DEVELOPMENT OF A COMMERCIAL LASER SCANNING MOBILE MAPPING SYSTEM - *STREETMAPPER*

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ABSTRACT:

The performance and availability of modern 3D laser scanning systems has created a demand for a system that can survey many kilometres of highway very rapidly. Airborne laser scanning can offer this type of data but aircraft operations are expensive. Tunnels and bridges can be analysed from the bottom up. The *StreetMapper* mobile laser scanning system was developed initially to fill a demand for measurement and recording of highway assets, but has since been developed for other applications. The system uses Riegl 2D laser scanners integrated with an IGI TERRAControl GPS/INS system. A practical mounting system was developed along with a calibration procedure. Route planning and GPS visibility prediction are important components of the system. The prototype *StreetMapper* system has been operating during 2005 with excellent results. The system has been used on a number of projects including highway asset measurements, indivisible abnormal load route planning and 3D city modelling. Also the *StreetMapper* provides detailed data on the facades of buildings and high resolution measurements of powerlines beside streets. The accuracy trials under normal conditions resulted in an RMS error between *StreetMapper* data and ground control points as better than 30mm.

1. INTRODUCTION

1.1 Background

Mobile mapping has been around for some time, but mainly these systems use video cameras instead of laser scanners. The problem with these types of systems is that they are unable to directly produce a 3D map. Those systems which do offer laser scanning are principally based within the academic environment.

There are three main reasons there are so few laser scanning mobile mapping systems in the commercial environment; (a) most airborne LiDAR systems are not eye-safe (Class I) at short range, thus making it dangerous to be operated in populated areas like cities, (b) the field of view will be limited, usually to 60º to 80º and (c) the GPS/Inertial Navigation System (INS) is not effective when satellite visibility is obscured by vegetation or buildings. However, recent advances in technology now mean that these issues can be overcome.

1.2 Motivation

The development of the StreetMapper system commenced to meet the requirements of a client with a large highway survey project. They required a robust and reliable medium range mobile mapping system using laser scanners. 3D Laser Mapping (3DLM), based in the UK, and IGI, based in Germany, collaborated to develop a new product to meet these needs. The system named StreetMapper uses IGI precise positioning technology and Riegl laser scanners.

2. TECHNOLOGY

2.1 The technical challenge

Laser scanners of a suitable specification became available from Riegl during 2005, thus the remaining challenge was to find an effective GPS/INS solution for use on the ground while moving.

Some trials were undertaken with a GPS/INS solution designed for aerial survey applications. In most situations during aerial surveys, there are no obstructions between the GPS antenna and the satellite, so once the GPS receiver has locked onto the satellites in view then the positional accuracy will remain high. However, on the ground, each tree and building will obscure the view of one or more satellites. This means the quality of the GPS solution and thus positional accuracy will vary. A good quality INS system will “bridge the gaps” in the GPS solution. Over a short time span, the INS system can accurately record the relative position of the system to augment the GPS solution.

Figure 1 and 2 show the effect on the resulting laser data when an inappropriate INS system is used, compared to results using a high quality INS. The gaps in the GPS data are not bridged by the INS resulting in discontinuities in the trajectory, which ultimately results in steps in the laser data. In addition, large errors will be seen in the elevation of the GPS trajectory.

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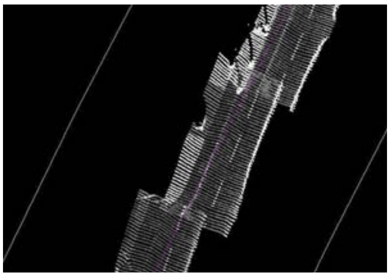

Figure 1. Low quality INS

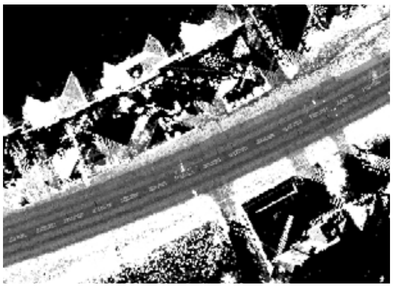

Figure 2. High quality INS

There are a handful of GPS/INS solutions on the market that are suitable for use on the ground, which include the IGI TERRAControl (the terrestrial alternative of IGI's AEROcontrol). A key criterion for the INS system was for the accuracy of the trajectory to be maintained during 120 second duration of poor satellite visibility.

The performance of the TERRAControl system is illustrated in the following two charts taken from the survey of the A14 in Cambridgeshire in the UK. Figure 3 shows the number of satellites in view against time. This shows clearly where the system has passed under three bridges and no satellites are visible.

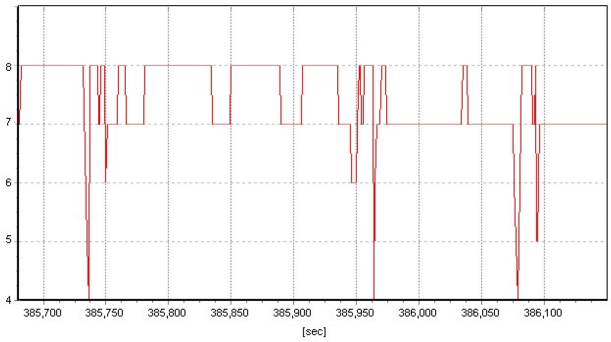

Figure 3. Number of satellites visible

Figure 4 shows the root mean square (RMS) positional error of the INS system against the same time period for the first chart (Figure 3). High positional errors can be seen that coincide with the three bridges and other areas where few satellites are visible. However, the INS has kept the accuracy within 45mm in elevation and 30mm in easting and northing.

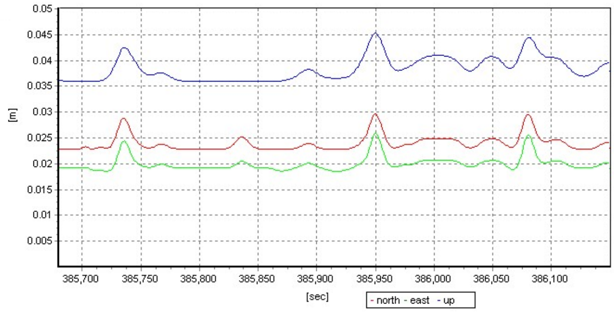

Figure 4. Number of satellites visible

The first StreetMapper system was assembled in mid 2005. Six months of reliability and accuracy testing were undertaken. This system can be configured with two, three or four laser scanners with an IGI TERRAControl GPS/INS system. A digital video system is also installed. Figure 5 shows the StreetMapper system with two laser scanners installed on the back of a van.

Figure 5. StreetMapper system with 2 laser scanners installed

2.2 Accuracy tests

An independent check of calibration and accuracy was undertaken at a residential estate where there were areas of good and bad GPS visibility. The survey was undertaken on two different days in order to account for varying GPS conditions. Multiple passes were also driven in order to assess repeatability.

Over 300 reference points were recorded using Rapid Static Differential GPS and compared in elevation with the StreetMapper data. Figure 6 shows a table of the resulting accuracy.

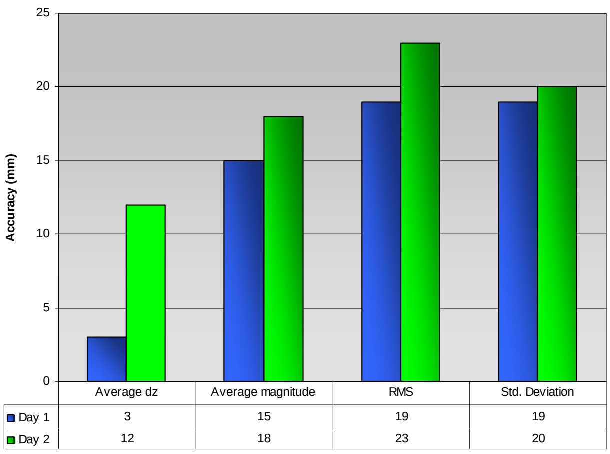

Figure 6. StreetMapper accuracy

The average elevation difference between the reference points and the StreetMapper points was 3mm and 12mm for Days 1 and 2 respectively. The RMS and standard deviation for both Days were in the region of 19 to 23mm.

Normally the accuracy of the StreetMapper is quoted in two different ways:

Relative accuracy

This means the accuracy of measurements between two points in the same region of the point cloud, for example, when measuring the width of the highway. This accuracy is typically 25mm.

Absolute accuracy

This means the accuracy of the GPS/INS trajectory. In areas of good GPS such as an airfield or main highway with few bridges, this accuracy can be 50mm. In built up areas, this accuracy can drop to 0.5m.

These definitions are very important when defining the optimum projects for employing the StreetMapper system.

2.3 Route planning

In order to achieve the best accuracy across the whole of a survey project, it is important to start and finish the survey session in an area of good GPS visibility. This means the a stable GPS positional solution is calculated before the INS data is relied upon in areas of poor GPS.

This means that route planning, with knowledge of likely GPS visibility, is important when using StreetMapper.

3. CASE STUDIES

3.1 Case study: Indivisible Abnormal Load Routes

In the UK, the transport of Indivisible Abnormal Loads (IAL's) often requires a route survey as no national database is maintained on suitable routes. Certain routes are maintained locally to by suitable for heavy or large loads, but even if these are used then the final leg of the journey may need surveying.

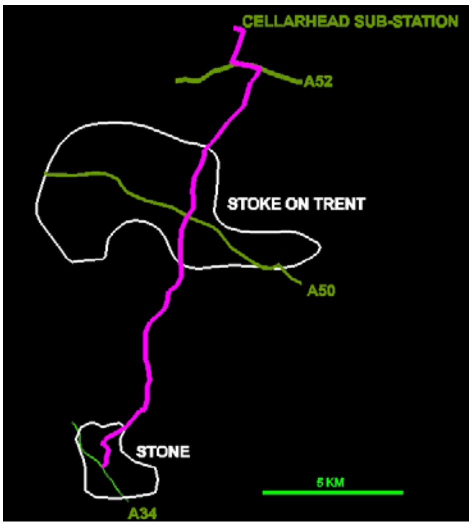

Figure 7 Route map

The StreetMapper system was used by the national power utility to survey part of the route from Ellesmere Port to Cellarhead Substation in Staffordshire to ensure route was suitable for transporting a large transformer. The route from Ellesmere Port to the A34 in Stone was already known to be suitable. The StreetMapper system was used to survey the route from Stone to the substation. The route map is shown in Figure 7.

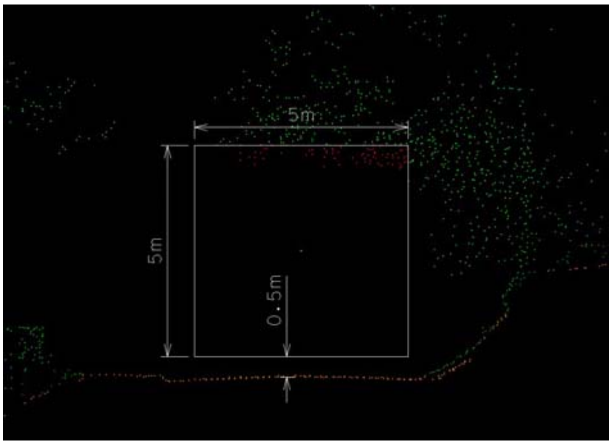

Figure 8 Analysis of pinch points

The total length of the route was 19km and the survey was completed in one hour by driving the length of the route at normal road speed. The result of the survey was a point cloud of 93 million points, at an average point density of 50 points per square metre. This was analysed by using software to highlight areas were points fall within a 5m by 5m section travelling along the route at a height of 0.5m above the road surface. A typical cross section of the data is shown in Figure 8. These pinch points were listed and the point cloud data was used by the client for more detailed analysis.

Figure 9 Plan view of data

3.2 Case study: Cambridgeshire Police

The Cambridgeshire traffic police have demonstrated the value of surveying trunk roads in their area using mobile laser scanners. When accidents occur, they use this data to reduce the time required to record accident scenes – and shorten the time before the road can be cleared.

During the survey of a serious accident, the crash debris must be accurately scanned but it must also be put into the context of the surrounding highway environment. It is typical that up to one hour can be spent surveying road markings, bridges, lamp-posts and other fixed objects. This time can be saved by using laser scan data to record these items.

Figures 10 and 11 show a typical highway map comprising road, pavements, footways, streetlights, barriers, signs, drains, road markings, street furniture, structures and verges. The scanned data can be vectorised into a number of formats depending on each customer's requirements, including GIS and CAD.

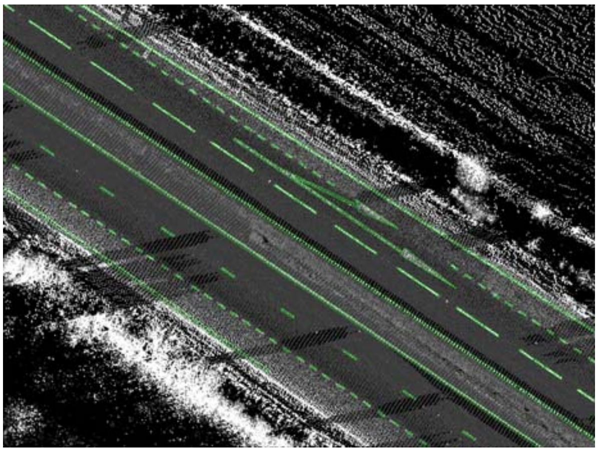

Figure 10 Plan view of highway data with road markings digitised.

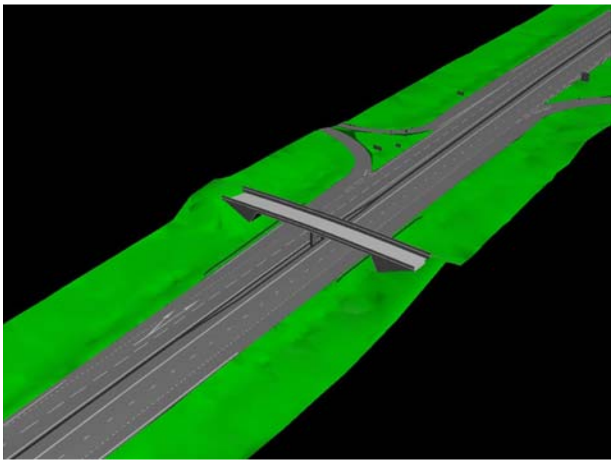

Figure 11 Perspective view of final 3D model created from StreetMapper highway data.

3.3 Case study: City Modelling

For city modelling applications, StreetMapper has significant benefits due to the speed and mobility. Traffic management is not required and large areas can be surveyed rapidly.

By being on the ground the StreetMapper system can survey the façades of the buildings that are not visible from aerial surveys. A typical point spacing of 30mm on the façade of building allows 3d models to be easily created using commonly available laser scanning processing software.

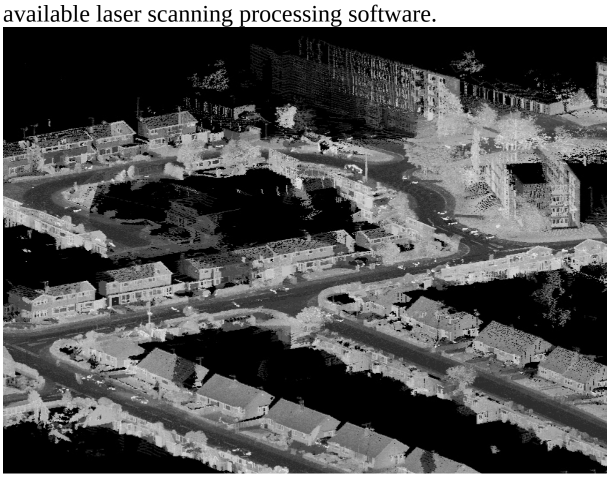

Figure 12. A typical point cloud of an urban area.

4. CONCLUSIONS

The StreetMapper system has been developed to overcome the potential difficulties caused by GPS visibility during mobile mapping operations. The performance of the system has been validated and is already in commercial use. Positional accuracy has been proven to be better than 30mm in good GPS conditions.

The benefits of using this system are:

- The StreetMapper system is much safer than a manual survey method. Narrow stretches of road on a main highway are hazardous places to be surveying the clearance height and width.
- Helicopter LiDAR surveys have been considered by they are much more expensive to mobilise than the StreetMapper.
- The field of view from the ground is far superior to a survey from the air. The most important pinch point might be obscured by a large tree or building when surveyed from the air.
- From the ground, at short range the resolution of the data is much higher. It is possible to resolve overhead cables down to 3mm in diameter, which is nearly impossible to do from the air.

5. REFERENCES

Redstall, M., 2006. Accurate terrestrial laser scanning from a moving platform. *Geomatics World*, July/August 2006, pp. 28-30.