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The Role of Photogrammetry in the Conservation Management of Al Mahatta Museum, Sharjah, UAE

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***Abstract* – The conservation management of cultural heritage sites is essential for preserving their historical significance, in which documentation plays a crucial role. Photogrammetry is commonly used in documenting cultural heritage assets, which is a technique that utilizes 2D images to create accurate 3D Models of sites or artifacts. Advancements in open-source software and cameras have made photogrammetry an ideal tool for documenting and visualizing cultural heritage properties compared to other complicated and expensive tools (e.g., 3D laser scanning). This paper explores the role of photogrammetry in the conservation management of Al Mahatta Museum in Sharjah, UAE. The study reviewed related work and investigated how photogrammetry early results can be used as a monitoring tool to identify material deteriorations, enhance the accessibility of information, and facilitate collaboration among different stakeholders. The methodology involved capturing thousands of stereo-pair images, to build a 3D model and ortho-mosaic images. The results demonstrate the potential use of early results of photogrammetry in conservation management. Limitations, such as large data processing, camera resolution, and altitude challenges are also discussed with considerations of improvement.**

I. INTRODUCTION

Cultural heritage sites hold immense value as they offer a glimpse into our past and serve as venues for scientific research and discovery. However, inadequate management can lead to severe damage or the complete loss of these sites, hindering our ability to comprehend their dimensions and architectural significance [1]. The conservation management of heritage sites plays a vital role in preserving cultural identity, promoting tourism, facilitating educational opportunities, and fostering community development. Documentation serves as the initial step in developing a comprehensive conservation management plan for these sites [2]. Before starting any repairs or modifications, the conservator must gain a thorough understanding of cultural property and its current state in order to identify problems in the building's structural system, in some cases, 2D drawings may be inadequate for understanding the building and its context, but 3D visual representations created by photogrammetry and arrangements in CAD software make the model more clear and more supportive of the building's condition [3].

One method of documentation is the use of 3D models, which enables scientific study, archiving site memory, and digital accessibility to physical structures [1]. The 3D model can be highly detailed or simply provide a brief description and general representation of an architectural scenario, the level of detail depends on various factors, including the purpose of the model, how the data is acquired, and who the user is (e.g., a specialist or a consumer) [1]. 3D models provide a chance to comfortably obtain the needed metric information in the office. Moreover, they serve as a foundation for a broader exploitation of cultural heritage Information Systems, multimedia representations and reproductions. Digital 3D models allow researchers to examine artworks at a higher zooming level than in real life, since they have virtual access to objects located far away, without the limitations of museum operating hours or access permissions [4].

Photogrammetry is one of the available techniques of 3D documentation, which utilizes images as input to generate various outputs, such as maps, drawings, measurements, or 3D models [5]. It employs multiple photographs captured from different angles to create an accurate 3D representation of a scene or object [5].

In recent years, significant advancements have been made in 3D photogrammetry. The availability of open-

source software like VisualSfM and Meshroom, along with cost-effective options such as Agisoft Metashape and 3DF Zephyr, in addition to fast processing software like RealityCapture, and CAD-compatible software like Autodesk ReCap Pro and PhotoModeler, have all facilitated the use of photogrammetry in documenting and visualizing cultural heritage sites, museum objects, and historical monuments in 3D [6]. Furthermore, cameras with high-quality lenses and resolutions are now available, making them ideal tools for photogrammetry.

One of the notable advantages of employing photogrammetry is its ability to document risky or inaccessible areas [5]. It also offers tools for efficient data collection, visualization, and analysis that enhance historical site management [7]. Furthermore, it considerably enhanced the identification of building materials, form, and spatial distribution while also reducing the time required for performing a task that used to be considered difficult [8]. This is especially important when the site is relatively large, as traditional active ground-based data capturing techniques are expensive and time consuming [9]. It is also a non-invasive technique, and the results are often comparable with those obtained through the much more costly 3D scanning [10].

On the other hand, Laser scanning technology is becoming a very promising alternative for a wide range of modelling applications, as airborne and ground-based laser scanners provide a quick acquisition of enormous amounts of 3D data which usually integrated with color high-resolution digital images. As a major advantage of this approach, real objects can be represented more adequately than using a single or group of photographs, by offering a better level of detail as well as a good metric accuracy[11]. This approach not only describes the current state of the monuments, but also their original form[12]. Although laser scanners offer many advantages, they also come with certain limitations, the main of which are, besides the high instrument cost, the need for expert operators, the time-consuming post processing and the challenge of documenting surfaces that are either highly reflective or have sharp edges [4].

Each method has its own benefits and drawbacks in different working domains and is based on the characteristics of the object. Due to the wide range of cultural heritage objects, no single method can be used to document every subject of cultural heritage and hence combining these techniques can result in a more precise and complete survey of historical sites [4]. The most proper technique is determined by factors such as the available budget, and the characteristics of the object that has to be documented. Several studies proved that multi-image photogrammetry is considered more affordable than laser scanning, as the latest software can produce dense 3D point clouds similar to 3D laser scanners [6]. Moreover, photogrammetry is appreciated for the color information it has and for making 3D data interpretation easier. As a result, photogrammetry becomes a serious competitor of laser scanning [4].

The early results obtained from photogrammetry can help specialists in obtaining damage assessment plans and material plans to identify the State of Conservation and factors affecting the property, as well as for the purposes of protection, management, and monitoring, which will lead to achieving what the site needs and to guarantee its sustainability, on the other hand, 3D models, since they are virtual, can be easily shared globally over the web and stored digitally, therefore the results of photogrammetry can facilitate the communication of tacit knowledge to a variety of groups involved in cultural heritage conservation management, including government institutions, preservation and restoration experts, planners and engineers, scholars, visitors, and stakeholders interested in architecture and cultural heritage. Consequently, this significantly contributes to the cultural heritage conservation management purposes.

The main research question of this study is to investigate how cultural heritage sites can be better managed, monitored, and interpreted by utilizing early results obtained from photogrammetry. In particular, the study aims to explore the aspects of using photogrammetry as a monitoring tool for identifying and measuring structural and material deteriorations, its role in facilitating accessibility and interpretation of information for visitors and heritage specialists. The limitations associated with its implementation in cultural heritage conservation management will be also discussed.

In this paper, Section 2 reviews the previous related studies of utilizing photogrammetry in cultural heritage conservation. Section 3 covers the justification of selecting Al Mahatta Museum as a case study; Al Mahatta Museum in Sharjah. The methodology is explained in Section 4, while the results are outlined in Section 5.

II. RELATED WORK

Structure from Motion (SfM) photogrammetry was used as an alternative to laser scanning for 3D modeling of historical monuments [6], in where the process of creating a 3D model of Safita Tower, a medieval monument in north-western Syria, was described using a SfM Photogrammetry technology. A Nikon Coolpix P100 10 MP digital camera and Agisoft Metashape software were utilized, and survey work was carried out to get control points. A traverse was established by eight stations in the exterior of the Tower, and the least-square adjustment was applied to obtain final station coordinates in a local coordinate system. Control points were measured on all façades of the Tower. The generated 3D point clouds were compared with an available point cloud acquired by a laser scanner. The precision of each surveying technique was determined by calculating the linear distance between the point clouds in CloudCompare with the Multi-scale Model-to-Model

Cloud Comparison (M3C2) algorithm. For example, as for the eastern façade, a TLS point cloud of the east façade (14200000 points) was used as a reference and the mean absolute difference is 0.06 cm while 97.73% of the computed differences are lower than 1 cm. This comparison proved that low-cost SfM Photogrammetry is an effective technique for 3D modeling of historical buildings [6]. The study focused on the practicality of using photogrammetry in documentation as an alternative to laser scanning, but it did not address how to use photogrammetry in areas that support cultural heritage conservation management.

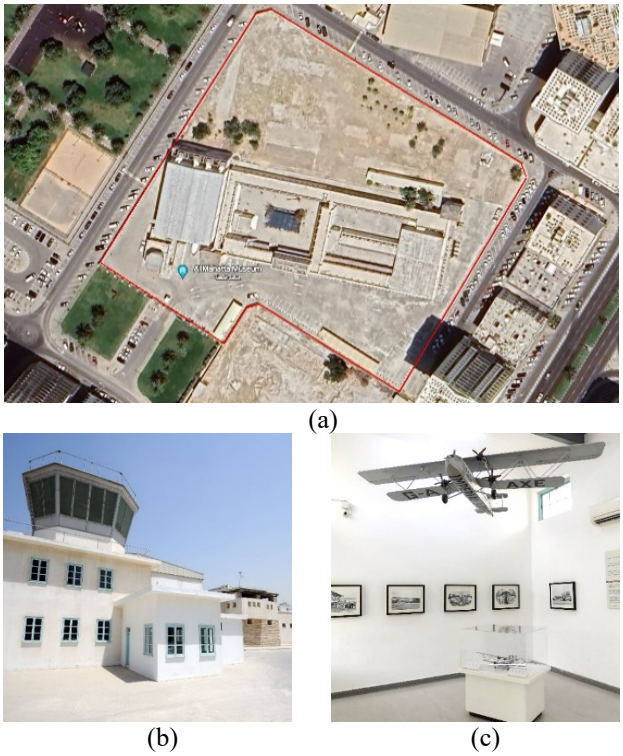
The study [3] evaluated the importance of digital close-range photogrammetry in documentation of cultural heritage. A historic structure in Konya (Turkey) that had been burned down was twice photographed, before and after the fire. Furthermore, photogrammetry was used to complete the building's measured drawings of the facade and its 3D model, as the software Photomodeler was used for the photogrammetric process. The building's current status and reconstruction work was explained, as well as how photogrammetry contributed to measured drawing, reconstruction, and restoration projects [3]. The study focused on the benefits of utilizing photogrammetry in cultural heritage documentation and conservation, However, it did not address how to utilize photogrammetry to develop a comprehensive conservation management plan for the site.

Computer technologies and photogrammetry were proposed as a preventative approach for detecting, measuring, and tracking the temporal development of some structural problems that were discovered, as well as assessing the degree of material conservation in [13]. A group of monuments from Spain's historical heritage were analyzed using Photomodeler as a photogrammetric system. A wire-frame model and a photo-realistic textured model were created for conducting the study [13]. The study focused on the control of structural problems detected using computer methods and close-range photogrammetry, nevertheless it did not address how to integrate the structural problems detected into a conservation management plan for the site.

While these studies collectively highlight the effectiveness of photogrammetry in 3D modeling, documentation, and structural problems detection for historical monuments, none of them specifically address the integration of photogrammetric data into comprehensive conservation management plans, further research is needed to explore how cultural heritage sites can be better managed, monitored, and interpreted by utilizing early results obtained from photogrammetry.

III. CASE STUDY

Our case study is a museum in Sharjah (Al Mahatta Museum), in the Al Mahatta area of Sharjah (Fig. 1.a), which highlights the history of flight in UAE, and it first opened its doors on March 14, 2000. It was the region's first airport, built in 1932, and was later turned into a museum (Fig. 1.b). It is an important site because of its unique collections that tell the story of aviation, from man's first attempts to fly to the first moon landing [14], as illustrated in Fig. 1.c.



(a) (b) (c)

Fig. 1. Al Mahatta Museum in the city of Sharjah, UAE (a: site borders, b: exterior of the building, c: Sample of the collections).

Al Mahatta Museum faces various risks and challenges, requiring a robust conservation management plan. The museum is exposed to environmental factors such as material decay and humidity, as shown in Fig. 2 and Fig. 3. Such factors may cause deterioration of the site structure over time, as shown in Fig. 4. A comprehensive and effective conservation management strategy is required to mitigate these risks and ensure the long-term preservation of the cultural heritage within the museum.

Fig. 2. Material loss in one of the museum's internal facades.

Fig. 3. Material loss in one of the museum's external facades.

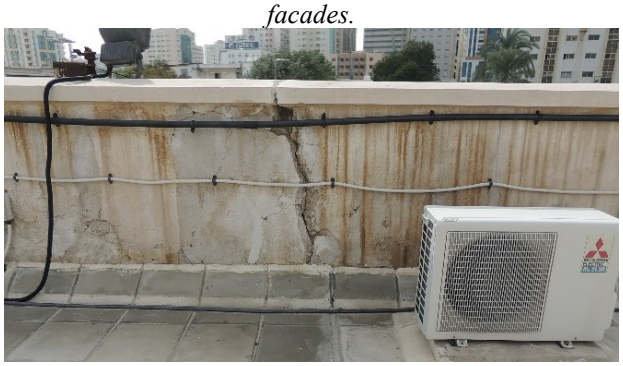


Fig. 4. Material deterioration of the museum structure as shown on the rooftop.

As part of the collaboration between ICCROM and Sharjah government, there is an ongoing project of documenting the museum using photogrammetry. The early results of the photogrammetry can be used to address the challenges at Al Mahatta Museum by monitoring the condition of the site structure, identifying any signs of deterioration or damage, and facilitating the implementation of appropriate conservation measures.

Furthermore, the utilization of photogrammetry at Al Mahatta Museum can enhance the accessibility and interpretation of information for both visitors and heritage specialists. Three-dimensional models can offer virtual tours and interactive experiences, allowing visitors to explore the museum's exhibits and aviation history more effectively. Heritage specialists, preservation and restoration experts, planners, engineers, and scholars can also benefit from the detailed digital representations provided by photogrammetry, enabling comprehensive analysis, research, and planning for conservation efforts.

IV. METHODOLOGY AND RESULTS

To discuss potential photogrammetry opportunities and obstacles, a preliminary site examination and context study was conducted, camera parameters were identified as well as the ideal time for capturing images, and the amount of overlap between photographs have been determined.

After taking the measurements required for Georeference, about 8000 photos of the site have been captured and sorted. The digital camera used in the project to collect close-range images is Canon EOS 5DS R, the shooting session was planned in such a way that unwanted foregrounds, backgrounds, as well as moving objects, are avoided. Images were captured carefully with an adequate overlap between them (80%), at different shooting distances to cover all the desired areas of the museum with the highest resolution possible (9248x6936 pixels). The ISO is set to the lowest possible value, while the aperture is adjusted to achieve the proper focus depth. During the photography process, no flash or zoom function was employed during the photography process and the images were all taken with the same settings. The obtained data has been imported into the software Agisoft Metashape to generate 3D Model (Point cloud, Mesh, Texture) for the site (Fig. 5, Fig. 6, Fig. 7), as well as the ortho-mosaic images for the facades. Fig. 8.a and Fig. 8.b show an example of the ortho-mosaic images. After importing the photos into Agisoft Metashape, a Built-in function was used to estimate the quality of each photo on a scale from 0 to 1 and to remove those which have values less than 0.5, as suggested by the software user manual [15]. In the first stage, the software generated the point cloud through a Multiview point stereo algorithm. The next phase was the creation of the mesh, high-quality generated parameters were selected, and Mild value was chosen for the Depth filtering property due to the importance given to fine details in building the model. The result was the construction of the mesh representing the site surface without colour and texture, at this phase, manual interventions were applied to edit and clean the model by removing points outside the interest area. After the mesh was built, it was textured and utilized to generate ortho-mosaics.

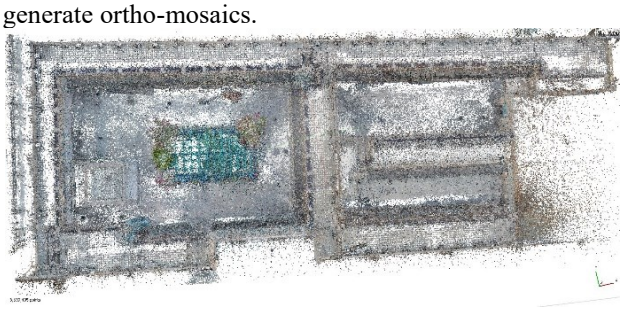


Fig. 5. Part of the generated point cloud for the complete site of Al Mahatta Museum.

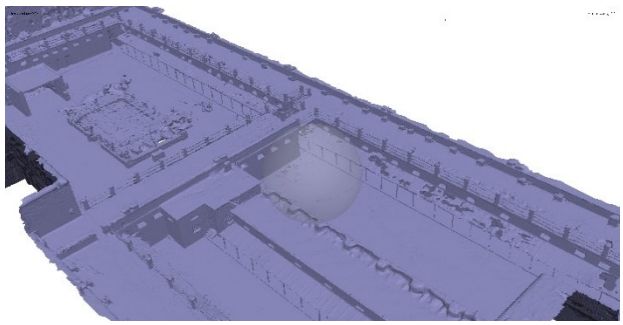
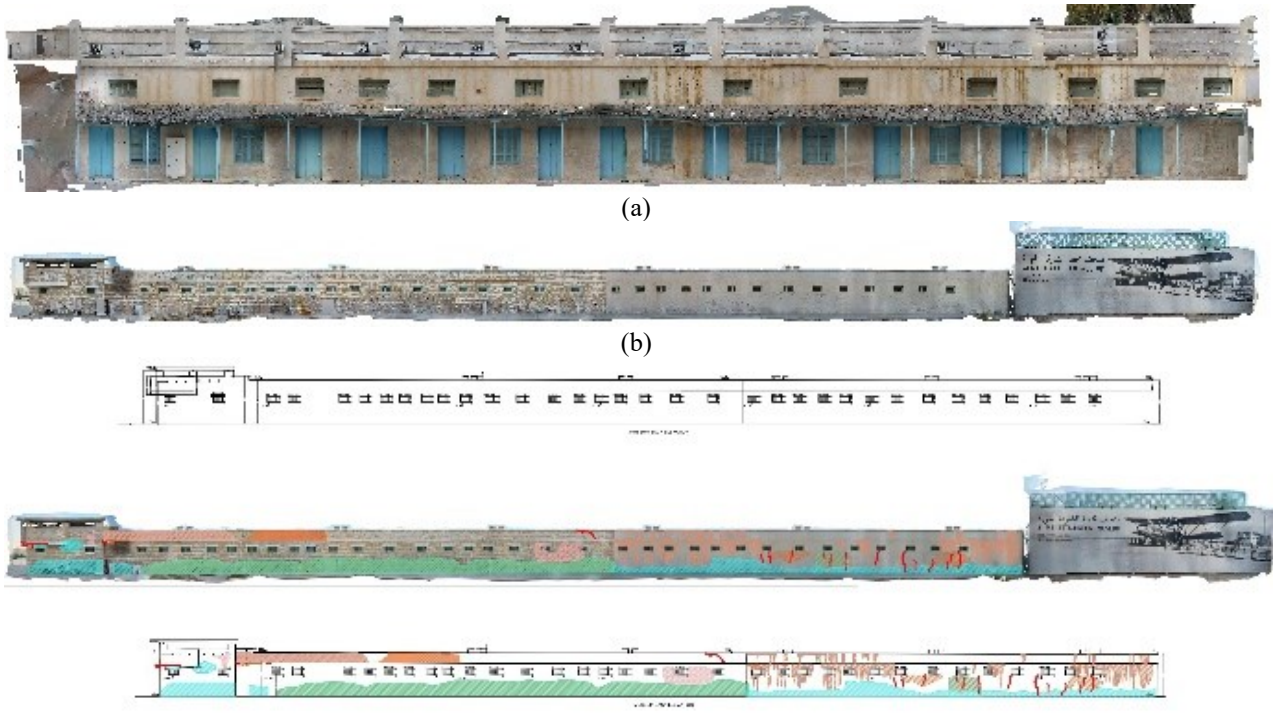


Fig. 6. The generated Mesh for Al Mahatta Museum.

Fig. 7. Part of the generated 3D Model for the site of Al Mahatta Museum.

The early results obtained from photogrammetry, which have been processed in CAD software, are used in assessing the damage and material mapping to identify the state of conservation and factors affecting the site, as well as for protection, management, and monitoring, as illustrated in Fig. 8.c. In this way, decay extension and intensity can be measured with high precision and with a high level of detail, for a correct time and costs estimation of each conservation step. Furthermore, the early photogrammetry results, which have been uploaded to different platforms like Sketchfab, might facilitate accessibility and interpretation of information among different stakeholders.



(a)

(b)

(c)

Fig. 8. The ortho-mosaic images obtained from phototgrammetry (a: an example of the internal site facades; b: an example of the external site facades, c: damage assessment)

The limitations associated with photogrammetry implementation in conservation management of Al Mahatta Museum can be summarized as follows:

- Storing and processing large data requires advanced configuration.
- The camera's resolution affects photogrammetry results.
- Capturing high-altitude parts requires the use of a drone.
- Photogrammetry cannot generate reliable results when applied to surfaces with poor lighting, reflective surfaces such as mirrors, or homogeneous surfaces such as smooth, plain painted walls.
- Weather factors like sun rays and rain, and physical obstacles such as the presence of trees and vehicles in front of facades, affect the measurement and photograph operations.
- The photogrammetry output is somehow sophisticated to be utilized by non-expert users.

V. DISCUSSION AND CONCLUSION

Each cultural site has its unique characteristics, physical conditions, and level of precision required; the conservation team can determine which recording approach would be most effective; one of the notable advantages of employing photogrammetry is its ability to document risky or inaccessible areas. Also, it is a cost-

effective method of generating 3D models of small objects to large complex objects such as historical sites.

Photogrammetry is widely used in cultural heritage documentation. However, the utilization of photogrammetry can enhance collaboration among different groups involved in cultural heritage conservation, it can also serve as a preventive tool for detecting, measuring, and tracking the temporal development of some structural problems, and finally, it can facilitate information access by visitors and conservation management specialists.

The photogrammetry process involved taking the necessary measurements and capturing thousands of stereo-pair images, which were then imported into Agisoft Metashape software to create a 3D model of the site as well as the ortho-mosaic images for the facades. The early results obtained from photogrammetry were used to identify the state of conservation. Additionally, 3D visual representations created by photogrammetry enhance the accessibility of information and facilitate collaboration among different stakeholders.

Despite the limitations associated with photogrammetry implementation, the results demonstrate that photogrammetry offers significant benefits for preserving and understanding cultural heritage sites like Al Mahatta Museum.

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