PRECISE MAPPING WITH 3D LASER SCANNING

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A possibility of using 3D laser scanning for collecting spatial data is discussed. Comparison with surfaces measured by conventional survey such as total stations or RTK GPS and 3D laser scanning is made. The advantages of this technique for modeling and mapping and providing a much more valid representation of the actual surface shape are represented. Systems that can measure several thousand points per second allow a spatial density distribution of observed coordinates much more that available with traditional surveying and photogrammetric techniques.

Overview and principles of terrestrial and airborne 3D laser scanning are presented. Some applications in mapping rural and urban territory, power transmission lines, mining, landslides, pipes and buildings are shown.

Conclusions about the accuracy of the terrestrial and airborne 3D laser scanning and its application for various purposes are made.

INTRODUCTION

Although surveying techniques have always played a primary role in collecting data for mapping, recently new instruments and methods for data capture and processing have introduced the chance to increase the mass and the variety of achievable information. Nowadays real-time monitoring systems based on robotic total stations and GPS, digital photogrammetric techniques, high resolution satellite imagery, satellite, airborne and ground-based InSAR methods, airborne and terrestrial laser scanners devices are able to give a set of powerful tools for the geometric surveying and modeling. In particular this paper is focused on the use of laser scanning technique, which has been pushed up in the latest years by the diffusion of the so called long range instruments, capable of measuring points as far as a few hundred meter from the instrument standpoint to the site to be studied.

This imaging system provides a user with a dense set of threedimensional vectors to unknown points relative to the scanner location. Given the volume of points and high sampling frequency, laser-imaging systems offers surveyors and photogrammetrists an unprecedented density of geospatial information coverage. For this reason, there is enormous potential for use of this technique in applications where such dense data sets could provide great insight into the valid representation of the region.

OVERVIEW OF LASER SCANNING

Both terrestrial and airborne laser scanners give as an output XYZ coordinates and picture of laser intensity. Determined by scanning about 6-8 million points easy and accurate become surfaces by using appropriate software. Prepared spatial models could be converted to any commercial CAD and GIS system for post processing.

Terrestrial laser scanning

A terrestrial laser scanner determines the distance between a large number of object points and the scanner by emitting laser pulses in different directions and detecting the echoes from the objects. So called pulsed scanners measure the travel time of the pulse towards an object and back. This technique therefore uses the intensity of the light signal to detect when an emitted signal returns to the scanner. An overview of measurement techniques and scanner specifications can be found in [Pfeifer and Litchi, 2004].

The unit itself has dimensions of 40 cm x 20 cm, weighs approximately 10-13 kg and can be mounted on a standard surveying tripod. The unit can be force-centred over a known control point as typical survey instrumentation. The rate of data acquisition is around 6000 points per second. A full scan over the horizontal range of 300° of arc and 80° in the vertical takes about 6 minutes, resulting in a data volume in excess of 2 million points. Trees, buildings, roads in addition to topography are clearly visible.

Leica claims an accuracy of 6mm at 50m for the Leica HDS 3000.
Opteh ILRIS 3D laser scanner provides dynamic measuring range capabilities (3 m- 1500m) with 6mm distance accuracy.
Callidus intended 3 different measuring ranges with appropriate measuring resolutions and maximum distances (in the radius) to secure a sufficient numeric accuracy of the measuring values:
- Millimeter up to 32 meter*
- Centimeter up to 80 meter*
- Decimeter up to 100 meter*
- Typical measuring range up to 30 meter*

*dependent on the remission of the material; under certain circumstances from 40 m on only with reflection material.
These measuring ranges can be changed during the scanning process and can be adjusted to the respective conditions.
Furthermore it is possible to record the intensity of the reflected laser impulse (remission).

Airborne Laser scanning

The data acquired by airborne laser scanners are collected by sending out laser beams to the ground using pulsed or continuous wave techniques. Therefore the distance is derived by measuring travel time or phase shift of the emitted signal. To improve coverage of the sampled area system manufacturers use varying techniques to deflect the laser beam during flight time. The result is called a digital surface model (DSM) because it contains both points from the ground surface and points from objects on top of the surface, like buildings and trees.

In order to receive an accurate information about the point position in plan and height three different measuring systems are used. Combination of GPS- and INS- system provides in every moment the precise position (WGS coordinates) and orientation (3 angles) of measuring system. The laser scanner only measures distances according to its position.

The planimetric accuracy of the laser points is approximately 0.5 m [6] where the point density is up to four points per square meter. The accuracy in height is 0.01 up to 0.15 m [3].

APPLICATIONS

Only in the last years, laser scanning is becoming popular as a measurement technique. Therefore existing literature is still sparse, both in frequency and in contents. These days however, laser scanning is more and more used for practical applications. Examples include mining [5], roads planning [3], power transmission lines and urban territories mapping [6], 3D city models [2].

Mining

Data collection for current methods of open mine mapping is long and often dangerous undertakings. Single point collection with a total station and pole man along various slopes and faces is labor intensive, costly, and most importantly, hazardous. Typically it required 2-3 surveyors and 4-6 survey assistants a full day to measure the open pit (depending on size) and two days to process the month-end survey data. The collection of information on stockpiles and month-end reconciliation took a further two days.

Figure 1. Bre-blast

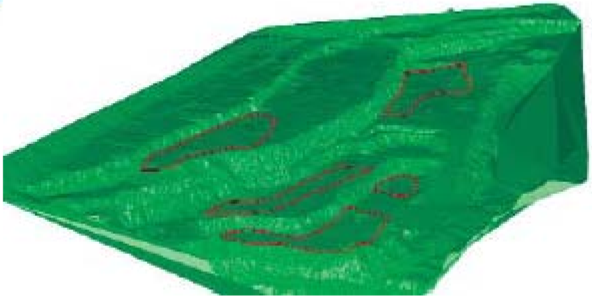

Figure 2.Post-blast

Both pre- and post-blast measurements, as well as stock pile volumes, can be collected much more effectively using laser scanning technology. Terrestrial laser scanner ILRIS-3D is used to collect survey points for volume calculation simultaneously with the mine survey crew. All data sets are easily geo-referenced based on a three-point transformation into any mine grid system in post processing. Mining software can manipulate the ILRIS-3D data to produce topographical surfaces. These surfaces can be queried against 3D numerical models of grade, density, or metallurgical quality, to generate a variety of reports. Volume accuracies are found to be well within allowable error budget, equaling or surpassing that of the survey and dispatch figures.

A table/face is scanned both pre- and post-blast. A comparison of the two data sets reveals highly accurate blast volume. Time required: Four hours. Size of survey crew: One. Wireframe model generated and area of volume calculation isolated.

Linear objects

Roads

Due to the high density of the laser scanner data, not only height information can be derived from the 3D-surface, but also the detailed shape of objects. This allows to automatically extracting the exact road geometry, as long as it is bordered by typical height changes. In the context of car navigation, this enables for laneprecise vehicle positioning and more precise route guidance. Additionally, this approach allows for validation, change detection or enrichment one of map data. Thus it enables 2D map producers either to perform validation or change detection against digital terrain models. When using high resolution DTM data topographic objects usually exhibit more details than currently present within the map database.

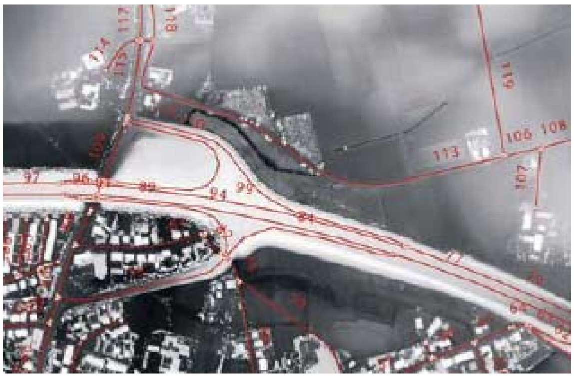

Figure 3. Overview of the test region

The test region covers a small part of Castrop- Rauxel in the western part of Northrine Westphalia, Germany. Its spatial extent is about 1 x 1 kilometres. The data are interpolated on a regular grid, the ground resolution is four points per square meter. It shows the last echo DSM overlay with labelled 2D lines derived from a cartographic database. Red colour lines denote road centrelines as present in the database. Darker colour values denote lower terrain. The test region is dominated by rural areas. It contains arterial roads as well as local access roads. From east to west a super highway crosses the test region. Field tracks can be seen in the northern part of the test region on the figure 3.

Power transmission lines

Mapping of power transmission lines by using airborne laser scanning is presented [6]. Because of the often change of the flying direction flight with helicopter AS350 in height 150-300 m is made. This variant provides the fastest and cheapest, and in the same time independent from weather conditions, flight compared with plane flight. Low flying speed of the helicopter ensures density 3-5 points per square meter. Laser scanner LMS-Q560 is used. Accuracy 0.5 m in position and up to 0.15 m in height is reached.

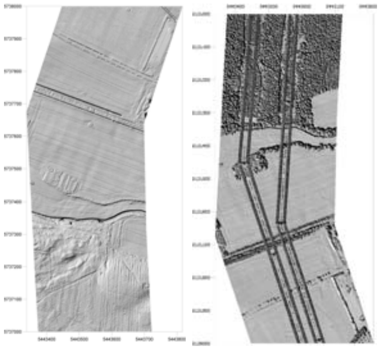

Figure 4. DTM (left) and DSM (right) as shadow visualization

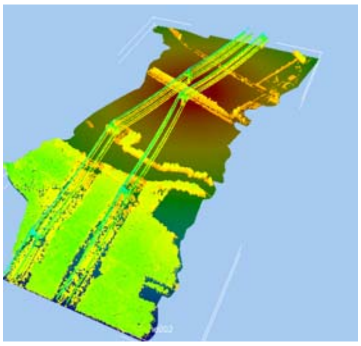

Figure 5. DSM as 3D pseudo-color visualization

Rural and urban territories

Digital surface model (DSM) and Digital Terrain Model (DTM) are easily obtained from 3D spatial data from airborne laser scanning [6] by using morphological filtering. Deviations in position <20 cm are determined by comparison between clear building contours and direct control measurement. Smooth surfaces are used to establish deviations in height. Comparison between interpolated from DTM height values and those measured from laser scanner is made. Data from DTS and DTM could be used in other CAD and GIS applications for solving different practical tasks.

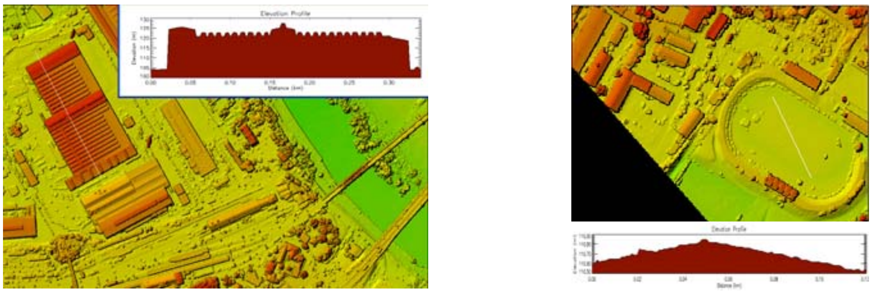

Figure 6. Rapid drawing of profiles from DTS and DTM

3D city models

Existing 3D city models, which are usually collected from airborne views, can additionally be used to support the further processing of data from TLS. Obviously, the airborne acquisition of 3D building models does not provide detailed geometry for the facades of the building. Consequently, this information, which is for example required to generate virtual views from pedestrian perspectives, has to be captured by ground-based approaches like TLS. However, a complete 3D model, containing facades as well as building tops can only be created, if data from airborne and terrestrial views are merged. One option especially suitable for visualization applications is the use of TLS to refine the geometry of relatively coarse building models as they are collected from airborne data by socalled displacement maps.

Leica HDS 3000 is used for terrestrial measurements. This system is based on a pulsed laser scanner operating at a wavelength of 532 nm. It is able to acquire a scene with a field of view of up to 360° horizontal und 270° vertical in a single scan. The typical standoff distance is 50 to 100 meters, but measurements of more than 200 meters are possible. The accuracy of a single point measurement is specified with 6 mm. The airborne measurements were carried out by the company TopScan using an OPTECH ALTM 1225 scanner. The data was collected at flying heights of 900m and a scan angle of 20°. This resulted in a mean point density of 1.5 points per square meter and a standard deviation of the single point measurements specified to 15cm. Georeferencing and its accuracies are shown in [2].

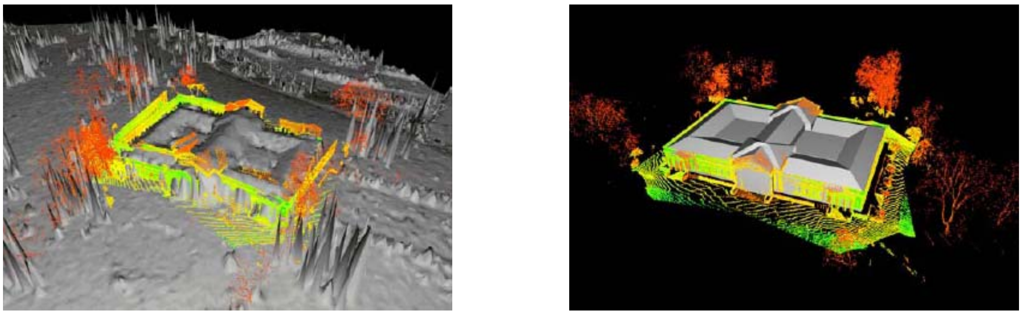

Figure 7. Super-imposition of directly georeferenced terrestrial and aerial laserscanner data (left) and virtual city model with result after alignment (right).

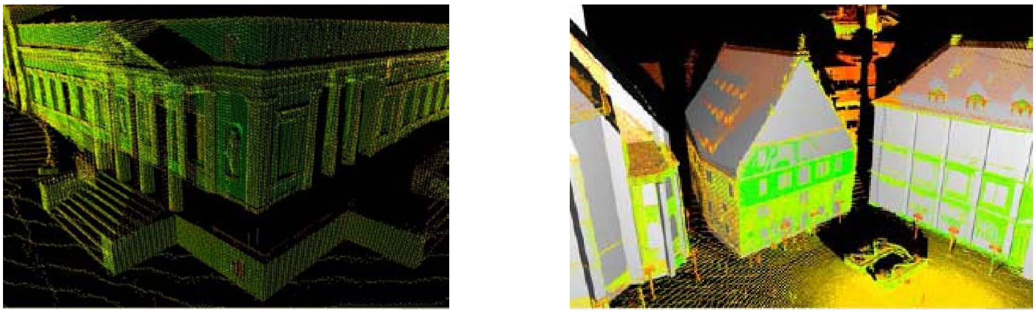

Figure 8. Detail of the aligned datasets: The alignment after iterative refinement (left). Multiple georeferenced point clouds aligned with a virtual city model (right).

BENEFITS AND ADVANTAGES

Laser scanning is a new versatile technology that offers ultra fast, high density and remotely captured 3D digital images of objects and surfaces. From a practical and overall economic standpoint, this feature set has proven beneficial over competing traditional surveying.

- Higher *productivity* – The superiority of laser scanning method in terms of acquired points per time unit is overwhelming. For example, 40 minutes are enough in order to perform a full scan including instrument setup and geo-referencing.
- Higher *spatial resolution* - Systems that can measure several thousand points per second allow a spatial density distribution of observed coordinates much more that available with traditional surveying.
- *Rapid nature of data capture*- the scanner offers a cost effective option for larger sites.
- More *detailed presentation* of the measuring surfaces.
- Removal of decisions regarding to specific detailed points to measure is an advantage of the scanner over conventional methods. Rather then choosing break lines, significant features edges or points, with the scanner are concerned with coverage of regions.
- Ability to *gather data in a non-contact manner*- This can be important when an area is culturally sensitive, or hazardous.
- Possibility for *input to a commercial CAD and GIS system* for post processing.
- Enables to join scans over identical points- By this procedure not only single points are considered but the whole selected areas of the point cloud are covered in best possible way.
- It is possible to combine scans obtained from different scanner positions .It's not necessary to do orientation if you work in local coordinate system, because the system software finds itself common parts from the images made from different stations and combines them in one.
- Only one person is needed for collecting data- Surveyor's time can be better spent on generating management information rather than collecting and processing data.

CONCLUSION

Three-dimensional laser scanning is currently used in high precision, small-scale industrial metrology applications as well as for airborne mapping. But with its rapid collecting of 3D data, high spatial resolution and reduced office work it tend to become a wide spread technique for creating 2D and 3D maps.

We cannot mention that 3D laser scanning is expensive technology. Depending on the special features the nominal cost of laser scanner is six to eight times more expensive compared to an ordinary total station and digital camera. Moreover a powerful computer is needed. Despite high equipment cost 3D laser scanning offers a cost effective option for larger sites due to the rapid nature of data capture. Today, scanning office efficiencies are in line with office efficiencies for conventional site surveys. Together, the combination of significant field labour savings plus office efficiencies on a par with traditional methods has proven to be a good decision in surveying practice.

Notwithstanding the possibilities of rapid data collection, the achievable accuracies of existing laser imaging system are somewhat untested. Manufacturers' specifications tend to vary from system to system and it would seem appropriate to quantify the accuracy and resolution of these systems in controlled environments before using it for a new task.

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BIOGRAPHY NOTES

Gergana Boyanova Antova is an assistant professor at the Department of Surveying and Geoinformatics, Faculty of Geodesy, University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria since 2001, where she lectures in basic and advanced courses in surveying, mathematical post processing of geodetic measurements, CAD systems and Geoinformatics.
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