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3-D Digital Documentation and Preservation of a Heritage Structure Using Advanced Technologies

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Abstract: Heritage Structures often possess Historical, Architectural, Associative and/or Cultural Significance. These Structures need to be cared about and well preserved to keep up the legacy of the structure. The 3D model of the structure is obtained through various equipment like photogrammetry, LIDAR, Unmanned Aerial Vehicles (UAVs), Terrestrial Laser Scanner etc. Their usage has proved to be both highly accurate and time saving when compared to the traditional methods. The data obtained from them is in the form of a cloud, mesh or spatial data which helps in arriving at efficient methods for the conservation of the structure. Using spatial data, on site remains, historical sources, the structure (if partially or completely damaged) can be digitally reconstructed and it can depict the evolution of the structure over the years after being constantly subjected to various external factors. The digitally preserved structure can also be used in the virtual reality space for further applications for instance to promote tourism or creating virtual environments. Using UAVs, historic Structures can be monitored periodically to study the disintegration of the structure. The paper also explores intermediate methods like Virtual Tour Environments (VT) and Information Modelling (IM) which lie between the 3D Digital Documentation and traditional methods.

Keywords: Cultural Heritage, Preservation, Digital Documentation, Reconstruction, Historic Structures

I. INTRODUCTION

Monuments serve as a reminder of our history. They are a nation's treasure and symbol of its civilization. A monument building is defined as an existing structure of national aesthetic merit. Monuments and buildings are recognized as aesthetic heritages in developed nations. It is the outcome of a necessity to improve existing buildings for new uses, as well as an awareness of the value of architectural heritage preservation. Existing structures degrade over time, leading to a situation in which they are no longer able to serve the function for which they were constructed. There was also a requirement to improve the working conditions and adapt them to new functions. Furthermore, when the most developed nations progress, the perception that they are becoming more advanced rises. Furthermore, as the most developed nations evolve, the belief that it is important to preserve the existing architectural history rises. Heritage building rehabilitation and restoration is both a sustainable development strategy and a cultural gesture. The repair and restoration of heritage buildings has become a major issue throughout the country, particularly in the most developed societies, and assessing the structural safety of existing buildings is a difficult task in general because the methodologies used differ from those used in the design of new structures, and the strengthening of existing heritage buildings can conflict with their aesthetic value. Civil engineering encompasses not only the design and construction of structures, but also the monitoring and maintenance of existing structures. To avoid accidents, crack damage must be detected as soon as possible. Crack detection is employed in the construction of both industrial and residential buildings, as well as the monitoring of historical structures that are exposed to the weather. Both image-based and range-based methodologies have long been used in 3D documentation of heritage buildings. The rising popularity of UAVs (Unmanned Aerial Vehicles) in recent years has given image-based techniques a distinct edge in obtaining aerial views, which was previously difficult to do with traditional terrestrial-based acquisition methods.

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II. LITERATURE REVIEW

The literature review paper related to study about 3D Documentation and Preservation of a Heritage Structure was carried out. The main objective was to know the various aspects in this field of study and the inferences derived after the various equipment and techniques.

P. Arias a et al.[1] We are informed about the preservation of structures.. This research examines a variety of architectural documentation methods. Computer approaches and close-range photogrammetry are recommended as a preventive method for detecting, measuring, and tracking the temporal progression of specific structural faults discovered, as well as determining the degree of material conservation. The study of a set of monuments from Spain's historical heritage. A wire-frame model and a photo-realistic textured model were created in order to conduct the study. Later work concentrated on the areas with the most severe structural issues.

MNA Gulshan Taj et al.[2] The advancement of technology in the design and navigation of low-weight and autonomous drones and UAVs has made their use in construction management and monitoring more viable and cost-effective. Based on real-time data obtained from drones and UAVs, this study proposes a framework for the development of a fully automated smart construction monitoring and reporting system. Using photogrammetry techniques, the data in the form of drone photographs from numerous locations and point clouds can be used to create a 3D model. This "drone model" can be compared to a BIM model at different phases of development to track progress.

Fabio Remondino et al.[3] An overview of the actual optical 3D measurements sensors and techniques used for surveying, mapping, digital documentation and 3D modelling applications in the heritage field. It also reports the actual problems in the reality-based 3D modelling pipeline as well as the main research issues in photogrammetry and laser scanning. The continuous development of new sensors, data capture methodologies, multi-resolution 3D representations and the improvement of existing 3D recording methods significantly contribute to the documentation, conservation and presentation of heritage information and to the growth of research in the heritage field.

G. Guidi a et al.[4] Cultural structures if neglected, get subjected to major threats which may lead to its partial or complete destruction in any case the 3D reconstruction plays a major role in the academic study of the structure and preservation of the cultural significance of the structure. The virtual reality space gives a new dimension to the data retrieved. It can be further used to strengthen the tourist attraction to the structure as the past and evolution of the structure is understood in a much better manner by viewing the reconstructed model.

F.I. Apollonio et al.[5] The experiments were carried out as part of the virtual reconstruction of buildings that are just documented by partial sketches, or partially built, or no more existing. This is done with the aim to (a) to emphasize the use of a semantic construction of the digital model, (b) to show conceptual similarity between the original plan (2D or handwritten) and BIM (the information obtained by the scanning of structure), (c) to propose new and more robust solutions to the 3D modelling from 2D drawings for Architectural Heritage artifacts, which allows us to verify the assumptions made during the reconstruction of the structure, (d) to make use of interactive technical reference, simulated global illumination rendering techniques and real-time photorealistic rendering, for the visualization of three-dimensional model.

Leonardo Gomes et al.[6] We are informed that a survey of different techniques that can be used to develop a complete 3D reconstruction pipeline with focus in Cultural heritage. The 3D digitization process has been divided in four major overviews: 1) 3D and 2D raw data acquisition, 2) 3D and 2D registration in a global coordinate system, 3) data integration in a single triangle mesh, and 4) texture generation by either combining or not with an external sensor.

Bogusława Kwoczyńska et al.[7] Terrestrial laser scanning TLS provides colossal data which can be retrieved and interpreted in both 2D and spatial imaging. This paper deals with the Terrestrial laser scanner TLS. The cloud of point data that the TLS provides is of significant importance as it aids in determining the deformation, distortion, displacements, cracks on the surface of the object, which in turn helps in arriving at efficient conservation and preservation measures to protect the structure of significance. As it scans about tens of thousands of points every second it's both accurate and time saving.

Mieke Pfarr-Harfst et al.[8] We are informed of all the possible approaches and typologies that can be used to obtain a 3D Digital reconstruction of Cultural heritage. There are 8 typologies listed in the paper such as 4D BIM, 3D scholarly environment, 3D laserscan data, photogrammetry, panoramic photos, etc. This paper is basically a research on this heterogenic and complex topic but further investigation is needed to enhance it with further types, as well as define all types based on earlier research and publications.

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Rebecca K. Napolitano et al.[9] While photogrammetry, laser scanning, and building information modeling (BIM) have improved 3D documentation in conservation, the manner of documenting must match the project's requirements. For certain sorts of tasks, the current methodologies are effective. A middle ground does not exist, however, for projects that require to show 3D conservation difficulties but do not have the funding or time to create a 3D model. An intermediate solution is presented, a workflow for virtual tour [VT] environments and information modeling [IM] and this workflow is tested on a case study. In this paper, conservation reports are compared using 2D plans against the VT/IM environment and the time, cost and data management of VT/IM are compared with methods of 3D documentation.

Zheng Sun et al.[10] Tibet is the highest region on Earth with a complex terrain at an average altitude of 4900 m that extends over one-eighth of China's land territory and to reach this countries local heritage they have used technologies that are portable, efficient and versatile such as Low-cost Unmanned Aerial Vehicles (UAVs) and Structure from Motion (SfM) algorithms. This paper evaluates the accuracy of the UAV-SfM method for surveying a Tibetan stupa and illustrates how the results could be elaborated in a next-step analysis and used for management purposes. There can be many changes to architectural heritage over time caused by natural or human factors over a wider range (e.g., mountains, rivers, and vegetation) which can now be detected and analysed due to the 3D data collected.

Hari K. Dhonju et al.[11] Despite its importance to humanity, tangible cultural property is frequently threatened around the world. Share Our Cultural Heritage (SOCH), a geo-crowdsourcing technology that can be used for large-scale heritage documentation and dissemination. Cultural heritage data such as written narrative, places, and photos can be gathered via portable devices thanks to web and mobile GIS. These data are georeferenced and made public through online mapping. Acquired photos are utilized to reconstruct heritage structures or artefacts into 3D digital models using photogrammetric modeling, which are subsequently shown on the SOCH web interface to allow public involvement.

Arnadi Murtiyoso et al.[12] UAVs have recently seen a lot of application in archaeology, usually to provide a general perspective of the surroundings. Fundamental ideas in photogrammetry and SfM (Structure from Motion) based 3D reconstruction is addressed briefly in this paper. A case study has been done on the State-of-the art platform. The aerotriangulation and dense matching findings are compared to laser scanning data, and numerous difficulties with the aerotriangulation and dense matching results were evaluated. The findings revealed that, while dense matching of these UAV photos can achieve centimeter precision, the quality of the on-board sensor often limits further precision.

Mohamed MARZOUK et al.[13] Heritage Building Information Modeling or HBIM is a form of reverse engineering tool which can be used extensively for the digital restoration of buildings.: Acquiring the raw LiDAR data, Processing the point cloud we can generate the model. The model thus obtained from HBIM model can be used to perform structural analysis using finite element model. The results give insight on the wide range of stresses acting on the various components of the structures. The deteriorations in the structure are also shown.

S. K. P. Kushwaha et al.[14] Cultural heritage structures are generally subjected to a lot of threats both from humans and natural calamities. This article delves deep into one particular method to indirectly preserve these structures which hold a significant value. About 11 scans from different positions of the study area (St. Mary's Church in Lansdowne, Uttarakhand, India) using a Terrestrial Laser Scanner (TLS) Riegl VZ 400 was carried out. The reiterations of the scanning is done to collect more accurate and detailed data.

Anahid Ehtemami et al.[15] Virtual Reality is an emerging technology which has proved to be both effective and interactive in its functionality. Virtual Reality can also be used to effectively exhibit the Visual data of the structures which hold a cultural, historical or architectural significance. The inclusion of audio, lighting etc.., can prove to increase the efficiency of the virtual reality space. This paper deals with the basic steps of development and conceptual modeling of the structures of significance. The Human-Computer Interface or the Interactivity is a successful venture as it is easy to use, effective and gives a very pleasant experience to the user. The portability for terrestrial acquisition and cost effective factor of Virtual Reality has helped it in being a better option amongst the traditional approaches.

III. CONCLUSION

Through the study of the various papers and research articles on the field of our research, an enormous amount of knowledge and in-depth understanding of 3D digital documentation is gained. The workflow, process of collecting spatial data, retrieval of the data in various forms (like cloud, mesh, etc.,), post processing of the spatial data, efficient and significant use of the collected data , features and characteristics of instruments like the LIDAR, Terrestrial Laser Scanner (TLS), Photogrammetry equipment etc.., and various other aspects have been understood in a better manner. Alternative methods like the virtual tour environments (VT) and informational modeling (IM) too have been studied about. Thus we

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arrive at a conclusion that the Heritage Structures which hold a great historical, architectural and cultural value need to be cared about, well preserved and conserved to avert any irreversible damage to the structure. For this one of the most efficient and successful ways is 3D Digital Documentation and Digital Reconstruction (if partially or completely damaged) which also paves its way into Virtual Reality for further use into various fields like tourism and academic study of the structures.

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