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COMBINING AIRBORNE AND TERRESTRIAL LASER SCANNING IN PRESERVATION OF CULTURAL HERITAGE

Abstract. Cultural heritage is an important factor in the life of every human being. It helps us to understand previous generations as well as the history of where we come from. In order to save cultural heritage for next generations, there is a need for their preservation. The main purpose of this paper is to show aspects concerning combining two technologies for acquisition and documenting of historical objects for preserving purposes. The recent development of computer and information technologies caused replacement of traditional acquisition methods with nowadays popular technologies. The paper also describes the principle of these technologies, terrestrial laser scanning (TLS), aerial laser scanning (ALS) and their main products. Advantages provided by these technologies are fast acquisition, very dense 3D point clouds with high accuracy and also a very short period of time for its processing. Riegl LMS – q680i and Leica ScanStation P20 3D laser scanner were used for surveying the area of Petrovaradin old town in Novi Sad, Serbia. Processing of raw data includes integration of two point clouds into one, noise filtering, meshing and drawings of the facade. The final step after processing of the data for Petrovaradin old town was a publication on the web in the form of panoramic images and point cloud viewer. In that way, anyone interested can view the data, perform measurements, draw cross sections or make a simple analysis. This project is a part of a (larger) project with the final model of complete area of Novi Sad.

Keywords. ALS, TLS, cultural heritage, preservation, laser scanning.

1. Introduction

Nowadays very popular technology of terrestrial laser scanning is used for collecting of detailed data of various types of urban objects. The main advantage of this technology is a capability of collecting a lot of details of the scanned object. On the other hand, airborne laser scanning has its advantage in capturing of the huge amount of the data in a very short period of time, but not so detailed as terrestrial laser scanning technology. From the previously written facts, it can be concluded that each of these two technologies complements one another. Application of these technologies is very wide. One of the application is in collecting of appropriate data of the specific object and generating a model which can be used as an accurate model for future reconstruction of an object and also as a digital form for future generations.

Collection of data of 3D city and landscape models has been a very popular topic nowadays. The representer of that is such a huge number of papers based on it. Eleftherios Tournas et al. [7] demonstrated an application of aerial and terrestrial laser scanning in cultural heritage preservation on the example of the building of Villa Rossa in Corfu [7]. The related topic was given in the paper of A.Fryskowska et al. [3]. They used a combination of two techniques for modeling of Nożyk Synagogue in Warsaw and also gave an analysis of transformation between different coordinate systems, now with a point of view of cultural heritage preservation. Another such a big project was presented in the paper of S.Dursun et al. [5]. Actually, they delivered 3D city models at different levels of details for Historic Peninsula of old Istanbul using terrestrial laser data and aerial images. Jan Böhm et al. write about the efficiency of integration of these two techniques (with its restrictions) for virtual city modeling using LASERMAPS [1]. The similar topic was described in the paper of A.Iavarone et al. [2]. They combined airborne and terrestrial data for modeling Toronto City Hall, Canada and as they said, these techniques with their characteristics offer endless possibilities. One in the row with a similar theme is a project of modeling of National University of Singapore campus (with buildings, roads, other man-made objects, dense tropical vegetation and DTM) [4]. Becker and Haala wrote about 3D object representation by cell decomposition, which is used for building reconstruction at different scales, also using these two named techniques of acquisition [6].

Application of terrestrial laser scanning in cultural heritage preservation and 3D documenting was described in [8, 10, 11] and the combination of TLS with other acquisition techniques also was given in [9, 12, 13,14, 15,16].

2. Matherials and methods

2.1 Study area. Donji Grad (*lat.Suburbium*) represents a part of Petrovaradin fortress with the baroque structure of the city. The historical value of this site has caused the preservation of objects, although in some parts it was not possible to prevent the occurrence of time (Figure 1). The facades of objects are with a lot of decors, painted with symbols of guard or saints beneath the roof.

Figure 1. Influence of time on appearance of facades of objects

2.2 Technology. Airborne laser system contains two basic segments, aerial and terrestrial. The principle of this aerial laser scanning system (also called LiDAR) is the use of phase differences and pulse echoes for measuring the distance from the air platform (which can be helicopter, plane..) to the points of the scanned object. The result of scanning is called point cloud which represents a collection of reflected points. The terrestrial laser scanner (TLS) is a combination of robotized total station and digital camera and it is also named as a ground-based laser scanner. The way it works is based on registration of continuous scan of the specific object around the mounted scanner on the tripod. Additional equipment for scanning is markers and tripod. Both of these previously described technologies have the same kind of data given by surveying. It is called point cloud and represents a collection of reflected points with information of X, Y, Z coordinates.

2.3 Methodology. Through next few chapters will be given the flow of processing of collected data.

2.3.1 Collecting of the data. For surveying of this area, there were used terrestrial laser scanner (Leica ScanStation P20) and aerial laser scanner (Riegl LMS – q680i). Surveying with terrestrial laser scanner lasted three days and there were 30 scan stations with 40 positions of markers. Next picture represents the positions of markers during the surveying of this part of the fortress (Figure 2).

Figure 2. Positions of markers

2.3.2 Merging data from two point clouds. After collecting the data the idea was to merge this two point clouds into one and this step was done in Leica Cyclone. As a reference point cloud was used point cloud given by terrestrial laser scanner because of higher accuracy of points. For combining of the data there was used the method of indirect registration by matching cloud to cloud.

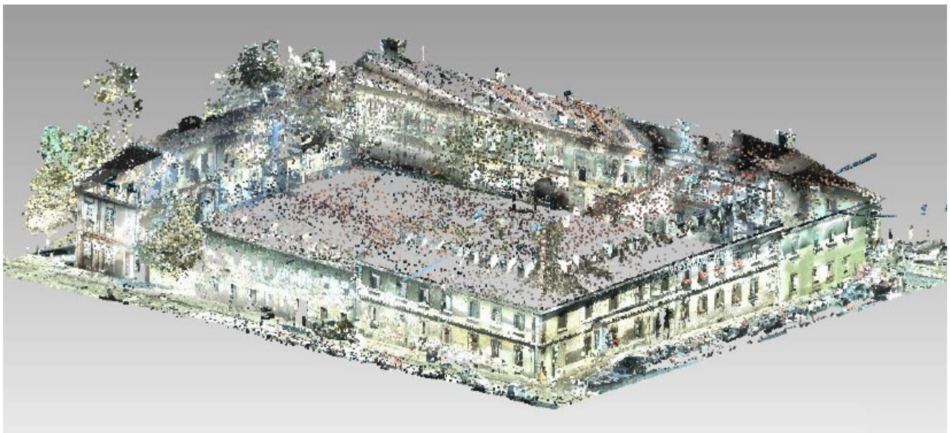

Figure 3. Merged point clouds (non filtered)

2.3.3 Processing of the merged point cloud. After merging two point clouds into one, there are few operations that have to be applied in order to get an appropriate model. These operations are resampling, noise reduction, filling the holes, meshing, reduction of a number of triangles. All of these operations have algorithms in Geomagic Wrap and it makes this processing of the data easier.

2.3.4 Publishing of point cloud using internet based application. Final merged point clouds were not base step only for object modeling. It also serves as data for publishing using internet-based application. In this case was used Potree application [17]. Supported profiles for visualization of the data are *.las, *.laz and *.ply.

The main advantage of this application is that offers to perform measuring different distances on the point cloud and this is so applicable to reconstruction process (Figure 4).

Figure 4. Measurements on merged point cloud

This is not the only option that we could use. Cross sections are the second great option also applicable for reconstruction of given object (Figure 5).

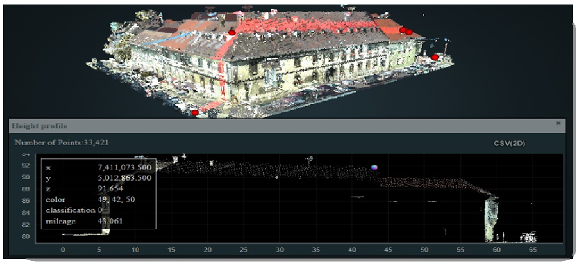

Figure 5. Cross sections on published point cloud in Potree application

According to the data quality specification that is given by GSA (General Services Administration). It specifies the required level of accuracy LOA (Level of Accuracy) and level of detail LOD (Level of Detail) of laser points. For this research were used LOA3 and LOD3 given in (Table 1).

Table 1. Level of accuracy and level of detail specified by GSA

GSA Level	LOA (Accuracy) mm (inch)	LOD (Detail) mm x mm (inch x inch)
1	± 51 (± 2)	152 x 152 (6 x 6)
2	± 13 (± 1/2)	25 x 25 (1 x 1)
3	± 6 (± 1/4)	13 x 13 (1/2 x 1/2)
4	± 3 (± 1/8)	13 x 13 (1/2 x 1/2)

What does LOA or LOD really defines? LOA determines the tolerance of positioning accuracy of the objects and it relies on the accuracy of individual points of the specified point cloud. LOD defines the minimum size of an object that can be extracted from the point cloud and it leans on a density of captured object[18].

3. Results

There are two final products made by this processing of the data.

The first one is final model of Petrovaradin fortress. Model is given in the picture below (Figure 6).

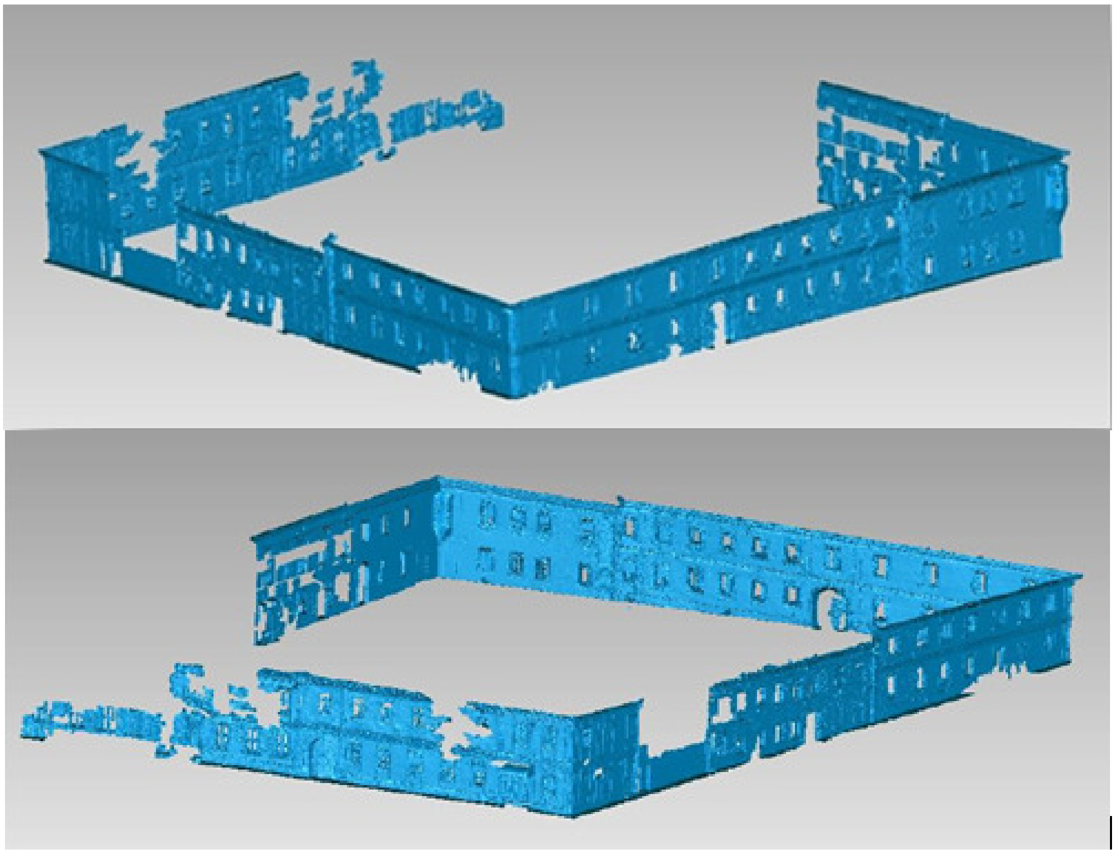

Figure 6. Final generated model of part of Petrovaradin fortress

Holes in the final model were caused by different auxiliary facilities that were mounted near the building because in the period of surveying there was preparation for its reconstruction (Figure 7).

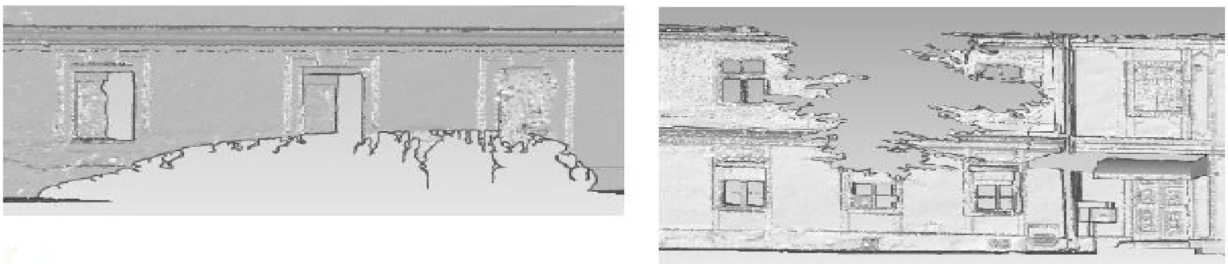

Figure 7. Damage on final model caused by mounted facilities around the building

The second thing is merged point cloud (now filtered, without noise) published using internet-based Potree application [17].

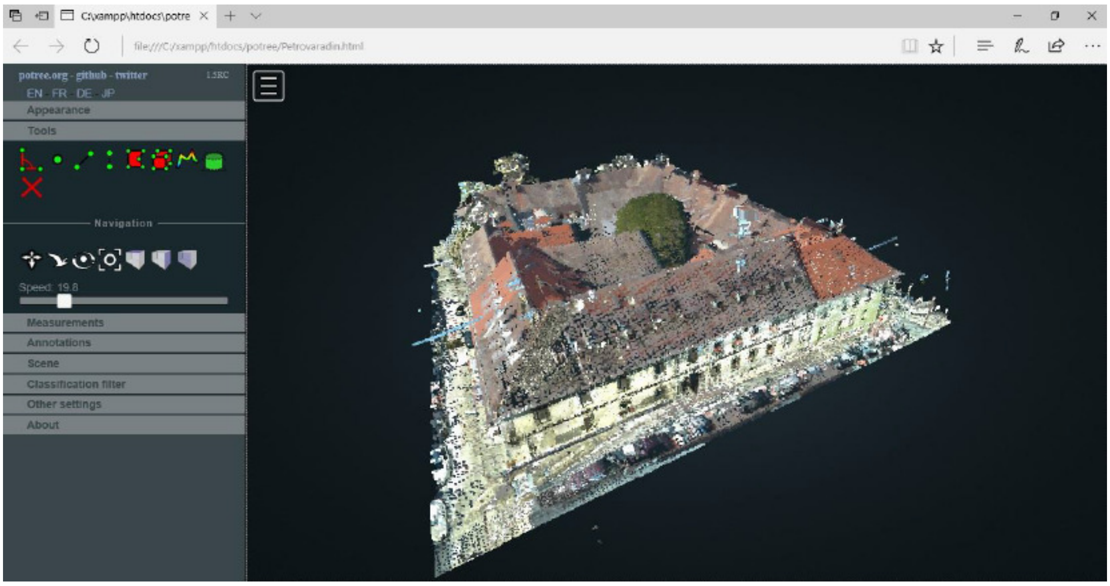

Figure 8. Published filtered point cloud in Potree

4. Conclusion

This paper has presented the combined use of terrestrial laser scanning and aerial laser scanning for the preservation of cultural heritage, which is nowadays very popular topic. These two technologies are complementary and they have basically the same principle of working. Both of them gave the same product, point cloud. Appropriate processing of the point cloud gives accurate 3D model which is good documentation for preserving complex heritage sites. Aerial laser scanning is so good for large areas and on the other side terrestrial laser scanning provides high-quality data on smaller areas. Petrovaradin fortress, as a case of study of this paper, is such a good example. Aerial laser scanning was used for large-scale surveying and terrestrial laser scanning for smaller scale which is probably the best combination. Maybe it is not the most accurate method as the data surveyed by total station, but it gives a lot of details and information of surveyed objects in short period of time. This paper has clearly shown that combination of aerial and laser scanning can solve requirements of 3D modeling of cultural heritage objects in use of preservation.

5. Literature

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