Combining of Scene Measurements by Laser Scanner and GPS Combination

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SUMMARY

Terrestrial laser scanning methods have been used three-dimensional (3D) surveying and modelling for many engineering applications such as 3D surveying, urban planning, 3D modeling, virtual realization, reverse engineering, and documentation of cultural heritage so far. Many scans are performed from different stations with terrestrial laser scanner (TLS) to obtain occlusion free 3D model. Since TLS measurements which were collected from different stations have local coordinates of their, all point clouds have to be registered common coordinate system to combine them. The registration of point clouds is translation and rotation relation to selected one. Furthermore, 3D point cloud data should be registered to georeferencing system to combine other spatial data. The georeferencing system is reference coordinate system for cadastral surveying, geographical information system (GIS) and spatial data integration. In addition, georeferencing system enables for us to see all measurements together and making decision easily. In this study TLS and GPS (global positioning system) combination was introduced for georeferencing of TLS data.

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1. INTRODUCTION

The TLS is the survey instrument which has the ability of rapidly collecting a high resolution 3D (x,y,z) and intensity data from an object or a scene. It scans field of view with defined point intervals. The colour data (red, green, blue) can also be recorded to the scan points by TLS. Laser scanning data is the point cloud in the local cartesian coordinates, centre of which is the instrument. Thus, many scans of the same object have to be registered to common coordinate system to obtain 3D point cloud model. Generally all scans are registered relation to coordinate system of the scan that was selected as a reference (Pfeifer and Briese, 2007). Many registration methods have been introduced by range data (Besl and McKay 1992; Chen and Medioni 1992; Gruen and Akca, 2005), integrated camera image (Al-manasir and Fraser, 2006, Altuntas, 2010), and range and image data (Dold and Brenner, 2006). TLS data can not be combined with the other spatial data without extra measurements. However if the scan was performed according to georeferencing system, all spatial data from the TLS, photogrammetry, theodolite and GPS would be obtained common coordinate system without any extra measurement. The georeferencing system is the most suitable coordinate system for this aim.

The georeferencing system may be national coordinate system or international reference frame such as WGS84, and the registration from one to the other is possible in anytime. The geoferencing is highly recommended for both registration of the laser scanner data, and integration of them with the topographic and photogrammetric measurements (Scaioni, 2005). The georeferencing is also an easy and fast method to supply spatial data for local based GIS such as Google Earth. For example, documents of cultural heritage can be exhibited in virtual museums located on GIS. Everyone can be access the information about the real world objects via the internet.

In this study, georeferencing methods of laser scanning measurements were explained, and TLS-GPS sensor combination was introduced. The rest of the article is organized in three sections as georeferencing methods of TLS measurements, TLS-GPS combination, and conclusion.

2. THE GEOREFERENCING METHODS

The georeferencing methods of TLS point clouds can be classified as independent model triangulation, 3D similarity registration, and direct georeferencing (Yildiz and Altuntas, 2009). Direct georeferencing measurements are also performed with mobile laser scanning (Talaya *et al*,2004), but it is out of scope of this study because it has different sensor combination and measurement method.

The independent model triangulation is performed simultaneous georeferencing of all point clouds as the similar to aerial triangulation. The registration according to the georeferencing system is performed by at least three ground control points (GCPs) on the whole scan field. The relationship between all the overlapping laser scanner data is established by at least three tie points. GCPs and tie points are signalized with special target shapes before scanning (Scaioni, 2002; Elkhrachy and Neimeier, 2006). 3D similarity registration is applied single or together for all scans. At the first, each scan is registered with least three GCPs into the georeferencing system. At the second, after all the scans are combined by any registration methods, three GCPs on the whole object are enough for georeferencing in that case.

The independent model triangulation and 3D similarity registration require extra time and labour for signalization and measuring of GCPs. However, laser scanning measurements can be collected relation to georeferencing coordinates by using direct georeferencing methods. The simplest method of the direct georeferencing is mounting theodolite on the laser scanner. Thus, the laser scanner can be centered on reference point and rotated to direction of georeferencing point (Scaioni, 2005). This method is suitable for surveying of large and complex surfaces such as excavating site, tunnel, road, and urban areas. The other method for the direct georeferencing is mounting GPS receiver on the laser scanner. The GPS receiver records position of the TLS measurements in the global WGS84 coordinate system while laser scanner is collecting the spatial data. The scanner orientation has been determined by either digital compass (Schuhmacher and Böhm, 2005) on the GPS receiver or two GPS points on the scan field (Waggot *et al*, 2005).

The registration parameters ($X_o,Y_o,Z_o,\omega,\varphi,\kappa$) between coordinate systems of TLS and GPS can be computed with least three common GCPs. Therefore, apart from the GPS receiver on the scanner, two GPS points are needed on scan field. There are different measurement strategies to georeferencing of laser scanner point clouds. First of all, initially, the translations (t_x,t_y,t_z) of the GPS relation to TLS coordinate system must be computed. In this study, TLS-GPS combination was designed for direct georeferencing of laser scanning measurements. The details of TLS-GPS configuration were given below section.

3. TLS-GPS SENSOR COMBINATION

The Topcon GPS receiver was mounted on Ilris 3D laser scanner (Figure 1). The GPS receiver must be fixed to TLS and translations (t_x,t_y,t_z) must be computed between phase center of these sensors. Since the rotation parameters will be changed on each station, they do not need to compute. The GPS receiver has to be mounted on the same position for every mounting to TLS, and the same parameters have to be used in each station. Hence, the apparatus was designed to fix the GPS onto the TLS. On the other hand, GPS and target shape were combined with special design (Figure 2, Figure 3). The dimensions of the target shape were created according to the average measurement distance, and the GPS was fixed on it as the center of them on the same vertical line.

To computation of translation parameters, the GPS was mounted on the TLS, and other GPS

on the target shape was located scan field. The laser scanning was performed, and then the GPS on the target was removed to different location on the scan field. The laser scanning was repeated for five GCPs on the scan field without moving the TLS. Similarly, the laser scanning was performed from other station for six GCPs. Then, the translation parameters (t_x,t_y,t_z) were computed for laser scans of these two stations (Table 1).
The registration parameters between TLS and GPS coordinate systems (Figure 4) are computed with TLS and GPS coordinates of GCPs by using Eq (1) and Eq (2)

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{GPS} = \lambda . R_{\omega\varphi\kappa} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{TLS} + \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix} = \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} - \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{GPSreceiver} \tag{2}$$

Where; $[X_o,Y_o,Z_o]^T$ and $R_{\omega\varphi\kappa}$ are translations and rotations respectively between GPS and TLS coordinate systems, and λ is scale. $[X\ Y\ Z]^T_{GPSreceiver}$ is GPS coordinate of the GPS receiver on the TLS, and $[t_x\ t_y\ t_z]^T$ is translations between TLS and GPS receiver.

Figure 1. TLS-GPS sensor combination

Figure 2. GPS receiver and target shape combination

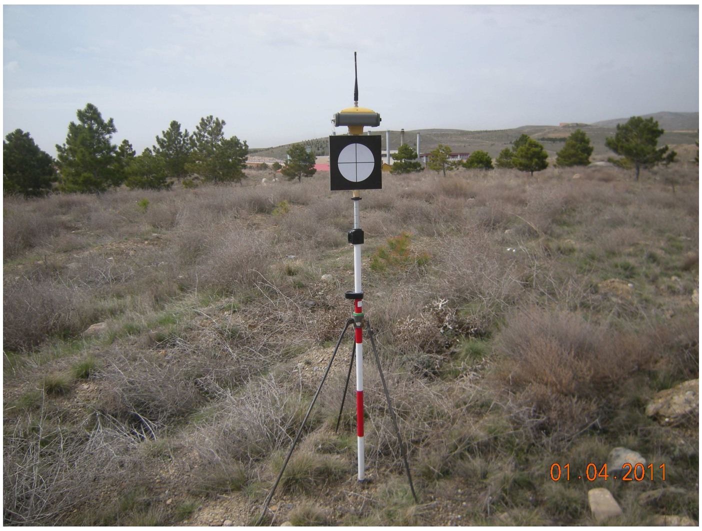

Figure 3. GPS receiver and target shape combination on scan field

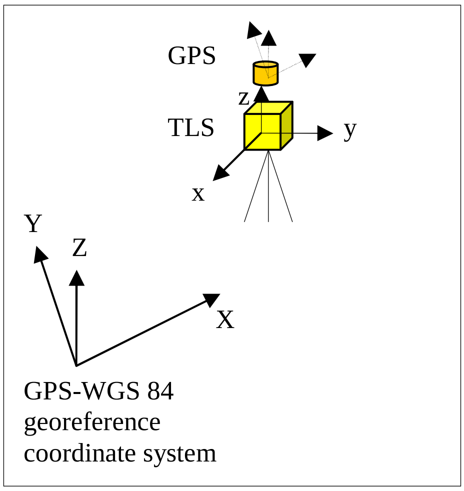

Figure 4. The coordinate systems of TLS and GPS

Table 1. The translation parameters and accuracies between TLS and GPS

	# GCP	t_x (m)	t_y (m)	t_z (m)	σ_x (m)	σ_y (m)	σ_z (m)
First measurement	5	-0.1365	-0.1118	-0.1285	0.0780	0.0727	0.0756
Second measurement	6	-0.1419	-0.0593	-0.1038	0.0180	0.0167	0.0176

The translation parameters on the Table 1 can be only used for low accuracy applications such as open mining and geological measurements. However, the parameters have to be estimated with high accuracy for urban and architectural measurements. The accuracy of the parameters depend accuracy of laser scanner coordinates of the GCPs. The TLS coordinates of GCPs are extracted from point clouds. If the GCP is long distance away from the TLS, point cloud coordinates can not be extracted with accuracies. The GCP on the scan field must not be located long distance away from the scanner for more accuracy.

4. CONCLUSION AND FUTURE WORK

The georeferencing of laser scanner point clouds is important to combine them with other spatial data. In this study, TLS-GPS combination was executed to laser scanning based on georeferencing system. The GPS receiver was mounted on the Ilris 3D laser scanner, and translation parameters between of them were estimated. The estimated parameters can be used only for low accuracy applications. In further study, the parameters will be estimated with high accuracy and laser scans will be performed by TLS-GPS combination.

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BIOGRAPHICAL NOTES

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