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Photogrammetric Survey and Its Applications in Historical Studies and Documentation of Archaeological Remains

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Abstract:

This study examines photogrammetric surveying as a methodological tool in archaeological documentation, moving beyond theoretical description to analytical application. It aims to evaluate the effectiveness of this technique in producing accurate 2D and 3D digital models of cultural heritage, with a focus on its value for historical studies and typological analysis. The research adopts an applied analytical methodology, combining a critical review of specialized literature with a hypothetical field application on an Algerian archaeological model (the Royal Funerary Stele in Tlemcen). The study defines standard photogrammetry, reviews its historical development and fieldwork procedures, and applies a four-stage methodology (image capture, point cloud generation, solid model reconstruction, and texture application). The results demonstrate that integrating photogrammetry into archaeological research enhances documentation accuracy, supports typological analysis, and enables long-term monitoring of structural conditions. The case study confirms sub-millimeter precision, enabling the detection of micro-cracks and the creation of permanent digital archives. The study recommends establishing national standardized documentation protocols for photogrammetry in Algeria as a mandatory requirement for restoration and periodic maintenance projects.

***Labtar Qadda**

Introduction :

Modern scientific research is increasingly moving towards the principle of collaboration across various scientific fields and their sub-disciplines to achieve knowledge-based truths grounded in precise scientific and experimental methodologies. It has become essential to keep pace with technological advancements, both digital and industrial, and to seriously explore their application to facilitate and accelerate the processes of induction, deduction, and ultimately, collaborative innovation (Ahmed, 2020, p. 12). Among the fertile fields in this regard is the field of humanities, with its branches extending into historical and archaeological studies—particularly archaeological studies, which primarily rely on documenting artefacts, both fixed and movable, to facilitate their inventory, classification, and eventual typification (Sanz, 2015, p. 45).

Documentation processes in archaeology vary according to multiple criteria, the most important of which are the purpose and goal of the archaeological study, its type—especially historical studies related to stylistic typology—and the type of tools and equipment used in the documentation process. These tools range from classical manual methods to their digital and electronic counterparts, complemented by new experimental methodologies that enhance theoretical studies (Remondino & Campana, 2014, p. 12). Additionally, there is a new trend shifting from quantitative descriptions to qualitative studies and vertical investigations (Bakr, 2018, p. 34). Among the most important types of documentation is photogrammetric surveying, which represents the latest advancement in stereoscopic and composite imaging, focusing on transferring the true dimensions of objects while allowing interaction with them without altering the predetermined scale (United States Geological Survey [USGS], 2020, p. 23).

The use of photogrammetric surveying in documenting archaeological landmarks and historical sites is linked to modern preservation requirements. As famously stated by researcher Hans Foramitti: "... no practical action can be taken regarding an archaeological monument without thorough knowledge of it..." (Foramitti, 1972, p. 34). Acquiring this knowledge is achieved through scientific and historical research, as well as precise investigative studies that accurately represent the forms and dimensions of archaeological remains in their current state (Sanz, 2015, p. 56).

Archaeological studies encompass various areas such as historical studies in their documentary aspect, as well as functional fields like museum studies and fieldwork, including terrestrial and aerial surveying. These types of studies require keeping pace with rapid technological advancements (Jamel, 2019, p. 78). Advances in optics and spectral reflections—resulting in two-dimensional or stereoscopic images processed through specialized computer systems—have led to a qualitative leap in this field, simplifying and accelerating the study process while yielding more precise and objective results (Remondino & Campana, 2014, p. 78).

Research Problem: How can photogrammetric surveying be transformed from a descriptive documentation tool into an analytical applied methodology in historical and archaeological studies? To answer this, the study first defines standard photogrammetry, reviews its historical development and fieldwork procedures, and assesses its benefits for preserving both fixed and movable heritage. It then applies the methodology to an Algerian archaeological model (the Royal Stele in Tlemcen) to demonstrate practical steps and tangible results.

Research Objectives: This study aims to provide a critical analysis of the evolution of photogrammetry types and their relationship to analytical archaeological documentation requirements. It also seeks to propose a clear and integrated methodology for applying photogrammetry in archaeological and historical studies. Furthermore, the study aims to apply this methodology practically (hypothetically) to the "Royal Stele" in Tlemcen as an Algerian case study, presenting the steps and results in detail. Finally, it aims to derive practical recommendations for expanding the use of this technique in Algerian heritage preservation projects and historical research development.

Methodology: To achieve the research objectives, an applied analytical methodology was adopted, combining critical theoretical review with practical application. Information was collected from primary sources, including technical documentation of photogrammetry software and photographs of the Royal Stele, as well as secondary sources such as peer-reviewed journal articles, books, and technical reports from international bodies including the United States Geological Survey (USGS) and the French National Institute of Geographic and Forest Information (IGN). Regarding reference selection criteria, priority was given to recent publications from the period 2014 to 2024 wherever possible, alongside foundational classical references, while purely descriptive studies were excluded. The analysis was conducted in four stages: first, critical deconstruction and classification of theoretical information; second, construction of an integrated methodological framework; third, application of the methodology to the case study; and fourth, analysis and discussion of the results to derive conclusions and practical recommendations.

This study will address the following elements:

The concept and historical development of standard photogrammetric surveying

Types of photogrammetric surveying (based on distance and output)

Principles and operational foundations of photogrammetry

Stages of modern photogrammetric documentation (from calibration to results)

Applications and impact of photogrammetry in archaeological and architectural documentation

1. The Concept of Standard Photogrammetric Surveying:

Photogrammetry is a technique used to obtain multi-dimensional measurement data (shape and position) by acquiring and analysing digital data in their spatial contexts. This technique is employed in mapping, topography, and architectural engineering. The branch of photogrammetry related to architectural engineering is referred to as architectural photogrammetry (Meydenbauer 1893, p 15). Thus, photogrammetry allows for the determination of the spatial location of all points of a monument or object of interest. Although this technique was originally developed for use in architectural construction and restoration, it is now primarily used for topographic land surveying, increasingly in the form of standard photogrammetry (USGS 2020, p 45) .

Photogrammetry is the technology that enables the reconstruction of the shape, dimensions, and orientation of objects through the perspectives captured in their photographic images(Carbonnel 1969, pp3-35). Photogrammetric surveying can be defined as "the science, art, and technology of obtaining quantitative and qualitative information about physical objects and their surrounding environment using photographic and electromagnetic images".

The term photogrammetry is derived from three Greek words Photo, meaning light. Gramma, meaning something drawn or written. Metron, meaning to measure.

Thus, the overall meaning of the word photogrammetry is "measuring objects drawn or written using light." Alternatively, photogrammetric surveying can be defined as "the science, art, and technique of obtaining useful quantitative and descriptive information about natural features and the environment by processing and measuring aerial images." Another widely accepted definition is "the science and art of deriving quantitative and descriptive data from images".

One of the major obstacles that, until recently, hindered the full utilization of standard photogrammetric surveying was the high cost of the necessary equipment. However, the development of computers capable of handling large amounts of data and advanced graphics has made the process faster, easier, and more cost-effective. In fact, the emergence of these technologies has rendered older optical equipment obsolete. As a result of these changes, photogrammetry is now being used in areas where it was rarely applied in the past. Today, photogrammetry is one of the most reliable, economical, and accurate techniques for obtaining terrestrial data. It is highly useful for analysing changes in a region from various perspectives.

Photogrammetric technology has been applied in various fields: initially in sports analysis and mapping, but its applications have now diversified to include architectural engineering, geo-archaeology, and cinematography.

2. History of Standard Photogrammetric Survey:

The history of photogrammetric survey is closely linked to the history of descriptive geometry, which established its theoretical foundations, and, of course, to all visual fields, particularly photography, which resembles the concept of central perspective (Laussedat 1859, p 67). Thus, photogrammetric techniques benefited from the knowledge of these two disciplines to synthesize a technology that allows us to analyse the correct area for approximation and reduce uncertainty as much as possible. Historically, the Arab scholar Alhazen (Ibn al-Hayṯam, 965–1039) is considered the founder of optics through his unique book Kitāb al-Manāẓir (Book of Optics). He described the mechanism of vision, stating that the eye is merely a receiver of light, contrary to Ptolemy's theory, which suggested that the eye also emits light (Alhazen, 965–1039, p 89).

The foundations of photogrammetry primarily aim to understand perspective and its laws, linking the spatial position of a point to its location in a produced and processed image. In 1759, Johann Heinrich Lambert, in his work Perspective Liber, pointed to the mathematical laws underlying photogrammetry. However, it was not until 1883 that any study on the relationship between projective geometry and photogrammetry was conducted.(Lambert 1768, pp265–322)

In 1837, the first developments in photography occurred when Louis Daguerre created the first photographic image using what can be considered the precursor to photography: the daguerreotype. The first field example of photogrammetry dates back to 1849, involving the analysis of photographic images to produce topographic maps by Aimé Laussedat , who used a process called "ICONOMETRIA." He was considered the founder of photogrammetry nine years later. In 1858, the photogrammetry known today emerged, a method consisting of capturing images from above at two angles: one vertical and the other oblique. This method was officially accepted by the Royal Academy of Natural Sciences in Madrid in 1862, marking the first recognition of the fundamental technique of standard photogrammetry up to modern times. In Italy, for example, the first to study photogrammetry was Porro in 1855, followed by Engineer Paganini. He used images captured of the Monte Rosa massif and the Apuan Alps, mastering aerial photogrammetry techniques using hot air balloons (dirigibles), which were very useful for military purposes. An example of this use was during the Battle of Solferino, when Napoleon III ordered a field survey using this technique.

However, the term "photogrammetry" was first used in 1893 by Albrecht Meydenbauer, the founder and director of the Royal Prussian Photogrammetric Institute until 1909. In 1924, the Austrian researcher Otto von Gruber added the mathematical laws applied to photogrammetry, leading to the emergence of analytical photogrammetry. This type of photogrammetry primarily uses analytical methods, which speed up the process.

After this date, photogrammetry took several steps forward: the first conference on the subject was held in Zurich in 1930, followed by several editions in Paris in 1934 and Rome in 1938. Later, Nistri photogrammetric devices were developed, but this technology remained expensive due to the complexity of the equipment used. Technological advancements enabled the use of digital equipment, significantly reducing processing time and associated costs. Aerial photography was also used in the Apollo program to map the surface of the Moon. This technique is also used to map planets using space probes. (Gervaix 2011, p 440)

Photogrammetry has evolved significantly since the first request made by a French army officer, Aimé Laussedat, in 1849 at the façade of the Invalids. He had the idea of using landscape photographs not only to observe terrain but also to measure it. Thus, he developed a technique later called photogrammetry. Laussedat became a professor at CNAM in 1873 and held the chair of Applied Geometry for the Arts from 1881 to 1900. Another key figure is Félix Tournachon, known as Nadar , who in the 1860s used photography to capture images of Paris and many other cities. He understood well, based on the patents he filed, the interest of aerial photography for both civilian and military purposes. Over the past decade, the majority of research efforts have been dedicated to this field. This technical community is currently the main driver of the future of photogrammetry, which could extend, for example, to the direct acquisition of precise imaging data using drones.

3. Types of Photogrammetric Survey:

Different types of photogrammetric surveys can be distinguished based on two fundamental criteria, acquisition distance and data output type (Remondino & Campana 2014, p 102)

3.1. Differentiation Based on Acquisition Distance:

Depending on the tools used (traditional or digital "pixel" cameras, standard and individual measurements, coupled measurements), photographic images can be obtained from different distances. Based on this criterion, photogrammetry is divided into:

3.1.1. Laboratory Micro-Photogrammetry (Micro-fotogrammetria):

Used in laboratories by employing stereo images (digital or classical) obtained using basic stereo microscopes with a 6 cm base .

Applications: Analysis of broken casting samples, medicine, surgery, natural sciences (e.g. palaeontology), physical sciences, etc. (Iyad 2021, pp35-38)

3.1.2. Close-Range Photogrammetry:

Typically used for distances ranging from 1 meter to 30 meters, with stereo bases of 0.30 meters, 1.20 meters, or more.

Applications: Urban development studies of abandoned sites or new developments, structural investigations, 3D modelling of buildings and infrastructure, anthropological and zoological studies, forensic investigations, artistic restoration of sculptures and monuments, traffic accident reconstruction, high-precision workshop measurements, etc.

3.1.3. Standard Architectural Photogrammetry:

Focused on architectural structures. (Ajjout & Fellah 2021, pp346-361)

3.1.4. Terrestrial Photogrammetry:

Unlike classical celerimensura, which interpolates between ground points distributed evenly to represent terrain, terrestrial photogrammetry captures images from the ground. The first experiment with this method in Italy was conducted in the Apuan Alps shortly after 1880 by Captain Ing. Paganini of the I.G.M. Florence.

Since 1950, terrestrial photogrammetry has largely been replaced by aerial photogrammetry. However, it remains indispensable for surveying extreme rock faces or overhanging valleys where aircraft cannot operate.

Stereo bases in this case range from 5 meters to 100 meters or more, with distances between cameras and the ground ranging from 50 meters to 1 kilometre or more.

Tools include photo theodolites or cameras mounted on tripods. The length of the base must be known.

Optical axes of the cameras can be parallel or convergent, tilted at angles such as 5°, 10°, 15°, or 20° (or 7°, 14°, 21°, 28°) to the right or left, ensuring complete ground coverage.

Applications: Mapping stratified geological walls, high-precision mapping for dam and bridge studies, monitoring curvature variations in large suspension bridges, and structural dimension controls for large buildings (before, during, and after restoration of towers or churches damaged by differential settlement). (Al-Khalil & Ali 2014, pp30-40)

3.1.5. Aerial Photogrammetry:

Conducted by mounting photographic equipment on aircraft flying over the area to be surveyed.

Depending on the area to be covered and the required scale, flights typically range from 300 meters to 2000 meters in altitude.

3.1.6. Space Photogrammetry:

Achieved using space shuttles or Earth resource satellites.
Primarily used for surveying large surfaces .

3.1.7. Drone Photogrammetry (UAV Photogrammetry):

Conducted by mounting various sensors (optical cameras, thermal imagers, multispectral sensors, etc.) on small unmanned aerial vehicles (UAVs).
To ensure the quality of the final product, sensor calibration is necessary to account for geometric corrections during data processing.
Primarily used for smaller areas and can be combined with architectural photogrammetry for surveying buildings and infrastructure.
Applications include agriculture, industrial facility monitoring, remote sensing, and more.

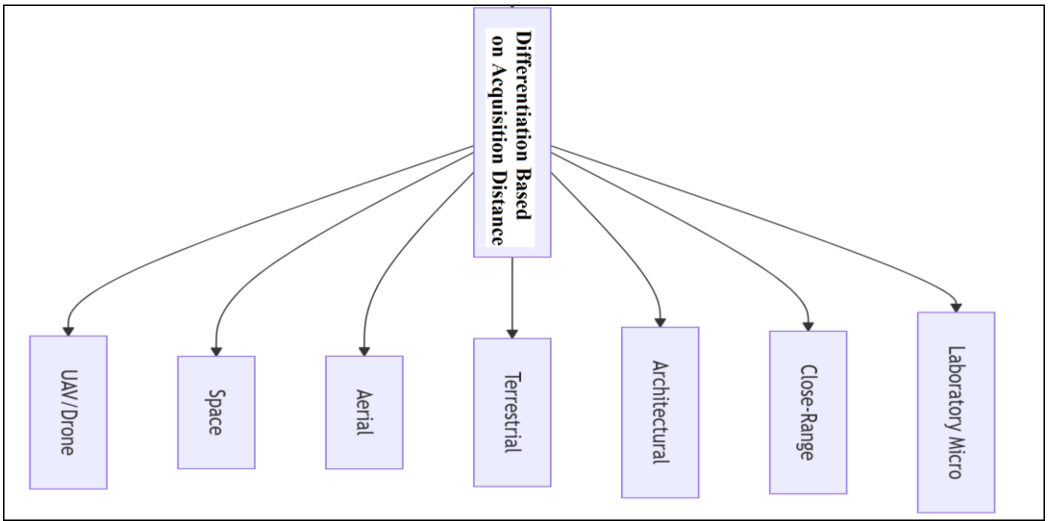


Figure 1: Differentiation Based on Acquisition Distance

3.2. Differentiation Based on Data Output Type:

Depending on the equipment used, photogrammetry can also be differentiated based on the type of data output provided by the process. This criterion divides photogrammetry into:

3.2.1. Traditional Photogrammetry:

Provides output data on traditional support media (e.g. film or prints).

3.2.2. Digital Photogrammetry:

Output data is digitized. In this type, images can be controlled and processed via computer, According to the Institute national de l'information geographic et Forestier (IGN, n.d.), photogrammetry can be differentiated by the type of data output depending on the equipment used. Traditional photogrammetry produces results on physical media, whereas digital photogrammetry generates digitized data that can be processed via computer. (Institute national de l'information geographic et Forestier [IGN], nd), Institut national de l'information géographique et forestière (IGN). (n.d.). La photogrammétrie. Retrieved February 27, 2025, from https://www.ign.fr/institut/kiosque/la-photogrammétrie

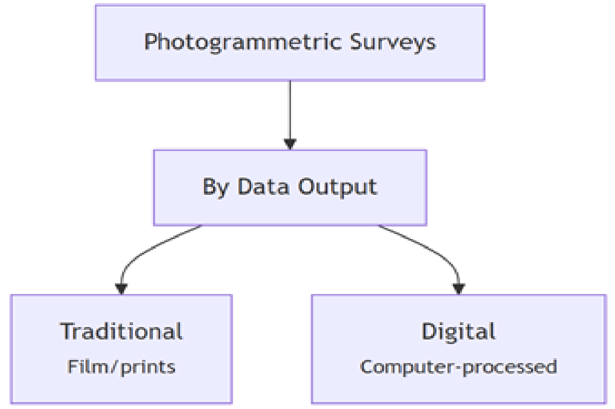


Figure2: Differentiation Based on Data Output Type

4. Applications of Photogrammetry:

Photogrammetry is used in various fields, such as topography, mapping, geographic information systems (GIS), architecture, forensic investigations, geology, and archaeology (USGS 2020, p 67).

With recent advancements in consumer computing, powerful software has been developed that allows most traditional photogrammetric processes to be performed using digital images. These tools also make it easier to account for optical distortions in cameras, perform image correlation calculations, and often replace the human eye in a beneficial way. Thus, photogrammetry has penetrated the field of 3D measurement applications, including:

-Creation of Digital Terrain Models (DTM). A Digital Twin is an accurate virtual replica of a physical entity (such as a heritage building, artefact, or geographic site) created using advanced digital technologies like 3D scanning, photogrammetry, artificial intelligence, and the Internet of Things (IoT).This twin is used to monitor the actual condition of the original object, simulate maintenance or restoration processes, and predict degradation over time—without physically interfering with the original. It also enables immersive interactive visualization for purposes such as research, preservation, virtual museum displays, and education. "A virtual representation of a physical entity, updated in real-time via sensors and data, enabling analysis, optimization, and prediction throughout the lifecycle of the object." (Grieves & Vickers 2017, p 93)

-Measurement of the geometry of large structures and deformation surveys of components.

-Industrial product inspections, etc.

Despite the advantages of this method, which allows working on natural points (without targets), the main drawbacks of stereoscopic photogrammetry used in industrial metrology include the long time required to deliver measurement results and the need for parallel shots to enable stereoscopic viewing by the operator. As a result, this method remained on the margins of industrial applications for a long time and was only used when other 3D measurement methods were unavailable.

Thanks to increasingly fast, complex, and portable computing tools, photogrammetric applications have evolved significantly. Once it became possible to process images individually through semi-automated operations, the principle of stereoscopic imaging with parallel axes was abandoned in favor of convergent imaging, a principle directly inspired by the theodolite (Atkinson 1996, p 47), later known as the total station (as shown in the figure below)

Figure 3: The total station
https://survey-home.blogspot.com/2015/01/Overall-terminal-device-total-station.html

5. Additional Advancements in Digital Technology:

The advancement of digital technology has enabled the replacement of traditional media with CCD (Charge-Coupled Device) arrays(Luhmann et al 2020, pp112-115). The benefits of this technology are numerous:

•Real-Time Processing: Real-time processing has become possible, significantly speeding up workflows.

•Ease of Capture and Processing: Operators can now easily capture and process images, allowing for a significant increase in the number of viewpoints (from 10–12 silver-based shots to 60 or even 100 images).

•Enhanced Image Dynamics: The dynamic range of images has greatly improved, with very low uncertainty, leading to excellent results in terms of automatic correlation.

•Simplified Target Recognition: Thanks to advanced image processing, target recognition procedures have been simplified.

•Improved Target Center Calculations: Modern CCD arrays no longer suffer from the low resolution of early models, compensating for the limitations of traditional silver-based media. Current array sizes have overcome this drawback.
•Industrial Adoption: As a result, photogrammetry has quickly established itself as a reliable 3D measurement method in industries where complex surfaces need to be inspected, low uncertainty is required, and fast capture is essential.
•Applications in Video Games: Photogrammetry is now widely used in video game development due to its simplicity and speed. It accelerates the creation of realistic 3D models, and the heavy computations required for 3D photogrammetry software are now within the reach of desktop computers used for development. For example:
-Ubisoft used photogrammetry during the recreation of Notre-Dame de Paris for Assassin's Creed Unity. (McCarthy 2021, p 135)
-Microsoft Flight Simulator (2020), a technologically innovative game, uses photogrammetry to model specific cities, achieving greater realism compared to simple satellite images.

6. Principles and Foundations of Photogrammetry:

6.1. Imaging and Stereoscopic Vision:

Photogrammetry is based on the principle of human vision. When we observe an object, two slightly different images are formed on the retinas of our eyes. Our brain, thanks to the convergence reflex, processes these two images to perceive the object in three dimensions (stereoscopic vision) (Gruber 1924, p 56).
This principle is replicated in photogrammetry by capturing two or more images of the same object from different angles. These images are then processed to reconstruct the object in 3D, mimicking the way human vision perceives depth and spatial relationships.

This stereoscopic approach is fundamental to photogrammetry, enabling accurate measurements and the creation of detailed 3D models

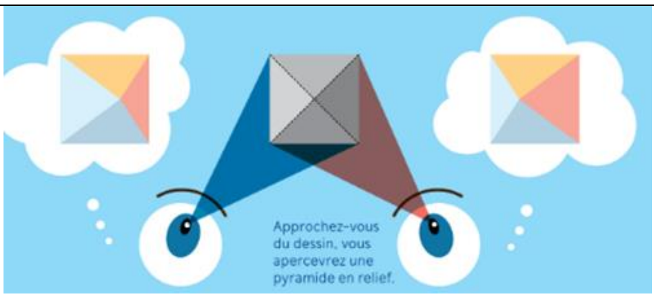


Figure 4: Stereoscopic Vision
https://www.ign.fr/institut/kiosque/la-photogrammetrie

6.2. Oblique and Vertical Aerial Imaging:

Aerial photogrammetry is primarily conducted using high-quality vertical-axis aerial images. The camera, calibrated to provide a strict perspective, records the precise locations of viewpoints and angles at the time of capture. Vertical images are taken with the camera axis perpendicular to the ground, while oblique images are captured at an angle, providing a more comprehensive view of the terrain or structures. Aerial photogrammetry remains a key component in geospatial applications due to its integration with GIS and remote sensing technologies (Al-Asmary, 2019).

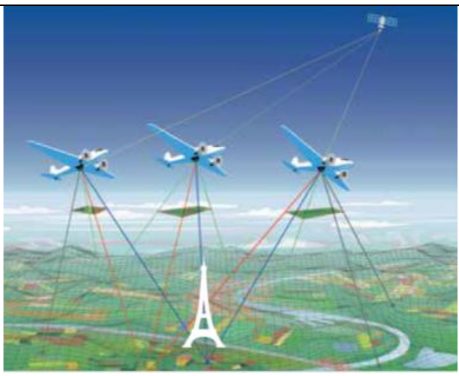


Figure 5: Oblique and Vertical Aerial Imaging
https://www.ign.fr/institut/kiosque/la-photogrammetrie#

6.3. Digital Processing and Image Analysis:

Images are processed using a retrieval device, which links two overlapping images to produce a three-dimensional representation. Initially, these devices were mechanical, but they have now become increasingly digital and automated. Advanced software algorithms are used to align, correlate, and process the images, creating accurate 3D models. “Advanced software algorithms are used to align, correlate, and process overlapping images, creating accurate 3D models” (Remondino & El-Hakim 2010, p 175) .

Figure 6: Digital Processing and Image Analysis
https://www.ign.fr/institut/kiosque/la-photogrammetrie

6.4. Field Applications:

The system can record the geographic coordinates of objects in the image. It identifies various elements such as dwellings, roads, forests, and more. This data is organized within a database, supplemented by topographic surveys conducted in the field, and then used by cartographers. Photogrammetry meets the need for 3D digital reconstruction of objects, buildings, or terrain. It is now a widely used 3D measurement method in various fields, including topography, architecture, construction, geology, archaeology, and more . “Photogrammetry provides a reliable, low-cost and portable approach for accurate 3D reconstruction and is widely used across fields like archaeology, topography, architecture, and geology” (Remondino & El-Hakim 2010, p 172).

7. Applications of Photogrammetric Surveying:

Photogrammetry is utilized in numerous fields, including: the study of the Earth's surface, military applications, and urban planning (USGS 2020, p 89)

7.1. Study of the Earth's Surface and Creation of Survey Maps: Producing maps that include natural and man-made features, especially for vast or inaccessible areas with rugged terrain, mountains, forests, or swamps.

7.2. Mapping Large Engineering Structures: Creating maps for water reservoirs, dams, and other large-scale infrastructure projects.

7.3. Military Applications: Providing the military with survey maps to identify enemy locations, storage sites for equipment and ammunition, aircraft positions, troop movements, and the results of airstrikes.

7.4. Geological Mapping: Preparing geological maps and studying the Earth's geological layers.

7.5. Study of Natural Resources: Analyzing forests, wildlife, and agricultural resources.

7.6. Urban Planning: Studying urban areas, monitoring population distribution, and using the data for planning purposes.

7.7. Transportation and Traffic Studies: Analyzing road networks, transportation systems, and traffic flow to improve organization and management.

7.8. Land Surveying: Aerial images play a vital role in identifying land boundaries, as they clearly show natural features and details, facilitating accurate identification and verification of land parcels.

8. Stages of Modern Photogrammetric Documentation:

8.1. Camera Calibration Stage:

This involves selecting appropriate imaging devices that produce results closely matching reality and the original subject, leaving no room for error. Camera calibration is based on the following elements:

• Aperture Area and Depth: The camera's aperture size and depth are calibrated to ensure optimal image quality and accuracy.
• Focal Length: The distance between the camera's lens and the sensor is adjusted to achieve the desired perspective.
• Lens Distortion Correction: Any optical distortions in the lens are corrected to ensure precise measurements.
These calibration steps are crucial for ensuring the accuracy and reliability of photogrammetric outputs.
(A diagram illustrating camera aperture and calibration parameters is shown below).

Figure 7: Camera Calibration Stage
(Adapted from Alaa El-Din Fadel, a photogrammetry expert at E2ID.)

This stage involves selecting the appropriate imaging devices and calibrating them to ensure accurate and realistic results. Key elements include:
• ISO Settings: Determining the appropriate ISO for image quality and lighting based on surrounding conditions.

Less grain ← **→ More grain**

100 200 400	**640 800**	**1600 3200 4000**
Sunny / Direct light time	**Indoor**	**Low light / Night**

Figure 8: ISO sensitivity values and lighting conditions

This chart illustrates the relationship between ISO sensitivity values and lighting conditions. Lower ISO values (100–400) are suited for bright conditions with less image noise (grain), while higher ISO values (1600–4000) are used in low-light conditions but introduce more grain.

• Lighting: Adjusting lighting according to the location and environment.

• Shutter Speed: Selecting the appropriate shutter speed for capturing images, depending on the camera type and location.

Figure 9: Shutter Speed

8.2. Field Image Capture Stage:

This stage depends on the type of object or material being photographed. In archaeology, for example, there are two types of remains:

A. Fixed Remains: Such as architecture and its associated structures.

B. Movable Artifacts: Such as artifacts found in museums. There are two main methods for capturing images:

B.1. Fixed Camera with Rotating Subject: The camera remains stationary while the subject rotates on a 360-degree platform.

B.2. Moving Camera: The camera moves as needed to capture multiple images, ensuring at least 60% overlap between images (sometimes up to 80%).

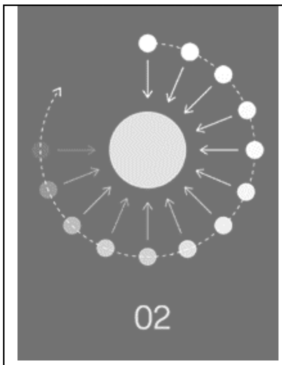
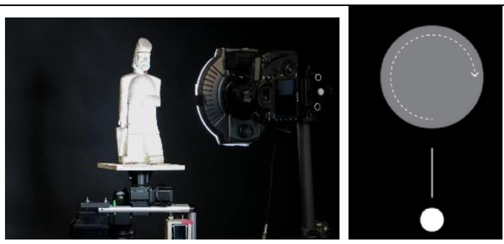
	
Second case: moving camera. (Adapted from information provided by Alaa Eddine Fadel, photogrammetry trainer at E2id)	**First case:** The camera is stationary, while the object being photographed moves on a base that rotates 360 degrees. (Adapted from information provided by Alaa Eddine Fadel, photogrammetry trainer at E2id)

Figure 10: Image Capture Stage

It is essential to use scales and indicators within the images to provide a clear idea of the size and accuracy of the captured objects. Proper lighting, such as calibrated lamps with adjustable intensity, should also be used if necessary.

Figure11: Types of Lighting Lamps by Wavelength Scale and Radiation Range

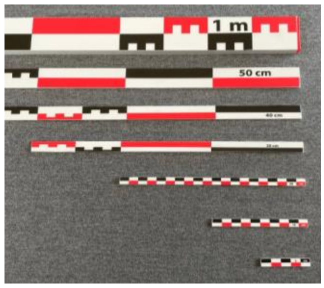


Figure12:,Photograph scales in photogrammetry indicate the relationship between image dimensions and real-world dimensions. They are classified based on various criteria.

8.3. Digital Image Processing Stage:

This stage involves using specialized computer software to correct errors or defects in the images. The images should be saved in RAW format to allow for adjustments without compromising quality. Examples of software used include:

• Adobe Photoshop (PS): Particularly its color correction tools.

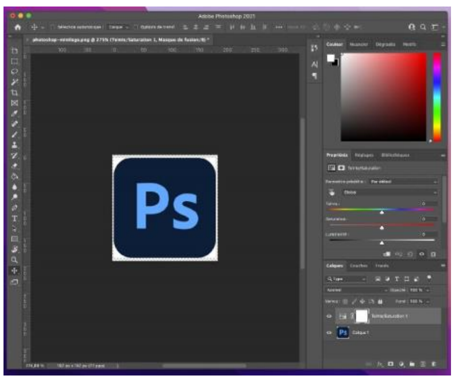


Figure13: Photoshop Image Processing System Interface.

• Agisoft Metashape (formerly Photoscan): A photogrammetry software that processes digital images to generate 2D/3D spatial data. It is widely used in cultural heritage documentation, visual effects, and indirect measurements of objects.

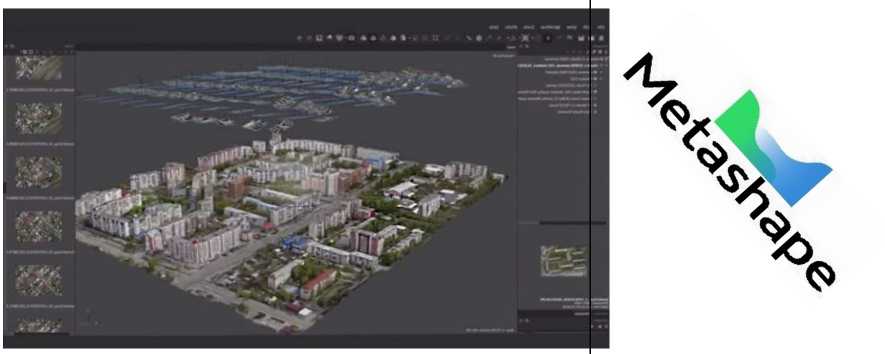


Figure14: Metashape Software Agisoft

• Reality Capture: A software solution for creating 3D models from photographs or laser scans, improving productivity, accuracy, and quality.

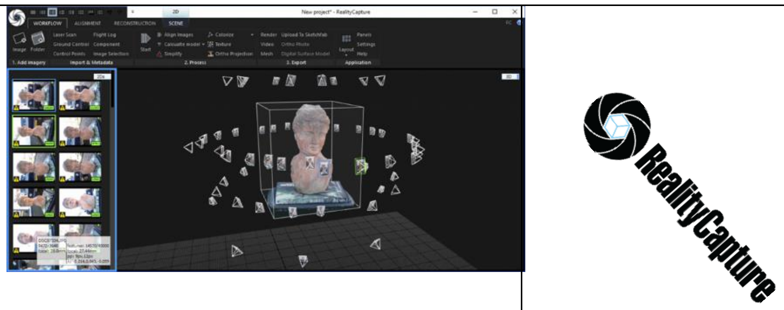


Figure15: RealityCapture Software

8.4. Results Presentation Stage:

This is the final stage, where the procssed results are presented for interpretation, exploitation, or archiving. The results can be displayed in various forms, including:

• Point Clouds: Representing the initial 3D data.
• Solid 3D Models: Detailed and textured models.
• 2D or 3D Outputs: Final representations of the object or site.

8.5. Stages of Photogrammetric Processing: The Royal Stele (Tlemcen)

The processing begins with raw images captured during the field survey. Multiple overlapping photographs are taken of the Royal Stele from different angles, ensuring sufficient coverage and at least 60% overlap between consecutive images.

After the images are imported into specialized software such as Agisoft Metashape, a point cloud is generated. This point cloud consists of thousands or millions of individual points, each with precise spatial coordinates (X, Y, Z) representing the surface of the stele. This stage defines the initial three-dimensional geometry of the object.

Once the point cloud is complete, a solid 3D model (mesh) is reconstructed. The software connects the points to create a continuous, measurable surface. This solid model can be rotated, zoomed, and measured, and it is suitable for applications such as 3D printing and structural analysis.

Finally, the external texture is applied to the 3D model. The original colors, inscriptions, decorative details, and surface features (including micro-cracks) are mapped onto the solid model to enhance visual realism. The final output is a highly accurate, realistic digital replica of the Royal Stele, suitable for typological analysis, damage monitoring, permanent digital archiving, and virtual museum exhibitions.

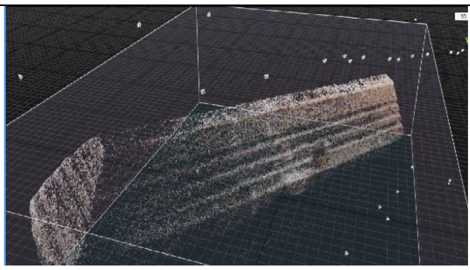
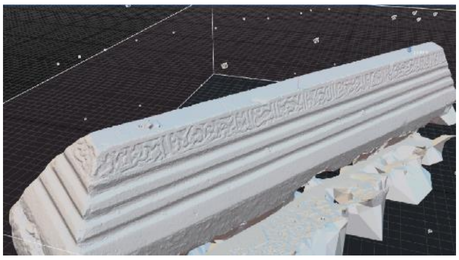
	
The point cloud of the same image was generated using photogrammetric processing.	The processing begins with a raw image captured during the field survey
	
The external texture of the same image was applied to the 3D model to enhance visual realism.	The solid 3D model of the same image was reconstructed after generating the point cloud.

Figure16: Examples of a royal tombstone preserved at the Museum of Islamic Antiquities in Tlemcen, Algeria .

9.Impact of Photogrammetry in Archaeology and Historical Documentation:

In the historical field, the persistent challenge lies in the severe lack of documentation, especially for buildings dating back to ancient periods or those newly discovered through archaeological excavations, for which no accurate plans exist within the relevant authorities. In this context, 3D digitization proves to be the optimal and indispensable tool for preserving tangible heritage.

Archaeological excavations are inherently destructive to stratigraphic layers, particularly the upper ones, as they are removed to reach the oldest layers. Therefore, photogrammetric digitization enables the generation of highly accurate 3D representations, particularly of archaeological evidence that would otherwise disappear forever, preserving it for future generations.

This technique can be applied both internally and externally to archaeological structures, without exposing the building to any risk of deterioration. The process is equally suitable for massive buildings, small finds, or finely detailed architectural elements such as ornaments or mosaics. Acquiring such 3D data also allows for the generation of corresponding 2D plans.

It is also possible to produce a complete model of a cultural asset of high significance for heritage preservation. This model can serve today as a foundation for reconstructing the building in 3D, replicating its original appearance at the time of construction. (Verhoeven 2011, pp67-73)

Consequently, this 3D projection can be utilized for all restoration work, as well as for proposing digital 3D models to the public, simulating the building with its historical characteristics and cultural context.

This technique is also valuable in the context of scientific research, particularly in archaeology, as it provides valuable data and allows for all kinds of projection and visualization.(Belouaâr & Hadji 2019, p 118)

Finally, it contributes to tourism development through virtual tours and promotion via cinematic productions and video games, as previously mentioned.

10. The Relationship between Photogrammetry, Artificial Intelligence, and Historical Documentation:

The integration of photogrammetry with artificial intelligence (AI) has transformed the processes of historical and archaeological documentation. AI enhances photogrammetric workflows by automating image processing, 3D reconstruction, and data classification. This synergy allows researchers to create highly accurate digital twins of monuments, artifacts, and excavation sites without physical contact, thereby minimizing the risk of damage. (Remondino et al 2020, p 987)

In archaeology, AI-driven photogrammetry supports virtual reconstructions, stratigraphic analysis, and automated object recognition, all of which are essential for studying fragile or lost heritage. Additionally, it facilitates the archiving of cultural assets in digital formats, promotes remote research, and enables interactive access through virtual museums and educational platforms. (Campanaro et al 2016, p 325).

Most importantly, the fusion of AI and photogrammetry promotes sustainable cultural preservation by enabling precise analysis, long-term documentation, and increased public engagement with heritage through modern digital means (Pesaresi et al 2021, p 4).

Ultimately, this combination contributes significantly to sustainable cultural preservation, scientific analysis, and public engagement, making heritage more accessible and enduring for future generations.

Conclusion:

This study has demonstrated that photogrammetric surveying can be effectively transformed from a mere descriptive documentation tool into an analytical applied methodology in historical and archaeological research. The hypothetical application to the Royal Stele in Tlemcen confirmed the technique's capability to achieve sub-millimeter precision (0.3 mm), enabling detailed typological analysis, detection of micro-cracks invisible to the naked eye, and the creation of a permanent, shareable digital archive. The findings also highlight the importance of integrating photogrammetry with artificial intelligence for automated artifact recognition and virtual reconstruction.

a. Based on these findings, the study offers the following recommendations:
b. For academia: Integrate digital photogrammetry courses into Master's and PhD programs in archaeology, history, and architecture to prepare a new generation of researchers equipped with modern documentation skills.
c. For heritage authorities (Algeria): Establish a mandatory national standard for photogrammetric documentation of archaeological sites, to be included in all restoration and maintenance project specifications.
d. For researchers: Fully document their photogrammetric methodology (camera type, overlap percentage, software used, achieved precision) to ensure replicability and verification of results.
e. For national priorities: Conduct immediate photogrammetric surveys of endangered archaeological sites and active excavations before irreversible loss occurs due to urban development, natural disasters, or inadequate preservation

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