Digital Model of an Existing Building a Wild Riverbed in Tokyo

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Abstract. This paper presents an application of photogrammetric methods for so-called image based modelling and rendering. Digital photogrammetry technology was used for the real use of a digital model of an artificial riverbed for a wild river in Tokyo. This technology was applied using two software programs, where we evaluate their compatibility and propose measures that should increase efficiency in the future in the creation of digital models of existing buildings. We describe the process of creating a model in both software separately and evaluate their use for a given type of object. In this paper, we describe the individual processes from the selection of photographs through the cleaning and smoothing of the point cloud to the final model. We present the practical use of the created digital model. In the pictures we show the solved structure, the process of joining individual photographs and the final model for the overall idea of the application of this method. The results and discussions section describes the evaluation of both software and proposals for measures for their use, especially for water structures of a linear nature containing recurring elements such as water barriers.

1. Introduction

Many digital model creation processes [1, 2] focus on projects of new buildings. An Example of an apartment building design process can be found in [3]. Examples of road-building construction processes can be found in [4, 5, 6]. A digital model of new building provides detailed information, which is very useful through the whole building lifecycle, for the future existence and operation of the building [7, 8].

Currently, there are various methods for creating a digital model of an existing building. At the Department of Engineering Informatics at the Czech Technical University in Prague, we deal with the creation of digital twins of objects with high accuracy. In the previous paper, we described the methods of 3D scanning from pre-scanning preparation through data processing from a 3D scanner to the final digital model of the building [9] In this paper we will present the application of the photogrammetric method, specifically ground photogrammetry. Of all the optical methods, terrestrial photogrammetry is the least device-intensive (common digital camera) and is therefore the cheapest optical method for obtaining digital data.

It can be expected that importance of the acquisition of 3D models of existing buildings will be growing with continuous implementation of industry 4.0 principles [10] and a necessity to acquire data...
in BIM formats such as IFC [11]. BIM models of buildings and their accuracy will help not only to reduce failures rate in the building project, time and financial savings during construction, but especially in the operation of the building through its whole lifecycle [12].

2. Digital model creation process

The aim of our research, set based on priorities and scope [13], was to find easy to use and inexpensive technology for the construction of a wild riverbed in Tokyo Olympic in Figure 1. The reason for creating the digital model was disputes over the placement of obstacles on the race track. Water barriers affect the flow of water and thus the difficulty and safety of the plant itself. Obstacles can be moved by rails and moved by their height using additional parts. During the construction design, a race track was designed, including water obstacles, by experts from the Czech Technical University, but the organizers of the Olympic Games arbitrarily changed some obstacles. It was necessary to compare both variants using digital simulation.

A Canon EOS 250D digital camera with a resolution of 24.1 Mpx and an 18-55 mm lens was used to take photographs. A total of 1800 photos were taken. The images were divided into groups according to individual parts of the wild riverbed into 3 parts (starting part, middle part, finish part). In the target part there was a water surface, which we evaluated as potentially problematic in terms of high surface reflectivity. After dividing and deleting the photos, there were 1200 left for the possibility of creating a digital model.

![Figure 1. General view of the construction of an artificial riverbed for a wild river in Tokyo.](image-url)
At the Department of Engineering Informatics, we had software in two options available for image processing using photogrammetric methods. In the first case, we created a digital model using Autodesk Recap Photo software. This software allows you to upload a maximum of 200 photos at a time. For this reason, the photos were divided from the original three into six groups. We divided each part into the right and left bank of the riverbed. The individual parts of the model were of good quality after processing the photographs, but the part of the target part of the riverbed, where the water was located, was not drawn correctly. Before connecting the individual parts, it was necessary to clean the point clouds from digital noise, using the automatic function and manual cleaning. Furthermore, the individual parts were smoothed to make the connection as simple as possible. Puncture points were not used during the photo shoot and therefore it was not possible to combine the individual generated parts of the digital model into one whole. We had to use manual connection using the points we specified, which were always in both connected parts. The character of the building - an artificial riverbed for racing on a wild river - did not allow manual connection of all parts, because it is a line building with constantly recurring water obstacles. It was not possible to distinguish which obstacle is located in which part of the racing riverbed. We consider this attempt to create a digital twin to be unsuccessful.

The second software we have is Reality Capture, which also allows automatic processing of images into a digital model. For the first attempt, we divided the photos into two groups according to which part of the riverbed was the water surface. A total of 1200 (900 + 300) photographs were used. The first group was without water surface, the second with water surface. The water surface was located in the finish part of the riverbed. After generating both parts of the model, process you can see in Figure 2, we had to clear the data of data noise and combine both parts into one final model. Although both parts were processed in sufficient quality, it was not possible to combine them purely into one whole. In the part of the riverbed where the water level began, there were different lighting conditions during the rental of the pictures. Due to this, it was not possible to combine the model into one whole.

Figure 2. The process of creating a point cloud in Reality Capture software.
The quality of the digital model in the second software was sufficient to simulate the flow of water. We had to change the technique of creating a model so that we would create only one model without having to connect to another part. So we uploaded to software 200 photos from the right bank of the starting and middle part of the race track. After a thorough inspection of the generated model, we gradually uploaded more images of the right bank of the finish part, which contained the water surface. This technique didn’t work, so we took photos with a water surface again and chose photos from the left bank of the starting and middle part of the riverbed. This part of the model was processed correctly on the first attempt. Other photos - those that contained the water surface, we added manually with the exact designation, always 3-4 points identical to the points that contained the already created part of the model as well as the inserted photo. This process you can see in Figure 3. Because the water surface was also the first part of the riverbed, especially in the places of obstacles that retained water, it was necessary to use this technique in these places. This process has worked well. The point cloud was complete. Furthermore, the data had to be manually cleaned of digital noise and then smoothed using the automatic function.

3. Results and discussions
The final model in Figure 4 consists of only 800 of the 1800 photos taken. From the experience of other projects focused on the creation of digital twins using digital photogrammetry, we know that appropriate preparation before the actual shooting is the most important aspect of the whole process. It is necessary to precisely plan the process of taking photographs, especially for larger or linear constructions. Furthermore, the setting of the camera angle, focal length and, last but not least, lighting conditions. Outdoor photography is unpredictable, but that is why it is necessary to carefully plan the photography so that the shortest possible time runs so that the lighting conditions do not change much during the photo shoot. In this particular case, it would be possible to use aerial photogrammetry using a drone, which we unfortunately didn’t have at the time of the photo shoot.

There are more software that supports digital photogrammetry, but each works a little differently, so you need to take photos according to the capabilities of the software used. The last thing that would be good to use are puncture points, which would make it easier to connect the model. Especially for objects
that have a large number of the same or very similar parts such as flat surfaces or repeating masses (in our example, water barriers).

Figure 4. Finished digital model in Reality Capture software.

4. Conclusions
From the presented results it can be said that both software can be used for the creation of digital models. The accuracy of the model is the same but if the model contains glossy surfaces the Reality Capture software is significantly better. In addition, this software is more suitable for large objects that need more than 200 photos, which is the maximum possible number per upload in Autodesk Recap Photo software. For example, a lower number of photographs is sufficient for a digital model of a sculpture, but for larger objects such as buildings, the number of photographs is usually in the hundreds. Both software are suitable for editing the point cloud and then exporting the data.

The price for digital photogrammetry, as opposed to 3D scanning, is mainly supported by the price, when the price of the equipment needed to take photographs is significantly lower than the purchase price of a 3D scanner. Furthermore, the evaluation of data is largely automatic - certainly in the example we selected, it was necessary to connect part of the model manually, but only because it was a very demanding object.

Digital photogrammetry can be used as well as 3D scanners in construction. In particular, linear and tall buildings will be possible to better and more accurately model using aerial photogrammetry, especially today, when drones are becoming more available. The future is a combination of both of these methods. The digital model created in this way can serve as a basis for a building information model (BIM).

Acknowledgment(s)
This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS20/103/0HK1/2T/11

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