Applying Terrestrial Laser Scanning in Engineering Survey

Theses of the PhD dissertation

Attila BERÉNYI
Department of Photogrammetry and Geoinformatics

Budapest University of Technology and Economics
Faculty of Civil Engineering

Supervisor:
Dr. Tamás LOVAS

Budapest, 2011

1 Aim of the research

Since the first terrestrial laser scanners appeared on the market at the end of the 20th century, the technology proved its applicability on several fields including cultural heritage, mining-, topographic-, architecture-applications or (urban) modeling.
Despite the fact that a growing number of civil engineering applications involve terrestrial laser scanning, engineering survey is barely ever listed in the potential application fields of the technology.
The main goal of the dissertation is to prove the applicability of terrestrial laser scanning in the field of engineering survey. To achieve this, laboratory investigations were carried out and measurements taken in real conditions were analyzed.
Additional goal is to help the current and future users of the technology with a detailed overview about the potential advantages and shortcomings of terrestrial laser scanning.

2 Background

The number of articles and papers dealing with terrestrial laser scanning in the national and international literature clearly shows that the technology is being investigated in several researches; in laboratory and in real conditions as well.
Pfeifer et al. (2008) investigated the correlation between the scanned object's material and the derived intensity information from laser scanned point cloud. It was stated based on measurement results of known-reflectivity materials that the results may vary by applying different scanners [11].
Mechelke et al. (2007) analyzed more scanners from the incident angle value's point of view. The results showed that incident angle of 45° or less results in significant deviations of reflections when applying phase based scanner [12].
Bucksch et al. (2007) used two scanners to investigate the effect of the different tones of grey color. They state that the lighter colors result in higher intensity values, while the number of returned points from the (almost) black area is higher than expected [13].
The first laboratory investigation in the Budapest University Technology and Economics on the Department of Photogrammetry and Geoinformatics was done in 2006. The results verified the manufacturer's claim on distance measurement accuracy [14].
Also in 2006 the Department of Photogrammetry and Geoinformatics made measurements with terrestrial laser scanner in real conditions in an engineering survey task [15].
The positive result of these experiments also inspired my research work.

3 Methods

To be able to justify that terrestrial laser scanning can be successfully applied in engineering survey tasks general laboratory investigations were carried out. These tests are extremely important if the goal is to prove the applicability of a new data acquisition technology.

3.1 Laboratory investigations

The laboratory investigations can be divided into three parts:

1. 3D accuracy assessment,
2. effect of colors and materials on the scan results,
3. analysis of the effect of incident angle.

I was able to test the method developed for 3D accuracy assessment with different instruments, thus besides the obtained numerical accuracy values, the developed evaluation procedure is also an important result of the research.
The results from the second and third investigations give an overview about the (partly) instrument independent factors that may influence the scanned result. These key factors are needed in order to test the applicability of terrestrial laser scanning.

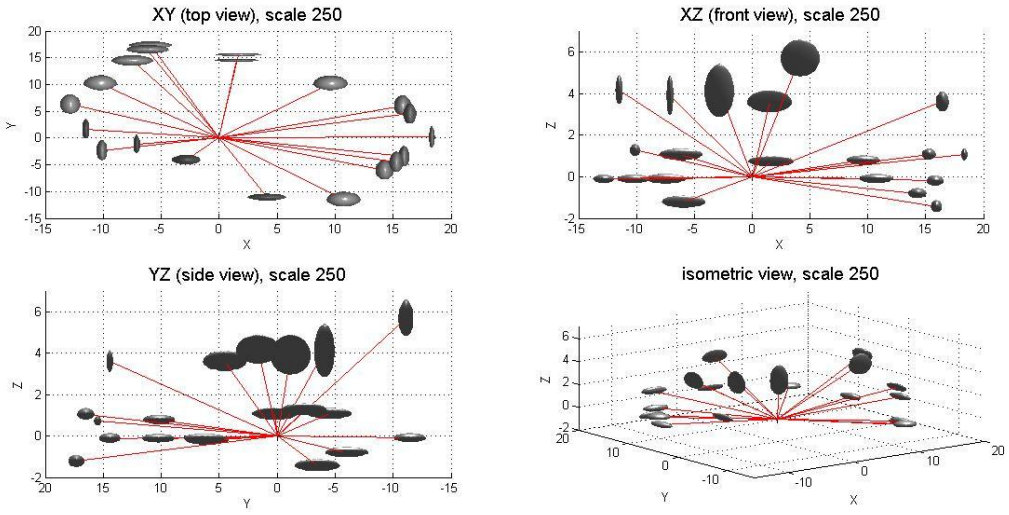

Figure 1: Error ellipses from the second accuracy assessment.

3.2 Industrial tests

The derived results describe the applied instrument well and also provide an overview about the instrument independent factors that could influence the results. These factors are extremely important from the aspect of technology's applicability.
After the laboratory investigations I tested the capabilities of the technology in real conditions at bridge load tests (Megyeri bridge, Szabadság bridge, Szebényi viaduct).
In the post-processing phase I used the measurements of traditional techniques (e.g. high precision leveling) as reference, and I also derived numerical (e.g. the displacement of cables at the Megyeri bridge) results and analyses (e.g. the misplacement of the trucks at the Szabadság bridge) that were not measured or could only be measured in a time-, and money-consuming way with traditional techniques.

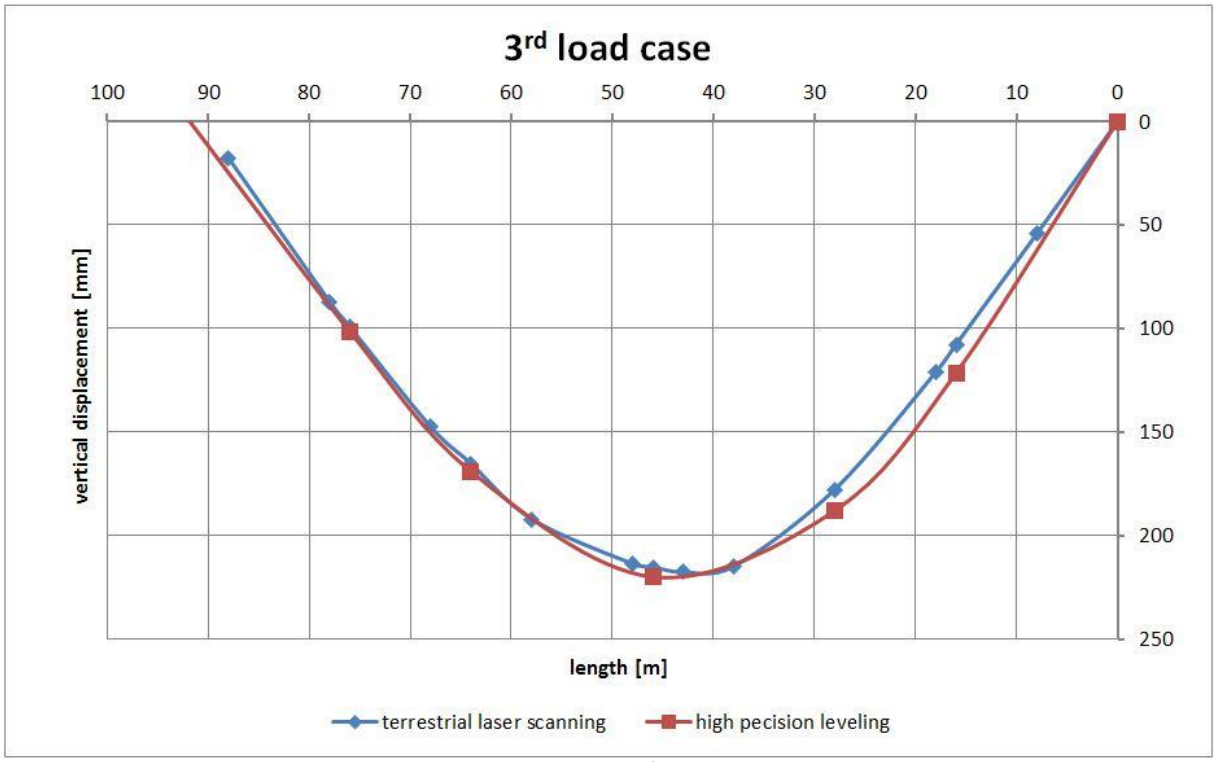

Figure 2: Vertical displacements in the 3rd load case of the Szebényi viaduct.

I analyzed the possibility of the application of terrestrial laser scanning for deriving the ambient-temperature-related deformation of sizable engineering structures (e.g. steel cable bridge).
The primary results proved that only with a few measurements the vertical displacement of the structure can be derived.

4 Summary

Based on the results of my research it could be stated that terrestrial laser scanning is applicable for engineering survey tasks. It is confirmed by the results of the comparison with the traditional techniques based on the measurement values, and the obtained additional information that were not derived or could only be obtained only in an unprofitable way.
However, it is important to note that terrestrial laser scanning should be applied with the traditional techniques (as complementary technology) for the widest range of results and not instead of them.

5 New scientific results

1. Thesis: I developed a laboratory investigation procedure for testing the three dimensional accuracy of terrestrial laser scanners in laboratory environment. The procedure is independent from the measurement technique of the instrument. The accuracy values given by the instrument manufacturers could be verified by the procedure, especially the accuracy of distance measurement.
   Publications: [1], [2], [4], [5], [6], [8]

2. Thesis: I developed a method to investigate the incident angle of terrestrial laser scanners. Numerical results were carried out for the investigated instrument that could support the development of precise survey plans.
   Publications: [1], [2], [4], [5], [6]

3. Thesis: I developed a technique to analyze the impact of the scanned object on the reflected laser beam. With this technique the effect of different colors and materials on the emitted and reflected laser beam's intensity could be investigated.
   Publications: [1], [2], [4], [5], [6]

4. Thesis: I proved that terrestrial laser scanning as primary data acquisition technique can be successfully applied at bridge load tests based on the comparison of data from the traditional techniques and data from laser scanning. I showed that terrestrial laser scanning could provide data from structural elements that were not measured by the traditional techniques or could only be measured in a time and money consuming way.
   Publications: [1], [3], [4], [5], [7], [9], [10]

5. Thesis: I proved the applicability of terrestrial laser scanning to analyze the deformation of steel bridges caused by the change of ambient temperature.
   Publications: [4], [5]

6 Publications related to the theses

[1] Berényi A. (2010): Laser scanning in engineering survey — An application study, Pollack Periodica 5/2: pp. 39-48.

[2] Berényi A. (2010): Földi lézerszkenner laboratóriumi vizsgálata, Geomatikai Közlemények XIII/1: pp. 29-33.

[3] Berényi A., Lovas T. (2009): Laser Scanning in Deformation Measurements, GIM International 23/3: pp. 17-21.

[4] Berényi A., Lovas T., Barsi Á. (2010): Terrestrial Laser Scanning in Engineering Survey: Analysis and Application Examples, ASPRS Annual Conference, San Diego, USA, 2010.04.26-2010.04.30: p. 8.

[5] Berényi A., Lovas T., Barsi Á. (2010): Terrestrial Laser Scanning – Civil Engineering Applications, International Archives of Photogrammetry and Remote Sensing XXXVIII/5: pp. 81-85.

[6] Berényi A., Lovas T., Barsi Á. (2010): Földi lézerszkenner laboratóriumi vizsgálata, Geodézia és Kartográfia LXII/4: pp. 11-16.

[7] Berényi A., Lovas T., Barsi Á., Dunai L. (2009): Potential of Terrestrial Laserscanning in Load Test Measurements of Bridges, Periodica Polytechnica - Civil Engineering 53/1: pp. 25-33.

[8] Berényi A., Lovas T., Barsi Á., Tóth Z., Rehány N., Tarsoly P.: Földi lézerszkennerek minősítő vizsgálatainak lehetőségei, Geomatikai Közlemények XII/2: pp. 87-94.

[9] Lovas T., Berényi A., Barsi Á., Dunai L. (2009): Földi lézerszkennerek alkalmazhatósága mérnöki szerkezetek deformáció mérésében, Geomatikai Közlemények XII: pp. 281-290.

[10] Lovas T., Berényi A., Barsi Á., Dunai L. (2009): A Megyeri híd terhelésvizsgálatának támogatása földi lézerszkenneléssel, Geodézia és Kartográfia LXI/1: pp. 20-26.

7 Bibliography

[11] Pfeifer N., Höfle B., Briese C., Rutzinger M., Haring, A. (2008): Analysis of the backscattered energy in Terrestrial Laser Scanning data, International Archives of Photogrammetry and Remote Sensing XXXVII/B5: pp. 1045-1052.

[12] Mechelke K., Kersten T. P., Lindstaedt M. (2007): Comparative investigations into the accuracy behaviour of the new generation of Terrestrial Laser Scanning systems, Optical 3-D Measurement Techniques VIII/1, Zürich, Switzerland: pp. 319–327.

[13] Bucksch A., Lindenbergh R. and van Ree J. (2007): Error budget of Terrestrial Laser Scanning: Influence of the intensity remission on the scan quality, GeoSiberia - 2007, Novosibirsk, Russia: p 13.

[14] Maksó M. (2006): Mérnöki szerkezetek deformációjának meghatározása földi lézerszkenneléssel, diplomaterv, p. 45

[15] Lovas T., Barsi Á., Polgár A., Kibédy Z., Detrekői Á., Dunai L. (2007): A dunaújvárosi Pentele híd terhelésvizsgálatának támogatása földi lézerszkenneléssel, Geodézia és Kartográfia LIX/10-11: pp. 32-39.