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How and where to use technology of laser scanning and aerial photogrammetry for building purposes – case study

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Abstract. Laser scanning is a method of high – accuracy mapping or reality capture that uses laser beams to quickly capture complete detail of the entire building construction project in a short time. Laser scanners are a great tool for measuring existing buildings but not always because they have the same problem as visual surveys-if you can't see it, you can't scan it, i.e. the laser beam from the scanner can't measure a certain part of the surface of the structure if this part isn't in the scanner's field of view. In particular, this limitation applies to the surfaces of the roof structures and certain parts of the facades. In these cases, the resulting point cloud may contain no information from the building surface what may be a problem for the final results. A possible solution is a combination of two technologies, terrestrial laser scanning and aerial photogrammetry. Aerial photogrammetry (or airborne imagery) means taking of photographs from an unmanned aerial vehicle (i.e. "drones"). The aim of this paper is to describe the use of these two technologies, it means, when it is better to use these technologies separately and when it is better to make their integration. As a reference building the Faculty of Civil Engineering, located in Kosice, Slovakia was chosen

1. Introduction

The rich, complete data captured with a laser scanner or a drone can provide the required information on existing building conditions with the accuracy needed for construction planning or for creating new as-built documentation what is in many cases the main purpose for digital surveying [1]. The purpose of a 3D scanner and a drone in the civil engineering is usually to create a point cloud of geometric shapes from the surface of the building because measuring with using a laser beam or aerial images are non-contact measurement of surface of buildings, allows enhancing the design process, speeds up and reduces data collection errors, saves time and money [2]. The survey yields a digital data set, which essentially a dense 'point cloud', where each point is represented by a coordinate in 3D space. All of these points are placed into the same local coordinate system to make up a point cloud, which represents the area, building, or object being scanned in a 3D space [3]. With the appearance of digital cameras photogrammetry entered a new era. Photogrammetry is the science of making measurements from photographs. The input to photogrammetry is photographs, and the output is typically a map, a drawing, a measurement, or a 3D model of some real-world object (e.g. some building structure) or scene [4]. Despite the considerable progress of these technologies, there are still some limitations, which have an effect on the quality of the final 3D model in the form of a point cloud. Even though current laser scanners can produce large point clouds fast and reliably, on the other hand many building objects contain places, which the scanner cannot measure, e.g. roof structures. In this situation the final product can be a problem because the point cloud does not contain all spatial information. In contrary, the digital aerial photogrammetry can provide solution for this problem [5].

2. Digital as-built surveying by laser scanning and aerial photogrammetry

In the field of digital spatial surveying of building constructions by terrestrial laser scanning technology, there are often limitation factors with the measurement of the surfaces from roof structures because laser scanning technology is characterized as noncontact surface measurement technology. These limitation factors may be, e.g., type of roof (flat, sloping or steep roof), roof shape, position of the roof towards to the terrain, angle of the roof, height, layout plan of the building, etc. and these limitations often have a significant impact on the quality of the resulting point cloud, especially in situations where the roof surface is not possible to measure by a terrestrial laser scanner from the terrain. The aim of this chapter is to describe the results of the methodology of integration of terrestrial laser scanning and aerial photogrammetry. As a reference building for this methodology the Faculty of Civil Engineering, located in Kosice, Slovakia was chosen. Looking Fig. 2 it can be seen that the Faculty of Civil Engineering has a simple layout in the L shape with a built-up area of 3150 m^2, a height of 20 meters and a roof angle of 24°.

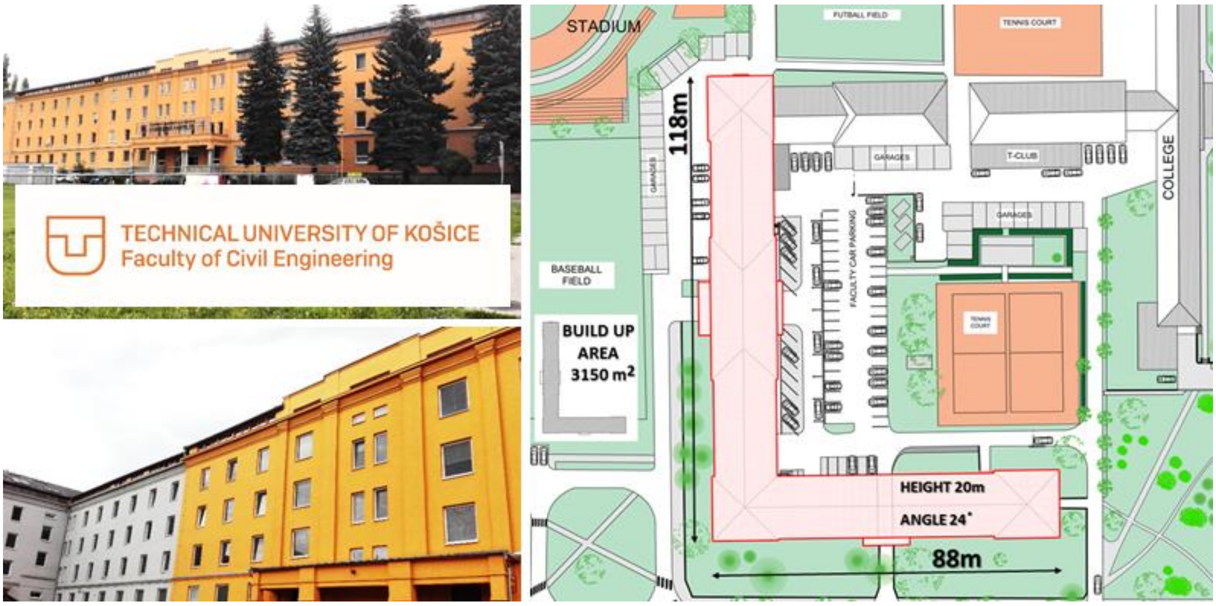

Figure 1. The situation of the Faculty of Civil Engineering, *source: author.*

The measurement of the Faculty of Civil Engineering was divided into two parts:

- **Terrestrial Laser Scanning - parts of the building selected for the laser scanner:** Exterior - facade of the building – completely,
- **Aerial photogrammetry - parts of the building selected for the drone:** Exterior - roof construction – completely.

For terrestrial laser scanning the laser scanner FARO Focus 3D X130 with a carbon telescope tripod, 12 reference spheres with a diameter of 145 mm and 6 reference spheres of 200 mm diameter was selected. The laser surveying took place in early October, i.e. the work had to be done by about between 6.00 a.m. - 6:30 p.m., because at that time it was almost dark in outside. The overall scanning time was from 6:45 a.m. to 6:30 p.m. (approximately 12 hours) and together was created 48 scanner positions. The dron DJI MAVICO PRO was used to create aerial images from the roof of the Faculty of Civil Engineering. Next was used the remote controller, DJI GO application and free online application the DroneDeploy. As a first step, it was necessary to set the drone flight plan. This plan can be either automatic or manual, i.e. aerial photographs can be created in automatic or manual mode during flight. The total time of data collection using the drone from the roof of the building was approximately 30 minutes (flight plan of the drone, aerial images in automatic mode, aerial images in manual mode). The overall of 302 aerial photographs were created and entire data collection process was created with one battery (*max flight time with one battery - 27 minutes - no wind*). The phase of data processing in this case consisted from three stages.

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2.1. The 1st stage - creating two point clouds from two technologies

For the first point cloud from laser surveying was used the Faro SCENE software. The overal time of these processes was about 3 hours. For the second point cloud from aerial surveying the Agisoft Photoscan Professional software was used. The overall time for creating the point cloud from 302 aerial photographs was 31 hours. The reason was that the point cloud was created in the highest possible quality. Of course, lesser quality means less time but also the computer's parameters are decisive for the overall time (in this case: processor Intel(R) Core(TM) i7, memory 64 GB, graphic card NVIDIA GeForce GTX 1070). At the end of this stage, two point clouds were created in two different local coordinate systems.

2.2. The 2nd stage - integration of two local coordinate systems into one,

The point cloud coordinate system of aerial images was adapted to the point cloud coordinate system from laser scans based on a few equal points from both point clouds (e.g. window corners). In this way, 6 points were created in a cloud of aerial photographs. If the Agisoft software is used to process aerial photos, it is important to note that working with coordinates is only possible with professional edition, not with standard edition. Thanks to these processes, both point clouds have one coordinate system.

2.3. The 3rd stage - connection of two point clouds into one.

Now both point clouds are ready for the final connection, i.e. in the last step, it is necessary to connect the point cloud from the facade with the point cloud from the roof construction. For this connection the CloudCompare software was selected and the final connection was automatic.

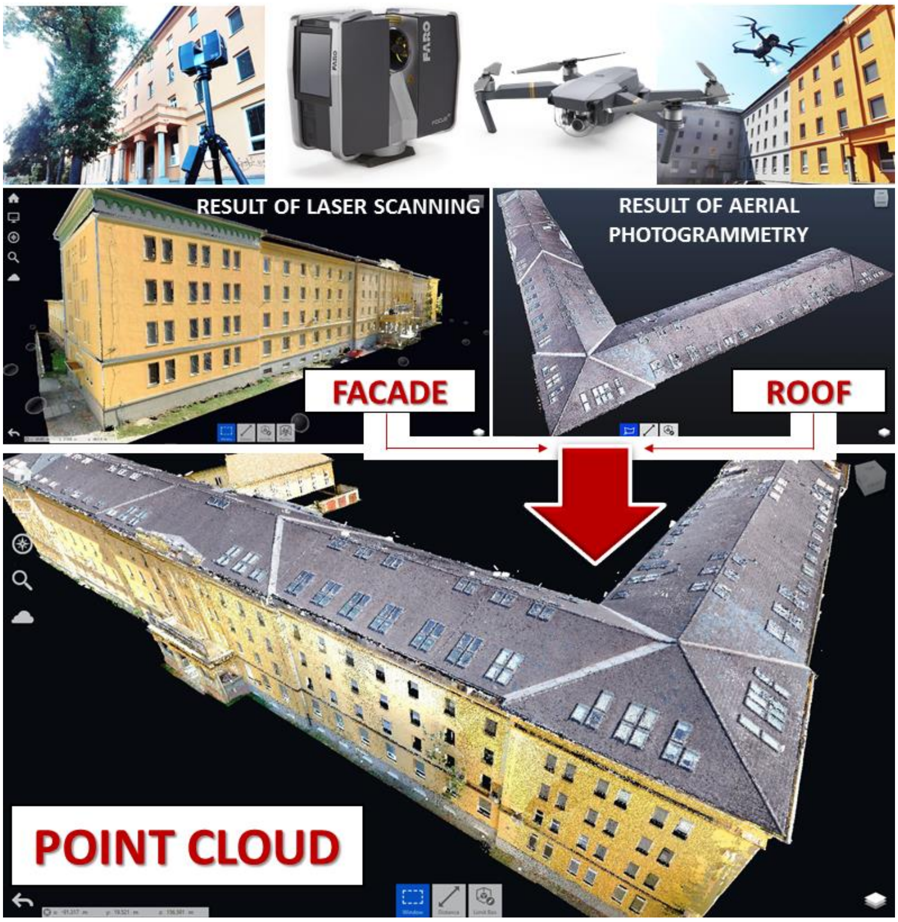

Figure 2. The result of integration of terrestrial laser scanning and aerial photogrammetry for the purpose of digital as-built surveying.

3. Digital as-built surveying by aerial photogrammetry

On the Faculty of Civil Engineering was also made the second digital as-built surveying but in this case only using a drone. The aim was to measure the complete building exterior including the roof and also the facade. In this case was overall created 1050 aerial images from the drone and overall data collection time was only 2 hours by contrast with the overall data collection time 12 hours by the laser scanner from previous case study. But these 12 hours was focused only on the facade of the building. If would by necessary to measure also the roof of the building with the laser scanner it would be necessary to create extra scanner positions at a distance of about 50-70 m from the building. In this case the overall laser scanning time would be increased maximum about 1 day; overall 2 days.

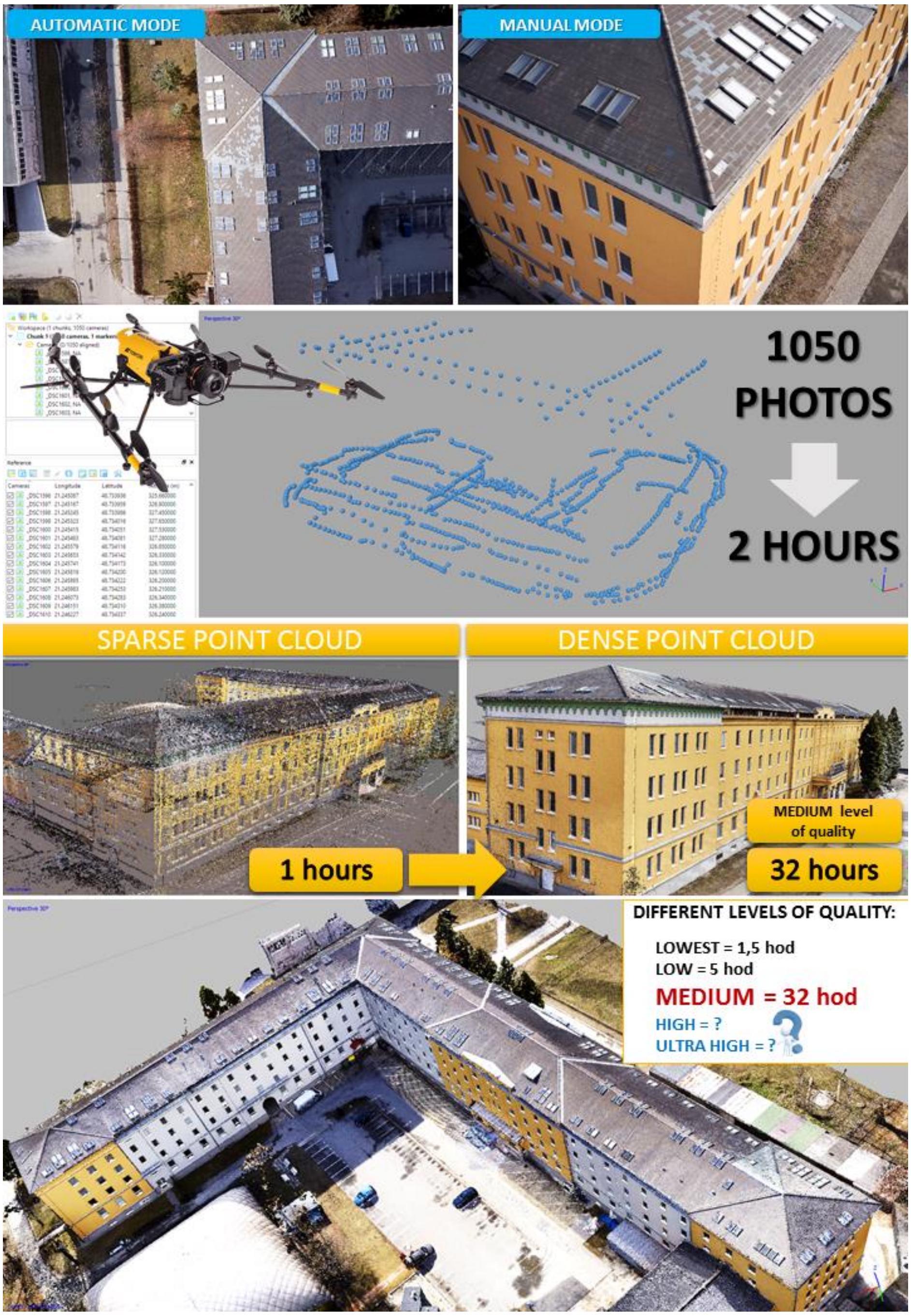

Figure 3. The result of aerial photogrammetry which was focused on the complete exterior of the Faculty of Civil Engineering.

For data processing of the aerial images from the drone was used the software Agisoft Photoscan but professional edition. The overall time of data processing was 33 hours. For the phase of data processing of aerial images from the drone, the quality of the dense point cloud is decisive for the overall time of data processing. In this case, only medium point cloud quality was selected and the overall time was 33 hours (1 day and 9 hours). The overall time for Ultra high quality of the point cloud? Expected time would by approximately 1 week or more. This implies that the phase of data collection by a drone is faster approximately about 90% by contrast with a laser scanner. But on the other hand the phase of data processing by a laser scanner is faster approximately about 60% (*medium quality of a dense point cloud*), 80-90% (*high quality of a dense point cloud*) by contrast with a drone.

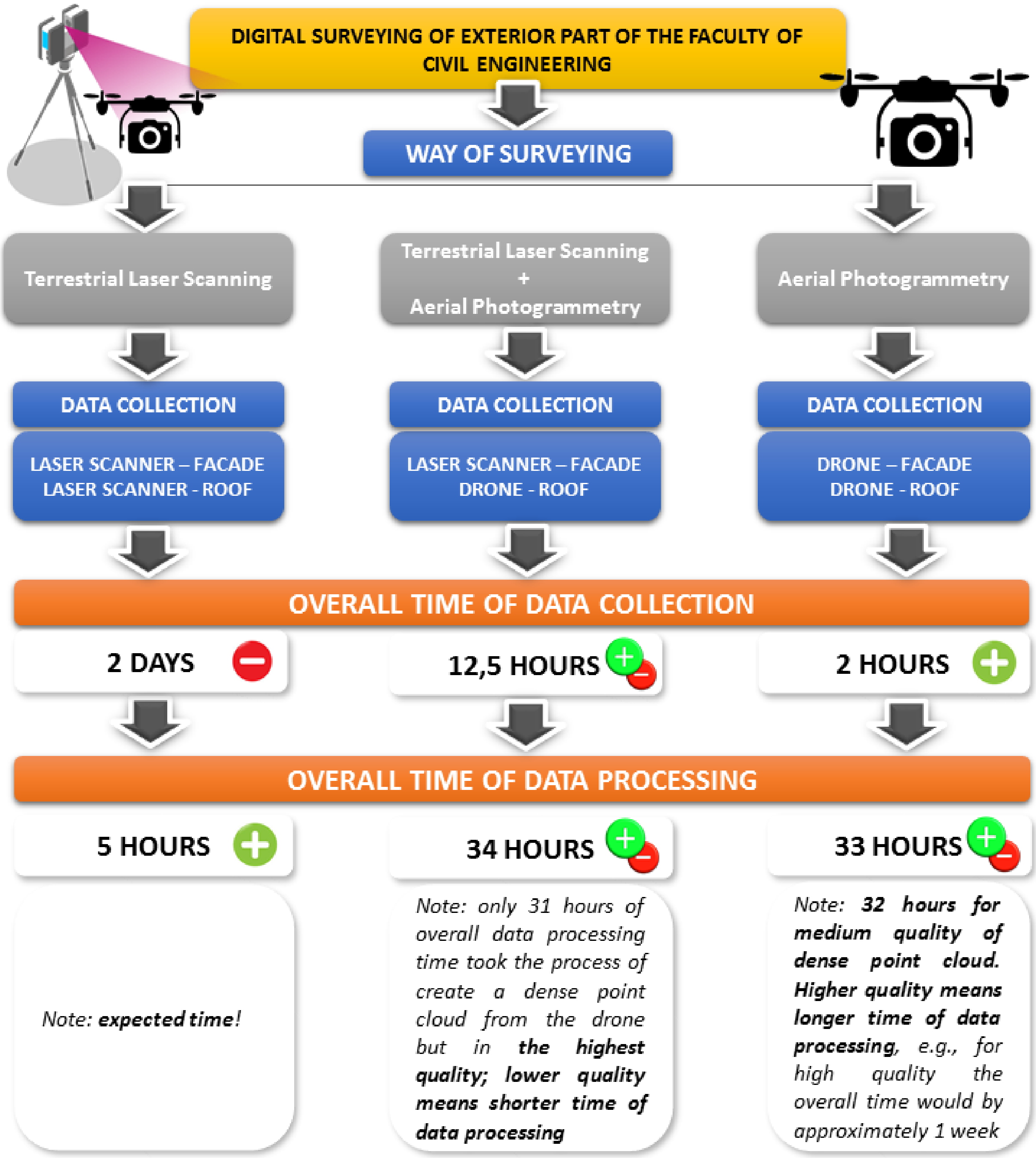

Figure 4. Digital surveying of exterior part of the Faculty of Civil Engineering – results

4. Conclusion

Technology of laser scanning and photogrammetry in general are definitely progressive technologies in the area of 3D digital spatial measuring in the construction industry but also in other sectors. The use of these two technologies is certainly huge and of course both technologies have their advantages and disadvantages. But there are situations where it is advantageous to use both technologies on one building. Of course in this case, each technology is used for another purpose or for another part of the building. Concretely for this article, terrestrial laser scanning and aerial photogrammetry technologies have been selected in order to bring in the form of a methodology a solution for the digital space measuring of those roof structures that cannot be measured by a laser scanner partially or completely. The solution of this methodology has been applied to the reference building at the Faculty of Civil Engineering of the Technical University in Kosice. This building could be measured in three ways. The first way is to measure this building by terrestrial laser scanning technology and aerial photogrammetry. The laser scanning was focused only on the facade of the building and measuring by a drone was focused only on the roof of the building. The combination of these two technologies for this building was very advantageous because with this way 100 % of exterior of the building was measured. Overall time for this process were 12.5 hours for data collection and 34 hours for data processing. The second way would be to measure the building using only a 3D scanner. In this case the overall scanning time would be 2 days and the overall data processing time approximately 5 hours but the shape, angle and height of the building represents non-ideal conditions for laser scanning, it means, that the final point cloud will be contain a lot of missing information from the roof space. The last way is to use for overall measuring only a drone. In this case the overall data collection time would be 2 hours and the overall data processing time 33 hours or more. This implies that the phase of data collection by a drone is faster by contrast with a laser scanner but on the other hand the phase of data processing by a laser scanner is faster by contrast with a drone.

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