolite instrument belonging to the 19th century, which is exhibited in the Historical Measuring Instruments Museum of Istanbul Technical University Geomatics Engineering Department, was modeled using photogrammetry and 3D scanner technique. Accuracies of the models were compared using measurements made with a caliper.

2. Material and Method

2.1. Camera

Nikon D800 device was used for photogrammetric 3D modeling of historical measuring instruments in the scope of the study. The sensor specifications of the camera are shown in Table 1.

Table 1. Nikon D800 Sensor Specifications.

Property	Explanation
Sensor type	CMOS
Effective pixel	36MP
Maximum resolution	7360X4912
Sensor format	Full Frame
Sensor size	39x24 mm
Minimum ISO	100
Maximum ISO	6400

2.2. Structure From Motion (SFM)

Photogrammetry is used for 3D reconstruction of objects from analog or digital images. In the current situation, 3D models can be created with terrestrial photogrammetry using photographs obtained from digital cameras and special software (Duran et al., 2017). The software used in the study works in accordance with Structure-from-Motion (SfM). SFM calculates the 3D coordinates of objects using conjugate points in two images (Duran et al., 2021). SFM automatically calculates camera positions and orientations (Fig. 1). An automatically extracted feature data from a set of images is simultaneously decoded using a highly redundant, iterative procedure of beam compensation (Westoby et al., 2012).

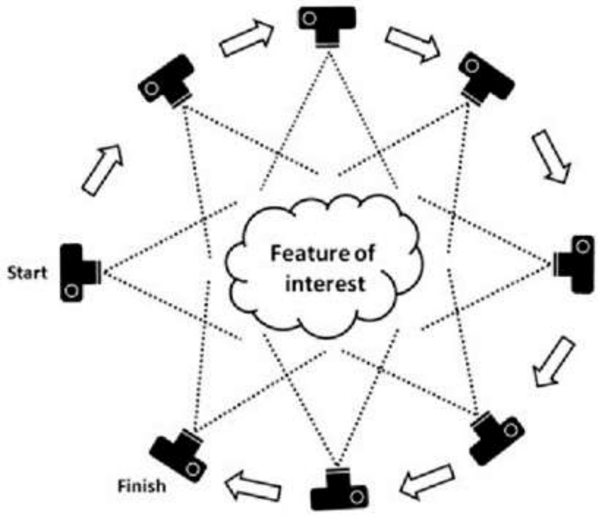

Figure 1. Structure-from-Motion (SfM) (Westoby et al., 2012).

2.3. Handheld Scanner

Contactless 3D scanners do not require physical contact with the object. They can scan objects with active or passive techniques. As a result, reverse engineering allows a precise point cloud to be produced for tasks such as virtual assembly, engineering analysis or rapid prototyping (Ebrahim, 2015). In this study, Scantech iReal 2E device was used to produce 3D models of historical measuring instruments (Fig. 2).

Figure 2. 3D scanner used in the study

An alternative to conventional laser scanners is structured light scanners. Structured Light is a method used for 3D reconstruction of surfaces, working with a method similar to triangulation (Schmalz et al., 2012). The triangulation principle, which can be accepted as the working principle of the structured light (Atik and Duran, 2021), is shown in Fig. 3. The 3D coordinates of an object point can be reconstructed in a calibrated system. In structured light scanners, one or more light patterns are projected onto a scene and observed by a camera. When light hits the surface of the artifact, it is distorted by the specific geometry available captured by a camera (Gebler et al., 2021). Captured images are then analyzed, allowing the depth and surface information of objects to be calculated based on the distortion that has occurred. In this way, the geometry of the artifact can be estimated, and thus a 3D model can be reconstructed (Xin et al., 2008).

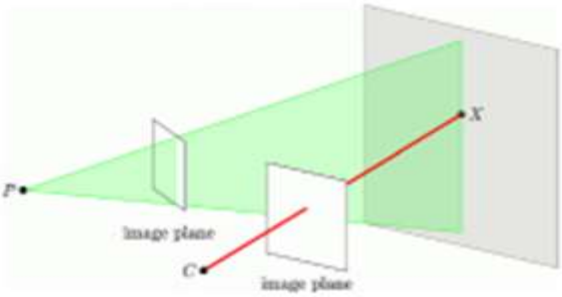

Figure 3. Principe of triangulation (Schmalz et al., 2012).

2.4. Theodolite

Theodolites are precision optical instruments capable of measuring horizontal and vertical angles, distances and dimensions between points, lines and objects in open areas or fields. The Theodolite tool appeared on the stage of history for the first time in 1571, when Leonard Digges defined it as "Theodolitus" in his book "Pantometria". The theodolite used in our study is dated the 19th century and was produced by the Sartorius firm (Fig. 4).

Figure 4. Historical theodolite

3. Experiment

Terrestrial photogrammetry and 3D scanning technologies were used in the 3D modeling of historical measuring instruments. First, the camera used in the modeling process was calibrated. With the help of the total station, a local coordinate system was established for the test area of the instruments. Within the scope of this study, Nikon D800 camera was used and calibration process was performed in Agisoft Metashape program. For the calibration process, 13 photos of the calibration board provided by the software were taken from different angles, and these photos were transferred to the software and the camera was calibrated.

While establishing the local coordinate system, firstly, two polygon points were established in order to calculate the forward estimation. Horizontal open, vertical angle and distance measurements were carried out from the points to the points in the test area with the help of a total station. A total of approximately 25 control points have been established on this test point (Fig. 5).

Figure 5. Image capturing platform.

Photographs of the objects placed in the text area where the local coordinate system was created were taken. On average, 80 photos were taken per model. After the photo shooting process was completed, the images were transferred to the software. Sparse point cloud, dense point cloud and mesh model were produced, respectively. Then the mesh model was textured.

In order for the scanner to detect the object more easily, the object was raised from the ground and objects of different colors and textures were placed around it. For scanning, it was rotated 360 degrees around the object and it was aimed to detect fine details. After the scanning process was completed, it was started to prepare the 3D object with iReal 3D software. Dense point cloud and mesh model were created, respectively, through the software.

4. Results

As a result of photogrammetric processes and 3D scanning, solid models of historical theodolite were produced (Fig. 6 and Fig. 7). Then, the lengths measured with the caliper on the real object were also measured on the models. According to the results obtained, the root mean square error (RMSE) for the photogrammetric model is 7.3 mm and for 3D scanning model is 1.3 mm. The results are presented in Table 2.

Figure 6. Photogrammetric model of the theodolite

Figure 7. 3D scanning model of the theodolite.

Table 2. Length measured using caliper from model and real object. The values are given as mm

Length	Reference	Photogrammetry	3D Scanning
1	10.20	9.65	10.10
2	18.10	16.90	17.10
3	20.95	19.40	19.70
4	20.90	19.75	19.60
5	22.80	21.30	21.00
6	39.70	38.10	37.10
7	92.70	76.80	92.90
8	116.70	101.75	117.90
9	21.50	17.50	21.40
10	40.80	35.75	41.60
RMSE		7.3	1.3

5. Discussion

In visual interpretation, it is seen that the light brightness in the model causes distortions in the pattern of the model. The inscriptions on the instrument can be seen clearly on the models. To evaluate the accuracy of the models created using two distinct procedures, length measurements were taken using a caliper with a 1/100 mm precision and the object's points were calculated. On the model, the lengths between the identical points were measured, and error estimations were done using the caliper size as a reference.

3D scanning method gives more accurate results than the photogrammetric method. During scanning, it was observed that reflective and transparent objects such as mirrors and glass were difficult to detect by the scanner. Attention should be paid to the light angle and image clarity during photo shoots. Images that are not obtained under suitable conditions cause distortions in the photogrammetric model. Among the reasons why the photogrammetric method gives less accuracy, errors that may arise from the operator, errors caused by the transparent and reflective structure of some objects, and errors caused by external factors such as the amount of ambient light.

6. Conclusion

In this study, historical theodolite from the 19th century on display at the Historical Measuring Instruments Museum of Istanbul Technical University Geomatics Engineering Department were modeled by photogrammetry and 3D scanning method.

Photogrammetric techniques successfully present historical artifacts in the digital environment. Because of the coordinated and scaled models, the reproduction and repair of the instruments is possible. Several models can be scanned and used in the future. As a result, a virtual museum may be built. Many individuals may view the models over the internet thanks to virtual museums.

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Author contributions

Muhammed Enes Atik: Original draft preparation, Methodology, Original draft preparation, Extended analysis.
Zaide Duran: Investigation, Funding, Writing-Reviewing and Editing.
Mustafa Yanalak: Conceptualization, Supervision, Visualization.
Dursun Zafer Seker: Data curation, Writing-Reviewing and Editing, Validation.

Conflicts of interest

There is no conflict of interest between the authors.

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