3D Modeling of Patrimonium Objectives Using Laser Technology

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Abstract

This paper aims to present the advantages of using the terrestrial laser scanning technology (TLS) as a method of creating a 3D database and 3D documentation. This state-of-the-art technology is an innovation that has the advantage of acquiring a large amount of data in a short time. This technology together with UAV equipment has the advantage of obtaining a digital terrain model. The creation of 3D patrimony models, archaeological objects and sites in their current state requires specialized equipment, knowledge, and have a powerful methodology capable of digitally capturing and shaping geometric details and fine layout of these sites. Digital recording, documentation and preservation are required because our patrimony (natural, cultural or mixed) suffers from various anthropogenic and/or natural actions (natural disasters, climate change and forgetfulness of human neglect).

Keywords: Leica C10, Leica GS08, patrimony, 3D model, UAV

Introduction

Since the early 2000s, TLS (Terrestrial Laser Scanning technology) has been evolving to provide accurate data and services. The technology is primarily used to quickly acquire three-dimensional information (3D). Cultural heritage objectives, bridges, cars, plants, rock crests, hydrotechnical nodes, highways, road accidents, and others can be modeled, analyzed and stored in a database, and if needed, make 3D laser documentation. At the moment, LiDAR is undoubtedly the most successful data acquisition technique introduced over the last decade (Lemmens, 2011). UAV-based LiDAR studies are particularly attractive for use in locations where there are regular landscape changes (e.g. in high erosion environments, building stability tracking), and so if LiDAR archives or other DSM archives (Digital Surface Model) need periodic updating (such as agricultural areas), appear on a scale that is too fine to be captured accurately by other topographic sensors in air or satellite. The ability of UAVs to fly in close proximity and with greater maneuverability than human crew will also provide a finer spatial resolution in the resulting DSMs and Digital Terrain Model (DTMs). In addition, through intelligent flight planning, UAV-LiDAR can achieve the collection of higher cloud point densities on key areas (James *et al*., 2007). As reference sources for obtaining a DEM using terrestrial spatial accuracy data, TLS data (Cook, 2017), LIDAR data, (Fonstad *et al*., 2013), total stations, GPS equipment and GPS RTK control points (Turner *et al*., 2015). The area of applicability of UAV equipment spreads through various civil applications, including reconstruction of high resolution areas (Anders *et al*., 2013), documenting cultural heritage and archaeological sites (Remondino, 2011), detection of agriculture and forest change (Mangan *et al*.,

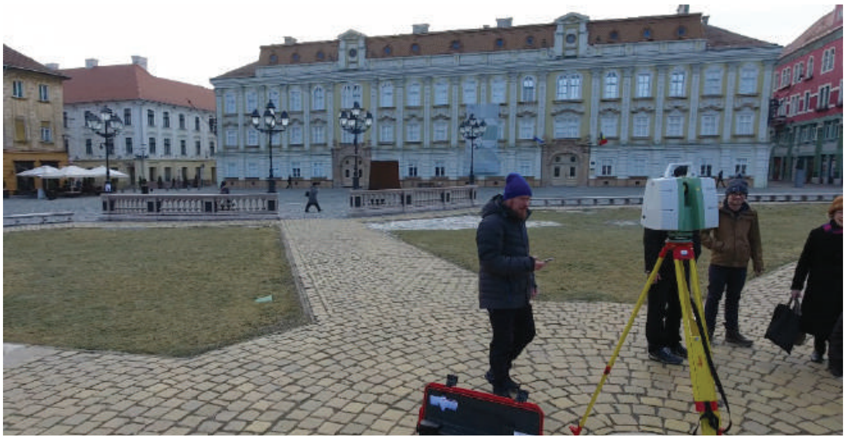

Figure 1. Union Square in Timisoara

Figure 2. UAV Phantom4 Pro together with the Leica GS058

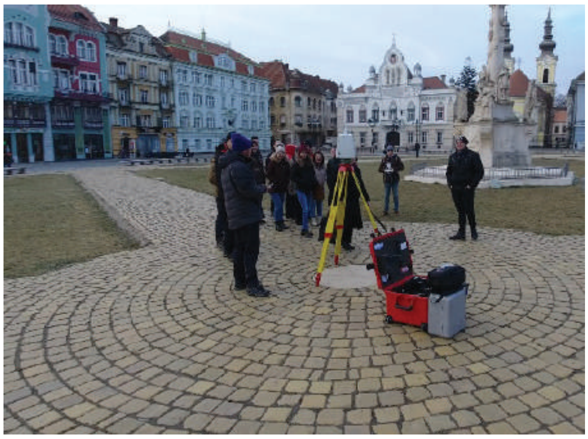

Figure 3. Union Square in Timisoara

2011), topography and mapping (Siebert and Teizer, 2014) land management (Barnes and Volkmann, 2015) and observation of wildlife (Koh and Wich, 2012). In this context, Pajares (2015) offers a detailed review of the wide range of UAV-based remote sensing applications.

Materials and methods

The location for measuring and obtaining the point clouds is Union Square, Timisoara city. We used a Leica precision 3D laser scanner, the ScanStation Leica C10, which records geometry of surfaces and structures, thus rendering digital image of the scanned lens (Fig. 1).

To complete the digital model for the top of the patrimony we used the UAV technique that was correlated with TLS (Terrestrial Laser Scanner) technique. Using UAVs has proven to be extremely useful because a complete scanning of the roof top that could not be carried out by ground-based 3D scanning, but accomplished by multiple flights with a UAV (Phantom 4 Pro) and finally get clouds of points. Roof assembly and overlay over Point Cloud resulting from TLS scanning was done by georeferencing cloud points using common points. The end was spectacular because we could have a clear vision of the heritage objectives both from the side and seen from above.

Air flights were made with the Phantom4 Pro UAV equipment and we used Agisoft PhotoScan Professional Version: 1.4.0 build 5650 (64 bit) to process aerial data and georeferenced images. To achieve the aerial image georeferencing, 8 control points (GCP - Ground Control Point) were placed on the ground, points determined on the ground using the GPS equipment, the Leica GS08 model using the RTK method. The aerial images were obtained with the Phantom4 Pro UAV equipment with a camera capable of capturing video at 4K at 30 frames per second and Full HD 1080p at 120 frames per second for slow motion. The lens is aspherical with a 940 (FOV) visual field that reduces distortion by 36% and 56% chromaticity

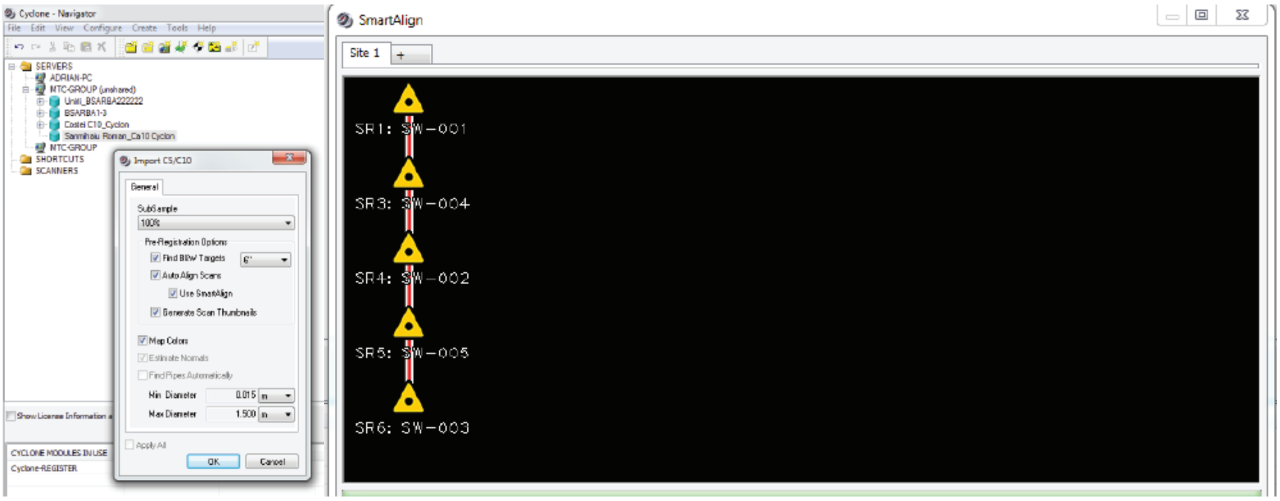

Figure 4. SmartAlign with Cyclone 9.1

compared to Phantom 3 (Fig. 2). To process the data obtained from terrestrial scanning, we used the Cyclone 9.1 version 9.1.5 program. 64-bit (Built 5387).

Results and discussion

1. Land Laser Trial (TLS) with ScanStation Leica C10

The present paper consists in the production and processing of the first set of field measurements with the ScanStation Laica C10 scanner on Union Square in Timisoara (Fig. 3).

Making measurements using the Leica ScanStation C10 scanner can be done in four stages, namely: measurement planning, scanning, downloading, and data processing. The data processing stage is about ensuring data quality and control. In order to be able to plan the measurements it is important to know what the purpose is and what the project requirements are. The goal is to create a digital data base and create 3D heritage documentation. When planning the number of stations, consider the scanning field of the instrument (360 degrees horizontally × 270 degrees vertically). Very important is the measurement distance and the density of points we want to collect. Depending on these parameters, the station time will be determined for each newly created station, as well as the scanning speed, which may be both oscillating and rotating, the method being automatically selected by the scanner according to the characteristics of the scanned area, so as to ensure maximum speed. In scanning stage there must be considered that most of the objects to be scanned are too large to be scanned from a single position. Therefore, it is often necessary to perform scans from several positions linked to each other by means of targets located at different heights. Thus, the heritage objective includes a number of 5 stations. Measurements were made in the field in 2018. The terrestrial laser scanning system enables high-resolution RAW images that can be georeferenced and used for spatial data analysis and texture processing. For scanning, we used 6-inch targets as well as Black & White targets. Downloading the device and data transfer can be done using the Lemo Plug with a GEV228 cable for connecting to your laptop or copying data directly to USB devices. Data processing and getting points cloud was performed by processing of the measurements, as mentioned above, with Cyclone 9.1 version 9.1.5. The position of each scan station is defined by the coordinates entered in the scanner. In order to achieve alignment of scan positions it is necessary to know the position and orientation according to a coordinate system. After scanning in Cyclone, scans are aligned. Aligning scans made from different stations into a single common station can be done either with

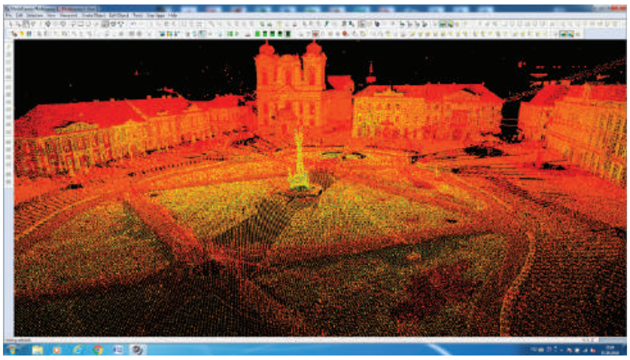
Figure 5. Point cloud obtained after alignment (colors used by the scanner)

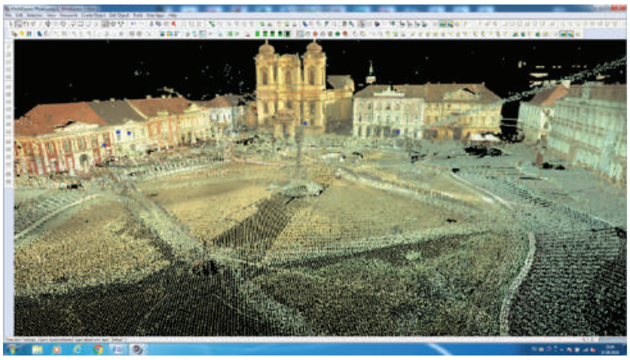
Figure 6. Point cloud obtained after alignment (colors taken from images obtained by the scanner)

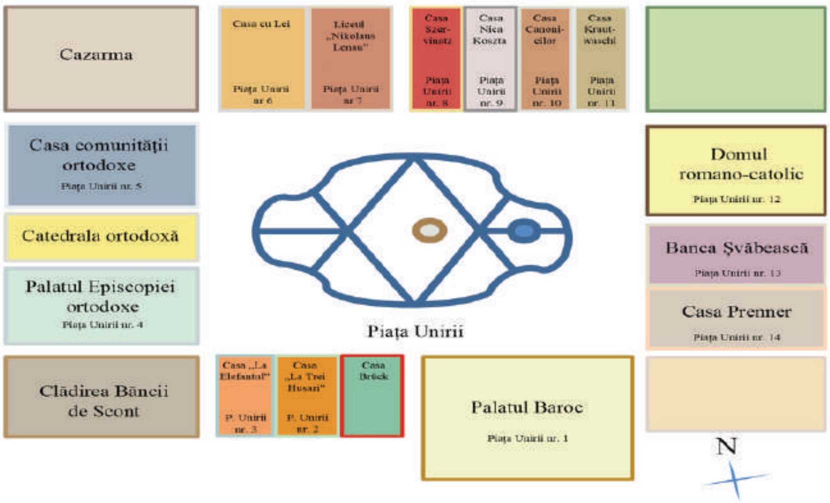

Figure 7. Map of heritage buildings in Union Square, Timisoara

the Smart Align option or by a 'Registering manual' with georeference naming (Fig. 4).

Recording of resulted cloud scores from different stations consists of introducing scans called "ScanWorld" into a single "Registration" record and adding automatic cloud point constraints "Control Spaces".

The merging of all point clouds (Fig. 5 and 6) and creating a single cloud point database is designed to facilitate point cloud manipulation, achieve real-world viewing of measurements, and could easily handle the millions of scanning points.

It is important that after the point alignment, the noise points (unwanted points) are eliminated. Besides this, you can also use automatic functions that segment point clouds depending on the desired intensity.

With `CloudCampare` you can reduce the number of cloud points (pint cloud) for better maneuverability and viewing. With the help of this program we also aligned the cloud points obtained from the Phantom 4 Pro UAV flights to complete the top parts (e.g. the roof) by identifying as many common cloud points as possible from the ground scan using the ScanStation Leica C10 scanner.

At the end of the work the data was exported in different formats requested by the architect: * .E57; * .ptx; * .x, y, z. For the presentation and viewing of historical monuments, a direct link was created and can be used to make a virtual tour of the heritage, TruViewSetup32-309.exe.

Figure 7 shows heritage buildings in Union Square, Timişoara (wikipedia). Figures 8-13 present some patrimony buildings scanned

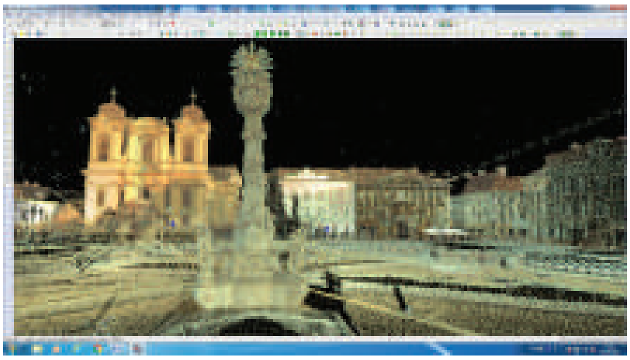

Figure 8. St. George Cathedral in Union Square, Timisoara (Roman Catholic Dome)

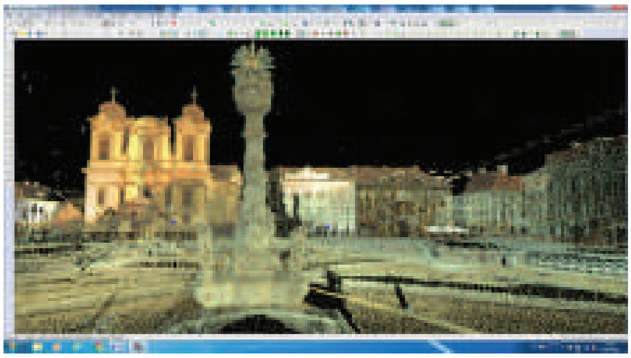

Figure 9. The Plague Column in Timisoara

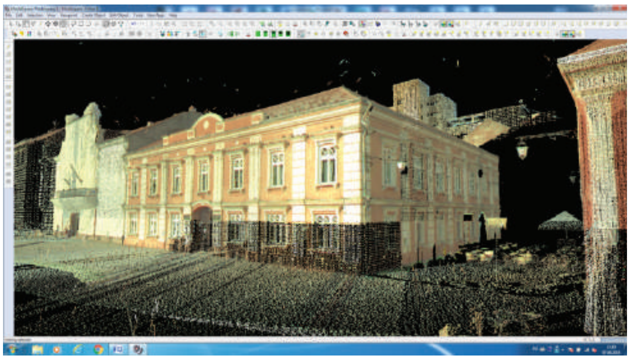

Figure 10. Nikolaus Lenau Secondary School

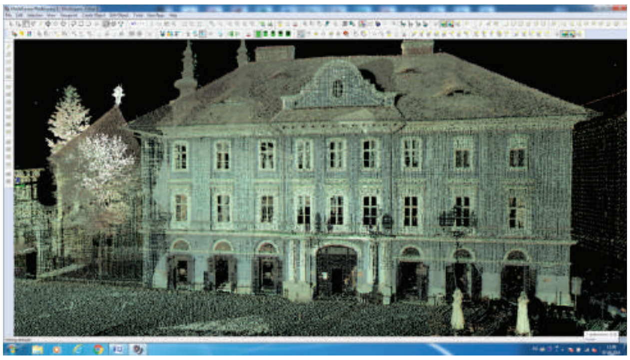

Figure 11. House of the Orthodox Community

using the ScanStation Leica C10 terrestrial laser as part of the work described.

2. Using digital photogrammetry based on UAV obtaining 3D models of cultural heritage

Although conventional remote teledetection still has some advantages and extraordinary improvements in high resolution satellite imagery it eliminates the gap between satellite and satellite mapping applications, UAV platforms are an alternative and a very important solution for studying and exploring our environment, patrimony or fast response applications.

Indeed, remote sensing technologies and methodologies for 3D cultural heritage documentation and modeling (Cowley, 2011) allow the generation of very realistic 3D results (in terms of geometric and radiometric precision) that can be used for many purposes, such as shape and color monitoring, simulation of aging and deterioration (Remondino *et al.*, 2010), virtual reality/graphic applications (Bruno *et al.*, 2010,), 3D warehouses and catalogs, internet-based geographic systems, computer-aided restoration (Fowles *et al.*, 2003), visualization and so on.

Despite these potential applications and the continuing pressure of international patrimony organizations, 3D modeling in cultural heritage is still not used as an implicit approach, and when generating a 3D model, it is often reduced to a 2D drawing due to lack of software or knowledge in the correct manipulation of 3D data by a non-expert. However, the availability and use of 3D data opens a wide range of future applications and allows for new analyzes, studies, interpretations, conservation policies, or digital restoration.

Thus, 3D virtuality should be used more frequently due to the great advantages that remote sensing technologies and the third dimension offer to the world of heritage and the recognition of digital documentation and conservation needs mentioned in many international studies. New technologies and new hardware improve the quality of 3D models in order to attract new people to the 3D world. We used a Phantom 4 Pro UAV equipment (Fig. 14).

Land Recognition and Ground Control Point (GCP) control points was the first step in the aerial image collection process. In order to complete the data processing operations including georeferencing, 8 control points (GCP) were used (Fig. 15), which were determined in the Leica GPS model, the GS08 , using the RTK method.

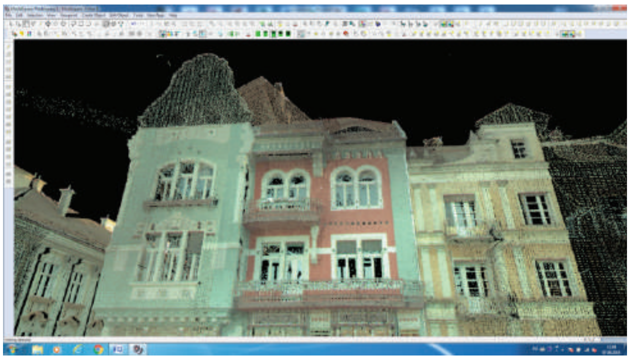

Figure 12. Brück House after restoration

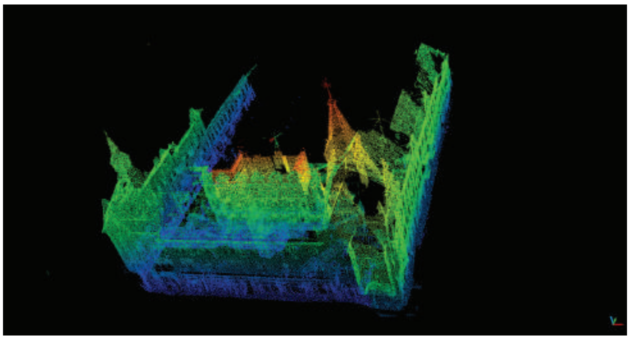

Figure 13. Presentation and coloring of cloud points by altitude

Figure 14. Obtaining aerial images, Union Square Timisoara

Figure 15. Ground markers used for georeference

The steps involved in generating a cloud of 3D Point Cloud clusters along with the estimated position and position of the camera stations and a solution for camera model parameters are similar regardless of the SfM/MVS software used. To accomplish this study, the main purpose was to ensure that all scenarios were based on the same PhotoScan project, resulting in minimal differences in processing steps. This study, which contained 78 high-quality, high-resolution images of both nadir and oblique flights, has an overlap of 80%-90%.

The 8 GCPs were loaded into the project, and primary alignment based on image coordinates helped identify the markers in each image. Each marker has been reviewed and edited when necessary to ensure that it has been located and centered in as many images as possible. Once these markers were placed (Fig. 16), the baseline project was used to analyze and change the coordinate system for the drone images (Fig. 17).

Steps to process aerofotogrammetric data were the following:

a. **Import and view photos** in **Agisoft PhotoScan Professional** Version: 1.4.0 build 5650 (64 bit) where 78 images were imported.

b. Image processing and **alignment with Agisoft PhotoScan Professional** Version: 1.4.0 build 5650 (64 bit).

c. Observing ground **marker errors** at the time of their completion.

d. Extract Density Clouds (**Build Dense Point Cloud**).

e. **Mesh Building** - PhotoScan Reconstruction Parameters Supports several reconstruction methods, which ultimately help to achieve optimal reconstruction for a particular set of data.

f. **Building texture** - the texture mapping mode determines how the texture of the object will be wrapped in the texture atlas. **Mapping mode**, **Blending mode** and **Texture size/count** will be considered.

g. Making the Digital Elevation Model (**DEM**).

h. Obtain Orthophotlan (**Build Orthomosaic**) based on georeferenced aerial images on the ground controls read by the Leica GS08 GPS.

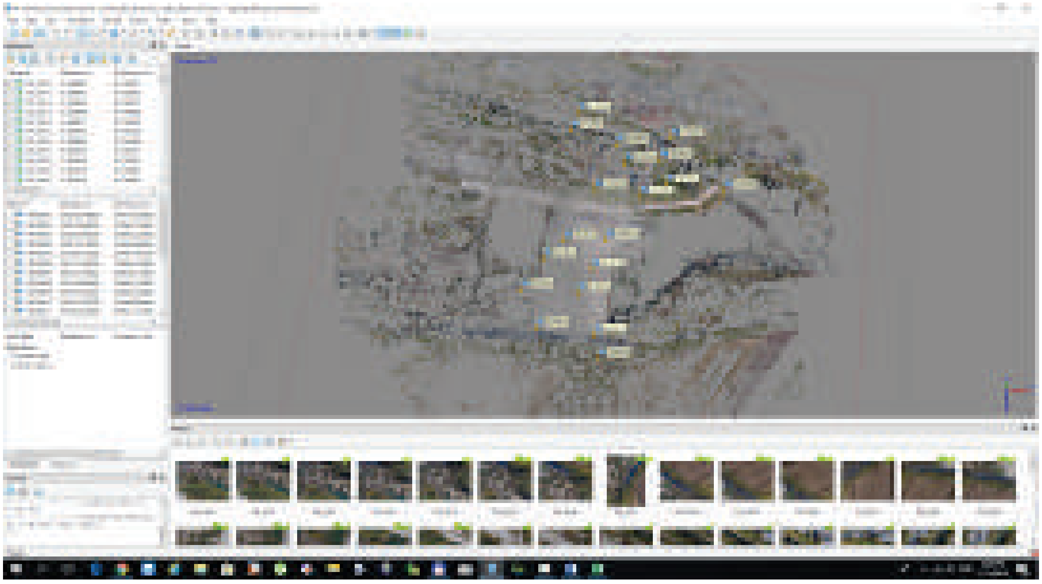

Figure 16. Presentation of GCP ground points

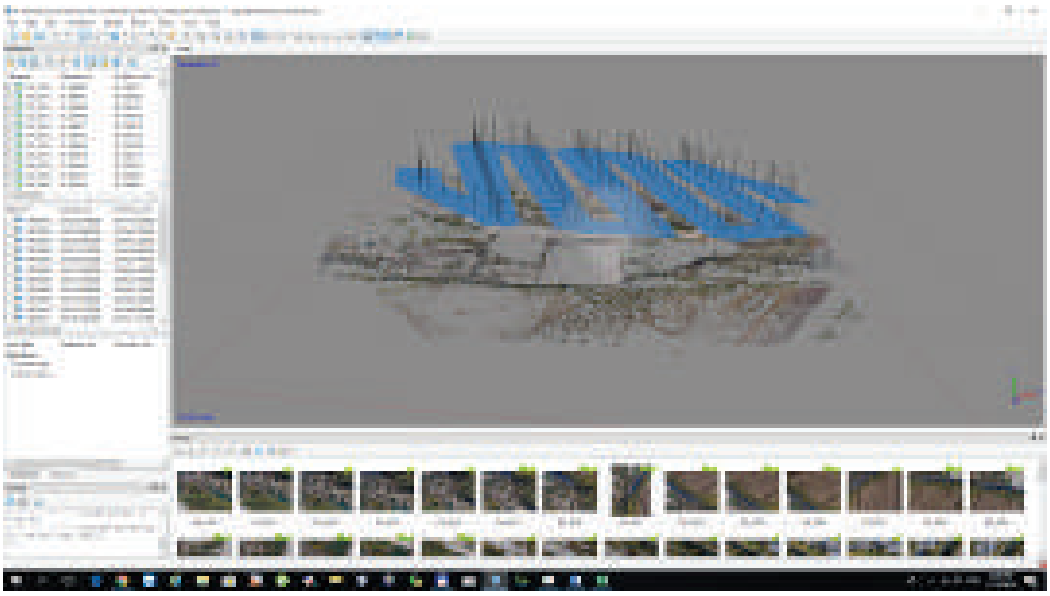

Figure 17. First alignment of aerial images

3. Digital Documentation and 3D Modeling

Although registered and digitally modeled, our patrimony also requires international collaboration and exchange of information to make it accessible in all possible forms. Nowadays, digital documentation and 3D modeling of cultural heritage should always include:

- Recording and processing a large amount of 3D information (possibly 4D) with multiple sources, multiple resolutions and more content;
- Managing and preserving 3D models (4D) made for later applications;
- Viewing and presenting results to share information with other users, allowing data retrieval through the Internet or advanced online databases (we can also mention here the virtual tour on the Internet, which makes it possible only by accessing an internet link);
- Digital and sharing inventory for education, research, conservation, entertainment, viewing or tourism purposes (Patias, 2007).

Conclusion

Due to the scientific advancement in the field of engineering (civil engineering), the problem of improving topo-geodetic equipment has been developed more and more so as to be able to cope with the evolution and technical progress.

In this context, a complex database can be created, from measuring heritage assets, stocking them, storing and processing data and placing them on a GIS basis.

With the help of this modern scanning technology, it is possible to carry out: monitoring of constructions, realization of surveys, analysis and reconstruction of facades, archaeological study, archiving, investigation of criminal areas and road accidents.

One of the main objectives is to create a 3D database together with the related 3D heritage documentation and mapping.

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