I-SiTE - Laser Scanning Revolutionises Site Survey

I.K. Kapageridis
Maptek/KRJA Systems Ltd, United Kingdom

ABSTRACT: MAPTEK's revolutionary I-SiTE 3D Laser Imaging System, presented in this paper, is a new means of collecting 3D information quickly and directly from any large scale environment. The system records accurately the location of features and surfaces in areas such as urban and industrial settings and mine sites, both surface and underground. Points sampled from the scene are used to build a data set which is a complete 3D rendering of the scene. By interactively viewing the data using the built-in software, it is possible to see the scene in ways that would not usually be possible. While laser scanning systems have been available for some time for small scale engineering tasks, their use in larger scale environments is not widespread.

1 INTRODUCTION

Maptek began work on 3D laser imaging in a Strategic Alliance with the Defence Science and Technology Organisation in Adelaide, Australia. VULCAN’s 3D capability was crucial in the decision to build a high performance laser scanner for defence purposes – a project still under development.

The I-SiTE System is a spin-off from that work. It is an eye-safe, robust and easy-to-use package for mining and other commercial applications. The software developed to handle the massive cloud of data points is the culmination of three years of intensive R&D effort.

2 SYSTEM DESCRIPTION

The I-SiTE System is a combined hardware and software package. The hardware includes a laser scanning device, a laptop computer with which to control the device and support data acquisition and a 3D workstation (Fig. 1). Combined with MAPTEK's VULCAN 3D software, the graphics environment represents the ultimate desktop system for post processing, data management and manipulation.

The laser scanning device is a pulsed laser range finder and a mechanical scanning system, able to measure a set of 3D points in any scene.

The laser range finder emits a laser pulse, illuminating the point on the surface to be measured. A portion of the pulse energy is returned to the scanner from the surface and detected. The time taken between the emission of the pulse and its detection is used to calculate the range. The amount of energy reflected depends on the characteristics of the surface, such as colour and roughness. The amplitude of the returned pulse is recorded, giving an intensity or brightness value. No reflectors or other infrastructure in the scene are required.

Figure 1. Parts of the I-SiTE 3D laser imaging system used in the field - the laser scanner (left) and a laptop (right).

The laser source and the detector are both solid state devices. The laser operates in the near infrared region at 0.9 µm. The imaging system is a Class 1 Laser product and thus eye safe. Depending on ambient lighting, the scan range is up 350 m - the minimum range is 2 m. Measurements are accurate to 2.5 cm over the entire range. The beam width of the range finder is 0.17 degree, or 30 cm at a distance of 100 m, allowing even small features to be captured in coarser scans.

A rotating polygonal mirror directs the beam in a vertical direction (fast scan), while the entire head rotates to move the beam in a horizontal direction (slow scan). Angle encoders record the orientation of the mirror and head for each range measurement, creating a raster pattern of range and intensity values with each point uniquely positioned in 3D. The vertical range is 80 degrees centered on the horizontal and the horizontal scan covers 340 degrees (Fig. 2).

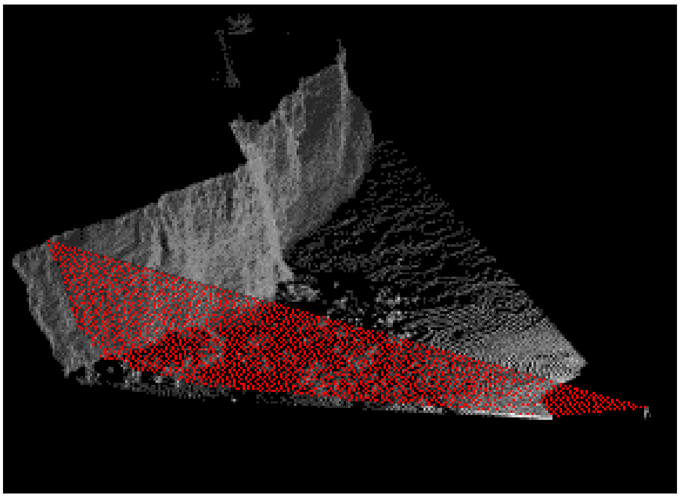

Figure 2. Acquisition of 3D points from a slope at varying horizontal and vertical angles using the laser scanner of the I-SiTE system.

With the laser capable of pulsing at up to 20 kHz, point data can be acquired at up to 6000 measurements per second. Data can be acquired at various angle resolutions, from very fine spacing to coarser measurements. A small angle increment results in more points being acquired in a given angular extent.

The entire laser scanning device with the range finder, scanning mechanism and associated processing electronics fits into a cylindrical package with a diameter of 21 cm, height of 44 cm and weighing 13.5 kg.

The laser scanning device is controlled fully via a laptop PC connected to the device through serial and parallel cables. The operator sets the scanner parameters and downloads the data onto the PC in real time. The data acquisition process can be monitored on the screen in 3D.

3 OPERATION

The system can be set up in the field by a single person (Fig. 3). The laser scanner is mounted on a standard surveyor's tripod and connected to the laptop computer. It requires a 12 V DC power supply - connected either to a supplied 12 V lead acid rechargable battery or to the battery of a car via a cigarette lighter adapter. The laptop computer relies on its internal battery supply.

Figure 3. Setting up of the I-SiTE system is easy under any conditions.

The operator can select the angles of the scan or use the system defaults. The left and right angle extents of the horizontal scan and the top and bottom of the vertical scan are shown on the screen. For example, where the angle extents are 80 degrees vertically and 180 degrees horizontally, at a coarse angle resolution of say 0.43 degrees (equating to a point separation of 75 cm at a distance of 100 m), about 75 000 points would be measured in around 15 seconds. If the resolution was increased to 0.1 degrees (approximately 19 cm at 100 m), about 1 200 000 points would be collected in less than 4 minutes. The system acquires data quickly and easily.

The data is immediately viewable in 3D using the I-SiTE software. It can be interactively viewed from any location, including from the point of view of the scanner. Any point can be queried for its distance from the scanner; distances between pairs of points can be measured. The 3D view enables the operator to quickly evaluate the quality of the data and if necessary change the parameter settings and make further measurements. It also highlights missing areas of the scene. Since the scanner can only measure what is directly in its line of sight, occluded parts of the surface can be captured by moving the scanner to a more optimal position or merging data from several locations.

Each point in the data set is coloured according to the reflected intensity. Looking at the data from the point of view of the scanner is equivalent to looking at a monochrome photograph of the scene (Fig. 4). The data can be coloured by mapping various colour ranges to intensity values, thus highlighting small intensity variations in the data.

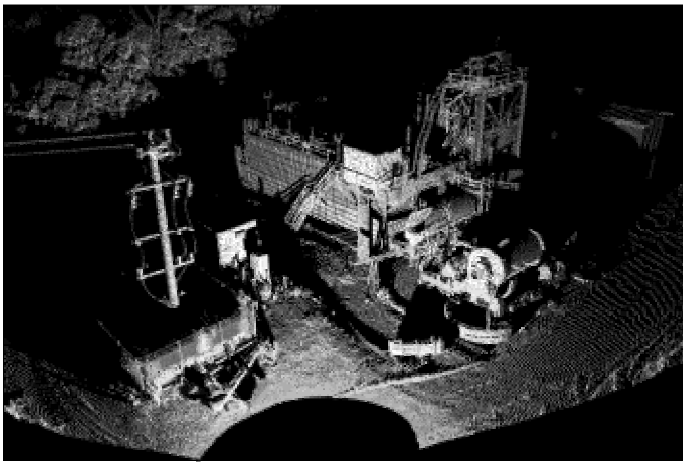

Figure 4. Perspective view of an I-SiTE scan from a mine's surface infrastructure.

If the location of the scanner in the scene is known, the data can be positioned relative to that point. Thus every point will have an absolute location in the measured coordinate system. While it is not necessary to have reflectors in the scene to acquire data, they can be useful to assist in merging scans. Reflectors show up as bright points in the data.

Because initially each point is measured relative to the scanner position, by selecting identifiable points common to a pair of scans, or nominating known location points, the operator can merge all the data into a common coordinate system. This process means the scanning device does not have to be levelled for use. In fact it can be tilted to ensure parts of the scene are visible for scanning.

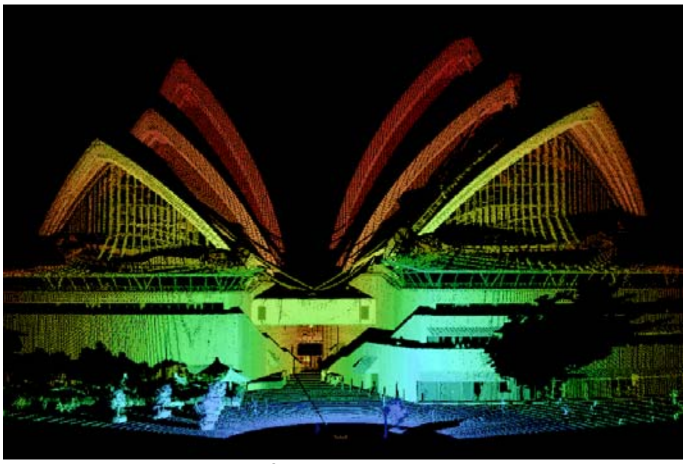

Figure 5. Laser scan of Sydney's opera house coloured by point distance from the laser scanner.

Once the data has been collected in the field, it can be transferred to the more powerful 3D graphics workstation for further processing and development and integration with existing spatial data.

4 DATA MANIPULATION

While some of the data manipulation can be done in the field, the ideal environment is Maptek's VULCAN 3D software on the graphics workstation. Within VULCAN, the points can be edited and filtered to remove extraneous data. Using VULCAN's modelling options, data can be triangulated to create surfaces, which are used to built up more comprehensive models. Because the data is recorded in the correct spatial location, it can be compared to related data, such as GIS or CAD models.

5 APPLICATIONS AND BENEFITS

Applications for the I-SiTE include:

- face survey of mines and quarries for structural and geotechnical analysis
- measurement of tailings and waste dumps
- slope stability and cavity monitoring
- stockpile and dump monitoring
- volumetric measurements (planned versus achieved)
- site analysis, as-planned versus as-built sites, plants and machines
- spatial equipment monitoring, change detection and bucket positioning
- accurate mapping of dangerous and unstable slopes
- civil engineering works
- rail, road and infrastructure mapping and modelling
- industrial infrastructure modelling - as-built versus as-planned geometry
- urban planning and mapping of buildings (Fig. 5)

The system is ideal for hazardous environments where it would be otherwise impossible to make measurements, such as unstable rock faces, or in areas where access is unavailable.

The rapid acquisition of data makes it useful in applications where the environment is changing, such as in stockpile management. Time is not wasted in post processing becuase of the immediate availability of the data. The speed of the system also means more accurate data can be obtained in a given time.

In construction areas, immediate access to 3D data in a common coordinate system makes it a simple task to compare as-built scenes to existing designs. Features that may not have been measured in a manual survey will also be captured.

Unlike photogrammetric techniques I-SiTE provides direct measurement and does not rely on the location of specific features in the scene to match image pairs.

The association of intensity data with each point adds additional information. For example in mining applications, while the location of the rock is important it is also useful to be able to locate different rock types, if they are visually distinct.

6 CASE STUDY – SHAMVA GOLD MINE

Shamva Gold Mine in Zimbabwe was the focus for the most challenging survey yet undertaken using the I-SiTE 3D Laser Imaging System (Gribble and McCallum 1999).

Underground production is only the most recent phase of mining at Shamva; its known history dates back more than 100 years. Between 1910 and 1930, a steep sided subvertical excavation was created using underhand stoping methods. It reached some 170m in depth, and now breaks into the existing underground workings. The final excavation comprises an elongate slot of some 700m in length and runs 120m across at its widest point.

This is one of the largest open stopes in the world. Such is the size of the excavation, it is said that some local people do not believe it could have been created by men! Records show, however, that the mine milled some 8.5 Mt of ore producing 43 350 kg of gold during its 20 years of production. VULCAN is used at Shamva for modelling and mine planning of the current underground operation. An active exploration program is now being undertaken to identify the full potential of the mine area. The main requirement was to model the excavation to give accurate tonnages of the remaining hill for resource and reserve estimations. The I-SiTE survey represents a key part of this procedure (McCallum 1999).

6.1 *Preparation & Reconnaissance*

Thorough preparation is vital for a project of this magnitude. Because of the known difficulty of gaining access to vantage points for the I-SiTE laser scanning, significant time was spent in reconnaissance and planning. This included walking all accessible areas of the pits, locating and establishing access to old adits, and entry to the underground workings which potrholed into the large open stopes.

Sites were chosen for the laser scans, and also for the registration markers. Registrations markers were used for this project so that in each scanned 'scene' known points could be located and transformed to real world co-ordinates.

Experimentation showed that 5.5 cm balls coated with reflective tape worked best as they were symmetrical, easy to place and could be detected at ranges up to 265 m. About 150 balls were deployed, and surveyed by total station to give real world co-ordinates – a time consuming part of the program.

6.2 *Laser Scanning*

Scanning and processing were divided into areas based on access and natural division (Fig. 6). For each of the 95 scans a systematic methodology ensured that reflectors could be identified in each scene, their scanned co-ordinates documented, and the image verified before moving the the next location. Dense levels of scanned data were acquired, as excess data could be filtered out during processing, rather than having to go back and repeat the scanning process.

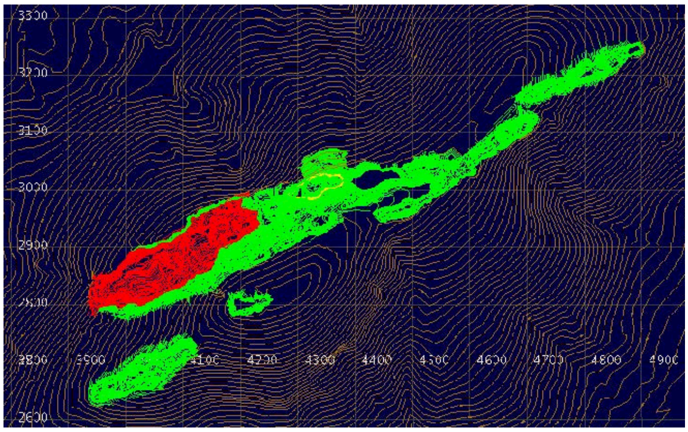

Figure 6. Main scanning areas of the Shamva gold mine.

6.3 *Processing*

Processing the scanned data was divided into transformation and model generation.

Transformation was achieved using a three-point algorithm, in two phases. Firstly the reflectors only were transformed for the scenes to be combined. After checking for accuracy, the actual scanned data was transformed.

In order to generate models, the transformed data was first loaded into a sample database where it could be displayed using appropriate colour schemes, for validation and filtering to remove excess data. Actually building the models had to overcome two problems – the large number of trees in the pit and producing a model of 'manageable' size for the graphics capabilities of the computers from the huge amount of scanned data.

6.4 *Modelling*

Contours of the pit shapes were digitised at vertical intervals using a viewing plane which showed data above and below the level of interest. By this method, trees could be eliminated, and any obscured areas readily interpreted.

Figure 7. Photograph (top) and model in VULCAN (bottom) of a slope. The amount of detail in the model is immense.

The resultant contours were then adjusted to fit the existing surface topography, and triangulated. The models can be easily handled on a PC (Fig. 7), and of course the original dense data is still available in VULCAN format for detailed studies.

The final models were combined with models of existing underground excavations, and could be used to constrain the block models in the resource estimation process, together with accurate stope outlines on the survey plans in areas where 'unknown' would more likely have been written only a few weeks previously.

7 CONCLUSIONS

The I-SiTE 3D Laser Imaging System provides real-time, fully coordinated spatial data. The precision and accuracy which is achieved leads into the automation of the targeted process (e.g. mining), with all the efficiencies that mechanical manufacturing operations enjoy. Costs can fall, utilisation of both equipment and ore resources can increase, and human safety can be greatly improved.

I-SiTE delivers dynamic data capture and visualisation to instantly build 3D models with accurate coordinate placement and analysis. This technology offers significant benefits in a wide range of mining, civil and defence applications.

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