DIGITIZATION OF BUILT HERITAGE THROUGH TERRESTRIAL CLOSE RANGE PHOTOGRAMMETRY: ADVANTAGES AND LIMITATIONS. ILLUSTRATION OF KSAR KENADSA SOUTHWEST ALGERIA

Ahmed Lairedj, Zineddine Seffadj

Salah Boubnider University of Constantine 3, Constantine, Algeria

Abstract: *The objective of this manuscript is to evaluate the efficacy of the methodology of terrestrial photogrammetry for the digitalization and three-dimensional modeling of the built heritage. This will be done by utilizing the case of Ksar Kenadsa as an exemplar and by contrasting the outcomes of three-dimensional modeling of the entities that arise from various alternatives of spatial and architectural arrangement.*

Keywords: *Terrestrial Photogrammetry; Digitalization; Three-Dimensional Modeling; Built Heritage; Ksar. Spatial Arrangement; Architectural Arrangement*

Introduction

Kenadsa is a city steeped in history including its ksar which is the peculiarity of ksour in southwest Algeria, thanks to its history which comes back to the arrival of Sheikh Sidi M'Hamed Ben Bouziane, to his spiritual and scientific role that represented the Zaouïa Ziania (Furon, 1958) And thanks to its spectacular architecture which is characterized by a wealth of architectural and decorative elements. This historic legacy is now largely in ruins.

Despite the multitude of research works carried out on this Ksar, it has never been digitized. The absence of modeling work slows down multidisciplinary scientific production around this legacy.

Surveys techniques have developed in the time; manual acquisition methods have gradually been replaced by digital ones. photogrammetry is one of this techniques which have been adopted and developed by architects and archaeologists since its first use by Maydenbauer in 1885 (Albertz, 2001).

This paper is about using close range photogrammetry in different spatial possibilities present in one site (ksar of kenadsa) to create 3d architectural models, then compare results in order to precise what situation is more favourable and easier to modulate from close range photogrammetry.

State-of-the-art

Many studies have explored and applied terrestrial photogrammetry, many of them have compared photogrammetry with laser scanning, (Elkhrachy, 2019) tried to evaluate the precision and accuracy of terrestrial photogrammetry by comparing photogrammetric point clouds using two cameras (Pentax and Canon) with few natural the data points attained through employment of a laser total station were utilized as control points. The findings suggest that the average disparities amid the derived three-dimensional structures and the reference points are within the bracket of 2.3 to 4.1 centimeters, in the absence of any control points. However, upon utilization of a few control points, the disparities were ameliorated to 1.4/1.6 centimeters. This research undertakes comparison of outcomes for a singular building frontage. In their 2017 study, Dhonju and colleagues (Dhonju et al, 2017) assessed the feasibility and advantages of utilizing inexpensive image-based modeling techniques for the purpose of conserving cultural heritage sites in Nepal, particularly in response to the catastrophic earthquake of 2015. The research findings suggest that this approach holds substantial promise given the multitude of historic edifices imperiled across the globe. However, it must be acknowledged that high-rise structures present formidable challenges that may necessitate the use of an unmanned aerial vehicle or comparable technology.. There are also numerous studies on image based modelling for complex modern buildings. The process of ground-based photogrammetry was juxtaposed with laser scanning in order to achieve precision in the modeling of architectural locations, as explored by Gonizzi Barsanti et al. in their study (Gonizzi Barsanti et al, 2013). Although the results were comparable, it was observed that the reliability of the accuracy in image-based modeling was not repeatable (Gonizzi Barsanti et al, 2013). The study conducted by Ippoliti and colleagues (Ippoliti et al, 2015) appraised the benefits and constraints of utilizing imagery as the foundation for architectural assessment. The location under scrutiny was a multifaceted historical courtyard. The outcome of the research demonstrated that 3D models and orthographic plans were effectively generated. However, it was discovered that the proficiency of the practitioner was an indispensable factor in the process (Ippoliti et al. 2015).

Alby et al (Alby et al, 2003) test close range photogrammetry as an architectural design tool in two different sites, where it is necessary to establish the survey of existing buildings. The use of a digitized representation in the very early phases of design allows to directly work with shapes and building volumetry, and to choose the working point of view independently of the initial photos. The utilization of the PhotoModeler software suite enables the amalgamation of digital model production within the architectural design phase. The research has facilitated the examination of compatibility concurrent with the evolution of both the digital model and the architectural project. It is imperative that each element reciprocally serves the other in a perpetual and uninterrupted evolution.

Research Content and Methodology

The aim of this work is to assess the quality of the 3d modeling performed from terrestrial photogrammetry. An evaluation that takes into consideration the representation of the different components of an architectural object which expresses a great historical and cultural value, the great importance of our object is not the only complexity that we have encountered but also its large surface and its multiples buildings which make the modeling task difficult. So our first step was to choose cases that will allow a fairly complete representation of the buildings, two selection criteria interested us, namely the spatial configuration (point, linear or surface element) and the geometric arrangement (horizontal or vertical).

After choosing the different study cases, we started taking the photographs following a logic that supports the coverage of the entire object in question. For this we used a Nikon 3300 digital SLR with a wide angle lens set at 50mm. The number of photos depends on the size and complexity of the object and the photos were taken in RAW format.

Then we proceeded to the modeling of each case using the AGISOFT PHOTOSCAN software which allows the realization of 3d models from photographs, the models were created by fixing the same configurations in order to be able to compare them reliably. After the completion of the 3-dimensional model, we proceeded to its explication with regards to several facets, specifically its geometric aspect, texture and colors. Each of these three aspects encompasses a number of concrete indicators. The description is based on the observation of the 3d model and the analysis of this model using the CLOUDCOMPARE software.

The next step is to compare the different 3d models by fixing the same aspects and indicators used in the description phase, for this we have built a comparison grid and relate the different cases and the different aspects. The grid was filled in with precise, brief language and expressions which above all allow the differentiation of preferences.

During the conclusive phase, the primary objective would entail the interpretation of findings and the subsequent response to the central focus of the investigation. This would involve demonstrating the constraints as well as the advantages inherent in the application of terrestrial photogrammetry as a tool for digitalizing and generating 3D models of architectural heritage structures.

Different Cases Choosing

The ksar of Kenadsa embodies an ancient settlement with a diverse range of functions, encompassing residences or individual dwelling units (referred to as "DIOR" in arabic), lodgings for guests (known as "douiriya"), a religious school (Zaouia), and a mosque. The coexistence of these functions has resulted in a remarkable abundance of architectural and ornamental features.

Conducting an architectural survey of the ksar through the use of close-range photogrammetry techniques presents an opportunity to explore various spatial contexts and configurations. The outcomes of these investigations necessitate further inquiry, comparing and contrasting the results to gain a deeper understanding of the effectiveness and limitations of this approach for architectural surveying and three-dimensional modeling within this region.

- **First case:** Double height planar form (a courtyard house with one floor)
- **Second case:** Horizontal element "long facade" (arcades gallery of the mosque)
- **Third case:** Vertical element "tower" (the old mosque minaret)
- **Fourth case:** punctual element “monument” (Mosque entrance).

Logic of Photography Campaign

First Case

At the two levels of the building, we captured comprehensive 360° images from four distinct angular points, which were connected by four linear pathways (Figure 1-A-).

Second Case

The photographic images were captured in a sequential and coherent manner, maintaining a consistent and concurrent orientation with the gallery space. The camera apparatus underwent a systematic rotation, both horizontally and vertically, in order to achieve a comprehensive and all-encompassing depiction of the subject matter. The horizontal alignment of the photographic frame was specifically and meticulously guaranteed through the deliberate and precise manipulation of the horizontal axis. (Figure 1-B-).

Third Case

The photographic constraint, as it were, is a complex and multifaceted phenomenon that poses significant difficulties in framing the object vertically due to its immense height, as well as the fact that the four vertical walls of the object in question are illuminated in a dissimilar manner and are only partially captured by photographic means.

The photographic images were captured utilizing a multi-image technique (Figure 1-C-) that encompassed the entirety of the object. The vertical framing of said images was accomplished, in part, through the subtle manipulation of the capture angle. Furthermore, a portion of the photographic images were obtained remotely from the vantage point of the terraces of adjacent structures, attributable to the inherent inaccessibility of the immediate surroundings.

Fourth Case

During the course of the photographic campaign, the object in question is regarded as the focal point of a multitude of semicircles. The resultant photographs were generated utilizing the technique of multi-image rotation (Figure 1-D-).

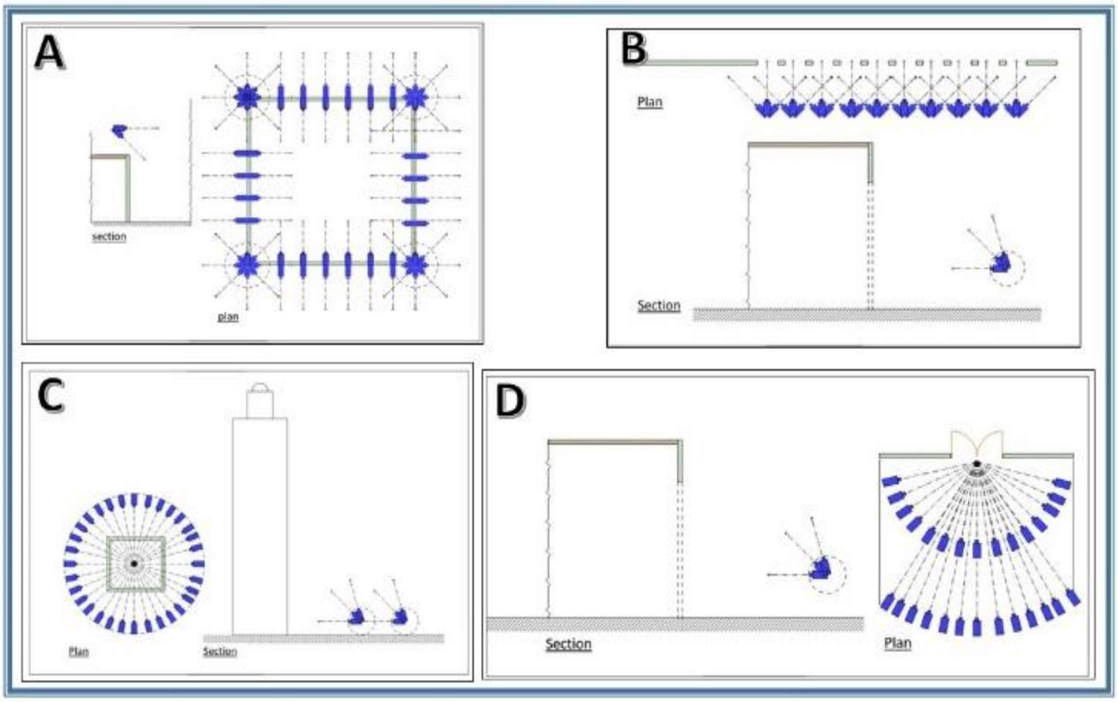

Figure 1. Camera orientations and diagrams of photography campaign: A- In the courtyard house, B- in the arcades gallery, C- at the minaret, D-At the mosque entrance.

Results

3d Models Description and Analysis

First Case

The model that is generated as an outcome of the procedure, as depicted in Figure 2, encompasses the entirety of the object, demonstrating a high degree of geometrical accuracy without any significant distortions. The polygons that are used for connecting purposes provide sufficient coverage of the entire model and effectively capture the essence of the object under consideration. The colors that are utilized in the model are not only aesthetically pleasing but also serve as an accurate representation of the object. Moreover, the model's textures have been crafted in such a way as to replicate the natural characteristics of the materials employed in the construction of the object, with the reliefs capturing their visual features. It is noteworthy that the model does not cover the components situated in the interior galleries of the patio, as well as the rooms that were not captured in the photography campaign.

The verdant hue that envelops the three-dimensional representation depicted in figure 3 serves as incontrovertible evidence that on the majority of surfaces, an individual has the ability to detect a solitary adjacent point within every 0.35 square meters of space. This particular finding is especially noteworthy when one takes into account the relatively low cost of the equipment utilized, as well as the complexity and sheer size of the object in question. As for the portions of the visual representation that are shaded in blue, these regions correspond to the areas that have been captured by way of photographs. One may also observe certain sections that are tinged with a sunny yellow hue; this chromatic alteration signifies that the model itself actually presents a greater quantity of neighboring points per 0.35 square meters of surface area.

Figure 2. Courtyard 3d model obtained from texture-mapping.

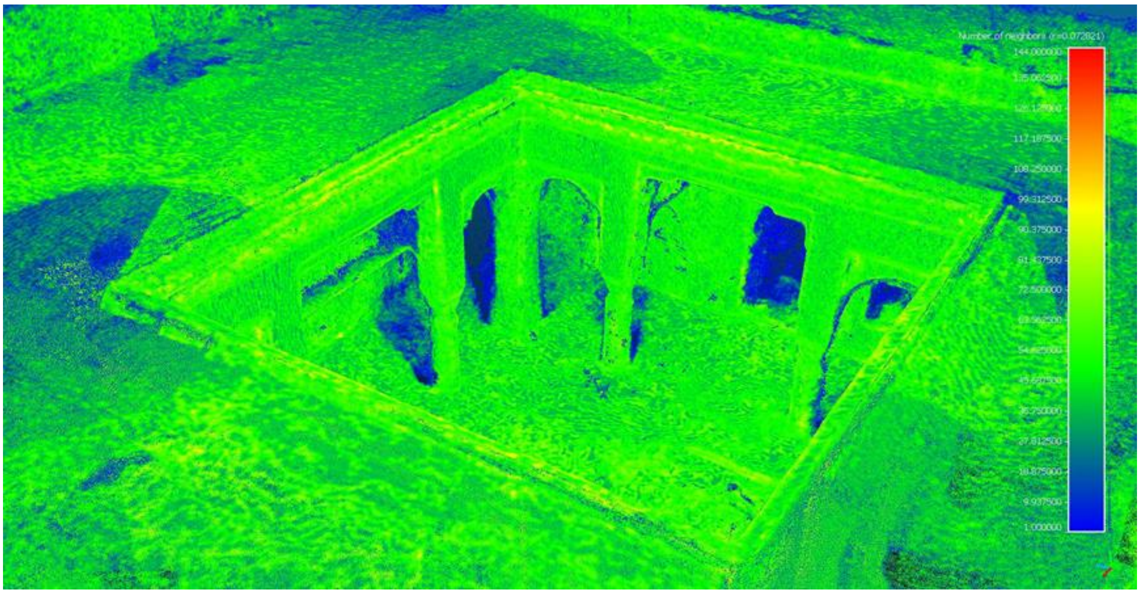

Figure 3. Number of neighbors calculation of courtyard 3d model obtained using CloudCompare.

Second Case

The model that ensues comprehensively encompasses the entirety of the object (figure 4). It dutifully portrays the linear and curvilinear attributes of the arcs. The polygons that constitute the surface are meticulously delineated.

Figure 4. Arcades gallery 3d model obtained from texture-mapping.

In the recesses of the gallery, one may encounter incomplete modeling as it remains unaffected by the acquisition. The hues that adorn the model are strikingly verisimilar, and the textures are deemed satisfactory.

The exterior portion of the arcades displays a commendable level of modeling, with an average number of neighbors present at a ratio of one point per 0.35 m2. This observation is solidified by Figure 5, where the most notable feature is the verdant hue present in the exterior section of the gallery. However, the photography campaign did not extensively cover the depth of the gallery, leading to a scarcity or complete absence of neighbors in this area.

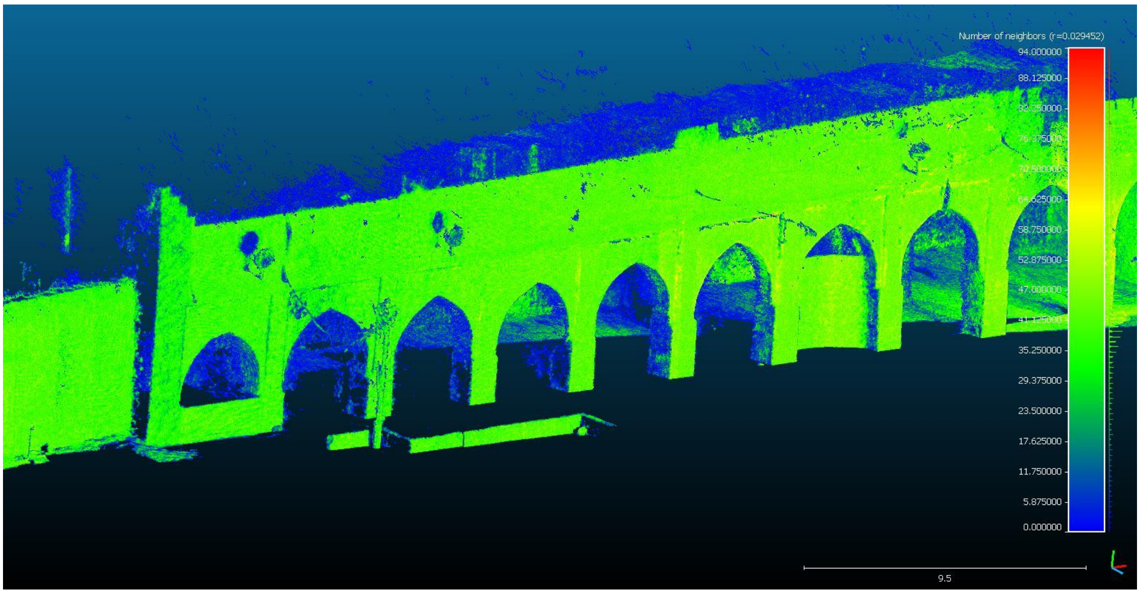

Figure 5. Number of neighbors calculation of arcades gallery 3d model obtained using CloudCompare.

Third Case

The model, in its current state, exhibits an inability to encapsulate the entirety of the object in question. While its geometric dimensions align with the proportional requirements of the object, a significant portion of the data remains unrepresented. Only a mere two walls out of a total of four have been deemed satisfactory in their modeling. Furthermore, the number of polygons pertaining to the connections has been minimized and subsequently distorted upon scaling. The utilization of authentic colors is present; however, the textures at the base of the model are more intricate in detail, whereas those situated towards the upper region of the model are less intricate.

Figure 6. courtyard 3d model obtained from texture-mapping.

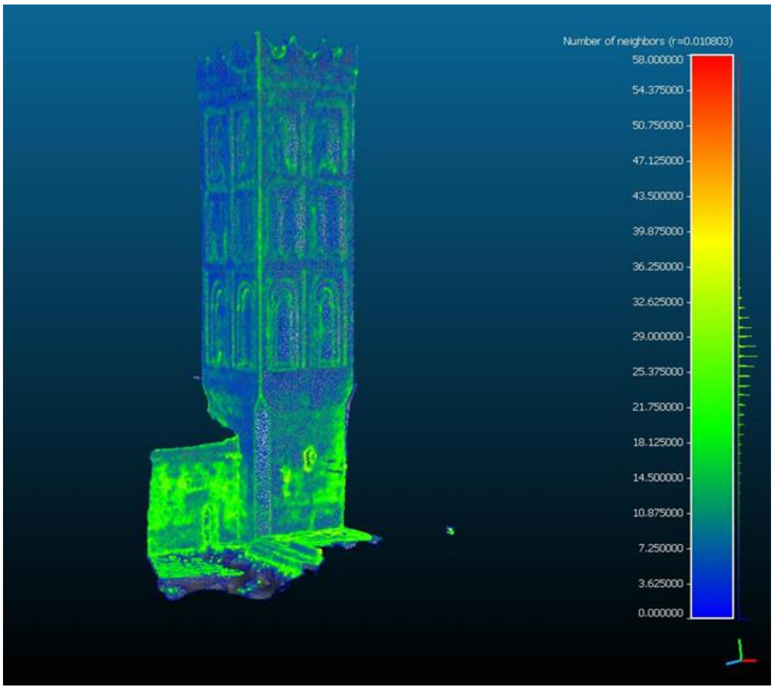

Figure 7. Number of neighbors calculation of minaret 3d model obtained using CloudCompare.

In the lowermost segment of the minaret, the density of neighboring points attains its maximum value, as indicated by the green markings in Figure 7, with a rate of one point per 0.35 square meters. Conversely, as one ascends to the uppermost portion, the number of points gradually diminishes. The further away we are from the point of capture, the more the 3d model becomes less real and offers us less information.

Fourth Case

The model covers the entire object without any geometric imperfection; the polygons cover the entire surface of the model and represent the recesses of the decorative patterns.

The model's white coloration is comparable to that of the object with the wall's decoration being accentuated by the shadow effect. The authenticity of the material's texture is decidedly acceptable, effectively conveying the nature of the object.

Figure 8. Mosque entrance 3d model obtained from texture-mapping.

After calculating the neighbors in the 3d model of the entrance to the mosque, we notice that they are well distributed and encompass the entire surface of the object. The existence of the blue color in figure 9 which represents the minimum number or the non-existence of neighbors is very limited, it is found in the depth of some sculptures and intrados.

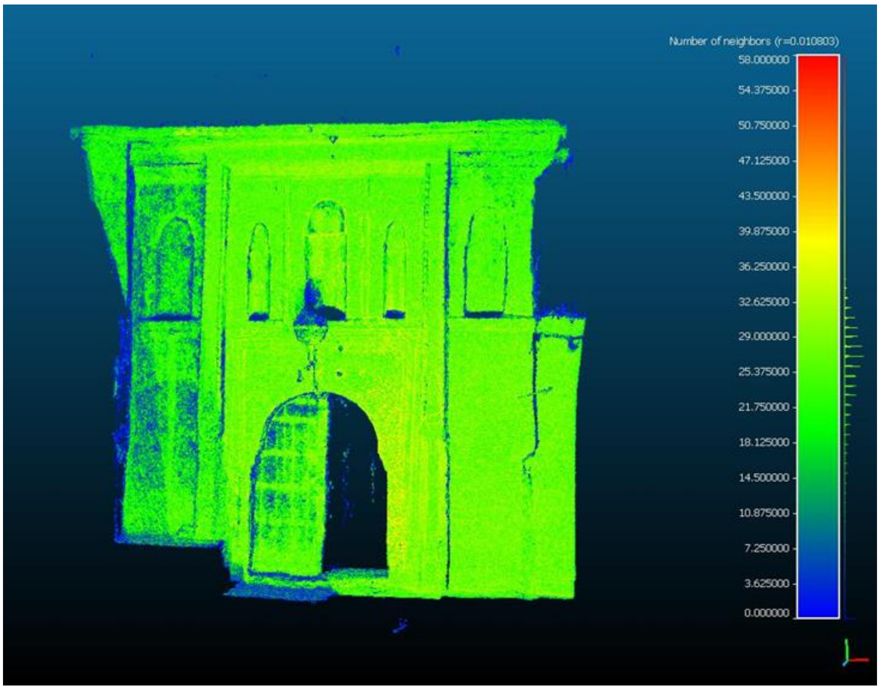

Figure 9. Number of neighbors calculation of mosque entrance 3d model obtained using CloudCompare

		First case Courtyard house	**Second case Arcades gallery**	**Third case Minaret**	**Fourth case Mosque's entrance**
Geometrical aspect	Precision	Quite precise	Quite precise	Not precise	Precise
	Shape deformation	Less distorted	Not distorted	Too distorted	Not distorted
	Number of neighbors	Almost sufficient	Almost sufficient	Insufficient	Sufficient
Textures aspect	Material	Representative	Representative	Not representative	Representative
	Relief	Real	Real	Not real	Authentic
	Reflection	Real	Quite real	Not real	Authentic
Colors aspect	Contrast	Good	Good	Good	Very good
	Sharpness	Clear	Clear	Less clear	Very clear
	Brightness	Real	Real	Not Real	Not Real

Table 1. A comparative analysis charting the varied 3-dimensional models in accordance with their respective geometric, textures, and colors aspects.

Conclusion

The comparison of the different models created using terrestrial photogrammetry in table 1 shows us that the best result obtained is that of the mosque entrance, with the three aspects of geometry, texture and color closely reflecting the object in question. The outcomes of the three-dimensional modeling of the gallery and the patio abode exhibit a high degree of similarity in terms of their representational fidelity. The two prototypes procured are quite faithful to actuality, albeit with certain distortions. The model of the minaret is the least representative of the results with significant deformation and a number of missing parts.

The interpretation of results obtained by our experiment in Ksar Kenadsa allowed us to evaluate the usefulness of the technique of terrestrial photogrammetry for the architectural objects modeling and digitalization. We can say that at least two factors related to the architectural object are important for choosing 3d modeling using the technique of terrestrial photogrammetry:

The distance from the object: the greater the distance from the object, the more the result will not be perfect. This distance manifests itself as a constraint during the photography campaign either by a great height such as the case of a vertical element with a considerable height or inaccessibility of the object in question due to physical obstacles or other type of constraints.

The object size: a limited size of the architectural object favors and facilitates its photographic coverage consequently the 3d model will be representative. The larger the size of the object, the more complicated the photographic coverage task will be and the number of photos increases, which also complicates the generation of the 3d model.

References

Albertz, J. (2001). ALBRECHT MEYDENBAUER, PIONEER OF PHOTOGRAMMETRIC DOCUMENTATION OF THE CULTURAL HERITAGE. XVIIIth International Symposium CIPA 2001, 18-21 Septembre 2001 Potsdam. Germany. pp. 19-25.

Alby, E.; Grussenmeyer, P.; Perrin, J.-P. (2003). Integration of close range photogrammetric surveys in the design process of architectural projects, CIPA XIXth International Symposium, 30 September- 4 October 2003, Antalya, Turkey “New perspectives to save Cultural Heritage”, pp.46-51

Dhonju, H. K.; Xiao, W.; Sarhosis, V.; Mills, J. P.; Wilkinson, S.; Wang, Z.; Thapa, L.; Panday, U. S. (2017). Feasibility study of low-cost image-based heritage documentation in Nepal. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 42(2W3), pp. 237–242. DOI: https://doi.org/10.5194/isprs-archives-XLII-2-W3-237-2017

Gonizzi Barsanti, S.; Remondino, F.; Visintini, D. (2013). 3D SURVEYING AND MODELING OF ARCHAEOLOGICAL SITES – SOME CRITICAL ISSUES –. ISPRS Annals of

Photogrammetry, Remote Sensing and Spatial Information Sciences. II-5/W1. pp. 145-150. DOI: https://doi.org/10.5194/isprsannals-II-5-W1-145-2013

Ippoliti, E.; Meschini, A.; Sicuranza, F. (2015). Structure from motion systems for architectural heritage. A survey of the internal loggia courtyard of palazzo dei capitani, ascoli piceno, italy. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 40(5W4), pp. 53–60. DOI: https://doi.org/10.5194/isprsarchives-XL-5-W4-53-2015

Elkhrachy, I. (2019): Modeling and Visualization of Three Dimensional Objects Using Low-Cost Terrestrial Photogrammetry, International Journal of Architectural Heritage, 14:10, pp. 1456-1467. DOI: https://doi.org/10.1080/15583058.2019.1613454

Furon, R. (1958). Le Sahara, Edition Payot. Paris

LAIREDJ Ahmed

Architecture Department, University Salah Boubnider, Constantine, Algeria,
Architecture Department, University Tahri Mohamed, Bechar, Algeria

LAIREDJ Ahmed; N 08 city of teachers 70 houses Lahmar road, Bechar,Algeria

ORCID https://orcid.org/0000-0003-2688-5786

lairedjahmed@gmail.com

corresponding author

SEFFADJ Zineddine

Architecture department, university Salah Boubnider, Constantine, Algeria

zseffadj@gmail.com

Received: 18 July 2023
Accepted: 29 August 2023
Published: 08 December 2023
DOI: https://doi.org/10.55630/KINJ.2023.090201

Translation of abstract and keywords into Bulgarian

Резюме: *Целта на това изследване е да се оцени ефикасността на методологията на земната фотограметрия за дигитализация и триизмерно моделиране на сградното наследство. Това ще стане по примера на Ksar Kenadsa като обект и чрез контрастиране на резултатите от триизмерното моделиране на елементите, които се появяват в различни алтернативи на пространствено и архитектурно подреждане.*

Ключови думи: *Наземна фотограметрия; дигитализация; триизмерно моделиране; сградно наследство; Ksar. пространствено подреждане; архитектурно подреждане*

KIN Journal, 2023, Volume 09, Issue 2

Science Series Cultural and Historical Heritage: Preservation, Presentation, Digitalization

Научна поредица Културно-историческо наследство: опазване, представяне, дигитализация

Научная серия Культурное и историческое наследие: сохранение, презентация, оцифровка

Editors	Редактори/съставители
Prof. PhD. Petko St. Petkov	проф. д-р Петко Ст. Петков
Prof. PhD. Galina Bogdanova	проф. д-р Галина Богданова
Copy editors	**Технически редактори**
Assist. prof. PhD. Nikolay Noev	гл. ас. д-р Николай Ноев
PhD. Paskal Piperkov	д-р Паскал Пиперков
© Editors, Authors of Papers, 2023	© Редколегия, Авторски колектив, 2023
Published by	**Издание на**
Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences, Sofia, Bulgaria	Институт по математика и информатика при Българска академия на науките, София, България

http://www.math.bas.bg/vt/kin/

ISSN: 2367-8038