Architecture
Image Studies
AIS Scientific Journal

Vol.6 , Issue 1, Territories, 2025

Drone-Based 3D Modeling for the Conservation and Restoration of Heritage Buildings

Dr. F Rahman, Assistant Professor, Department of CS & IT, Kalinga University, Raipur, India. E-mail: ku.frahman@kalingauniversity.ac.in

Ashu Nayak, Assistant Professor, Department of CS & IT, Kalinga University, Raipur, India. E-mail: ku.ashunayak@kalingauniversity.ac.in

Abstract
The technology to assess this nation's local architectural legacy must be lightweight, effective, and adaptable. Economical drones and Structure-from-Motion (SM) methods can fulfill these requirements. Recent research utilizing nadir photos from economical drones and SM methods has demonstrated favorable metric outcomes (achieving centimeter-level precision) modeling two-dimensional items (properties, rooftops, and facades). Constructing a comprehensive 3D model of past buildings is highly desirable, necessitating a camera system capable of producing nadir and side views with varying starting points. The findings demonstrated that the drone-derived modeling is accurate for most measuring. The precision and thoroughness of the 3D model facilitated the execution of Historic Buildings Information Modeling (HBIM) and deformation of structures research. The information was amalgamated with geographic information (landscape and architecture), enabling visualization, administration, and assessment at a broader scale. Given the affordability, portability, and comprehensiveness of drone and SM, this instrument holds the potential for studying historical legacy.

Keywords – 3D Modeling, Drone, Restoration, Heritage Buildings, Conservation

1. Introduction

Architectural heritage symbolizes a region's personality, linking the past to the present by embodying local culture comprehensively [1]. It plays a crucial function in maintaining the link between individuals and the past context of an area. Architectural history is an irreplaceable asset to the advancement of civilization and serves as a crucial repository of a nation's past. Building a legacy, a vital element of equitable growth, holds substantial cultural, economic, and scientific importance [2]. Recording and safeguarding architectural treasures are essential for preserving national culture's preservation and continuation within equitable growth. Various challenges, including architectural decay, environmental alterations, pollution, harmful building techniques, and conflicts, jeopardize the long-term health of the built environment, resulting in its loss and even annihilation [21]. It is imperative to implement strategies that foster the sustainable conservation and use of the built environment.

The application of geomatic technology to Cultural Heritage (CH) has an extended history [4]. The advantage of employing these techniques lies in their capacity to record the present condition of heritage objects and offer insights into their historical context. Drone photography provides measurement tools characterized by adaptability, dependability, security, and user-friendliness [5]. These devices can be used within minutes; starting points can be offered on-site, and final precise figures are computed swiftly, often utilizing online resources.

With the proliferation of digital pictures, Computer Vision (CV) commenced the development of algorithms capable of orienting a succession of pictures [6].

Integrating standard image introduction techniques in photography with novel methodologies has facilitated the acquisition of precise 3D models, leveraging the high degree of computerization in computer vision without necessitating prior knowledge while simultaneously employing demanding geometric frameworks and models established through conventional photography [24].

The significance of developing 3D models is broadly acknowledged for collecting metric and geometrical data, although they present other options for utilization [8]. They can facilitate the generation of conventional 2D plant and section depictions, as well as serve as sources for Geographic Information Structures (GIS) [9], Building Informative Models (BIM) [10], Virtual Reality (VR) [11], and 3D printing [12] equipment to produce actual reproductions. 3D models provide a chance to examine artworks, as analyses are conducted directly on digital copies, potentially yielding fresh perspectives and information.[26]. From an architectural standpoint, the prior creation of a 3D model can serve as an excellent asset for executing a precise and effective treatment.[3].

2. Background

The amalgamation of economic drones with Structure-from-Motion (SM) methods enhances the documenting of historical buildings by offering more versatility and broader coverage [22]. A drone system equipped with many cameras is more effective for picture acquisition; nevertheless, it is significantly more costly and requires a license for usage in many nations. Inexpensive drones render low-altitude picture acquisition accessible and feasible for customers with constrained budgets. SM techniques created by the artificial vision industry simplify the image-based modeling procedure.[13]. Integrating drones and SMs facilitates the 3D modeling of extensive and intricate architectural landmarks by utilizing cost-effective and highly flexible image libraries. The latest research evaluating the precision of the drone-SM approach for documenting historic buildings has addressed three factors: the calibration of cameras, camera system, and Ground Command Points (GCPs) with established geographic coordinates [14].

Camera calibrating is essential for quantitative 3D reconstruction utilizing images. The camera's internal properties, such as main points, focal length, and radial lens distortion, are extracted during the procedure [24]. Photography and visual computing groups adopt distinct methodologies for camera calibration, contingent upon their research aims. The photogrammetry industry favors an independent calibrating technique before aligning the image to attain enhanced accuracy.[15]. Coded objectives are typically employed to improve the human or semi-automated identification of objectives [16]. The machine vision community utilizes concurrent calibration of cameras and picture alignment for automated tasks. This process is referred to as self-calibration.[25]. Objectives are unnecessary for self-calibration, as a feature-based measurement of cameras is performed using the identical photos employed for modeling the object.[7]. Feature-based calibration of cameras is used in historic building surveys as it accelerates outdoor measurement procedures and eliminates the necessity of positioning targets in hard-to-reach locations.

Aspects that enhance the precision of feature-based calibrating encompass a converging camera system with a substantial Baseline-to-Depth (B/D) proportion, fluctuations in picture size, and a profusion of detectable characteristics on surveyed objects [17]. The camera system pertains to the geometrical connections between the surveyed items and the picture block. It has a significant impact on the precision of feature-based calibrating.

Using nadir pictures for two-dimensional objects (e.g., rooftops or facades) in planning a camera system is relatively uncomplicated, as it primarily involves a limited number of considerations, including image overlapping and Grounding Sample Durations (GSDs) [18]. The situation becomes even more intricate when dealing with 3D items necessitating a converging sensor network utilizing oblique views. Factors like lens rotation, picture scale, and light changes affect metric accuracy.

Most surveys for historic buildings have utilized solely nadir photos. Roofs and facades are individually shot and sculpted. This method is impractical for documenting historical buildings due to the intricate nature of items and the necessity for fieldwork effectiveness. The predominant need is a comprehensive camera system capable of generating a complete 3D rendering. In airborne image-based surveying, outside factors are employed to geo-reference 3D outputs and reduce potential camera system distortion during bundle correction.

The Global Positioning Services (GPS) integrated into low-cost drones are now unreliable. GCPs are extensively utilized for enhanced precision [19]. They can be recorded with a complete station, electronic/ optical equipment used in contemporary mapping, manually positioned targets, or natural characteristics of the surveyed item. The entire station typically measures targets with a precision of approximately 1.5 mm; variations in device efficiency, proximity to the goal, and operator error yield differing readings. An extensive array of accurate and uniformly dispersed GCPs improves the precision of surveys.

This study employs a meticulously built converging image system, incorporating feature-based camera measurements and extensive GPS, to guarantee metric precision necessitated by the necessary field productivity and challenging conditions of assessing heritage buildings [20]. This study evaluates the dependability of the technique for determining historic buildings and its feasibility as a cost-effective, lightweight, and adaptable substitute.

3. **Drone-based picture-gathering model**

The unmanned aerial vehicle employed was a DJI Phantom 4 quadcopter drone outfitted with a digital camera. The 35 mm comparable lens signifies a significant enhancement compared to earlier models, as the wide-angle optics often employed in inexpensive drones produce pictures with pronounced radial aberrations that diminish the measurement quality of structure-from-motion restorations. The rotatable wings facilitate flight and landing in confined areas and can be controlled by a single individual. The battery allows for an optimal flying duration of 25 minutes at low altitudes; the permitted flight duration decreases to 15-25 minutes due to the reduced atmospheric density. The crucial task is the acquisition of photos, as both sensor calibration and 3D modeling depend on the identical set of images. The comprehensive camera system must fulfill feature-based calibrating requirements, enhance metric precision, and ensure adequate picture overlap. Several principles govern the capture of images: (1) the 3 x 3 rule of photography, which stipulates that a minimum of three photos must represent each necessary surface to ensure fullness, and (2) an increased B/D proportion to enhance metric precision.

These guidelines developed a camera system characterized by substantial picture overlap. Due to unpredictable yet bright sunshine, all photographs were captured during an inclement time to mitigate the adverse impacts of fluctuating light, such as heightened contrast among surface shades of gray and elevated sensor distortion. While inadequacies can be addressed with a picture's pre-processing approach that includes color balance, picture blurring, and color transformation, it is prudent to ensure constant illumination circumstances if a prolonged wait is feasible.

The Phantom 4 drone facilitates flying along a predetermined trajectory; however, this proved impossible due to the accuracy of internal model and the continual alterations in lens alignment. Six flights were conducted manually, resulting in disparities between the actual camera system and an optimal camera network. To rectify this issue, 360 photos were acquired; after eliminating duplicate and hazy photographs, only 320 were utilized for models. The device's limited sensor size necessitates minimal intervals between picture-capturing spots and items to provide an optimal Ground Sampling Delay (GSD). The lengths vary from 10 to 25m, with associated GSDs from 4.5 to 8.5 cm.

This research employed ground surveys with a total station to assess the quantitative precision of the technique.

- Assessment of GCPs

A measuring and control system was created to acquire a ground control point. Fifty-five uniformly dispersed GCPs were surveyed using a total system. The organic elements, such as the edges of murals on the stupa, were utilized because they tend to be more enduring than print marks for future possible measures for comparisons.

- Laser Scanner

The precision of a drone-derived simulation was evaluated against the ground reality models produced. Field tests were conducted at 11 sites utilizing high/ medium precision with a Leica ScanStation C10 and an additional webcam. The supplier states that the precision in this range is 4-6 mm. The utilization of the outside camera significantly reduced the necessary field duration; however, each station still necessitated 10-20 minutes. The total duration for completing the scanned operation was around 5 hours, primarily transporting the scanning device and establishing pre-scan sites on the uneven terrain surrounding the stupa.

- Processing data

Automatic image-based analysis was conducted using the Agisoft PhotoScan program. The machine-learning methods included the retrieval of image roles, the creation of sparse and dense scores, mesh construction, texture visualization, and the production of Digital Environment Modelling (DEMs). The 50 models detected via all stations, were individually allocated to their respective places on the detailed models. The geometric connections between the retrieved picture fragments and the 3D structure were improved by utilizing the spatial coordinates of the GCPs. This process is referred to as Bundle Modification.
A sealed mesh area was created from the point clouds using the Tested Poisson technique, which guaranteed that the radius from the drone-derived modeling and the modeling was calculated via a points-mesh comparison rather than a points-point analysis. The points-mesh assessment ensured that the estimated range was the closest one connecting the two theories, unaffected by point intensity.

4. Results and Findings

This section presents the reconstruction of the 3D model. The outcomes are juxtaposed with the design recreated with alternative commercial programs. Historical conservation professionals' contentment regarding the restoration quality and the singular drone-based 3D modeling is presented herein.

4.1 Attendees

Respondents were selected using the virtual snowball selection technique. This method is particularly beneficial because it effectively broadens the geographic scope and connects with those experiencing accessibility issues. The justification for utilizing the online snowball sampling approach is its ability to increase the sample size while improving representation, as it facilitates control over the amount and variety of replies during the entire procedure.

Utilizing the method of snowball sampling, the research first identified the primary participants, who acted as related participants and were selected among the acquaintances of the investigators and participants who participated in the aforementioned pilot research. The research immediately performed an eligibility evaluation for the referral sources. The research chose a cohort of ten people who indicated their readiness to serve as study assistants in the survey distribution. Fifteen helpers were allocated across multiple nations, guaranteeing extensive regional coverage. Email, WhatsApp, WeChat, and other digital social tools mainly distributed the survey.

To preserve the group's representation, the research endeavored to control the recommendation chain's orientation about educational levels and regions to the fullest extent. The research collected a total of 64 replies, thereby meeting the required sample size. All respondents were notified that their involvement in the study was optional. The answers provided demonstrated a notable degree of representation, especially for educational attainment and geographical locations. To ensure data quality, three replies were removed due to inadequate quality, evidenced by trends such as consistently choosing the first option for every query and exceedingly brief responses of under five minutes. This rigorous filtering approach culminated in a dataset including 61 correct answers.

4.2 3D reconstruction

The rebuilding process was performed on an NVIDIA GPU. Two hundred forty-eight photos were processed using CU-Recon and Colmap to recreate the 3D point cloud. The program Colmap encountered a failure in this reconstructing effort, necessitating increased memory for the same quantity of pictures. The software Colmap encounters a constraint resulting in an “out of storage” error. The rebuilding scope for DJI Terra must be selected first. The recreation in DJI Terra exclusively depicts the structure, omitting the surrounding environment. DJI Terra is significantly constrained in its reconstructing technique due to the absence of the GPS, as it depends on picture alignment.

The research thoroughly rebuilt all features, encompassing structures, furnishings, scenery, and texturing. The intricate surface details of the old edifice and its environs are accurately depicted. The depth mapping makes the clarity of edges and distinct limits more pronounced. The software possesses superior quality of 3D geometrical data compared to other rebuilt versions. CU-Recon generates the most distinct textures, exhibiting the least distortions compared to all other solutions.

The outcomes in DJI Terra indicate an incomplete restoration of the façade because of poor point distribution. The visualization findings indicate that Metashape and Pix4D cannot generate a comprehensive model of the examined historical structure. The outcomes of the two programs exhibit a more significant loss of information in the main framework. The result of Pix4D is overly simplistic, leading to increased noise. The rebuilding time in CU-Recon is considerably quicker than that of other programs. The software demonstrates outstanding efficiency and adaptation capability when faced with a hitherto unencountered large-scale historical legacy without post-processing.

Table 1. Fundamental details of the responders

Questions	Count	Percentage
Mean age	32.4	-
Median age	34.2	-
SD age	13.4	-
Men	40	50
Women	40	50
1 to 5 years working experience	25	31.25
6 to 10 years working experience	35	43.75
> 10 years working experience	20	25
Bachelor degree	45	56.25
Master degree	25	31.25
Ph.D. degree	10	12.5
Working in developed country	15	18.75
Working in developing country	65	81.25

4.3 Fundamental details on the participants

Eighty valid respondents completed the survey. Fundamental data regarding the participants was gathered and organized in Table 1. The average age is 32.4 years, and 50% of the respondents are male. All respondents possess expertise in heritage conservation. Twenty respondents have over ten years of experience in historic protection, representing 25% of the total. 43.75% of respondents have over five years of professional experience in this domain. 31.25% of respondents have employment experience over the last 5 years. Twenty-five individuals had a master's degree, while most were Ph.D. students expected to obtain their degrees within three years. 12.4% of participants hold a Ph.D. degree. Among the respondents, 18.75% are employed in wealthy nations, while the remainder are engaged in emerging economies.

Table 2. Drone experience analysis

Question	Average
Having drone?	0.52
Having drone license?	0.38
Having drone working experience?	0.81
Having images of construction with drone?	0.31

The outcomes of the drone operation are presented in Table 2. The findings indicate that the average score for "Do you own one drone?" is 0.52. Forty-two percent of the respondents possess a single drone. Only 23% of respondents had a drone operational certification. This is due to the absence of regulatory frameworks for drone operations in many nations. Despite the implementation of pertinent restrictive regulations by numerous countries, implementation remains relatively lenient. The proportion of respondents possessing a single drone operational license is exceedingly low. In response to the inquiry "Have you handled drones before?", the mean answer is 0.81, indicating that 81% of respondents possess experience operating a drone. It significantly exceeds the average figure of the general population, which Is about 38%. The study prioritizes the pleasure of photographing structures with aerial vehicles, explicitly focusing on using a single drone to document architectural history. In contrast to the 81% of respondents who piloted the drone, 31% possessed experience photographing structures with unmanned aerial vehicles.

4.4 Satisfaction Level

Table 3. Satisfaction analysis of 3D ulfilmen

Questions	Average	SD
Clearness	3.7	1.5
Precision	4.1	0.7
Integration	4.7	0.5
Authentication	4.3	1.5

The evaluation of customer satisfaction regarding the 3D recreated model produced by CU-Recon encompasses four dimensions, with average satisfaction values displayed in Table 3. The poll results indicated an average score of 3.7 and a standard variation of 1.5 for the clarity of the rebuilt picture. Respondents engaged in preserving heritage exhibited the lowest happiness regarding clarity across the four assessed dimensions, with professionals favoring generated mesh representations over 3D point clouds. The mean approval rating from the questionnaire about the correctness of the 3D cloud of points is 4.1. The average satisfaction rating regarding the honesty of the 3D point cloud is the greatest amongst the four objects, at 4.7, accompanied by a slight mean variance of 0.5, signifying a consistently high degree of satisfaction with authenticity. Moreover, respondents reported an average happiness level of 4.5 regarding genuineness.

The evaluation of respondent satisfaction for the two imaging methods is founded on three criteria. The findings are presented in Table 4. The degree of satisfaction across the three areas exhibited a consistent trend. Appreciation levels were significantly greater for single photographing with drones than for Light Detection and Ranging (LiDAR)-based scans. The average satisfaction rating for single drone imaging for equipment mobility is 4.2, surpassing the 3.4 value

Table 4. Scanning satisfaction analysis

Question		Portability	Functions	Price
LiDAR scanning	Average	3.4	2.7	1.6
	SD	1.3	1.6	1.3
Drone	Average	4.2	4.7	4.9
	SD	0.4	0.8	0.9

for LiDAR-based scanning. The difference in levels of happiness grows more evident in operational contexts. Individual photographing with drones achieved an average happiness score of 4.7, whilst LiDAR-based scanning trailed with a score of 2.7.

Respondents reported substantial pleasure in assessing the cost, a crucial element of public participation, resulting in a mean rating 4.9 for individual drone shooting. The percentage of people who reported being extremely pleased is 61%, far above the other two categories. LiDAR-based scanning got a significantly diminished mean happiness score of 1.8 in this context. A one-way test was employed in this investigation. The findings indicated that only drone photography, regarding mobility and prices, garnered markedly higher fulfilment levels than LiDAR-based scanning. However, the disparity in operational satisfaction was not substantial.

4.5 Results of the regression analysis

The following section identifies the factors influencing satisfaction regarding the reconstructed quality of CU-Recon by analyzing multivariate regression. The factor that depends is the happiness level, defined as the average of the four criteria. The independent factors comprise individual information and drone expertise, including years of employment, countries of employment, possession of a drone, possession of a drone pilot license, prior drone operation, and expertise in photographing buildings with drones. The results are presented in Table 8. Parameters such as age and level of education were omitted from the study due to their lack of relevance in each approach, demonstrating no substantial link with

Table 5. Satisfaction analysis of reconstruction

Variable	Coefficient	SD
1 to 5 years working experience	-0.542	-0.132
6 to 10 years working experience	-0.412	-0.103
> 10 years working experience	-0.364	-0.132
Working in developed country	0.232	0.132
Working in developing country	0.184	0.023
Having drone?	0.187	0.142
Having drone license?	0.253	0.183
Having drone working experience?	0.243	0.162
Having images of construction with drone?	0.463	0.121

contentment concerning reconstruction ability. The framework exhibited a significant variation in happiness levels, with a predictive value of R = 0.482.

Table 5 indicates that “owning a drone,” “operating a drone,” and “capturing photographs of buildings with a drone” correlate with elevated satisfaction levels regarding reconstruction accuracy. Ownership of a drone enhances contentment by 0.84. “Operating a drone” is a predictor with statistical significance that can increase pleasure by 0.243. Happiness can be improved by utilizing drone photography for building documentation at a rate of 0.531. In addition to these three factors, the standard results indicate that 1-5 years of work experience is the most significantly different prediction (-0.542). As the working year extends, contentment diminishes. This could be due to professionals with extensive expertise overly accustomed to traditional techniques to embrace new digital approaches. Unexpectedly, the developmental status of a country affects its citizens’ contentment levels. Employment in an advanced country enhances contentment by 0.132, demonstrating a more significant impact than employment in a developing nation (0.162).

5. Conclusion

This research assesses the precision of the technique for scanning and demonstrates how the findings can be further developed for subsequent analysis and management applications. Further research must address the issue of the absent interior model, possibly by implementing a hand-held Mobile Laser Scanner technology. This method’s centimeter-level precision and resolution provide rapid and reliable data collection under diverse lighting circumstances and visitor participation. Upon the precise registration of the two versions (drone-derived and MLS-derived), the comprehensive stupa model will facilitate additional developments, including sectional drawings (incorporating known wall and floor widths) and determining the center of mass for the structural evaluation. A further intriguing use of the proposed technology is the amalgamation of the resultant bird’s-eye-view orthophotograph of the built environment with satellite images accessible on GIS platforms. Alterations to buildings over time, resulting from natural or anthropogenic influences across a broader spectrum (e.g., terrain, waterways, and flora), can be identified and examined. Recording these alterations is crucial for heritage buildings since the connection between particular structures and the surrounding geographic setting has persisted for centuries.

References

1. Li, W., Xie, Q., Shi, W., Lin, H., He, J., & Ao, J. (2024). Cultural rituality and heritage revitalization values of ancestral temple architecture painting art from the perspective of relational sociology theory. Heritage Science, 12(1), 340.

2. Otieno, J., & Wanjiru, G. (2024). Seismic Innovations: Strengthening Tall Buildings with Advanced Earthquake-Resistant Technologies. *Association Journal of Interdisciplinary Technics in Engineering Mechanics*, *2*(3), 18-21.

3. Taşkaya, S. (2022). Extraction of Floor Session Area of Building Plots by Length Vector Additional Technique in Different Types of Zoning Building Organizations. *Natural and Engineering Sciences*, *7*(2), 136-147. http://doi.org/10.28978/nesciences.1159231

4. Agapiou, A., & Skarlatos, D. (2023). Geomatic Sensors for Heritage Documentation: A Meta-Analysis of the Scientific Literature. Heritage, 6(10), 6843-6861.

5. Jessin, J., Heinzlef, C., Long, N., & Serre, D. (2023). A systematic review of UAVs for island coastal environment and risk monitoring: Towards a Resilience Assessment. Drones, 7(3), 206.

6. Donkor, K., & Zhao, Z. (2023). Building Brand Equity Through Corporate Social Responsibility Initiatives. *Global Perspectives in Management*, *1*(1), 32-48.

7. Matsuno, Y., & Yamamoto, S. (2013). A Framework for Dependability Consensus Building and In-Operation Assurance. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, *4*(1), 118-134.

8. Carrasco, C. A., Lombillo, I., Sánchez-Espeso, J. M., & Balbás, F. J. (2022). Quantitative and qualitative analysis on the integration of geographic information systems and building information modeling for the generation and management of 3d models. Buildings, 12(10), 1672.

9. Gassar, A. A. A., & Cha, S. H. (2021). Review of geographic information systems-based rooftop solar photovoltaic potential estimation approaches at urban scales. Applied Energy, 291, 116817.

10.Olanrewaju, O. I., Kineber, A. F., Chileshe, N., & Edwards, D. J. (2022). Modelling the relationship between Building Information Modelling (BIM) implementation barriers, usage and awareness on building project lifecycle. Building and Environment, 207, 108556.

11.Safikhani, S., Keller, S., Schweiger, G., & Pirker, J. (2022). Immersive virtual reality for extending the potential of building information modeling in architecture, engineering, and construction sector: systematic review. International Journal of Digital Earth, 15(1), 503-526.

12.Pessoa, S., Guimarães, A. S., Lucas, S. S., & Simões, N. (2021). 3D printing in the construction industry-A systematic review of the thermal performance in buildings. Renewable and Sustainable Energy Reviews, 141, 110794.

13.Wu, Z., & Margarita, S. (2024). Based on Blockchain and Artificial Intelligence Technology: Building Crater Identification from Planetary Imagery. *Natural and Engineering Sciences*, *9*(2), 19-32. https://doi.org/10.28978/nesciences.1567736

14.Woods, J. M., & Adcock, S. J. (2023). Estimating animal location from non-overhead camera views. Applied Animal Behaviour Science, 266, 106032.

15.Yang, J., Neundorfer, N., & Wang, L. (2022). Modeling Network Traffic via Identifying Encrypted Packets to Detect Stepping-stone Intrusion under the Framework of Heterogonous Packet Encryption. *Journal of Internet Services and Information Security*, *12*(4), 56-73. https://doi.org/10.58346/JISIS.2022.I4.004

16.Das, S., Khanwelkar, D. R., & Maiti, J. (2024). A semi-automated coding scheme for occupational injury data: An approach using Bayesian decision support system. Expert Systems with Applications, 237, 121610.

17.Yang, J., Xie, E., Liu, M., & Alvarez, J. M. (2023). Parametric Depth Based Feature Representation Learning for Object Detection and Segmentation in Bird's-Eye View. In Proceedings of the IEEE/CVF International Conference on Computer Vision (pp. 8483-8492).

18.Varshosaz, M., Sajadian, M., Pirasteh, S., & Moghimi, A. (2024). Automated Two-Step Seamline Detection for Generating Large-Scale Orthophoto Mosaics from Drone Images. Remote Sensing, 16(5), 903.

19.Sohl, M. A., & Mahmood, S. A. (2024). Low-Cost UAV in Photogrammetric Engineering and Remote Sensing: Georeferencing, DEM Accuracy, and Geospatial Analysis. Journal of Geovisualization and Spatial Analysis, 8(1), 1-24.

20.Cuca, B., Zaina, F., & Tapete, D. (2023). Monitoring of damages to cultural heritage across Europe using remote sensing and earth observation: Assessment of scientific and grey literature. Remote Sensing, 15(15), 3748.

21.Kiyala, J. C. K. (2024). Climate Change and Climate Wars in the Anthropocene. In Climate Change and Socio-political Violence in Sub-Saharan Africa in the Anthropocene: Perspectives from Peace Ecology and Sustainable Development (pp. 27-76). Cham: Springer Nature Switzerland.

22.Pepe, M., Alfio, V. S., & Costantino, D. (2022). UAV platforms and the SfM-MVS approach in the 3D surveys and modelling: A review in the cultural heritage field. Applied Sciences, 12(24), 12886.

23.Tychola, K. A., Vrochidou, E., & Papakostas, G. A. (2024). Deep learning based computer vision under the prism of 3D point clouds: a systematic review. The Visual Computer, 1-43.

24.Kang, S., Kim, S. D., & Kim, M. (2021). Structural-information-based robust corner point extraction for camera calibration under lens distortions and compression artifacts. IEEE Access, 9, 151037-151048.

25.Kolides, A., Nawaz, A., Rathor, A., Beeman, D., Hashmi, M., Fatima, S., ... & Jararweh, Y. (2023). Artificial intelligence foundation and pre-trained models: Fundamentals, applications, opportunities, and social impacts. Simulation Modelling Practice and Theory, 126, 102754.

26.Hutson, J. (2024). Digital Cultural Heritage Preservation. In Art and Culture in the Multiverse of Metaverses: Immersion, Presence, and Interactivity in the Digital Age (pp. 99-141). Cham: Springer Nature Switzerland.