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MOVING TOWARDS A NEW LIFE CYCLE ANALYSIS APPROACH BY IMPLEMENTING LOW COST STRUCTURAL 3D MONITORING OF HISTORIC BUILDING SAFETY BY MEANS OF IMAGE BASED MODELLING.

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Abstract
A building's structural safety is often remit to human life fatalities and the measures of social protection and security often used following the collapse of a portion of the building. It is quite clear that, if it were possible to monitor the increase of static deterioration, it would be easier to prevent the collapse. There are two fundamental aspects closely linked to the building's collapse: the first concerns the security of lives and the second concerns the well-being and quality of life when it is considered in relation to Cultural Heritage survival. Unfortunately, the high cost of a 3D survey does not usually permit a constant monitoring of the visible instability.
The paper aims to carry out a low-cost workflow for structural 3D monitoring of historical buildings based on Image Based Modeling (IBM) techniques. IBM techniques create a 3D model of the sample by taking a structured dataset of images according to photogrammetric rules. In recent years, the experimentation of several research teams demonstrated the affordability of these techniques, which are able to ascertain data with accuracy within a millimeter (according to the size of the sample and the camera resolution).

1. Introduction

The complexity of many buildings can make the understanding of structural behavior difficult to assess.
For example, ground movement can lead to serious problems if the safety margins of structural strength or stability are compromised. Most buildings will crack at some point in their life cycle. Monitoring changes in crack size is an important diagnostic tool for determining the causes and subsequent reparation interventions required. Cracks can often be the first sign of a serious defect and should be analyzed without interruption to reveal the direction of movement and impact of cyclical effects to avoid the problem worsening.
The possibility to guarantee the highest possible level of public safety is closely linked to the constant monitoring of both environmental and structural decays. The most effective method for achieving the right level of protection is to maintain a constant control of the static and dynamic aspects. The technical action utilized to monitor the building's safety is a 3D survey repeated appropriately and on a constant basis. Nevertheless, the high cost of the 3D survey by means of laser scanning [1] doesn't permit a constant and frequent monitoring of the visible instability and this lack of intervention often represents the first cause of the building's collapse.
A historical building collapse not only constitutes a danger for public safety, but also constitutes a cultural loss for both current and future generations. It is absolutely essential that this risk should be eliminated and all available methods must be attempted in order to make the building safer and reduce the risk to human lives.
For this reason, we implemented a methodology

that enables the monitoring of the building's stability without the high cost of 3D survey and potential post-processing difficulties.
The paper aims to carry out a low-cost workflow for structural 3D monitoring based on Image Based Modeling (IBM) techniques. IBM techniques render a 3D model of the object of study by taking a structured dataset of images according to photogrammetric rules. In recent years, the experimentation of several research teams [2, 3, 4] demonstrated the affordability of these techniques, which are able to ascertain data with accuracy within a millimeter (according to the size of the sample and the camera resolution).

1.1. Case Study

The case study has been chosen in consideration of its cultural significance in the historic city centre of Palermo, Italy. We have chosen the historic building "Palazzo Asmundo", a 17th century structure located in front of the cathedral of Palermo (fig. 1). The façade presents several cracks in the plaster and this could be the first announcement of a more significant structural problem. We developed a workflow to monitor these cracks in order to give structural experts enough information to discern the approriapte technical intervention to undertake.
To ensure a correct and reliable survey it is necessary to detect at least three different points on the façade that will be used for future alignments between the different temporal monitoring 3D models.
In this case, these points were easily established due to the clearly defined geometry of the windows and cornices and that the investigation was focused on a restricted portion of the façade.

Fig. 1. Palazzo Asmundo in its urban context.

Fig. 1. Palazzo Asmundo in its urban context.

1.2. Methodology

1. *Image Based Modeling techniques on a historical architectural building.*

In recent years, IBM techniques have been widely used in the field of cultural and architectural heritage by paying particular attention to the diversity of materials and the size of the object [5, 6]. However, there is still an incredible lack of investigations aimed at verifying and indicating a methodological pipeline in low cost structural 3D monitoring in the field of building safety.

2. *Data Set*

As previously stated, IBM techniques are based on the processing of properly obtained structural image datasets in order to have at least two overlapping images of the object. To elaborate a building's façade is a fairly straightforward process, so the data set can be obtained by regularly following the photogrammetric and Computer Vision rules often indicated in the default tutorials of the specific software. In fact, the presence of all decorative and architectural elements (windows, doors, mouldings, architraves, friezes, cornices, etc.) give a redundancy of information that allows the correct elaboration of the 3D model, since the individuation of homologous points is easy. Clearly the 3D models obtained by means of these techniques are a direct function of the resolution of the images. To perceive the cracks and other details a system that allows close-range images should be used.

3. *Employed Package: Agisoft PhotoScan*

As of today, among all existing image-based 3D modeling packages, Agisoft PhotoScan is the most affordable and utilized software. Based on the latest multi-view 3D reconstruction technology [7], it operates with arbitrary images and is efficient in both controlled and uncontrolled conditions. As opposed to free web-based packages (123D Catch, Recap, ARC 3D), Photoscan gives the user the possibility to properly set the parameters of the 3D reconstruction. The reconstruction takes place in two steps: first the software performs a 3D alignment between the images and gives back a sparse point cloud, it is subsequently possible to obtain a dense reconstruction wherein the intricacy and textures are computed. Choosing the correct sparse and dense reconstruction parameters will affect the quality of the 3D model in terms of sharpness of edges and smoothness of surfaces.

In this case, the geometric features of the architectural detail led us to choose a high quality reconstruction and a moderate depth filtering reconstruction with a generated model of 1.7 Millions vertices and 3,4 faces. Then we proceeded with the texturing of the model that has been exported in .OBJ format.

Table 1. reports all the specifications inherent to the dataset including Ground Sampling Distance (GSD).

Table 1. Specifications summary of the dataset

	Camera	Resolution	Focal length	Number of Images	GSD	Processing time
Detail	Nikon 5200	24 Mpix	18 mm	24	0,03 m	25 min
Overall Façade	Nikon 5200	24 Mpix	18 mm	47	0,03 m	56 min

Fig. 2. Façade 3D model

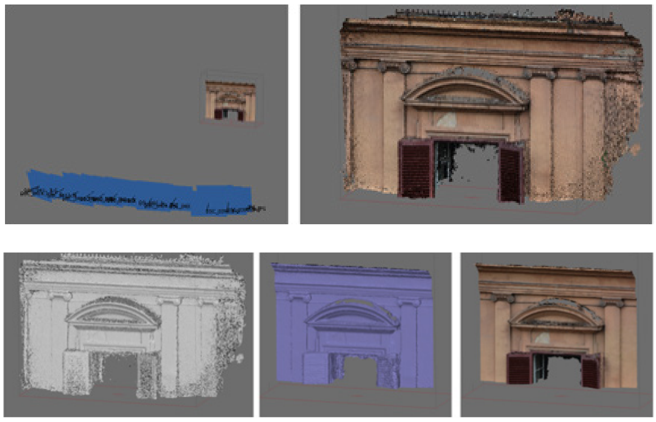

Fig. 3. Architectural element 3D model

2. Results

The results obtained render a 3D textured model as accurate and detailed as the highest image resolution. This model will provide structural experts with enough information to discern the appropriate technical intervention to undertake and the best monitoring to preserve the building's life cycle. The cracks in the building are extremely visible and measurable which allows monitoring over time.

3. Conclusion and Discussion

The experimentation carried out constitutes the foundation on which developing a low cost methodology for structural 3D monitoring for building safety should based. The obtained results show the effectiveness of the method. Experts will be employed with useful elements for critical decisionmaking on the monitoring, timing and modality that beset the degradation and causes of damage and therefore the appropriate technical intervention to implement. One possibille approach to implement in order to maintain a low cost, constant monitoring of the building would be to install two web cameras in front of the façade. The camera calibration could offset the low resolution of camera default values. Employing a system that can monitor movement helps to diagnose potential issues at an early stage, and forecast what maintenance will be required in the long term.

Potentially, we could maintain the constant monitoring of Cultural Heritage sites in cities while keeping costs low and following straightforward calculations. We could avoid building collapses and the high costs of restoration.

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