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An Example of the Use of Photogrammetry for Archiving the Shapes of Natural Materials and Creations

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Abstract. We can find cultural monuments everywhere. Smaller ones are often made from available and cheap natural materials - stones. However, due to the weather, due to their smaller dimensions, are often subject to vandalism, damage caused by careless handling or accidental damage. Sometimes they are just pieces of stone, but they have a deeper meaning in connection with cultural value, and for example by studying them in office spaces in the form of 3D models. In our contribution, we focus on the protection, study and preservation of such cultural and artistic monuments made of natural materials or generally stone natural formations or even large stone or brick surfaces. In our article, we want to focus on the practical feasibility rather than the mathematical background, as we believe that this information is much more useful in practice. We point out that it is advisable to use drones to check the condition of materials.

Introduction

In Fig. 1 we present an example of the loss of cultural heritage. In the first row on the right, we can see the building as it existed in 2007. After 15 years, only the torso of one corner part remained of it - the bottom row on the right. But the situation is also very similar, for example, in surface or underground mines, where mining activities transform the character of the landscape. By extracting a significant part of the deposit, some of its parts are definitely lost. That's why we try to preserve them in digital form. A big help in our efforts is photogrammetry, where we make significant use of it. Currently, commonly available technical means are already at such a level that they allow their use not only for recreational activities, but can also replace professional means to a significant extent. Today, it would be hard to find a person who does not own a mobile phone or tablet. Photos obtained from these devices allow the creation of such 3D models that are a faithful copy of the real object. Acquiring photos is not only tied to ground activities, but we can also use drone and robot technology to a large extent. The created 3D models are also of great importance in the educational sphere, where the great benefit is not the sculpted model but the created model from a real object [1-4].

Using drones makes it possible to take the right pictures. Radácsi and his colleagues present a method using a drone to go through the shelf system of a decentrum, where the inventory is mapped using photographs, and the images are sent by the drone to a computer for image processing. In the case of image processing, QR code extraction and recognition are performed [5,6]. The method is complicated by the fact that in the center it is difficult to navigate based on the GPS coordinates due to the Faraday cage effect, so the drone's route must be automated, taking into account various aggravating circumstances. This method can be used well to examine the condition of outdoor monuments. With the help of the drone, we can automate the production of high-quality and high-resolution images by entering exact GPS coordinates. In the case of image processing, a high-resolution 3D model can be created.

Fig. 1 "Nebojsa" mansion in Slovakia. From the left side from the top: The mansion from the postcard from 1899, the mansion from the postcard before 1945, the mansion in 2007, an inscription describing the sale of bricks, the abandonment and deliberate dismantling of the mansion, the rest of the mansion in 2022 [7-10].

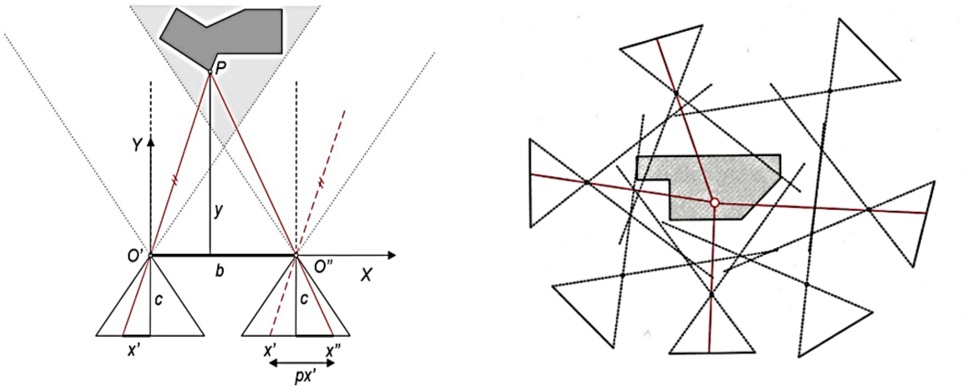

Fig. 2 Normal case of stereophotogrammetry on the left and convergent imaging on the right [11].

One-frame photogrammetry, also called projective, can be considered the simplest of the photogrammetric methods. It uses a mathematical model of the projective transformation between two planes derived from projective geometry or the central projection of the plane. With the help of stereophotogrammetry, points on the imaged object can be evaluated not only horizontally, but spatially. Currently, the most widely used photogrammetric method is convergent imaging with a general orientation of the image axis. It is a multi-frame method that requires special photogrammetric software for analytical processing. The biggest advantage of convergent imaging, compared to stereophotogrammetry, is the just-mentioned general position of the axes of the camera shots (albeit always in an effort to maintain a sufficient overlap of the images and for the object in the images to occupy the largest possible area), and thus using this method objects of any shape can be measured and dimensions [11].

In creating the 3D models, we have been looking at two areas. The first is the creation of 3D models of large religious buildings and the second is the creation of 3D models of museum artefacts. Both areas have their own specificities that we have to accept. In the case of sacred buildings, there are often cases where part of the building is missing - for example, part of the roof. This is due to the smaller number of photographs that show that part of the building. Here we have to manually attach additional photos. Since these are larger buildings, some details may remain unrecorded [12]. For museum artifacts, the biggest problem is proper lighting. Busts and sculptures are usually not illuminated from all sides evenly. A strong difference in contrast - e.g. a strongly illuminated front part and a weakly illuminated back part can cause flaws on the dark side as well as incorrectly connecting the two parts, which the software starts to process as if separately. It creates a 3D model of the dimly lit part from the photos that capture the dimly lit part and vice versa. These parts are not connected but are separated and displaced from each other. Eliminating this problem requires a lot of time in post editing [13].

Material and Methods

In the next text, we would like to point out the practical implementability rather than the mathematical background, as we are of the opinion that this information will be of much better use in practice. As we see in Fig. 3, the first step is to obtain photos of the given object with sufficient coverage. We recommend at least 30 percent. Obtaining photos is not tied to the condition from all sides, but it is important to focus on obtaining photos at least from the point of view from which we want to obtain a partial 3D model. This is also suitable in those cases where we want to create a model from, for example, a rock wall or similar, where it is not realistic to obtain the shape of its opposite part.

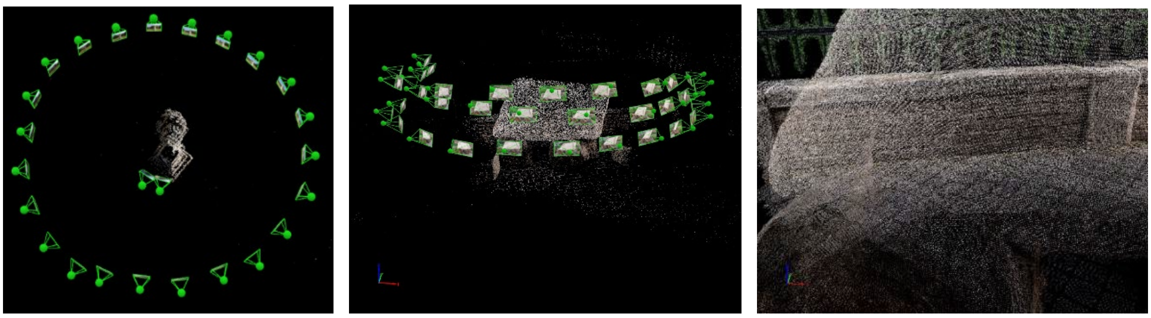

Fig. 3 From the left: An example of the layout of the camera overlay when obtaining photos of the entire object; camera position only when obtaining photos from the front of the object and Tie points; object point cloud.

The first step is the selection and elimination of bad, noisy photos or photos with a significant deviation from the average lighting conditions. These have a significant impact on the quality of the model, so let's try to get the photos in each shot under the same conditions. We will then use photogrammetric software to create a 3D model. There are several software that can be freely available or paid. We used the software Pix4Dmapper Pro ver. 2.0.104 – 64 bit. This has already proven itself in the past when creating 3D models of museum artifacts. One example is shown in Fig. 4, bottom left row, where this 3D model was created as part of a thesis [14]. Used hardware: Intel(R) Xeon(R) CPU E5-1650 v3 @ 3.50GHz, RAM: 32GB; GPU: NVIDIA Quadro K4200 (Driver: 9.18.13.4121). Used Camera: Model Name OPPOReno5Z_4.7_4000x2256 (RGB). In the case of good photos, the software will create a model without the need for further editing. All these models presented by us were created in this way. If necessary, it is possible to make further manual adjustments either at the level of Tie points or Point Clouds, e.g. attaching another photo, matching the position of points on individual photos, etc. If the Points Cloud is already generated, the Triangle Mesh will be used to create the model itself. The latter may contain fragments outside the scanned object, e.g. grass or part of the flower planting, which is fine.

47.758270, 18.127148 47.757055, 18.129382 47.757271, 18.095961

47.755935, 18.128501 47.755922, 18.128533 Lapidarium museum, Slovakia

Fig. 4 Models of various memorial plaques or engravings on natural stone together with their Google maps coordinates and a bust stored in the Lapidarium museum.

We can notice that when shooting only half, the distant background behind the subject will create a 2D vertical surface. We see this in Fig. 4 top left. All other models were created from photos taken from all sides. An example of turning the model can be seen in Fig. 5. We can use these methods with great advantage, e.g. when studying the structures of large natural stones and fractures, brick walls or various other objects from the office premises. Thus, it is not always necessary for an expert to go to the site, but e.g. other employees can create a series of photos and the expert will create a model from them. These procedures will similarly find their application in mineralogy.

Fig. 5 3D model of the memorial stone from different viewpoints. The stone is located at Google maps coordinates: 47.758339, 18.127019. It was installed only after the creation of Google Street View.

Photogrammetry is offered as one of the attractive methods in the current field of cultural heritage protection. Even cheaper phones or tablets already have various high-quality cameras that are suitable for this purpose, which eliminates the need for professional equipment. Thus, the necessary equipment is available, cheap and commonly used in everyday life.

With the help of drones, we can also approach places that would be difficult for humans, such as high-rise historic building parts, only from above or from the side or its parts accessible from a height (see Fig. 6). Our method is also supported by Zhou's research, according to him, many buildings reflect local customs, social conditions, economic level, human-earth relations, and have high artistic and tourism development value. In his article, he built a three-dimensional model of the village based on drone tilt photography technology, and revealed the steps and methods of using consumer-grade drones to extract the landforms and three-dimensional modeling of traditional villages, and offered new opportunities for technical support for the protection of traditional villages. He contributed 7.9% to the repair works of village buildings with his method [15].

Fig. 6 A castle wall and hard-to-reach cornerstones

These procedures may also be suitable for students who have a visual non-verbal learning style, but also as project teaching procedures (intuitiveness, trial and error, ...). Photogrammetry uses knowledge from various fields, such as mathematics, geometry, physics, but also professional subjects such as optics, geodesy and, of course, mainly computer science. Therefore, it is also suitable for building subject relationships. Here, of course, we also understand the real connection of theory with practice. We mention secondary school as a suitable age category, where these procedures are of the greatest importance in implementation.

Last but not least, we would like to touch on the time required to create 3D models. The total generation time consists of three parts, namely Time for Initial Processing, Time for Point Cloud and Time for 3D Textured Mesh Generation. Our observations show that there is only a weak correlation between the model creation time and the number of photographs. A much stronger relationship exists between Time to create 3D model and Number of 3D points. These were obtained based on Tie points. In all cases of our measurements, this association showed a power-law regression dependence. However, there is a dependence between the number of photos and the quality of the model. We report the results of our observations in Table 1.

Table 1 The quality of the 3D model and the time required for creation

	250 photos	100 photos	50 photos
Quality of model	Good !	Good	Enough good *
Time of creation	Approx. 50 min	Approx. 20-30 min	Approx. 10 min

* Good for educational purposes. With risk of surface ripple.

! A large number may cause an errors

Conclusion

In conclusion, we can state that the 3D model created by photogrammetric procedures fully reflects reality. It enables non-abrasive measurements of the dimensions and volumes of real objects, but due to the full color and detail, it also retains its technical, technological and cultural value. It can be used for study and preservation for our future generations. Although such monuments or objects may disappear from our daily life, considering the trend of today, we can say that the 3D model remains in the digital world even after the destruction of the real object and can still be available in the form of a model. We present an effective method using drones, which can be well used to examine the condition of outdoor monuments. With the help of drones, we have the opportunity to automate by entering exact GPS coordinates, and we can take high-quality and high-resolution images. In the case of image processing, a high-resolution 3D model can be created. The method does not require a drone with special features, just a consumer-grade drone, but you must have a high-resolution camera.

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