Dynamically tangible cultural heritage monitoring from web video sources

Ioannis Kavouras*
ikavouras@mail.ntua.gr
National Technical University of Athens
Athens, Greece

Ioannis Rallis*
irallis@central.ntua.gr
National Technical University of Athens
Athens, Greece

Nikolaos Doulamis*
ndoulam@cs.ntua.gr
National Technical University of Athens
Athens, Greece

Anastasios Doulamis*
adoulam@cs.ntua.gr
National Technical University of Athens
Athens, Greece

ABSTRACT

Climate change is serious problem, which can negatively affect the tangible cultural heritage. An actively solution to this problem is the long-term continuous monitoring of the cultural heritage, which is impossible in many cases. In this work we propose a methodology based on web video sources for generating high fidelity 3D meshes and estimating geometrically changes, which can indicate possible damaged areas. The ancient theatre of Epidaurus was selected for demonstrating the methodology and by using two YouTube video sources, high fidelity meshes were generated and compared by using free and open-source software. This work concludes on that tangible cultural heritage monitoring is possible by using web video sources.

CCS CONCEPTS

• Social and professional topics → Cultural characteristics; **• Computing methodologies → Computer graphics**; **• Applied computing → Archaeology**; **Engineering**.

KEYWORDS

climate change, tangible cultural heritage, monitoring, structure from motion, 3D

ACM Reference Format:
Ioannis Kavouras, Ioannis Rallis, Nikolaos Doulamis, and Anastasios Doulamis. 2023. Dynamically tangible cultural heritage monitoring from web video sources. In *Proceedings of the 16th International Conference on PErvasive Technologies Related to Assistive Environments (PETRA '23), July 05–07, 2023, Corfu, Greece.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3594806.3596552

*All authors contributed equally to this research.

PETRA '23, July 05–07, 2023, Corfu, Greece

ACM ISBN 979-8-4007-0069-9/23/07…$15.00
https://doi.org/10.1145/3594806.3596552

1 INTRODUCTION

Climate change is a serious problem of our times, which causes significant problems in many social, economic and cultural aspects of our society. Weather patterns and extreme climate events threatens the tangible cultural heritage, which according to UNESCO [10] includes monuments, artefacts, and groups of building and sites and further categorized in movable, immobile and underwater. Temperature increment combined with changes in relative humidity, wind, and precipitation [5] can change the chemical composition of a monument's material (i.e., calcination) [26].

Cultural heritage documentation [18] and monitoring have been suggested in many works [2, 14, 16] as a solution for mitigating this problem. A recent work [30] suggests the usage of web video sources for generating 3D models of an existing monument. In this direction, works dealing 3D rconstuction from in the wild web based image datasets have been proposed in [21] by exploiting density based clustering algorithms. Furthermore, UAV-based photogrammetry [22] is capable to produce high resolution models. Thus, the combination of these ideas and technologies, can be used for generating high fidelity 3D meshes for cultural heritage monitoring. Fuzzy representations in the area of 3D prediction modelling have been also presented in [9].

In this work we propose a methodology for cultural heritage monitoring based on web multimedia (i.e., images, videos) data sources. The dataset collection focuses on UAV footage video over archaeological sites or monuments, which are capable for generating 3D meshes by applying the structure from motion (SfM) algorithm. Long-term monitoring can be achieved by repeating this process for multiple video over the same area for different time periods to generate multiple 3D meshes of the same resolution and compare them using appropriate software.

This manuscript is limited to the presentation of the methodology and its applicability. The Ancient Theatre of Epidaurus [6] has been selected for demonstrating the proposed methodology. For this matter, two UAV footage video, with time difference of 2.5 years, have been downloaded from YouTube and using Meshroom, a free and open-source 3D Reconstruction Software, for generating the 3D meshes and further editing was applied in Blender (for 3D geometry) and GIMP (for the image texturing). Finally, the monitoring is achieved by tracking changes between the 3D meshes. This is achieved by comparing the 3D meshes in CloudCompare software.

The contribution of this research is twofold. Firstly, we propose a methodology for generating 3D meshes from web video sources for the same area and estimating geometrical differences between the models for long-term cultural heritage monitoring. The differences in geometry may indicate possible damage in the archaeological structure. Secondly, the proposed methodology significantly minimizes the time and cost of long-term monitoring for cultural heritage, because it is heavily depended on free and open-source tools and can be applied for any monument worldwide from anywhere, as long as there are at least two video of the same archaeological structure for different time periods.

The rest of this manuscript is organized as follows: Section 2 provides similar works and state of the art approaches for CH monitoring. In Section 3 a brief description of the proposed methodology is provided. Section 4 presents the applicability of the proposed methodology in the case study of the Theatre of Epidaurus. Section 5 concludes this work.

2 RELATED WORK

The 3D reconstruction of cultural heritage monument using web sources is not something new. Similar ideas have been proposed in the works of Kyriakiaki et al. [19] and Doulamis et al. [8]. The first work proposes a methodology for producing cost-effective 4D models of cultural heritage structures and artefacts from 2D data over the web by using computer vision [4] and photogrammetric (i.e., structure from motion [24] algorithms. The second work proposes a methodology for 3D reconstruction [20] of cultural heritage monuments using images from Twitter.

Dante Abate [1] in his research propose a four step methodology: (i) photogrammetric survey, (ii) dense point cloud and orthophoto production, (iii) 2D and 3D multi-temporal change detection, (iv) data interpretation. In his case study he used two datasets of the church of Stavros tou Missiricou in Nicosia, Cyprus, with a time period difference of 8 years, for creating orthophotos and 3D point clouds. Furthermore, by cloud comparison [23] and displacement calculation [32, 33] he estimated possible damage in the facade's structure.

A different approach suggests the usage of UAVs for collecting datasets of archaeological sites and photogrammetric algorithms like structure from motion for 3D mesh and BIM models creation [31]. Indicative example can be the work of Young Hon Jo et al. [17] where they compared 3D meshes created by terrestrial laser scanning and UAV technologies for 3D digital documentation. Fotia et al. [11] combined UAV survey and 3D printing technologies for 3D modeling and printing the Saracen Tower Remains in Southerns Italy. These technologies can be efficiently used in 3D monitoring and documentation of cultural heritage.

Herban et al. [15] approached the problem of digitization of cultural heritage by using spherical 360° low-cost cameras and the structure from motion algorithm to generate a 3D mesh for Colonada in Buziaș (a large structure in Romania). Furthermore, their generated 3D mesh was compared to a terrestrial laser scanner [35] 3D mesh for estimating the capability of their approach. The comparison showed a difference of 15 centimeters for 80% of the points. Bakirman et al. [3] performed a similar experiment by comparing a 3D mesh, of a historical building, generated by an ultra light UAV and a terrestrial laser scanner with similar results.

Summarizing, the current literature investigation contains works that propose the usage of web sources for cultural heritage and UAV captured datasets for photogrammetric processing. Additionally, some studies uses cloud compare algorithms for estimating the efficiency of low-cost capturing technologies with more advanced systems like terrestrial laser scanners. Taking into account the current literature, we contribute by proposing a long-term low-cost methodology for cultural heritage monitoring based on web video sources containing. Our methodology is capable for estimating differences in an archaeological structure by comparing multiple 3D meshes generated from video sources of different time period.

3 PROPOSED METHODOLOGY

In this work we propose a methodology for long-term cultural heritage monitoring. The methodology is completely based on free and open-source software and tools. For the demonstration example we used Meshroom [27] for the SfM algorithm, Blender [28] for editing the 3D geometry of the generated meshes, GIMP [29] for texture enhancement, and CloudCompare [7] for comparing the differences between the 3D meshes. The proposed methodology is compromised by five main steps: (a) Data collection, (b) pre-processing, (c) processing, (d) post-processing, (c) 3D mesh comparison. Figure 1 illustrates the architectural workflow of the proposed methodology.

Data collection is the first step of the proposed methodology and the most critical, because it affects significantly the following processes. A good dataset can be a UAV footage video from YouTube (YT) or any other web site (e.g., social media, archaeological websites, etc.), which visualize the area of interest from a continuous capture and multiple positioning angles. Additionally, the video frames needs to be as possible noisy free, without watermarks or description text, because these features will be appeared in the final model (see Figure 4b). The pre-processing step includes the conversion of the video file to a set of images (i.e., the video's frames) and the removal of noisy frames like title, description, watermarked, etc.

The next step (processing) is the creation of the 3D textured mesh by feeding the image dataset to the Structure from Motion algorithm. Usually, the generated 3D mesh contains noisy vertices that need to be removed. The removal processing can be utilized inside any 3D editing software (e.g., Blender, 3Ds Max, etc.) either manually by deleting noisy meshes or geometries, or automated by using a decimate modifier algorithm.

Furthermore, the model needs to be scaled and rotated to match the reality. The scale factor is calculated by dividing a known distance of the archaeological structure by the corresponding distance measured in the 3D mesh, as shown in the Equation 1. The real distance can be measured using an online map like google earth, OpenStreetMap, etc, while the distance in mesh can be measured inside the 3D software editor. All models needs to be scaled and rotated accordingly to match reality in order to proceed with the comparison phase later on.

$$ScaleFactor = \frac{RealDistance(m)}{MeasuredDistanceinMesh(m)} \quad (1)$$

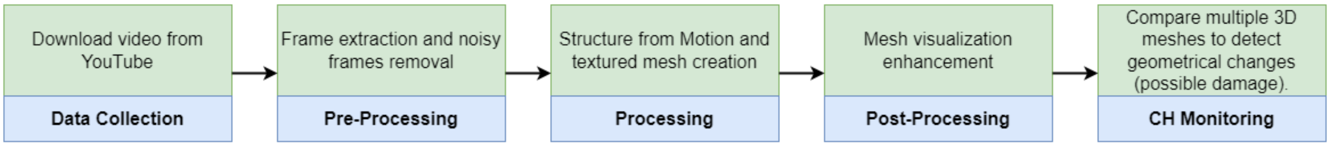

Figure 1: The architectural workflow of the proposed methodology.

In addition, it is important to localize the pivot point of the model to the same point for all models, otherwise the mesh comparison will produce wrong results. In some cases, texturing enhancement (e.g., saturation, contrast, etc.) is necessary for improving the visualization of the model. Finally, the generated meshes can be imported to a software with the capability of comparing mesh geometries and point clouds for detecting geometrically differences, which may indicate damage in the monument's structure.

4 EXPERIMENTAL RESULTS

4.1 Brief description of the area of interest

The Ancient Theatre of Epidaurus (Figure 2) is one of the best preserved and most familiar monuments of ancient Greece and located on the Sanctuary of Asklepios in Peloponnese (Greece), south of modern Epidaurus (Nea Epidavros), across the Saronic Gulf from Athens [25]. The theatre was inscribed on the UNESCO World Heritage List in 1988 along with the Temple of Asclepius [6]. It was constructed in the 4rth century BC and is most recognized by its aesthetic and acoustic characteristics [34].

Figure 2: The ancient theatre of Epidaurus.

4.2 Data Collection and Pre-Processing

For the test purposes of this work we downloaded two video from YouTube. Please note that few of the frames, in the sequences, have been manually removed, to facilitate the reconstruction process. Numbers in parentheses correspond to the remaining number of frames. Table 1 presents a brief description of the dataset. The first video source [12] was uploaded on 27 January of 2021 with time length 2 minutes and 14 seconds in 30 FPS. This video produced a dataset of 134 images, from which 132 were used in the SfM process. The second video video source [13] was uploaded on 30 Aug 2019 and its time length is 2 minutes and 47 seconds in 30 FPS. A dataset of 167 images was produced from this video, from which 130 images were used in the SfM process. For testing purposes the second video source is watermarked on the top right corner and, also, some frames contain description text.

4.3 3D Mesh Creation and Post-Processing

The successful execution of the SfM algorithm produced the textured meshes which are illustrated in Figure 3 for the first (3a) and second (3b) video sources respectively. It is observed that these meshes contain noisy geometries (e.g., floating islands, noisy vertices, etc.), which need to be cleaned.Furthermore, they need to be scaled in reality's dimensions, rotated until the ground is paralleled with the XY plane, and locate the pivot point (i.e., origin point) to the shame position in both meshes. The 3D meshes after applying these changes are shown in Figure 4. Finally, texture enhancement (Figure 5) improves significantly the visualization of the 3D meshes. Texture enhancement includes changes in contrast, brightness, saturation, etc of the 3D mesh's image texture.

4.4 Comparison between the two meshes

The last step of the methodology is the comparison of these two models in CloudCompare (CC) software. Figure 6a illustrates the two meshes after they imported in the CC. In the case of different pivot points there will be observable distance between the meshes and it is important to be corrected before the comparison. In addition, it is important for the meshes to have similar number of vertices (i.e., similar polygon geometry and resolution). In the case of huge difference in vertices' number, the Blender software provides the subdivision surface modifier, which can interpolate vertices and increase the resolution of a model. The generated mesh of the first video source has 64567 vertices and the mesh of the second video source has 76169 (i.e., 11.602 difference in vertices). Figure 6b illustrates an overview of the vertices, before the comparison of the 3D meshes (i.e., distance calculation).

Figure 7 illustrates the comparison between the 3D meshes by selecting the vertices of the first video source to compared and the second video source to reference options in CloudCompare distance calculation, while Figure 8 illustrates the same comparison by swapping the options (use the mesh of first video source as reference and the mesh of the second video source as compared option). The algorithm colorized the point cloud of the compared mesh as illustrated in Figures 7b and 8b and the distances were measured in millimeters. Blue color indicates distance values near 0, while the red color near the maximum distance value. Figure 9 illustrates the represented histograms of the colorized point clouds. It is observed that for the case of Figure 7b the maximum distance is mostly observed in foliage areas with approximated value of 4.00m. This distance value is because there is no foliage information in the reference model. The main structure of the monument is colorized with blue, which indicates distances bellow 0.5m and from Figure 9a most values are near 0. For the Figure 8b the maximum distance is similarly observed on the foliage areas with a value of 1.25m (Figure

Table 1: Dataset Description

Video Source	Date	Video Length	Frames per Second (FPS)	Image Frames
[12]	27 Jan 2021	2min 14sec	30	134 (132 used in SfM)
[13]	30 Aug 2019	2min 47sec	30	167 (130 used in SfM)

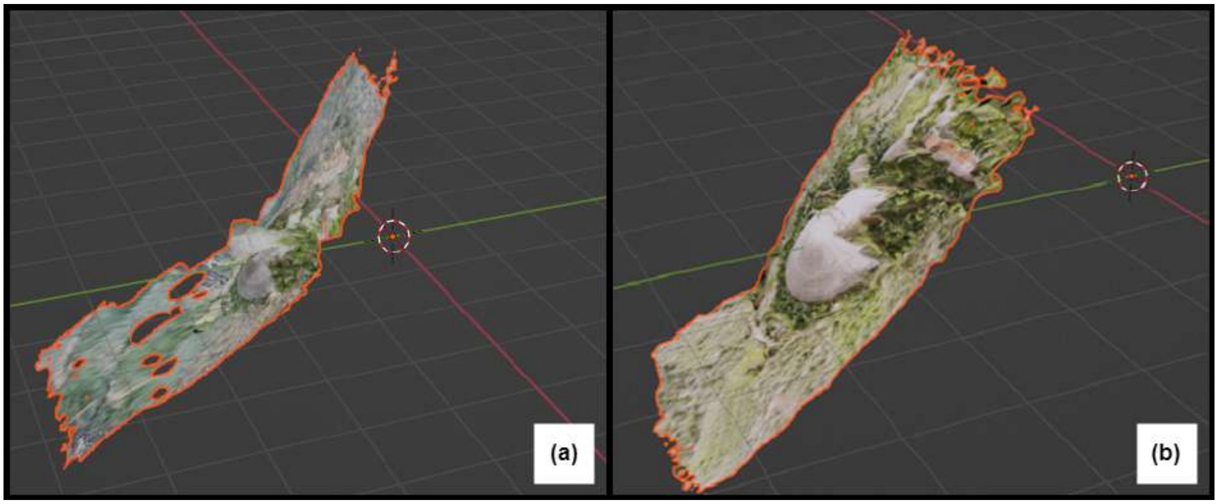

Figure 3: The product of SfM algorithm from the first video source. (a) The first video source. (b) The second video source.

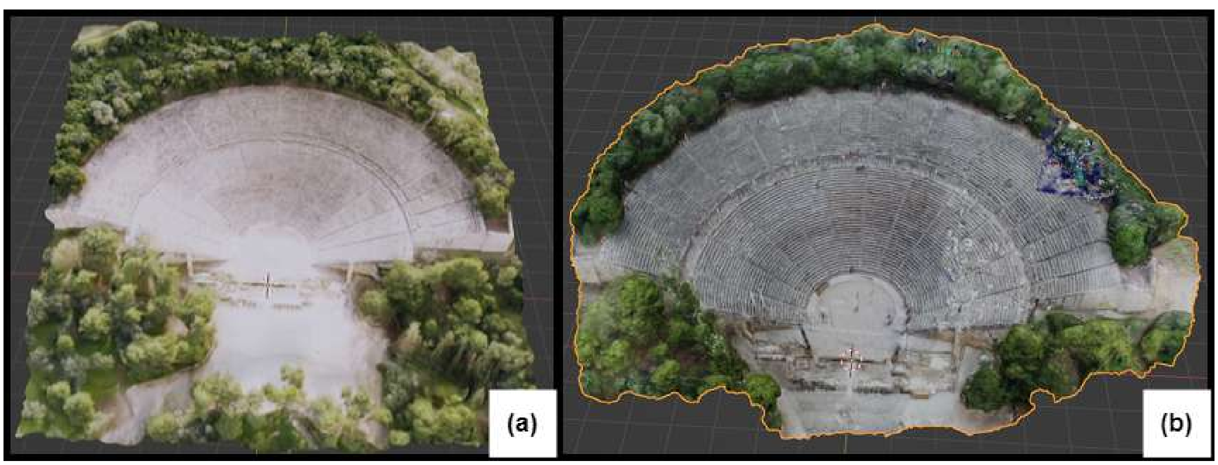

Figure 4: The 3D Meshes after noise removal and transformation (scale, rotate, locate to the point of origin) correction. (a) The first video source. (b) The second video source.

9b), while on the main structure of the monument there are values in blue (<0.3m) and the green area (0.3m-0.5m) similarly to the previous analysis. By taking into account negligible inaccuracies that occurred along the processes of the methodology (i.e., user rounding errors in scaling calculation, possible slightly different rotation and negligible difference in the location of the pivot points), these differences are considered negligible, and it can be assumed that the theatre of Epidaurus has not been significantly changed during these 2.5 year difference.

5 CONCLUSIONS

This manuscript proposed a methodology for creating 3D meshes of tangible cultural heritage monuments by using an image dataset provided by web multimedia sources. The methodology was demonstrated for the theatre of Epidaurus in the Sanctuary of Asklepios, which is protected by UNESCO since 1988. Two YouTube video sources with an uploaded time difference of 2.5 years were used for the successful creation of two high quality 3D meshes. These

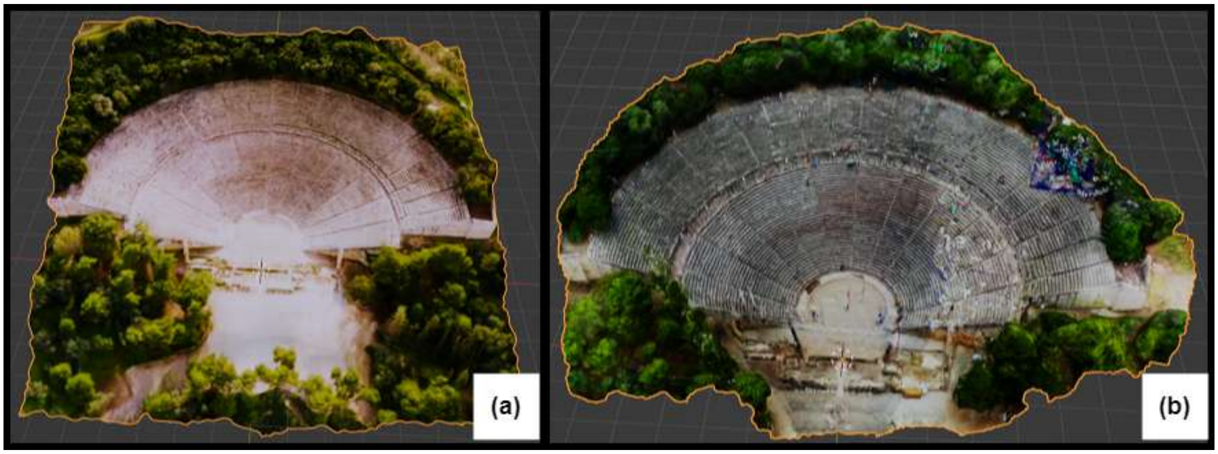

Figure 5: The 3D Mesh of the first video source after texture enhancement. (a) The first video source. (b) The second video source.

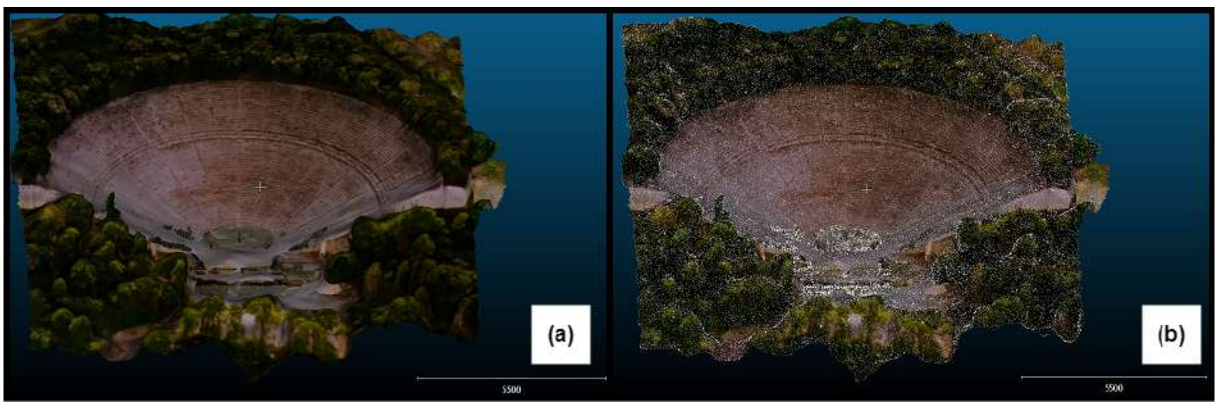

Figure 6: (a) Importing the two meshes in CloudCompare. (b) Viewing the point clouds of the two meshes in CloudCompare

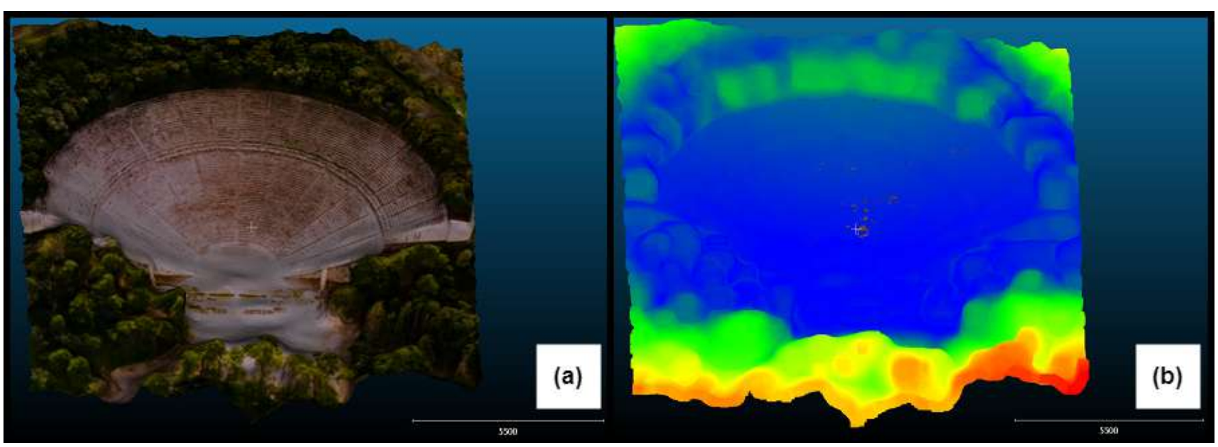

Figure 7: (a)Compared mesh (b) Showing the point cloud of the first video source mesh after distance calculation. (Blue = distance near 0, Red = maximum distance)

meshes imported to CloudCompare software, in which their geometrically differences were calculated. The main advantages of the proposed methodology can be summarized as follow:

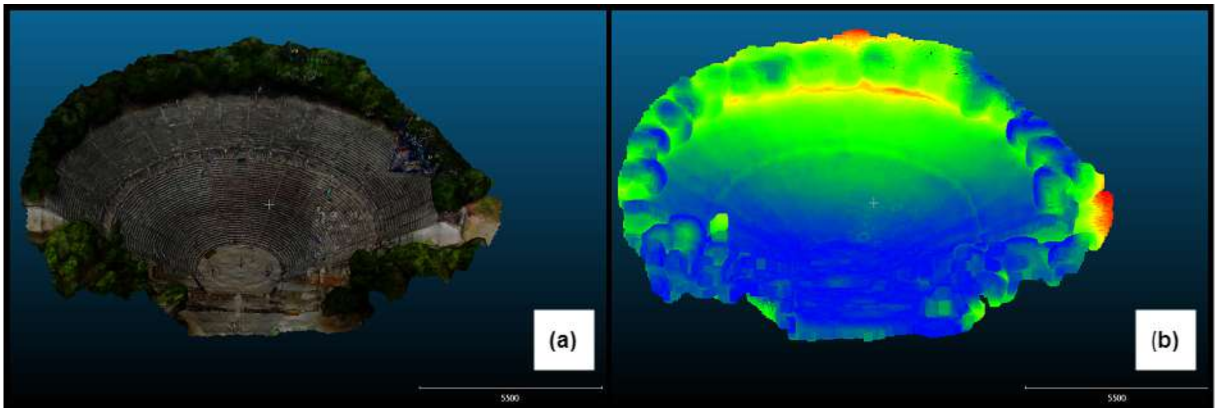

Figure 8: (a)Compared mesh (b) Showing the point cloud of second video source mesh after distance calculation. (Blue = distance near 0, Red = maximum distance)

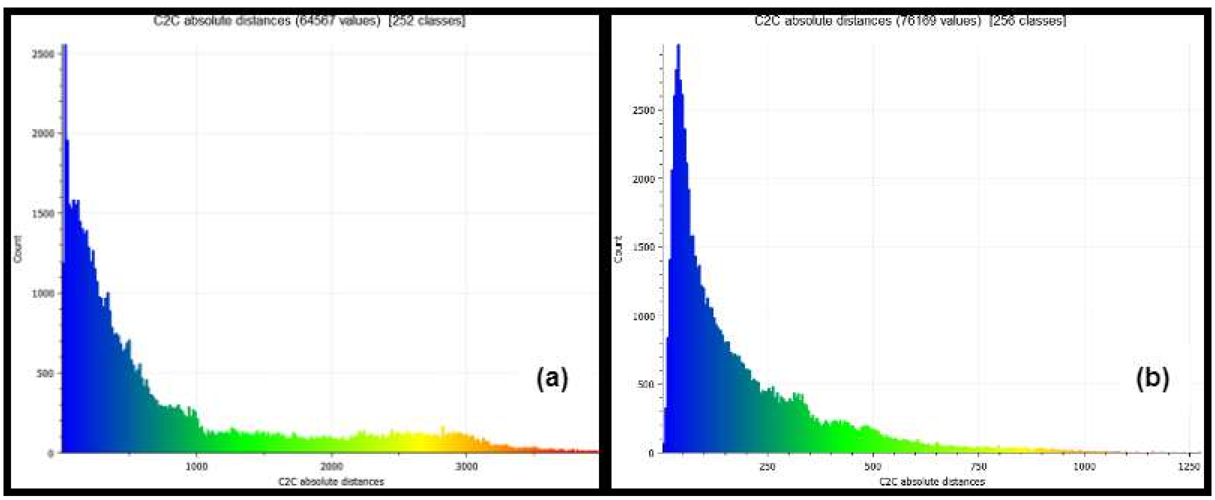

Figure 9: The histogram of ht distances. The absolute distance is on millimetre.

(1) The data collection is based on web sources, thus no field work is needed and can be used from anywhere.
(2) There are many free and open-source software that solve the SfM problem easily, thus it can be used from anyone.
(3) The whole process can be achieved in less than 24 hours, depended on the size of the dataset.
(4) The software used for the demonstration was free and open-source, which means that the proposed methodology is zero cost.

Some of the disadvantages of the methodology can be the lack of dataset for a specific area, or that the available dataset produces low resolution 3D mesh, which cannot be used for monitoring changes. The methodology is currently at an early stage and further research in this field is needed, however this manuscript can safely conclude that tangible cultural heritage monitoring is possible using multiple datasets from web sources.

ACKNOWLEDGMENTS

This paper is supported by the H2020 Marie Curie Programme (MSCA) YADES "Improved Resilience and Sustainable Reconstruction of Cultural Heritage Areas to cope with Climate Change and Other Hazards based on Innovative Algorithms and Modelling Tools" with grant agreement No. 872931.

REFERENCES

[1] Dante Abate. 2019. Built-heritage multi-temporal monitoring through photogrammetry and 2D/3D change detection algorithms. *Studies in Conservation* 64, 7 (2019), 423–434.
[2] N Aste, RS Adhikari, M Buzzetti, S Della Torre, C Del Pero, F Leonforte, et al. 2019. Microclimatic monitoring of the Duomo (Milan Cathedral): Risks-based analysis for the conservation of its cultural heritage. *Building and Environment* 148 (2019), 240–257.
[3] Tolga Bakirman, Bulent Bayram, Burak Akpinar, M Fahri Karabulut, Onur Can Bayrak, Alper Yigitoglu, and Dursun Zafer Seker. 2020. Implementation of ultra-light UAV systems for cultural heritage documentation. *Journal of Cultural Heritage* 44 (2020), 174–184.
[4] M Lo Brutto and Paola Meli. 2012. Computer vision tools for 3D modelling in archaeology. *International Journal of Heritage in the Digital Era* 1, 1_suppl (2012), 1–6.

[5] Dr. Chiara Bertolin & Prof. Dr. Dario Camuffo. 2014. Climate for Culture - Climate change impact on movable and immovable cultural heritage throughout Europe. http://unfccc.int/resource/docs/convkp/conveng.pdf (Accessed on 20 Feb 2023).

[6] UNESCO World Heritage Centre. 1988. Sanctuary of Asklepios at Epidaurus. https://whc.unesco.org/en/list/491/ (Accessed on 20 Feb 2023).

[7] CloudCompare development team. 2023. CloudCompare Software. https://www.danielgm.net/cc/ (Accessed on 20 Feb 2023).

[8] Anastasios Doulamis, Athanasios Voulodimos, Eftychios Protopapadakis, Nikolaos Doulamis, and Konstantinos Makantasis. 2020. Automatic 3D Modeling and Reconstruction of Cultural Heritage Sites from Twitter Images. *Sustainability* 12, 10 (2020). https://doi.org/10.3390/su12104223

[9] N.D. Doulamis, A.D. Doulamis, A. Panagakis, K. Dolkas, T.A. Varvarigou, and E. Varvarigos. 2004. A combined fuzzy-neural network model for non-linear prediction of 3-D rendering workload in Grid computing. *IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics)* 34, 2 (2004), 1235–1247. https://doi.org/10.1109/TSMCB.2003.822282

[10] UNESCO Institute for Statistics. 2009. Cultural Heritage. https://uis.unesco.org/en/glossary-term/cultural-heritage (Accessed on 20 Feb 2023).

[11] Antonino Fotia, Antonino Modafferi, Antonino Nunnari, and Sebastiano D'Amico. 2021. From UAV survey to 3D printing, geomatics techniques for the enhancement of small village Cultural Heritage. (2021).

[12] GEOPAHAS. 27 Jan 2021. Drone flight over the archaeological site of Epidaurus, Greece. https://www.youtube.com/watch?v=W606j0zI0gs (Accessed on 20 Feb 2023).

[13] Nicolas Flyer Gr. 30 Aug 2019. Ancient Theatre Of Epidaurus, Aerial Footage! https://www.youtube.com/watch?v=ws5vcXwW5pU (Accessed on 20 Feb 2023).

[14] Annika Haugen, Chiara Bertolin, Gustaf Leijonhufvud, Tone Olstad, and Tor Broström. 2018. A Methodology for Long-Term Monitoring of Climate Change Impacts on Historic Buildings. *Geosciences* 8, 10 (2018). https://doi.org/10.3390/geosciences8100370

[15] Sorin Herban, Domenica Costantino, Vincenzo Saverio Alfio, and Massimiliano Pepe. 2022. Use of low-cost spherical cameras for the digitisation of cultural heritage structures into 3d point clouds. *Journal of Imaging* 8, 1 (2022), 13.

[16] Adrián Hinostroza and Jimmy Tarrillo. 2022. Wireless Sensor Network for Environmental Monitoring of Cultural Heritage.. In *SENSORNETS*. 171–175.

[17] Young Hoon Jo and Seonghyuk Hong. 2019. Three-dimensional digital documentation of cultural heritage site based on the convergence of terrestrial laser scanning and unmanned aerial vehicle photogrammetry. *ISPRS International Journal of Geo-Information* 8, 2 (2019), 53.

[18] E Karachaliou, E Georgiou, D Psaltis, and E Stylianidis. 2019. UAV for mapping historic buildings: From 3D modelling to BIM. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences* 42 (2019), 397–402.

[19] Georgia Kyriakaki, Anastasios Doulamis, Nikolaos Doulamis, Marinos Ioannides, Konstantinos Makantasis, Eftichios Protopapadakis, Andreas Hadjiprocopis, Konrad Wenzel, Dieter Fritsch, Michael Klein, et al. 2014. 4D reconstruction of tangible cultural heritage objects from web-retrieved images. *International Journal of Heritage in the Digital Era* 3, 2 (2014), 431–451.

[20] Ioannis Liritzis, Pantelis Volonakis, and Spyros Vosinakis. 2021. 3d reconstruction of cultural heritage sites as an educational approach. The sanctuary of Delphi. *Applied Sciences* 11, 8 (2021), 3635.

[21] Konstantinos Makantasis, Anastasios Doulamis, Nikolaos Doulamis, and Marinos Ioannides. 2016. In the wild image retrieval and clustering for 3D cultural heritage landmarks reconstruction. *Multimedia Tools and Applications* 75 (2016), 3593–3629.

[22] Yue Pan, Yiqing Dong, Dalei Wang, Airong Chen, and Zhen Ye. 2019. Three-dimensional reconstruction of structural surface model of heritage bridges using UAV-based photogrammetric point clouds. *Remote Sensing* 11, 10 (2019), 1204.

[23] Rachna Pathak, Anil Saini, Arnav Wadhwa, Himanshu Sharma, and Dhiraj Sangwan. 2021. An object detection approach for detecting damages in heritage sites using 3-D point clouds and 2-D visual data. *Journal of Cultural Heritage* 48 (2021), 74–82.

[24] Hafizur Rahaman and Erik Champion. 2019. To 3D or not 3D: Choosing a photogrammetry workflow for cultural heritage groups. *Heritage* 2, 3 (2019), 1835–1851.

[25] Glenn Rawson. 2021. Epidaurus. In *Meet the Philosophers of Ancient Greece*. Routledge, 277–279.

[26] Stathis C Stiros. 2020. Monumental articulated ancient Greek and Roman columns and temples and earthquakes: archaeological, historical, and engineering approaches. *Journal of Seismology* 24, 4 (2020), 853–881.

[27] AliceVision team. 2023. Meshroom Software. https://alicevision.org/#meshroom (Accessed on 20 Feb 2023).

[28] Blender's team. 2023. Blender's Official Site. https://www.blender.org/ (Accessed on 20 Feb 2023).

[29] Blender's team. 2023. GIMP's Official Site. https://www.gimp.org/ (Accessed on 20 Feb 2023).

[30] Kyriacos Themistocleous. 2017. Model reconstruction for 3D vizualization of cultural heritage sites using open data from social media: The case study of Soli, Cyprus. *Journal of Archaeological Science: Reports* 14 (2017), 774–781.

[31] Kyriacos Themistocleous. 2020. The use of UAVs for cultural heritage and archaeology. *Remote Sensing for Archaeology and Cultural Landscapes: Best Practices and Perspectives Across Europe and the Middle East* (2020), 241–269.

[32] Kyriacos Themistocleous. 2023. Monitoring Cultural Heritage Sites Affected by Geohazards in Cyprus Using Earth Observation. In *Sustainable Conservation of UNESCO and Other Heritage Sites Through Proactive Geosciences*. Springer, 359–377.

[33] J Valença, D Dias-da Costa, ENBS Júlio, H Araújo, and Hugo Costa. 2013. Automatic crack monitoring using photogrammetry and image processing. *Measurement* 46, 1 (2013), 433–441.

[34] Stamis Vassilantonopoulos, Panagiotis Hatziantoniou, NA Tatlas, T Zakynthinos, D Skarlatos, and JN Mourjopoulos. 2011. Measurements and analysis of the acoustics of the ancient theatre of Epidaurus. In *Proceedings of EAA Conference on the Acoustics of Ancient Theaters, Patras, Greece*.

[35] Isabel Martinez Espejo Zaragoza, Gabriella Caroti, and Andrea Piemonte. 2021. The use of image and laser scanner survey archives for cultural heritage 3D modelling and change analysis. *Acta IMEKO* 10, 1 (2021), 114–121.