Applicability of Laser Scanning to the Measurement of 3-D Terrain Model for Street Design

Mika Jaakkola, Rauno Heikkilä

Oulu University, Research of Construction Technology
P.O.Box 4400 (Kasarmintie 4), FIN-90014 Oulu, Finland
mika.jaakkola@oulu.fi, rauno.heikkila@oulu.fi,

ABSTRACT: This paper describes the first results of R&D project "Intelligent Street" carried out in Finland. The aim of the project is to develop new measuring and design methods and tools for street design and construction. Usability and accuracy of laser scanning technology was tested in field-tests done in Itäreimarintie street pilot in Helsinki area June 2003. Implementations of measurements using helicopter based 3-D laser scanning technique are presented and evaluated. Terrasolid Ltd. software products for laser data processing was developed and tested in this project.

KEYWORDS: Street Design, Street Construction, Laser Scanning, Accuracy, Reliability

1. INTRODUCTION

Process of street design and construction is even today very time consuming and complex process because of numerous information sources, participants, design technologies and tools used in working process. Information chain in street construction process consists (Fig. 1) of measuring of source information, modeling source data, design, construction, quality control and documentation. Reliable and extensive source information of existent situation is basis to perform total process of street design and construction done properly.

Air borne laser scanning is widely used measuring method to develop existing topography for road design and construction process in Finland. The City of Helsinki has used helicopter laser scanned data for developing city plan since 1999. Laser scanned data has not yet been broadly used as source information of digital terrain model for street design and construction process because of still inadequate accuracy and partly undeveloped tools for these purposes. At the same time such traditional measuring techniques as robot tacheometers and RTK-GPS devices as well as 3D-CAD tools are generally used in street design and construction process. Present practice demonstrates that laser scanning technology is clearly more effective measuring method for DTM measuring in fairly large new road construction production than traditional aerial photography or survey by tachymeter or GPS. The applicability of laser scanning technology to smaller street construction production is not yet confident. It is essential to carry out does laser scanning measuring achieve sufficient accuracy and economy as source information technology for street design process. For example, can kerb line be measured sufficient accuracy by this technology? Flying altitude and speed of helicopter in city area are limitations, which affects attainable accuracy of laser scanning measuring results. On the other hand laser scanned models (Fig. 2) can be developed for versatile purposes during street design process, for example visualization of designs.

All the required measurements should be performed with sufficient accuracy, adequate reliability and acceptable costs. We can determine the accuracy to mean the capability to produce errorless results. Reliability of measurement means the capability to maintain accuracy during measurements. Economy of measurement is defined as the proportion of the pecuniary advantages produced by the measurement to the measurement consists themselves. [Heikkilä]

Pereira & Wicherson (1999) has reported accuracy measurements of laser-DTM. The accuracy (RMSE) of the laserscanned DTM Z values was found to be between 4-9 cm. Huising and Pereira (1998) has tested Saab Top Eye systems accuracy.

Flat bare soil terrain cover accuracy (RMSE) was 10 cm and asphalt cover accuracy was 8 cm.

This paper describes the first results of R&D project "Intelligent Street" carried out in Finland. The aim of the project is to develop new measuring and design methods and tools for street design and construction. One of the reasons for this lase scanning accuracy study is that in Finland orderer's of the street designs do not yet have enough information about accuracy and reliability of laser scanning measuring method.

The usability of laser-data processing and modeling and street design software solutions of Terrasolid Ltd. were developed and tested in this project.
Accuracy of laser scanning technology was tested in field-tests done in Itäreimarintie street pilot in Helsinki area June 2002. Produced DTM-data was used in pilot street design process.

In the study the following applicability criteria were formulated for testing:

- can the determined measurement tasks be executed by this scanning technique?
- is accuracy sufficient for the performance of the determined measurement tasks?
- is it possible to achieve adequate reliability in these measurements?
- can we consider the measurements to be economical?

2. MATERIALS AND METHODS

Laser scanning of the pilot street

The objective of the field test was to measure accuracy of helicopter based laser scanning data from 100 m altitude and on different surface types. Scanning mission was done with TopEye helicopter based system in June 2002. System was equipped with 7000 Hz scanner and 3056*2032 digital camera. Test resort was Itäreimarintie Street in Vuosaari and situates in sparsely inhabitated area in eastern Helsinki. It is 1050 m long, curved street. In this measuring process Helsinki City Surveying department took care of GPS ground receivers used for helicopter positioning.

In modeling process TerraScan and Terra Match software's were used to classify and remove unnecessary points and correction of orientation parameters using automatic or semi-automatic rutines. Digital photos taken during the scanning flight was fectified by TerraPhoto software and photos was also used as aid in modeling process. This process was supporting the Finnish Terrasolid Ltd. software company's product development project. The product product family consists a group of solutions for different phases of infrastructure measurement and design process.

The main phases of modeling process were:

- Adjust overlapping laser scanned data strips
- Deleting errorneous points
- Classifying points by own definition (ground, low-, medium and high vegetation, buildings)
- Remove unnecessary points by thinning and rate of change in elevation
- Laser-DTM and digital photo data of Itäreimarintie -street was implemented as a result of modeling process.

Reference measurents

Reference measurements was done in four different cover surface. Survey was done as tacheometer measuring and it was realized by Helsinki City Street Department.
First area is forest area near street resort. Second reference area is constructed area and third area is asphalt road. Fourth area is grass and partly sand field. Photos of the refeference areas with some Z-difference measurement results are presented in pictures 2-5.

Accuracy of laser scanning was studied by comparing reference measurements with those at same locations derived from laser-DTM (table 1). The tachymetric measurements was used as Z-co-ordinate reference. The errors were grouped according to systematic and random errors. The comparison was made as an computation of root mean square error (RMSE) of the differences between the reference and the laser-DTM.

3. RESULTS

The results of the tests in measurement areas 1, 2 and 4 were that laser-DTM average systematic Z error was between five to ten centimeters above the ground. At first measurement results measurement area 3, asphalt road, average systematic errors sign was different than other areas. DTM of the area 3 was about seven centimeters below the ground, which gave a reason to distrust correctness of the measuring values. Flight strips in question was checked and the reason for deviation was found to be banking of the helicopter in that spot. After the failed strip data was removed, average systematic error was at same level as in other areas. Look results at table 2. After correction process average deviation of laser-DTM in all four areas was found to be 6,6 cm above the ground truth. Standard deviation (RMSE) of all test measurements was 9,1 cm.

Standard deviation of measuring results varied very little, from eight to nine centimeters, at grass field, asphalt road and constructed area. In forest area standard deviation differed others and it was 12,4 cm.

In this point of the study we do not have enough information to consider if laserscanning can be economical measuring method compared to traditional methods.

As a result of Terrasolid Ltd software developing work, new tools for TerraScan software was developed during the first half of this project. Most important innovation has been new semi-automatic building and roof modeling tools. There was also developed new algorithm to good effect. It can be used to identify for example kerb lines of street from the point cloud. In this project point density was not yet sufficient to use this tool to identify kerb lines.

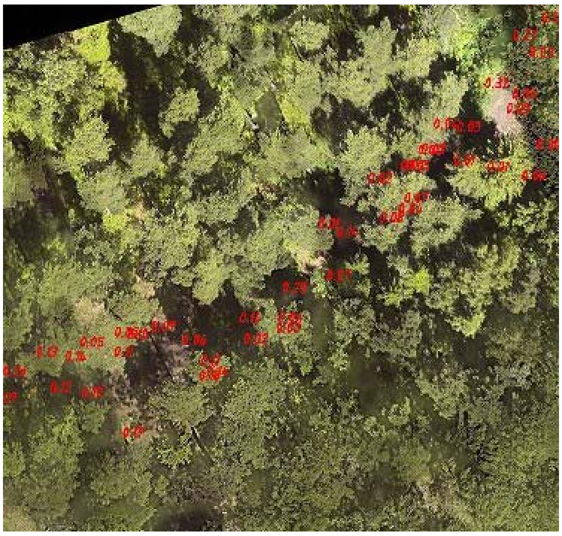

Figure 2. Part of the measurement area 1 - reference points of the forest area.

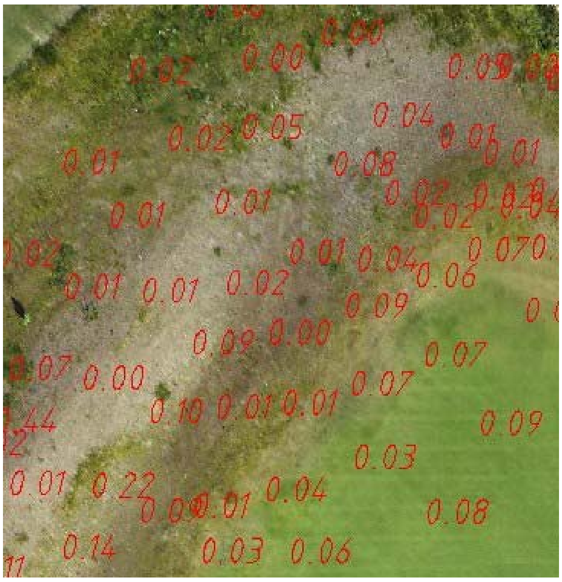

Figure 3.Example of measurement area 4 - reference points of grass golf field.

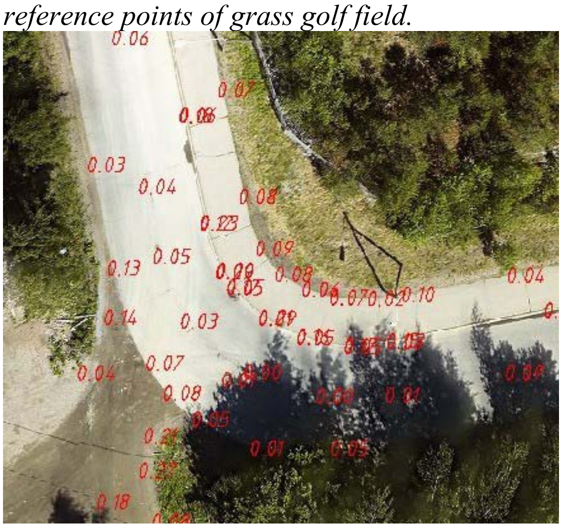

Figure 4. Measurement area 3 - reference points of the road.

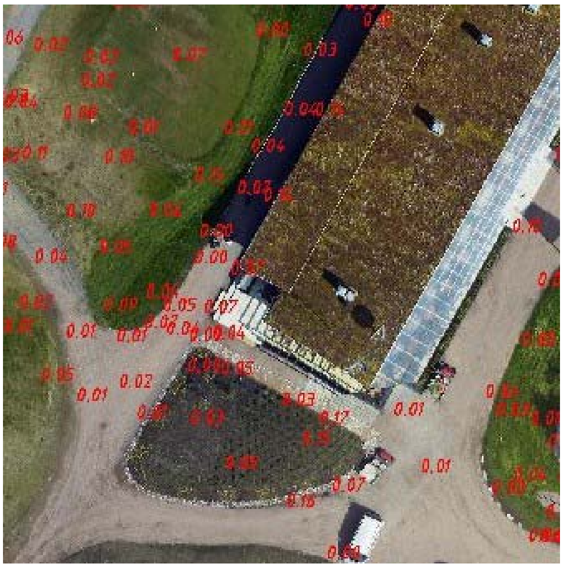

Figure 5. Part of the measurement area 2 - reference points of the buildings and roads.

4. CONCLUSION

On the basis of measurement results accuracy and reliability of helicopter laserscanning measurements was evaluated to be adequate for street design processes DTM-data. These accuracy results are parallel to Hyyppä & al (2002) measurement test results as well as accuracy reports reported by Huising and Pereira (1998). Reference measurements are still requirement to achieve necessary reliability for laser scanning.

Integrated laser scanned DTM and 3-D building models (fig. 6) is appropriate part of initial data of street design process.

In street renovation projects, which are situated in urban environment the usability of laser scanning in is not yet demonstrated. In this continuing project it is next aim to find out.

Developed software tools for processing laser scanned point clouds enable to model 3D-buildings with sufficient accuracy. Also bending lines of different structures are possible to identify by developed tools.

5. REFERENCES

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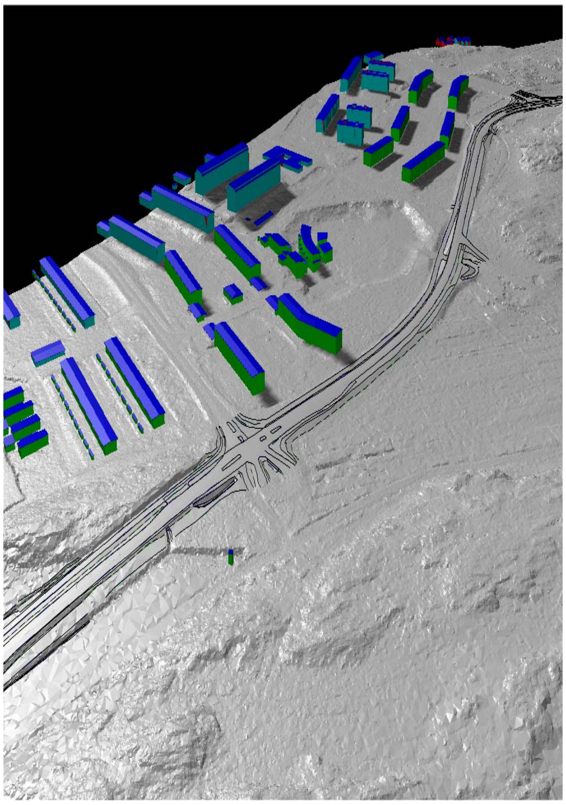

Figure 6. Digital terrain and integrated building models based on laser scanning measuring in Vuosaari area in the city of Helsinki. Road lines, edges and ditch lines are still measured by tachymeter and GPS.

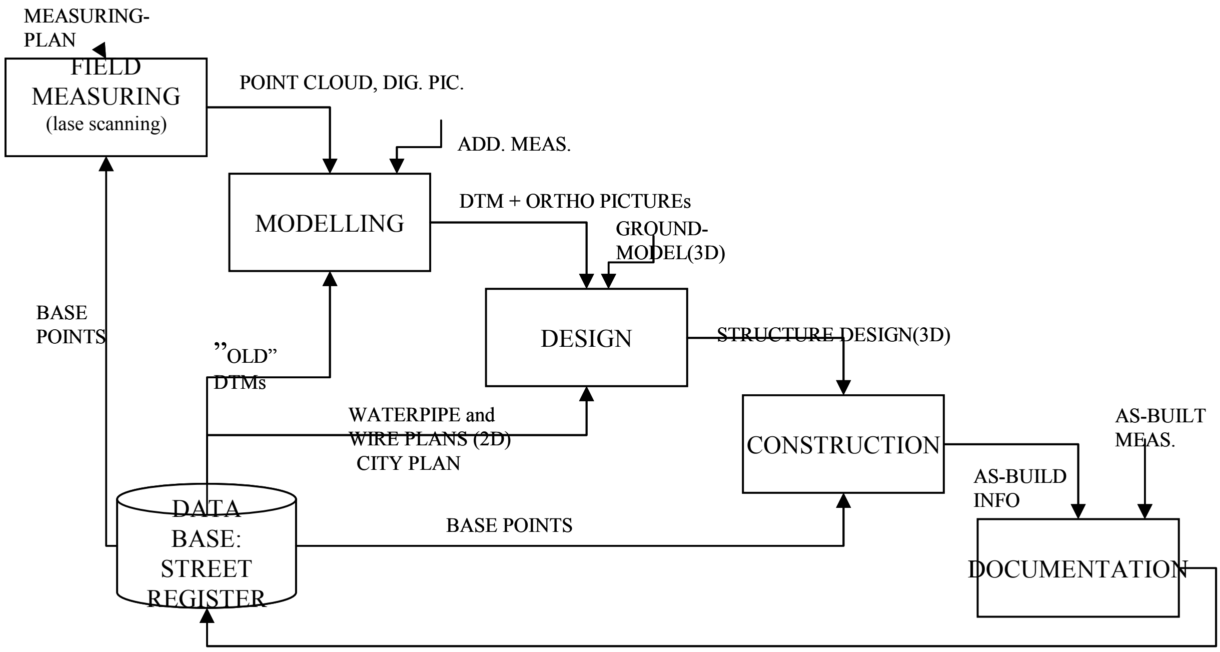

Figure 1. The information chain of street design and construction process.

Table 1. Example of reference measurement results.

Number	Easting	Northing	Known Z	Laser Z	Dz
27	62432.890	22940.310	3.895	3.925	+0.030
28	62424.860	22938.780	3.900	3.858	-0.042
29	62418.030	22937.890	3.912	3.865	-0.047
30	62412.340	22937.930	3.928	3.927	-0.001
31	62408.220	22939.950	3.894	3.847	-0.047
32	62406.200	22941.800	3.879	3.816	-0.063
33	62404.810	22938.760	3.874	3.679	-0.195

Table 2. Results of the test laser scans. In area 3 banking of helicopter caused failed measurement results (in brackets). After correction systematic error was at same level as in other areas.

measurement object	average [m]	standard deviation [m]	points [count]
area 1: forest	0,077	0,124	100
area 2: constructed	0,049	0,083	229
area 3: asphalt road	(- 0,068) 0,043	(0,066) 0,087	79
Area 4: grass field	0,095	0,090	184