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Digitizing the Past: The Role of Photogrammetry in Architectural Heritage Conservation

Sadik Saipi

Abstract

We live in an era where technology enhances every aspect of our lives, making work and living easier. Modern architecture has significantly evolved due to technological advancements, especially tools like BIM (Building Information Modeling). Today, innovations such as photogrammetry are revolutionizing fields like conservation, restoration, and the adaptation of existing buildings. This research focuses on photogrammetry, a method that allows for the digital preservation of architectural heritage, protecting it from decay and ensuring its future preservation. Photogrammetry offers a more efficient and time-saving alternative to traditional methods of documenting architectural heritage, which often require complex software like 3D Max, Maya, or Blender. These tools demand extensive training and time to model structures. In contrast, photogrammetry simplifies and speeds up the process, offering a more accessible solution. Additionally, photogrammetry promotes sustainability by facilitating the readaptation of existing buildings rather than constructing new ones, aligning with the Sustainable Development Goals. The best way to promote sustainability is by repurposing and revitalizing the built environment rather than expanding it. This paper explores photogrammetry's potential on a larger scale, examining its historical development, contemporary case studies, and scholarly reviews. It aims to offer new insights into the integration of photogrammetry in everyday architecture, emphasizing its importance in preserving and enhancing the built environment for future generations.

Keywords: Photogrammetry, Architectural Documentation, 3D Modeling, Technology in Architecture.

Introduction

Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena (Wolf & Dewitt, 2000; McGlone, 2004).

In areas of conservation of architectural heritage, readaptation of the built environment, digital recreation, and urban development, which are all contemporary and relevant, we don't use the best method out there. Till now we were using software to manually design and model different 3D objects, but their usage requires us a lot of time to learn and master, and even more to use them in modelling, which is time and energy consuming, and even than there is a possibility of making mistakes which will result in unreal and not completely trustworthy 3D models, but there is a solution for all of this problems and it is called photogrammetry.

Photogrammetry is a method of extracting 3D information from different inputs, like photographs, and then generating trustworthy 3D objects out of them. Generally, there are two different types of photogrammetry, based on what kind of input we provide to the software, and they are:

1. Aerial Photogrammetry
2. Close-Range photogrammetry

Aerial photogrammetry, as the name suggests, is a method of capturing aerial or high-elevation pictures of three-dimensional objects such as buildings, terrain, and even cities with different hardware like drones, aircraft, and by capturing overlapping images, using software to extract three-dimensional information. Advancements in hardware and their mass use make this really cheap and effective now days, and development of software such as different programs that have an option of machine learning and AI make this type of photogrammetry really affordable and relatively easy to learn by individuals in the field, such as architects, engineers and other relative specialists. Advanced photogrammetry software uses feature-matching algorithms and machine learning to optimize tie point identification, facilitating precise triangulation and detailed 3D models. Post-processing capabilities enable accurate maps, elevation models, and georeferenced outputs, making aerial photogrammetry a valuable tool in fields from urban planning to environmental monitoring.

Figure 1

A landscape and homes are rendered using photogrammetry software.

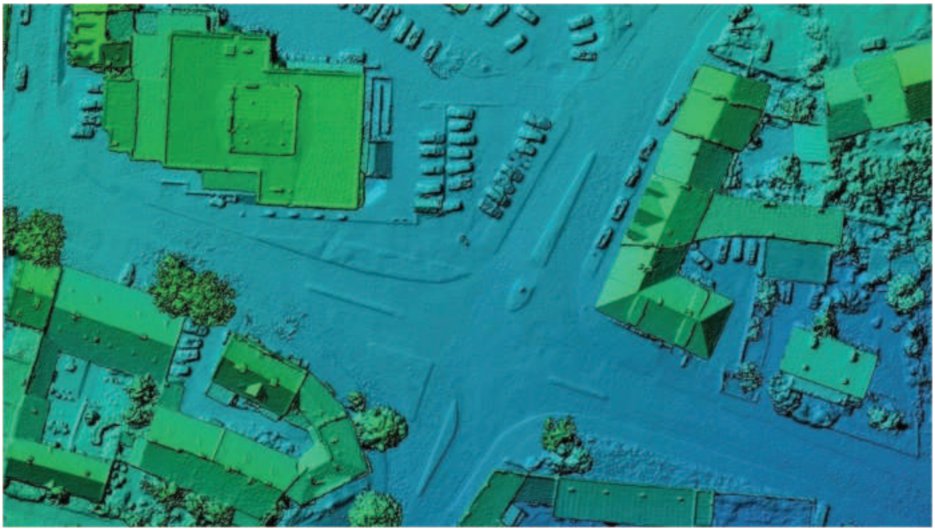
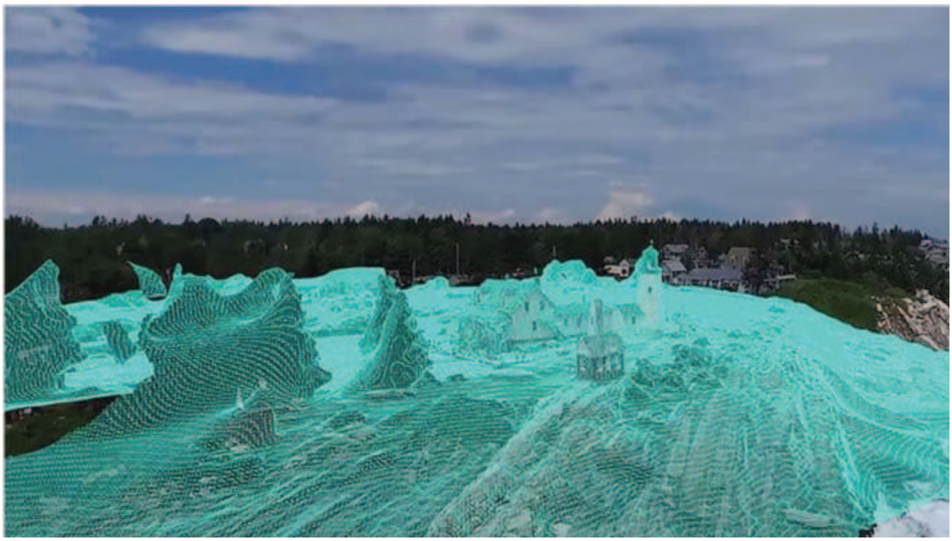


Figure 2

Image created by processing photos taken from a drone



Close-range photogrammetry is a similar method of photogrammetry, but the input is different and its usage is different from the previous one. Close-range photogrammetry, as the name suggests, is a method of capturing detailed three-dimensional input from objects that are closer to the camera, and the best use is for architectural conservation when we want to capture details of a building on the exterior or in its interior. Archaeology is another field where this method could be used. By capturing artefacts from close proximity, we can extract 3D data from the images and use it for different purposes.

Figure 3

Close-range photogrammetry

Today, a lot of software is used for photogrammetry, such as 3D Zephyr, COLMAP, Luma, RealityCapture, but leading BIM software are also implementing photogrammetry in their software, such as Autodesk with the special program used for photogrammetry called Autodesk ReCap, Revit, and Archicad. A lot of this software is free, which helps in cost efficiency and training for using this method. In this research paper, we will delve deeper into the method of photogrammetry, research relevant case studies, and discussions in contemporary scholarly discourse, and explain how this method is supposed to be used and how it will improve and help architectural practice in the contemporary world.

Literature Review

In a historical context, people developed an idea for photogrammetry long before photogrammetry existed. Projective geometry has its origins in the early Italian Renaissance, particularly in the architectural drawings of Filippo Brunelleschi (1377–1446) and Leon Battista Alberti (1404–72), who invented the method of perspective drawing. After them, Leonardo da Vinci in 1490 further developed ideas of perspective and geometry, which are the basics of photogrammetry. Many developments on perspective followed in the coming centuries; Johan Lambert, for example, in his 1759 treatise 'Perspectiva Liber' used space resection to determine the position in space from which an image was created. It was not until 1883 that the relationship between projective geometry and photogrammetry was established by Sturm and Hauck. Projective geometry is a branch of mathematics that deals with the relationship between geometric figures and the images as projected on another surface (Hauck, 1883).

During the centuries, there were a lot of developments of photogrammetry, and in 1849, we have Aime Laussedat, who is considered the father of photogrammetry, who used terrestrial photographs to conduct his first perspective architectural survey at the Hôtel des Invalides in Paris. In 1850, he used the Camera Lucida (patented in the early 1800s by Sir William Hyde Wollaston) to produce architectural surveys of the Panthemont and the Fort de Vincennes in Paris, while a year later, he started using photography. Laussedat also experimented with aerial photography using kites (1858) and balloons (1862). In 1864, the Spanish Academy of Sciences officially recognised photography as a means for topographic compilations and awarded Laussedat the Gold Medal (Granshaw, 2019). After him there is a lot of technological advancements in photography, better cameras which were used for capturing even better quality images, invention of airplane and after it different aircrafts that were used for aerial mapping of whole cities, development of digital plotters and computer which resulted in culmination of photogrammetry and in 1963 Lawrence Roberts submitted his PhD in MIT on 'Machine Perception Of Three-Dimensional Solids' which discusses the extraction of 3D information from 2D photographs. Photogrammetry, in conjunction with computer vision technologies, has provided us with new means for obtaining three-dimensional data from two-dimensional images. In 1990, the ISPRS symposium in Zurich was devoted to 'Close Range Photogrammetry Meets Computer Vision'. (Roberts, 1963.) But at the time, due to the high cost for necessary hardware equipment for photogrammetry it was a method which was used by a small group of people, but now days all of the hardware needed for it is not that expensive and it is more accessible to masses which makes this method ideal for contemporary architecture. “Photogrammetry was traditionally confined to a small community due to the high costs of equipment and specialized skills required, but technological advancements have made it accessible to a broader audience” (Kasser & Egels, 2002, p. xv). By 2008, the capability to create high-resolution 3D models from overlapping photographs had become a reality. The integration of photogrammetry with computer vision technologies allowed for the extraction of three-dimensional information from digital images, resulting in the generation of 3D point clouds and models. An early milestone in this evolution was Microsoft Live Labs’ development of Photosynth, initially introduced as an application and service in 2006 and formally released in 2008. Photosynth utilized pattern recognition to seamlessly stitch images together, extract spatial points, and produce a 3D model of the photographed scene. Despite its discontinuation, Photosynth represented a pivotal innovation in 3D reconstruction, enabling remote 3D modeling without requiring users to possess advanced photogrammetric expertise. Subsequent years saw the emergence of similar services, such as ARC 3D Webservice and Autodesk’s 123D Catch (also discontinued), which further democratized 3D modeling for non-experts. However, these platforms often functioned as “black boxes,” offering users limited control over the reconstruction process, as image processing was conducted on external servers.

In recent years, various software solutions have advanced the field of photogrammetry. Free and open-source tools such as VisualSFM, Meshroom, MicMac, Colmap, and Regard3D have provided accessible alternatives for researchers and practitioners. Proprietary solutions like 3DF Zephyr, PhotoModeler, RealityCapture, and Metashape have also gained prominence, with Metashape emerging as a leading choice for 3D photogrammetry applications, particularly in cultural heritage documentation.

Results

In this chapter we will talk about case studies of photogrammetry and see its usage in practice, I will talk about one project I did myself by using photogrammetry and it is project I did as my master thesis called “Echoes of the past visions for the future: Rethinking Kalaja fortress for the future era”, where I used photogrammetry to create 3D model of the whole fortress in few days, and I will explain process behind it.

Method of photogrammetry I used for this project is aerial photogrammetry, I used a DJI drone mini 3 pro for capturing images of the fortress with aerial perspective, plan view of it and after that photos at 45 degree angle.

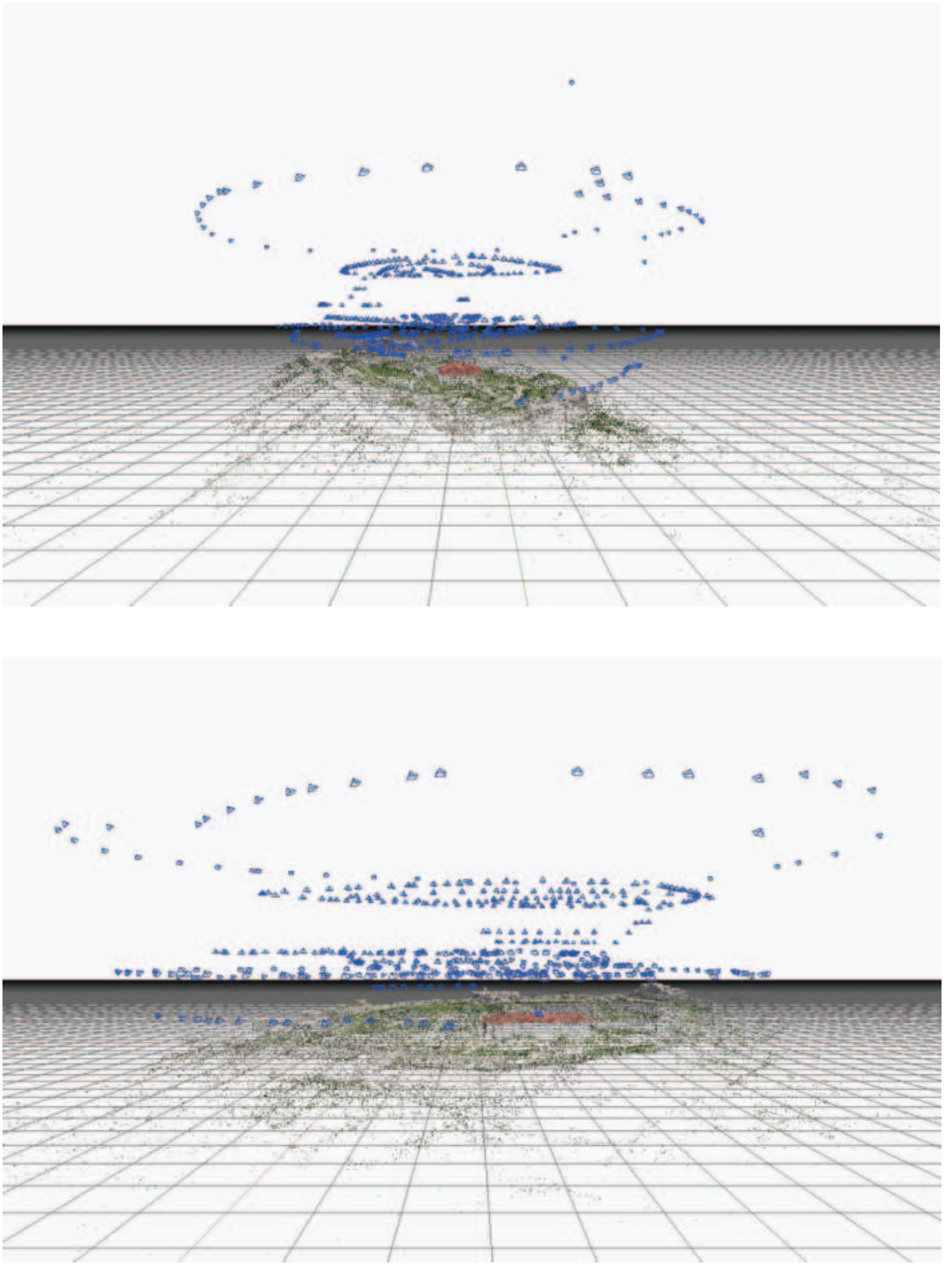
Figure 4-7

Sample images for photogrammetry

After capturing around 300 images of the fortress, from different angles, I proceeded with software part of the job. For this project I used program called 3Df Zephyr, in there I uploaded all of the images I captured and from them I extraxted point cloud which is used to continue with 3D modelling and creating a 3D mesh.

Figure 8-9

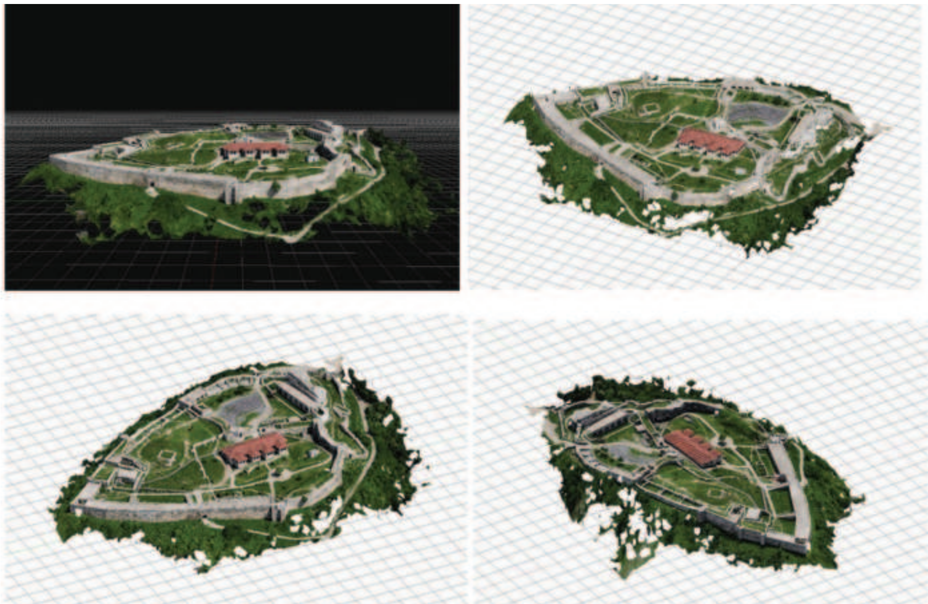
Point Cloud Extraction



After extracting point cloud from captured data, as you can see in figures above, point cloud is bellow and blue triangles represent spots from which the photos were captured you proceed with connecting the dots and generating simple mesh of the 3D object. After creation of the mesh, you extract textures from the images and apply them on the mesh and you can see the results on the following figures.

Figure 10-12

Final product textured mesh



In order to create this three dimensional object of the fortress I spent a week, because of the effectiveness of the photogrammetry I were able to do it alone, and it would took a whole group of people to do modelling manually a lot of time and resources because the whole area is around 3.4 hectares, and manually doing all of that is nearly impossible, and even than there would be mistakes during the process. In today's world, there are a lot more case studies. Italy is doing a lot of improvements in this field as they are trying to digitalize the architectural heritage they have. St. Peter's Cathedral in the Vatican, Rome, was published online last month, so anyone can virtually visit it from anywhere in the world. It was all done by the use of photogrammetry methods, a mix of both. For the exterior, they were using aerial photogrammetry, and for the interior, a mix of aerial and close-range photogrammetry. As we can see, photogrammetry proves itself better than traditional methods used for 3D modelling of existing objects, and it should be encouraged to be used and talked about more in architectural theory.

Results

The major goal of this study was to investigate the possibilities and limits of photogrammetry as a tool for recording, analysis, and restoration in architectural and historical preservation settings. Throughout this research, numerous features of photogrammetry, such as accuracy, cost-effectiveness, convenience of use, and applicability in complicated architectural situations, were critically studied.

Outcomes for this study were studied through an extensive literature review and a case study of the project I did, as well as the practical experiences of using the photogrammetry method in contemporary architectural theory. The main point of the study was to show the high accuracy of using this method in contemporary architecture and to show that it is cost-effective and less time-consuming than traditional methods used in the field today. "Digital photogrammetric workstations have simplified processes significantly, allowing engineers and technicians in other fields to perform photogrammetric work" (Kasser & Egels, 2002, p. xiv). Photogrammetry has capacity to create detailed 3D objects out of images and scans of it and sfter that used in many different puroposes such as digital preservation of architectural heritage, augmented reality and 3D walkthrough of different buildings which could be accessible throughout the world, such as mentioned Saint Peter cathedral which is now accessible worldwide, extraction of correct measurments of existing buildings, objects or terrains if there is no necessary data, and the list goes on and on on the endless possibilities this method provides us. "The use of digital images allows us to automate more and more tasks, even if a large part of the automation is still at a research level" (Kasser & Egels, 2002, p. xv).

In terms of cost-effectiveness, photogrammetry presents a promising alternative to traditional surveying techniques, especially when considering the rapid advancement of affordable technologies, such as drone-mounted cameras. "Photogrammetry was traditionally confined to a small community due to the high costs of equipment and specialized skills required, but technological advancements have made it accessible to a broader audience" (Kasser & Egels, 2002, p. xv). Photogrammetry reduces the need for costly on-site measurements, which can be particularly beneficial for large-scale or remote projects. Furthermore, photogrammetry eliminates the need for physical contact with fragile or inaccessible elements of a building, reducing the risk of further damage. The study also found that photogrammetry could significantly shorten project timelines. The automated process of generating 3D models from a set of photographs is much quicker compared to traditional manual surveying or laser scanning. This efficiency makes photogrammetry an attractive option for projects that require quick turnaround times or that involve multiple survey phases, such as ongoing conservation efforts or monitoring of construction progress. Photogrammetry's flexibility in dealing with complex and intricate architectural details was another significant advantage observed in this study. The ability to accurately capture and recreate ornamental facades, intricate carvings, and geometrically challenging forms has been explored in various studies. Despite its many advantages, photogrammetry is not without limitations. One of the main drawbacks is its reliance on a large number of high-quality photographs, which can be time-consuming and labor-intensive to obtain, particularly for large structures. Additionally, although photogrammetry is effective in capturing visual information, it may not always provide sufficient data for subsurface analysis, requiring complementary techniques such as geophysical surveys or traditional excavation methods. Another limitation lies in the software and hardware requirements for processing the images and creating 3D models. The computational power needed for photogrammetry can be expensive, and less advanced equipment may struggle to handle complex datasets, limiting the technique's accessibility for smaller-scale or underfunded projects. Future research could focus on the development of more accessible software and tools that could streamline the photogrammetry workflow while maintaining high levels of accuracy. Furthermore, the study's results point to the need for more extensive field testing, particularly in varied environmental conditions, to better understand the full range of photogrammetry's capabilities and limitations. The integration of photogrammetry with other technologies, such as Building Information Modeling (BIM), is an exciting avenue for future research. By combining photogrammetric data with BIM, it is possible to create dynamic, data-rich models that not only document the current state of a building but also assist in its ongoing management and restoration. This integration could significantly enhance the effectiveness of conservation efforts by enabling more precise monitoring and tracking of structural changes over time. In addition, the combination of photogrammetry with other data-gathering technologies, such as thermal imaging or LiDAR, could provide a more comprehensive understanding of the building's condition. Such multimodal approaches could improve the accuracy of damage assessments and inform more targeted restoration strategies.

In conclusion, photogrammetry is a powerful and versatile tool for architectural documentation and heritage preservation. It offers significant advantages in terms of accuracy, cost-effectiveness, and time efficiency. However, its limitations, particularly in terms of environmental factors, hardware requirements, and data processing challenges, must be carefully considered. Future developments in photogrammetric technology, as well as its integration with other digital tools, will likely expand its applications and improve its effectiveness for a wider range of architectural and heritage conservation projects.

Conclusion

To summarise, photogrammetry has emerged as a revolutionary instrument in the area of architecture, notably for the conservation, restoration, and adaptation of architectural heritage. The capacity to digitise and rebuild 3D models of existing structures using this approach provides unsurpassed precision, efficiency, and sustainability. Unlike traditional 3D modelling tools, which may be time-consuming and error-prone, photogrammetry enables faster and more accurate documentation, giving architects and conservators a significant tool for conserving our built environment for future generations.

Photogrammetry applications, both aerial and close-range, have increased dramatically as technology has advanced. Aerial photogrammetry, aided by inexpensive drones and software integration that uses AI and machine learning, has transformed the way we document and analyse architecture. This breakthrough not only saves time but also decreases human error, resulting in the construction of precise and dependable 3D models that are critical for conservation efforts. Photogrammetry also plays an important part in the larger discourse regarding architectural sustainability. By allowing for the modification and repurposing of existing structures, it encourages architectural heritage preservation while minimising the need for new construction, resulting in a more sustainable approach to urban development.

This study demonstrated the enormous potential of photogrammetry in building restoration and its incorporation into modern design practices. As this technology advances, it promises to affect the future of architecture by improving how we connect with, maintain, and adapt our built environment. We can ensure that historical structures are not only rescued from degradation, but also given new life in a way that respects their legacy while embracing modern advances, by continuing to explore and utilise photogrammetry.

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