SURVEY PLANNING FOR DOCUMENTATION OF A MONUMENT FOR THE UNDERSTANDING, PRESERVATION AND RESTORATION

M. K. Verma [1]*, M. Yadav[1]

[1] Geographic Information System (GIS) Cell, Motilal Nehru National Institute of Technology Allahabad, Prayagraj, India
(mukesh.2018rgi51, ssmyadav)@mnnit.ac.in

KEY WORDS: Terrestrial Laser Scanner (TLS), Survey planning, Point Cloud, Monument, Measurement

ABSTRACT:

The three-dimensional (3D) preservation and repair of historic sites are increasingly in practice using modelling and digital documentation. This study focuses on replacing conventional techniques of historical documentation by creating a digital documentation procedure employing laser scanning for 3D mapping of a monument located in Prayagraj, India. To quickly record the entire monument structure, four scanning stations were planned, where three for the facades and one for the interior. A 3D structure of the monument and its elements dimension that included structural, architectural, historical, and non-engineering information was the end product. Researchers, architects, and conservationists can use this laser scanning-based technique to analyze data in great detail to identify weaknesses and conservation requirements. In order to preserve the monument's cultural relevance, it can also be used for virtual tours. Digital documentation can also provide an accurate monument record for restoration needs, protecting the monument from human- or natural-caused damage. Overall, 3D Modelling and digital documentation are valuable tools in heritage conservation, providing comprehensive records of heritage sites and aiding in practical conservation and restoration plans while making cultural heritage accessible to a broader societies.

1. INTRODUCTION

The world is losing its architectural and archaeological cultural assets more quickly than can be recorded. War and unchecked development are examples of human-caused calamities (Amans et al., 2013). The preservation of cultural assets has seen a significant increase in three-dimensional (3D) laser scanning technology usage. In particular, the conservation of cultural heritage has welcomed new technological developments. 3D Modelling offers a way to capture historical locations or artefacts (Troccoli and Allen, 2004).
It would be wise to collect comprehensive spatial data to preserve monuments in danger of degradation due to natural and societal influences. The method of gathering data has always been simple, but processing power is slowly improving, especially for greater computation capacities. The laser point cloud was widely used as a potent data source for creating 3D models of objects. LiDAR can identify and measure the dense structures. In 2013, archaeologists published stunning photographs of dozens of previously hidden temples in Cambodia's rice paddies (Tegelberg, 2010).

Laser scanning can be used to model complex things and take precise measurements. It can be used to document historical events where high accuracy in x, y, and z coordinates is essential because it generates this information quickly without sacrificing resolution. The surveyed point cloud can be modelled with the right tools to create an incredibly accurate representation of the items. In some circumstances, laser scanning is preferred choice for 3D surveying than photogrammetry and other conventional techniques since it can quickly create a dense and accurate point cloud representing objects (Gruen et al. 2005). When choosing between laser scanning and photogrammetry, one should take into account the accuracy, speed, cost, scale, and planned application of the 3D data. Table 1 presents the advantages and disadvantages of the two strategies. We can get around the limitations of each sensor and take advantage of their complementing capabilities by combining LiDAR and camera data in order to acquire a more thorough picture of the surroundings. With the use of this method, we are able to collect information that is more precise and in-depth than what we could get from either sensor alone (Bok et al. 2011).
Historical and archaeological sites are non-renewable resources susceptible to human and environmental influence, exist in relatively confined areas and should be protected by local, national, and worldwide communities (Lercari et al., 2018). One of the biggest causes of damage to cultural assets is looting, political instability and climate change. Over 10,000 Buddhist temples, pagodas, and other buildings may have been in operation in Bagan, Myanmar, between the 11th and 13th centuries. Although more than 2000 are still in existence, they are constantly at risk from earthquakes like the one in 2016 that damaged several hundred temples (Amadori et al. 2021).
To help with construction efforts, detailed digital recreations of the structures can be created using data scanned before the earthquake. Political and economic strife puts structures in danger that have endured intact for hundreds or thousands of years and have only avoided tragedy because of the unpredictable nature of earthquakes or other natural calamities.

	Laser Scanning	Photogrammetry
Pros	Accuracy within mm	Cheaper equipment
	High resolution	Accurate texture visualization
	Automated process	Can operate at various scales and dimensions
	Less time in data collection	
Cons	Cost of equipment is high	Less accurate compared to laser scanners
	Noise in the data	Shadows, low illumination degrades the image quality

Table 1. Benefits and drawbacks of photogrammetry and laser scanning for surveys (Ulvi, 2021).

* Corresponding author

The first large-scale stone engraving in China, Yungang Grotto, which has a thousand-year history and is a recognised world cultural heritage, was severely damaged by wind erosion and required restoration to preserve its detailed 3D information (Ling et al. 2017).

2. STUDY AREA

The selected study area is a monument located in Chandrasekhar Azad Park. This park is tantalizing in Prayagraj (erstwhile Allahabad), Uttar Pradesh (INDIA). It is a public park that was built in the year 1870. It unfolds across 133 acres and is the biggest park in Prayagraj. It houses a monument as shown in Figure 1. It is a beautifully constructed large canopy carved out of limestone.

According to the 1958 Ancient Monuments and Archaeological Sites and Remains Act, as amended in 2010 by the Ancient Sites and Remains (Amendment and Validation) Act, this monument has been designated as having national importance.

Figure 1. Image of a monument in Chandrasekhar Azad Park, Prayagraj, INDIA.

3. SURVEY PLANNING

3.1 Terrestrial Laser Scanner

The terrestrial laser scanner is used for 3D mapping, the FOCUS3D X330 laser scanner from FARO is one of the 3D mapping tools available in industry that is used for land surveying and 3D documentation (Figure 2). Objects up to 330 metres away can be scanned with the Focus3D X330. Fewer scans are required to survey large structures, land-site excavations, and wide terrains, which speeds up project scanning completion. The laser scanner is perfect for applications based on surveying since it can correlate individual scans in post-processing. The Focus3D X 330 can acquire data quickly and with good precision while laser scanning. With extremely low noise, the FARO Focus3D X 330 provides good quality scan data at extended range.

Following the data collection, the registration process has to be carried out to stitch the laser scans. For complete geometry acquisition a 3D scene has to be scanned from several angles. After scanning, the next step is to register individual point clouds into a single point cloud. Tie points or objects (such as spheres or cylinders) are necessary for registration. Engineering topographic surveys, detailed archaeological surveys, surveys on the preservation of historic buildings, surveys on deformation and monitoring, forensic surveys, urban mapping and Modelling, and environmental surveys are the primary uses of the TLS. As shown in Figure 2, the instrument (TLS) is used for the heritage mapping application.

Figure 2. (a) TLS (Faro Focus 3D X330), (b) Registration kit required for the registration of multiple laser scans.

3.2 Data Collection

Four scans were taken for complete 3D mapping of the selected monument (Figure 1). Three scans were taken to acquire the whole structure from the outside, and one scan was taken from the inside of the monument to cover the entire interior geometry (Figure 3). Few objects like checkerboard and spheres of specified dimensions were placed to register all the scans acquired from the monument (Figure 2(b)).

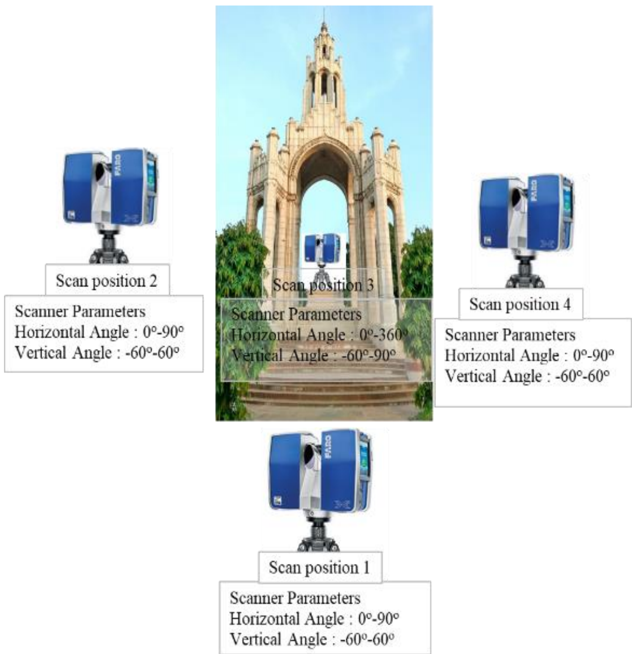

Figure 3. Survey planning to acquire the entire 3D structure of the monument.

In addition to having three common points/objects, it's important to consider the distribution of those points for accurate registration (Figure 4). Proper planning of the survey helps to ensure the availability and accessibility of these common points. Time and resource management can be optimized by using advanced registration techniques and technologies such as iterative closest point (ICP) algorithms and LiDAR scanners (Shi et al. 2020). A well-executed registration process can lead to precise and valuable insights for various applications such as mapping, construction, and archaeology.

https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-1607-2023

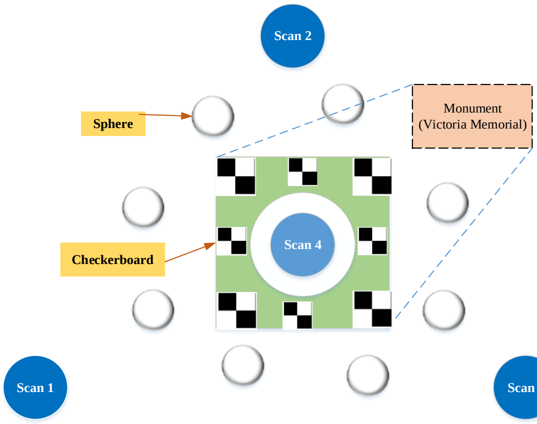

Figure 4. Placement of sphere and checkerboard used for registration of laser scans acquired from multiple stations.

Figure 5. Top view of the monument in the form of 3D point cloud.

4. METHODOLOGY

Using the FARO Focus 3D X330 laser scanner, both LiDAR data and images are acquired to capture structural and texture information, respectively, of a given area. The LiDAR data and images obtained from the integrated DSLR camera are combined to generate a color-coded LiDAR point cloud (Figure 6). The four TLS stations' color-coded point clouds acquired from the surveyed area are registered to produce a comprehensive 3D model of the monument presents as a LiDAR point cloud (Figure 5). Measurements of the monument's height and shape can be obtained from the 3D point cloud, serving as a reference for preservation and restoration purposes. Additionally, time series data of the monument can be collected by repeatedly scanning with the FARO laser scanner, which detects changes over time. A time series analysis of the monument can be used for restoration purposes to examine texture and damages.

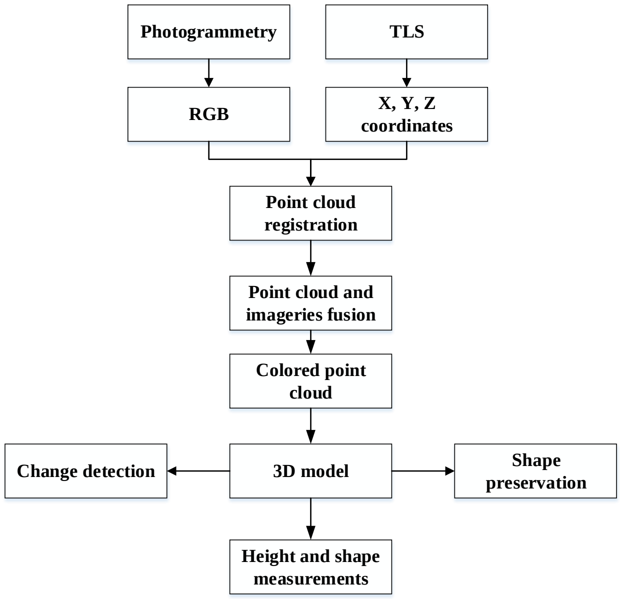

Figure 6. Overall methodology flowchart.

5. RESULT AND DISCUSSION

Am efficient tool for point cloud processing along with TLS from FARO is Scene software, which offers a variety of features like noise and outlier removal and point cloud registration, which is used to create a comprehensive 3D representation of scanned scene. To create a comprehensive 3D model of the monument in this instance, the Scene inbuilt programme was utilised to register four scans made with a FARO laser scanner.

The point clouds are combined with images to create a coloured point cloud, which can be helpful in differentiating the different parts of the monument and make the point cloud data more aesthetically appealing.

The major goal of this research work was to create a point cloud of the complete monument, which can provide precise measurements of the monument's components that are challenging to get manually without affecting the monument. For the restoration of monuments that have been harmed by various activities, this is especially helpful. Open source software (i.e. cloud compare) is used to perform all measurements in the monuments' 3D model.

A several types of measurements that are helpful for comprehending and maintaining the monument can be taken using the point cloud model, which offers an accurate picture and geometry of the monument. For various investigations and studies, it is feasible, for instance, to get measurements like surface area, volume, and dimensions.

The point cloud model provides a realistic representation of the monument and allows for a variety of metrics that are useful for understanding and preserving the monument. It is possible, for example, to obtain measurements like surface area, volume, and dimensions for various inquiries and studies. The geometrical analysis and measurements performed are shown in Figures 7-14.

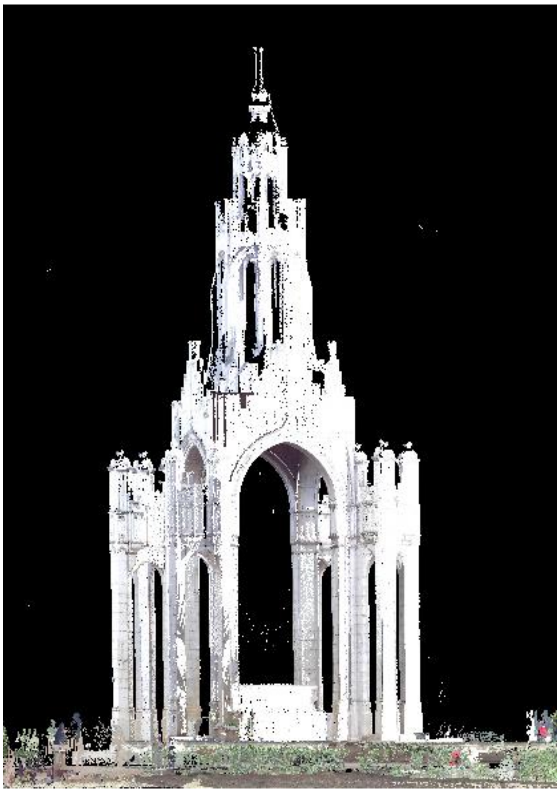

Figure 7. 3D model of the monument represented in terms of its point cloud.

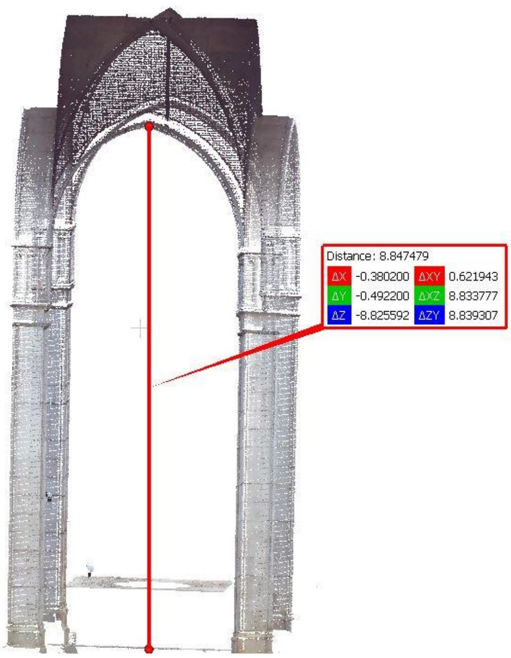

Figure 8. The monument 's entrance, where height is measured as 8.85 m.

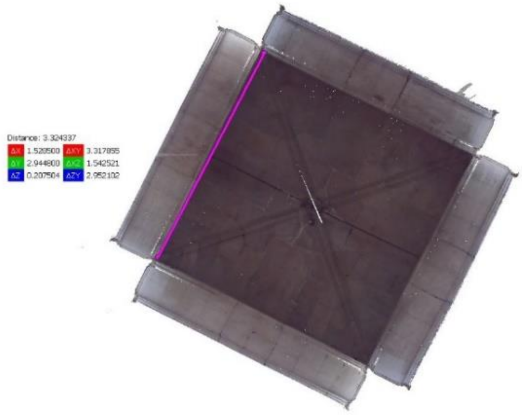

Figure 9. Measurements of the side of the square top of the monument, which is 3.32 m.

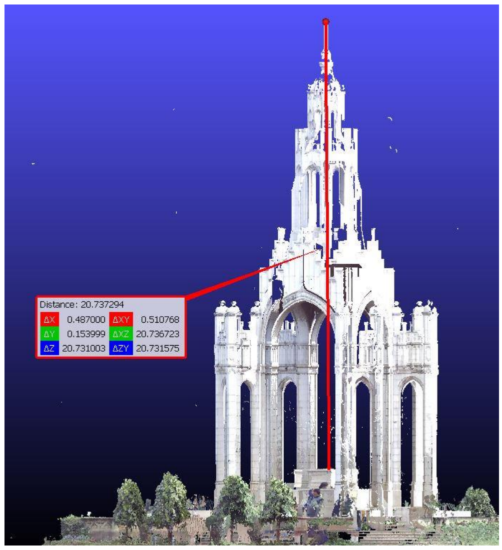

Figure 10. Measurement of the height of monument from its base that is 20.73 m.

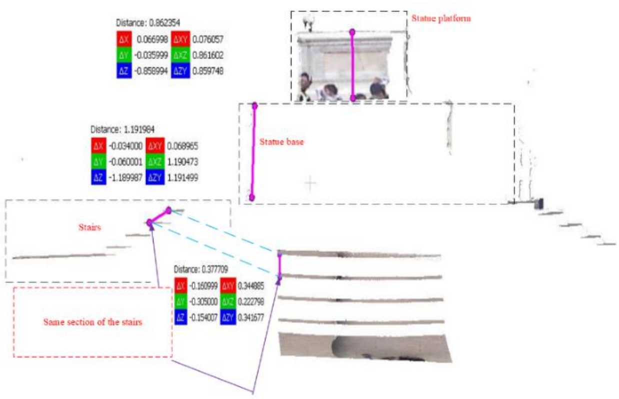

Figure 11. Other measurements for the estimation of the complete height of the monument.

After combining the measurements from Figure 10 and 11, the total height of the monument from ground was obtained 23.17 m.

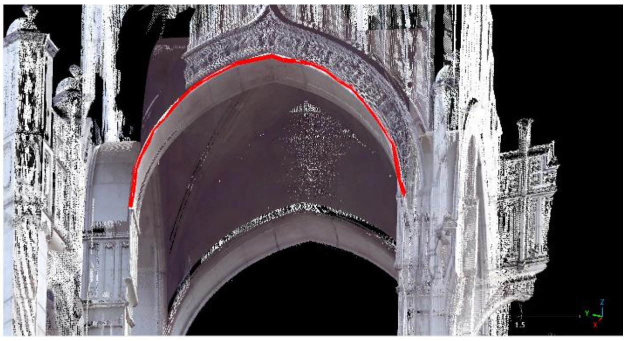

Figure 12. Measurement of the curved portion length of the monument that is 6 m.

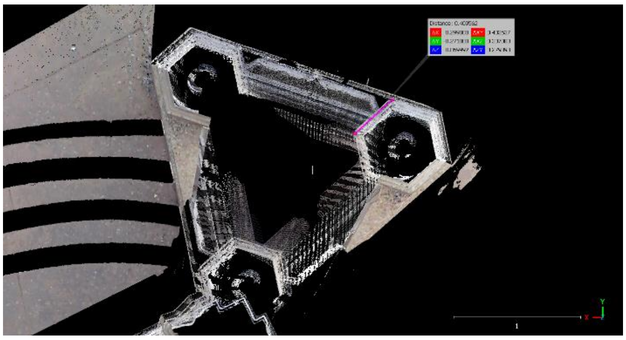

Figure 13. Measurement of the dimension of hexagonal pillars of the monument (dimension=0.4 m) using its point cloud.

Figure 14. Measurements of the element on the pillars of the monument in its point cloud.

6. CONCLUSIONS AND FUTURE WORKS

In the fields of civil engineering, conservation, and restoration, accurately assessing a monument's structural elements is crucial. Engineers and conservationists can create efficient plans for the preservation, restoration, and maintenance of a monument with the help of structural measures, which also provide crucial information about the monument's state.

For the monument's safety as well as the safety of those who visit or work near it, structural measurements are essential. Any structural flaws or vulnerabilities can be found and fixed before they have a negative impact on the environment. Furthermore, structural measurements can help with the monument's future planning. Plans can be established to strengthen or reinforce the structure if it is discovered to be unstable or at risk of collapsing, assuring its long-term safety and stability.

Large monuments can be viewed virtually by using panoramic photos and point cloud data obtained by Terrestrial Laser Scanning (TLS) (Elbshbeshi et al. 2023). By giving tourists who would not have the chance to visit in person an immersive and realistic experience, these virtual views have the potential to transform the tourism sector. TLS technology makes it possible to produce incredibly accurate and detailed 3D models, which can then be utilised to create interesting and educational virtual tours.

Furthermore, the procedure of rehabilitation depends greatly on structural measurements. Restoration experts can precisely replicate the original components and guarantee that the monument retains its original character and integrity by carefully measuring the original components. Additionally, these data are essential for safeguarding the monument for upcoming generations. Engineers and conservationists can create plans to safeguard the structure from future harm or deterioration, maintaining its durability and cultural relevance. By comprehending the stresses and strains on the structure.

In our upcoming work, we intend to analyse the monuments' time series data using both TLS and TS instruments. We will take into account employing Global Navigation Satellite System (GNSS) receivers in addition to TLS and TS if the survey site is too big to finish in a single day. We will then be able to set up permanent control stations to gather time series data.

REFERENCES

Allen, P., Feiner, S., Troccoli, A., Benko, H., Ishak, E., & Smith, B., 2004, September. Seeing into the past: Creating a 3D modeling pipeline for archaeological visualization. In *Proceedings. 2nd International Symposium on 3D Data Processing, Visualization and Transmission, 2004. 3DPVT 2004.* (pp. 751-758). IEEE.

Amadori, M. L., Mengacci, V., Vagnini, M., Casoli, A., Holakooei, P., Eftekhari, N., ... & Germinario, G., 2021. Organic Matter and Pigments in the Wall Paintings of Me-Taw-Ya Temple in Bagan Valley, Myanmar. Applied Sciences, 11(23), 11441.

Amans, O. C., Beiping, W., Ziggah, Y. Y., & Daniel, A. O., 2013. The need for 3D laser scanning documentation for select Nigeria cultural heritage sites. *European Scientific Journal*, *9*(24), 75-91.

Bok, Y., Jeong, Y., Choi, D. G., & Kweon, I. S., 2011. Capturing village-level heritages with a hand-held camera-laser fusion sensor. International Journal of Computer Vision, 94, 36-53.

Elbshbeshi, A., Gomaa, A., Mohamed, A., Othman, A., Ibraheem, I. M., & Ghazala, H., 2023. Applying geomatics techniques for documenting heritage buildings in Aswan region, Egypt: A Case study of the Temple of Abu Simbel. Heritage, 6(1), 742-761.

Fang, J., Zhang, Y., Zhang, Y., Guo, H., & Sun, Z., 2022. High-Definition Survey of Architectural Heritage Fusing Multisensors—The Case of Beamless Hall at Linggu Temple in Nanjing, China. *Sensors*, *22*(9), 3369.

Gruen, A., & Akca, D., 2005. Least squares 3D surface and curve matching. ISPRS Journal of Photogrammetry and Remote Sensing, 59(3), 151-174.

Lercari, N., Campiani, A., & Stuardo, R. L., 2018, October. Intra-site Digital Documentation of the Ancient Maya city of

Palenque, Mexico. In *2018 3rd Digital Heritage International Congress (DigitalHERITAGE) held jointly with 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018)* (pp. 1-8). IEEE.

Ling, J., & Gao, F., 2017. Cultural Analysis of Yungang Grottoes under Multicultural Background. In Asia International Symposium on Language, Literature and Translation (p. 498).

Shi, X., Liu, T., & Han, X., 2020. Improved Iterative Closest Point (ICP) 3D point cloud registration algorithm based on point cloud filtering and adaptive fireworks for coarse registration. International Journal of Remote Sensing, 41(8), 3197-3220.

Tegelberg, M., 2010. Hidden sights: tourism, representation and Lonely Planet Cambodia. International Journal of Cultural Studies, 13(5), 491-509.

Troccoli, A. J., & Allen, P. K., 2004. A shadow based method for image to model registration. In *2004 Conference on Computer Vision and Pattern Recognition Workshop* (pp. 169-169). IEEE.

Ulvi, A., 2021. Documentation, Three-Dimensional (3D) Modelling and visualization of cultural heritage by using Unmanned Aerial Vehicle (UAV) photogrammetry and terrestrial laser scanners. International Journal of Remote Sensing, 42(6), 1994-2021.