RESULTS OF THE OEEPE WG ON LASER DATA ACQUISITION

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ABSTRACT

To get an overall view of the state-of-the-art concerning production and use of laser data and to profit of the already existing experiences, a working group was initiated within the OEEPE. It seemed necessary to evaluate on one hand the new surveying systems, integrating GPS, INS, laser scanners and possibly other sensors, and on the other hand to evaluate new methods for analysis of laser scanner data, e.g., for DEM generation and urban modelling.

The tasks of the WG are carried out in four parts. The first part was to investigate the user requirements of laser scanner data and derived products. This was done in the form of a questionnaire, concerning the requirements of the users, but also user definitions of derived products. Analysis of the questionnaire shows that laser scanning is so far mainly used within the mapping communities. There are many consultant agencies that hope for other applications, e.g., telecommunication and power industries, but so far these are minor applications. The main reasons for using laser data are cost effectiveness, high precision and point density. The last two reasons are also given by those institutions testing laser data, mostly universities. The reasons for not using laser scanner data are mainly lack of knowledge, price and that the organisations have not reached so far yet.

In the second part of the project the WG is organising test flights by some companies offering laser data. The test field will be in the south of Germany, and the analysis of the data sets are expected to give answers to several open questions, such as the requirements for DEM generation or 3D city models regarding point density and positioning accuracy.

The project of the WG will continue with the evaluation of the acquired data, part three, and finally end with a workshop or tutorial presenting the final results, part four.

1 INTRODUCTION

With airborne laser scanning technique, a new method of data collection has evolved with a high potential for different mapping purposes. The first articles about laser scanning technology were published in the beginning of the nineties. Data were mainly used for the determination of Digital Surface Models (DSM) or of Digital Elevation Models (DEM). Up to now the results have mainly been used for visualisation of landscapes or for derivation of products such as DEMs. Also engineering tasks like power line measurements are important applications. More complex tasks, as the derivation of 3D city models, are research topics at several universities. Both the numbers of data providing companies and the number of application areas are growing very rapidly. The OEEPE therefore decided to initiate a working group on Laser Data Acquisition in order to get an overall view of the state-of-the-art concerning production and use of laser data. When the WG was initiated in spring 1998, a handful of systems were operating. Now, close to 30 systems are in use.

As often the case, users were accepting the data product as delivered. The requirements of the different users were not well known up to now. Therefore, one aim of the project was to investigate the requirements and possible applications more in detail. A growing market was already to be expected when the work started.

2 LASERSCANNING – HOW IT STARTED

When entering the market, laser scanning technology promised to be an alternative to traditional photogrammetric methods used for different survey tasks since it offers a high point density of high geometric accuracy. The advantages of the technology is achieved by taking profit of high frequency lasers, high precision airborne Inertial Navigation Systems (INS) and high precision scanners. These are combined with multi-channel GPS receivers to result in a complete topographic system. The technology was said to have advantages over photogrammetric methods in forest areas or in coastal zones where photogrammetric point measurements are problematic.

Several companies offer laser scanning flights. The basic technology as described in the previous paragraph is the same. The differences are in general the different lasers used and the various scanning technology leading to different point distributions. Most companies are in addition offering derived products such as DEM or 3D city models, using their own software. For these products, the classification algorithms are of high importance.

3 LASERSCANNING TECHNOLOGIES – STATE OF THE ART

3.1 The Technology in General

As already described, three important components determine the technology: the laser, INS and Differential GPS (DGPS). The basic idea is to calculate polar coordinates for the laser point. The laser rangefinder itself measures the distance between the aircraft and the laser point. The direction of the beam is calculated by combining the angle of the scanning system with the aircraft's angles, given by the INS. The position of the aircraft and thereby of the origin of the laser beam is known by using DGPS, and finally the coordinates of the laser points can be calculated in the European Terrestrial Reference System 1989 (ETRS89).

As the laser beam can be extremely focussed, the diameter of the laser spot on the ground is only of some decimetres and varies from 0.3 to 1.5 m for different systems. The reflection coefficient of the ground determines which portion of the emitted signal returns to the laser. It is depending on the wavelength of the laser and differs especially for white and black surfaces. Most of the "second generation" scanners systems offer the possibility to register the reflectance value of the returned signal. As the reflectance depends on the surface material, the differentiation of the reflecting surface material is possible. "Natural surfaces" (vegetation) have a higher reflectance value than man made materials like asphalt or concrete. This possibility opens the field for extended or even new applications.

In the laser scanner theme issue ISPRS journal of Photogrammetry and Remote Sensing, vol 54, July 1999, a thorough investigation of laser scanning systems and techniques can be found.

3.2 Pulsed Laser

Most systems are using a pulsed laser where the distance is given by measuring the time the laser emission, modulated by a distinct pulse of some nanoseconds, needs to run the double distance from the aircraft to the laser point. Even though the diameter of the laser beam is very small, it is not infinite. So, often the beam meets two or more obstacles partially, especially in forest areas. This results in two or more reflections of the pulsed beam returning to the laser rangefinder. Most of the systems are capable meanwhile to register all pulses returning to the laser rangefinder, at least the first and the last pulse (first pulse mode / last pulse mode). Based on these measurements, different applications are possible.

3.3 Continuous Wave Laser

Another system design is using a multi-frequency sidetone concept for the distance measurement. The laser beam is intensity modulated by a sinusoidal signal. The received sidetone phase is compared to the phase of the emitted sidetone. The distance is finally calculated from the phase shift which is proportional to the time the beam needs to run the distance between the aircraft and the ground. Two or more modulation frequencies are necessary to solve the ambiguity that occurs since the wavelength is normally smaller than twice the distance between the aircraft and the laser point.

3.4 Scanning Technology

While the laser rangefinder used for the distance measurements are more or less similar, the differences in the scanning technique are more important. Scanners are used to reach at a more or less wider strip of laser points. To achieve that, mirrors or, for one system, fibre optics are used.

In most of the systems, a swinging or rotating mirror is mounted in the front of the pulsed laser deflecting the laser beam to the ground. The scanning angle of the mirror is registered or interpolated for each laser pulse. The technique results in z-line pattern or almost elliptical line pattern of the laser points on the ground. These systems are very flexible while the laser frequency, the scanning frequency and the scanning angle can be changed.

One system is using fibre optics to build a push-broom of laser measurements. The laser beam is deflected in the different fibres of the fibre optic, which is opened to a push-broom. This results in parallel profiles of laser points on the ground and a very high point density in the flight direction.

4 AIMS OF THE PROJECT

4.1 Background of the Project

When starting the project, only a limited number of private companies were offering the data capture and the required post-processing, often using proprietary software developed by each company. As the laser scanning technology and also some laser parameters, as wavelength and laser frequency, varies between different systems, the results are difficult to compare. There is so fare no standard concerning accuracy and reliability of data or recommendations for different parameters such as maximum point distances for a specific application. The main task therefore was to get an overall view of the state-of-the-art concerning production and use of laser data.

4.2 Initial aims of the Project

The initial aim of phase I of the project was to investigate the user requirements of laser scanning data and derived products, such as DEMs and 3D city models. A questionnaire was to be set up, concerning the requirements of the users, but also the user definitions of the derived products. Users of laser scanning data were also to give information about their definitions and understanding of these products. The first results of the questionnaire where only presented shortly during two meetings.

In phase II a test area was established comprising both built-up areas, forests and engineering objects such as power lines and railroads. The area should be surveyed by as many suppliers as possible. Data should be made public and tested for different applications by the members of the WG.

5 RESULTS FROM PHASE I

The main work in phase I has been the formulation of the questionnaire and the compilation of the answers.
The questionnaire was to investigate the current user requirements for laser scanning data. People were asked to give some details concerning laser data, used for different purposes as DEM / DSM derivation in wooden and/or urban areas, orthophotos, interpretation, 3D city models and so on. At the same time state of the art in research and development should be brought out, concerning the surface data and the derivation of other products such as DEM or 3D city models.

The questionnaire was sent to about 300 addresses in 32 different countries of Europe. Of these, 79 were answered, corresponding to a return ratio of about 27 %. This is considered as a good return rate, revealing a high interest in laser data. This is confirmed by the 40 organisations that are not using laser data yet, but who are very interested in doing so. There are in addition 21 organisations that are testing laser data, most of them (15) universities. A quarter of all organisations that answered the questionnaire already used laser data in production. The answers have been compiled in graphic form to make it easier to analyse. The most important results and the corresponding graphics are given here.

There has been a good geographical distribution of both sent and returned questionnaires. Since the result has been dependent on addresses given to the WG, countries with WG-members are generally better represented than other countries. Even though as many as 49 % of the received questionnaires told that they did not use laser scanning, they still found it worth returning the form (see Figure 1). Most users and potential users are working at administrations whereas most universities entitle themselves testing data.

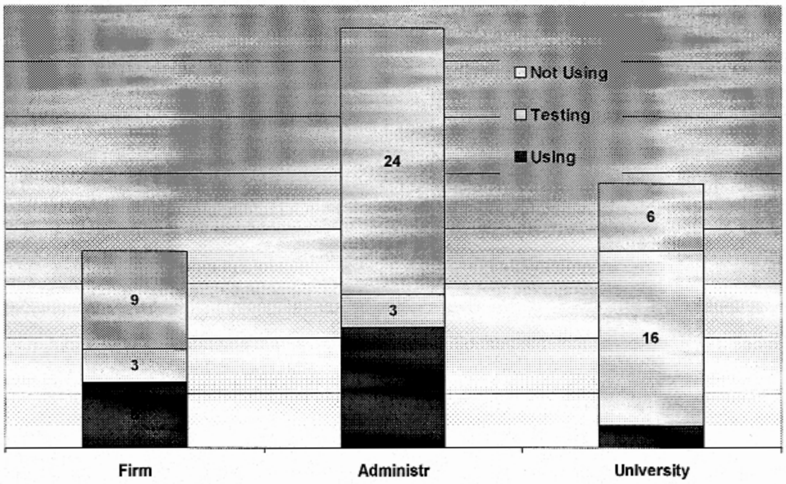

Figure 1: Distribution of the Questionnaires sent back

5.1 Organisations Using Laser Data

It seems like laser scanning is so far mainly used within the mapping communities (see Figure 2). This can also be due to the fact that the questionnaires were mainly sent out within this area. There are many consultant agencies who hope for other applications, e.g., telecommunication and power industries, but so far these are minor applications. But the different applications show the high potential of the new technology which is probably not yet coming up against limiting factors. The main application areas of laser data are the production of DEM or DSM and the main reasons for using laser data are point density, high precision and cost effectiveness (see Figure 3). Users also mention short production times as very important.

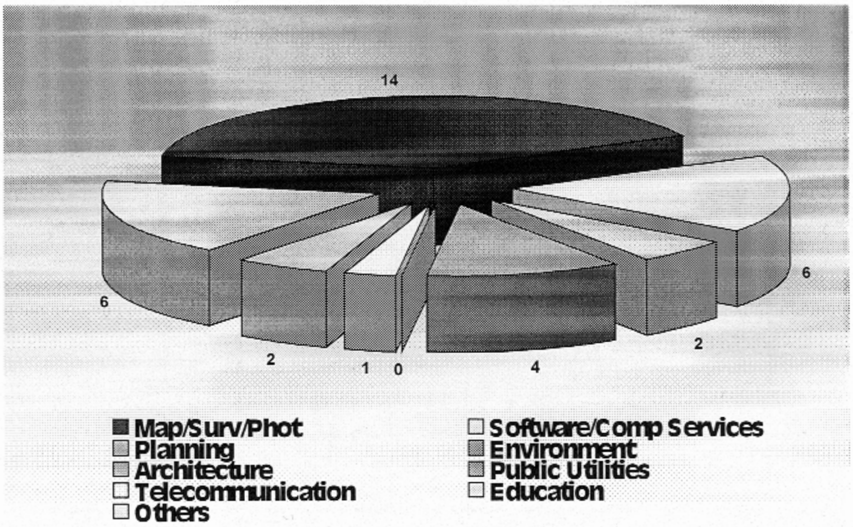

Figure 2 : Types of Organisations that are Using Laser Data

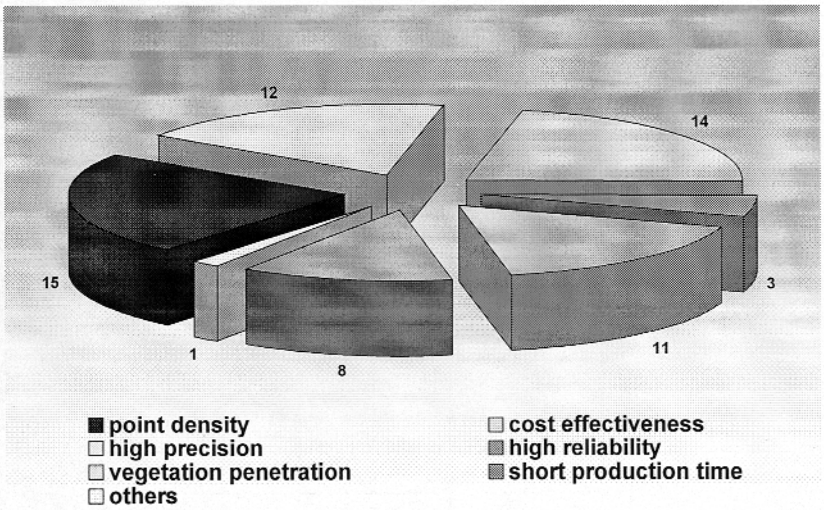

Figure 3: Reasons for Usage of Laser Data

5.2 Organisations Testing Laser Data

If firms and administrations dominated the previous section, this part is dominated by universities. Otherwise the result is very much the same. The interest is turned more towards 3D city models, and the main reasons for using laser scanner data are point density, high precision and vegetation penetration (see Figure 4).

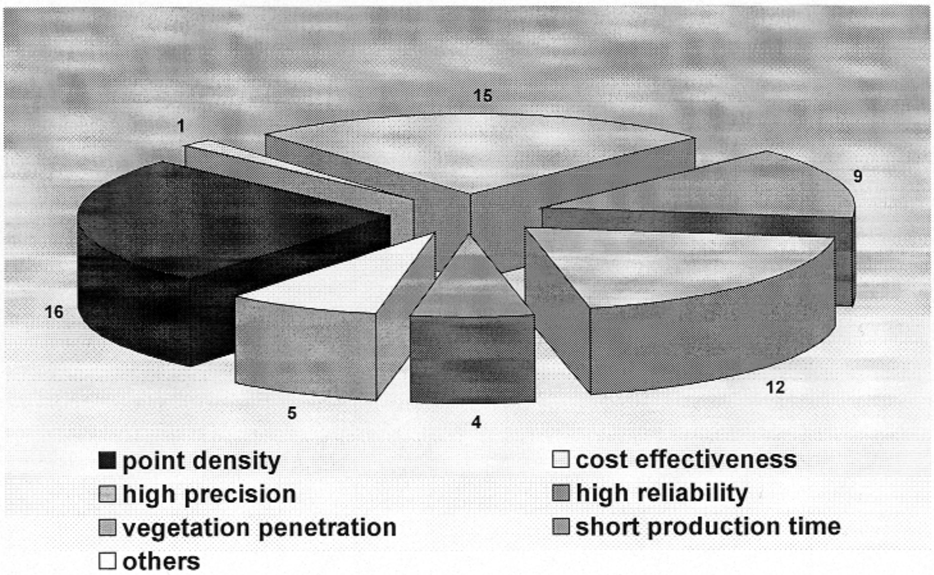

Figure 4: Reasons for Testing Laser Data

5.3 Organisations not using Laser Data

The many questionnaires sent back of those organisations that are not using laser data showed the high interest that existed already at that time in laser data. The reasons for not using laser scanner data are mainly lack of knowledge, price and that the organisations have not reached so far yet (see Figure 5). Pricing seems to be a difficult issue, since this reason is used both in favour of and against the use of laser scanning. The most probable explanation is that the price for small test areas is high. In addition all the advantages as they are given by the users can only be evaluated after the first tests within the own agency, comparing the new production line to the old one that is very different, also compared to other agencies.

More detailed graphics and results of phase I can be found at the Working Group's home page: http://www.geomatics.kth.se/~fotogram/OEEPE/oeepe_laser_main.htm.

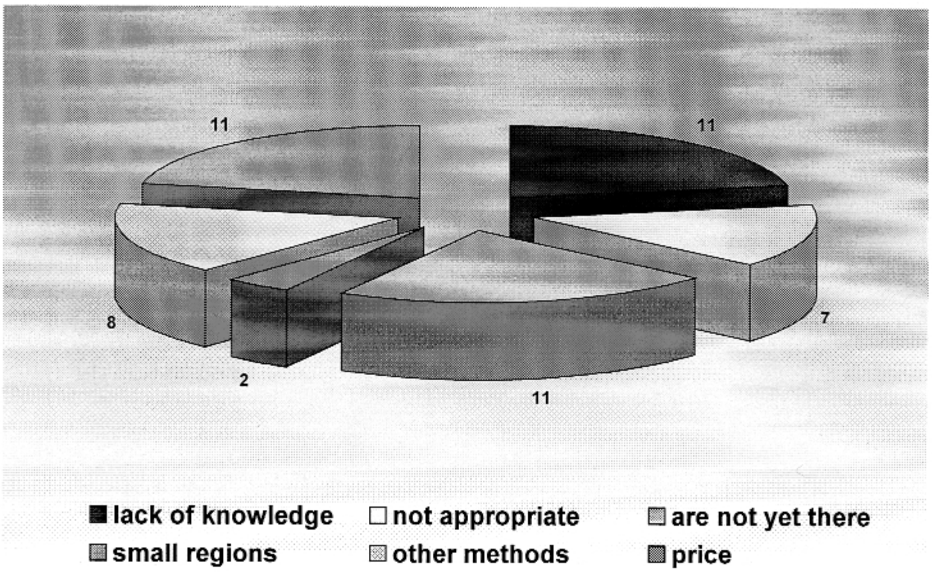

Figure 5: Reasons why not using Laser Data

6 PHASE TWO OF THE PROJECT

The aim of the second phase was to establish a test field that can be used for testing and evaluating laser scanning systems and data processing algorithms. The area should be surveyed by as many laser data suppliers as possible. The test area was found including both built-up areas, forests and engineering objects such as power lines and railroads, but there were several problems related to this:

- The test area should satisfy several different types of applications, e.g., open fields, forests, dense city areas, power lines and water surfaces.
- If the absolute accuracy of the systems are to be evaluated the checkpoints in the test field must be of very high quality.
- The test field should be located in a, for as many as possible, convenient place.

The negotiations with the companies showed a big interest in participating in the project even though the companies are not paid. The possibility to show the high potential of different applications based on laser data seems to be attractive enough for data providing companies to combine the test flight with another order to be carried out.

It was finally decided to use the Vaihingen / Enz test field that has already been used for other OEEPE projects. In addition, the companies were asked for some data of the Stuttgart city centre. This enables some tests for the derivation of 3D city models, an application that, following the results of phase I, is one of the most promising ones regarding the expectations of user.

Field measurements for the check areas and some concise objects finished in February. At the same time, the first flights were done. When finishing this paper, data were not yet delivered, but the WG is expecting to have results available before summer.