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Research Article

Building partial 3D models of cultural monuments

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Abstract – "Contemporary society does not value the cultural heritage of its ancestors", is often heard. But this is not always due to people's reluctance and indifference. There are also objective reasons. Many cultural monuments cannot be maintained because of property rights and other intentions of the owners, sometimes because of lack of funds or because of political reasons - after the change of political regime there is no longer a strong motivation to protect and maintain the cultural monuments of the past regime. These monuments are slowly disappearing and are inevitably being gnawed by the ravages of time. This situation has not been helped by the COVID 19 pandemic, and it is not helped by the current post-pandemic era. The modern age and the modern technologies it has brought with it, even in the area of heritage protection, can be of great help to us. Everyday devices such as mobile phones, tablets and other ICT devices, which can be used to create 3D models without the need for professional equipment, are a good tool for preserving cultural heritage in digital form for an almost indefinite period of time. Therefore, this possibility is becoming accessible to the general public, even to individuals. We are already witnessing a rapid expansion of computer science and it can therefore be assumed (as our own experience has already taught us) that what we cannot currently complete or process perfectly, we may be able to do in the future. It therefore makes sense to address this issue. It is not always necessary to create a perfect model of a large building, but sometimes it is enough to preserve, for example, one wall, a fresco or a part of a real monument. And this is the area we will focus on in our paper.

Keywords – Photogrammetry, 3D Models, Pix4D, Tie-Points, Culture Heritage

I. INTRODUCTION

The technologies of our time allow us to use techniques and methods that were unthinkable a few decades ago. In the field of cultural heritage protection, we often come across 3D models that have been created for the purpose of digitizing large religious buildings or even smaller objects. There are practically two technologies available to us today. One is photogrammetry and the other is the use of various Lidar devices. Photogrammetry seems to be preferable, especially in difficult terrain or where the use of Lidar equipment would be impossible - for example, in densely vegetated areas or areas inaccessible by terrain. [1] In these cases, we use cameras mounted on drones. [8] Drones are nowadays quite well spread. Their use is both intuitive - simple

and they do not require any complicated maintenance. Therefore, they are increasingly being encountered in various areas of the economy, where they also bring positive economic results. [6, 10] They also find their justification, for example, in warehouses, where they can identify individual goods using QR codes, or in logistics, where they already have artificial intelligence and many tasks are automated. [4, 7, 9] They also often find their use in the field of terrain or rural mapping, where they are very helpful, for example, in revitalization tasks. [1] In the future, itcan be expected that they will also find their place in the educational process. We have already shown in our studies [2, 3, 4] that they are an excellent tool to support cross-curricular relationships. Students at different levels of study and in different schools receive sufficient education in electronics and computer science to be able to understand drones not only on a user level. [11, 12, 13, 14] They are also very popular for leisure activities, which we can also use to preserve cultural heritage. Simplyoi only by giving students a sense of their aimless flying. But we must also be mindful of the rights of students and their protection from, for example, dangerous stalking or surveillance. [15]

II. Materials and Method

An example of creating a 3D model will be shown with a concrete example. In Komárno, Slovakia, there is a fortress that has experienced its great glory for many decades and resisted enemies. It is a unique fortification object that is part of the most extensive fortress system in Central Europe, which extends over the territory of the Slovak Republic and Hungary. The oldest part, the so-called Old Fortress, was built in the 16th century on the site of a medieval castle. In the 17th century, it was enlarged by the so-called New Fortress. After it was shaken by two strong earthquakes in the 18th century, the Fortress lost its military character.

Fig 1 View of one wall of the fortress from which we will create a 3D model. This is the wall of a brick building that served the army until a few years ago.

However, as a result of the military campaigns of the French Emperor Napoleon I, it was rebuilt, modernized and expanded in the early 19th century into the most extensive fortress system of Austria- Hungary, which was to accommodate an army of up to 200,000 if necessary. [16] Efforts to preserve it continue and we have chosen it as our object. We have already mentioned above that it is not always necessary to create a 3D model of the complete structure, but often only a part of it is sufficient. We have chosen one of its walls, which is already in great need of repair. In total, we took 28 photos from the ground and tried to create a 3D model of the wall. We show one photo out of the 28 in Figure 1. We used Pix4D software to create a partial 3D model.

It is a professional photogrammetric software with which we have achieved positive results in the past. We processed the photos in the Intelligent Robotics Centre of J. Selye University with the following hardware parameters:

- CPU: Intel(R) Xeon(R) CPU E5-1650 v3 @ 3.50GHz
- RAM: 32GB
- GPU: NVIDIA Quadro K4200 (Driver: 9.18.13.4121)

The photographs were obtained in two approximate rows at such a distance that the object of our interest, in our case the wall of the building, was dominant in the photographs and that there was an overlap between the images. However, this is not the only condition. For the sake of preserving the 3D dimensions, it does not hurt if there are also more distant objects in the photographs. Since photogrammetry relies on different views of the same object, we have to move along the wall, always perpendicular to the wall, when acquiring. Multiple photographs taken from the same location just by changing the position of the camera by a few degrees will not lead to success. The software will not create a 3D model even if only a partial one.

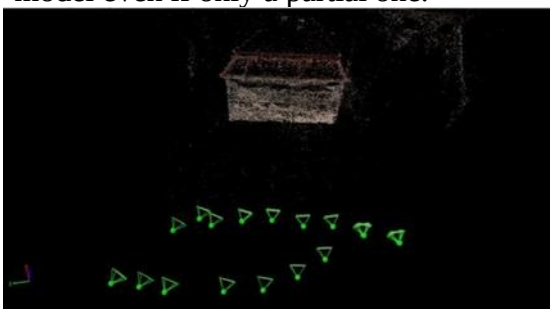

Fig 2 Positioning of cameras in relation to the wall

III. RESULTS AND DISCUSSION

The position of the cameras can be seen in Figure 2, where the points in front of the cameras represent the so-called tie-points. These are points that have

been identified in multiple images - for example, the corner of a particular single brick. In figure 3 we show the Number of Automatic Tie Points. The number of Automatic Tie Points (ATPs) per pixel averaged over all images of the camera model is color coded between black and white. White indicates that, in average, more than 16 ATPs are extracted at this pixel location. Black indicates that, in average, 0 ATP has been extracted at this pixel location.

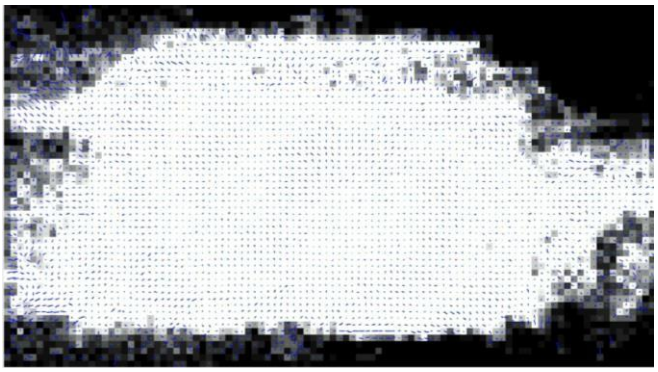

Fig 3 Number of Automatic Tie Points

So it is important that the white area covers our area of interest, which is met in this case. The ideal case (but not in every circumstance) is one where the entire square area is white. The worst case, on the other hand, is when the square area is all black.

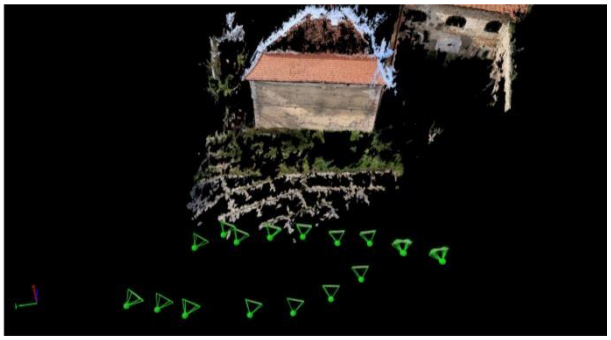

Fig 3 Point Cloud of the wall

In Figure 4, we show the Point Cloud wall and the nearby surroundings. It is clearly evident that tie-points and point clouds are not one and the same. While Tie-points do not carry any information about the position of a point within the coordinatesystem, Point Clouds already do. Since it is a metric system, measurements of length, area or volume can also be made on these points if needed. If we also want to make measurements on the model, either the photos must have GPS data, or we must calibrate the individual distances and represent the results with respect to this calibration. The final 3D model is shown in Figure 5. In case of preview, it is available here: https://skfb.ly/oGLUJ.

Fig 5 Final 3D model

We could notice that the model is not perfectly smooth, but contains noise especially at the edges and typical characteristic errors of 3D model creation. Their mechanism of occurrence depends on many factors, but from a practical point of view it is important that these are removable defects. This is discussed in more detail in our publications [2, 3, 4]. Of course, cropping in another software tool is not excluded either.

Just to illustrate, photogrammetry does not only serve in the field of cultural heritage protection or rural mapping - control of cereal crops, the state of deer in the hunting grounds, etc., but it also provides a helping hand in various fields of biology. Figure 6 shows a 3D model of a tree trunk.

Fig 6 Sorbus aucuparia L. 3D modell. Available for download at: https://skfb.ly/ozPJH

In the picture above we see a 3D model of a damaged tree trunk. By making the 3D model easilyportable, anyone who wants to examine it doesn't have to physically move to a specific location in nature, but can view it from the comfort of their office. This forces a great possibility of re-viewing it at any time.

IV. CONCLUSION

They were a part of our lives when we were growing up. We walked past them and maybe didn't always realise their beauty and the fact that they were an aspect of the cultural expression of the society at the time - they were beautiful then, and they had the spirit of beauty that was there. Yes, we are talking about cultural monuments of various sizes. From small commemorative plaques of well-known personalities to life-size or larger-than-life statues to basilicas and cathedrals. Everyone has a place where they live, a place where they reside, a place that is important to them. In our surroundings we find many small and large monuments that are important for society but also for us, for people. And it is these monuments, to which we are bound by a certain mysterious bond, that were and are part of us, and perhaps it was or still is they that inspire us to our actions and our growth. Whether we are talking about social monuments or monuments of a personal nature - the facade of a family home, an inscription in the brickwork from a grandfather, etc., 3D models seem ideal for archiving and preserving them in digital form. At heights, UAVs are also helpful. Photogrammetry as a 3D model creation tool can create a realistic 3D model in realistic colours using non-abrasive methods, which we can print with a 3D printer when subsequently processed. We are talking about small museum artifacts and objects made of materials that naturally decompose over time. So we don't only have to work with existing models, but we can also create our own outputs, which we can then use in the educational process. After all, we only need to consider that, for example, Notre Dame in Paris could also be reconstructed after a fire based on photographs collected from tourists - [17]. Therefore, it makes sense to engage in this activity, which will certainly help future generations to understand our life and our culture.

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