Spatial Imaging the New Surveying Revolution

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SUMMARY

New technology continues to affect the everyday life of a surveyor. Some of these technologies start out just as a curiosity. This has been the case for 3D scanning for many years. Now due to the maturing of the technology and software, Spatial Imaging has evolved as the next true surveying technique.

Understanding the technology and the techniques involved is essential for the future of the modern surveyor. Knowing the capabilities and the different data types is the first step in understanding how this technology can benefit a surveyor to provide new and wide range of high-end deliverables to his current and future customers. Also it is critical that we understand the benefits and the limitations of the technology to make the best judgment on when to use it.

This presentation explores this new world of Spatial Imaging and how it will impact the present and future of a surveyor. It will examine the technology, and techniques used to produce a variety of everyday data outputs and new highly valuable deliverables. For students considering surveying as a profession, it illustrates how this exciting new field of surveying can impact their future.

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1. SPATIAL IMAGING TECHNOLOGY

1.1 Historical perspective

It has been more than twenty years since the first 3D scanner was commercially introduced. These early scanners were initially developed to solve specific problems of non-contact measurement for applications within facilities such as nuclear power plants. The range of measure for these devices was limited as precise measurements were often required. These instruments also required the use of a specifically configured and dedicated laptop computer. Due to the large amount of data required to manage and data processing to produce results this had to be carried out on server-based workstations.

As the technology advanced speed, range, accuracy, and ease-of-use it has developed to adapt 3D scanning to a broader range of surveying applications. Instruments have reduced in size, weight, and become more portable with operation from a handheld data collector. Introduced by Trimble in February of 2007 came the merging of the total station, imaging and 3D scanning technology into a single instrument. The Trimble® VX™ Spatial Station provides the surveyor with the flexibility to carry out traditional surveys as well as the ability to capture complex data with 3D scanning and images via integrated digital camera technology.

Personal computer advances have had a significant impact in enabling the adoption of spatial imaging technology to where it is today, as an accepted surveying practice. Speed of the processor for fast data processing and powerful graphics drivers allow for efficient management of large amounts of three-dimensional data and images. The significance of PC power has ensured that complex three-dimensional deliverable can be processed within a reasonable amount of time to satisfy demands for project site use.

2. APPLYING SURVEY TECHNIQUES

2.1 Traditional techniques

In the past, cumbersome and unreliable techniques have been a part of the 3D scanning data collection process. Due to the limitations of the technology, techniques such as the placement of a large number of spherical or rotating flat targets or cloud-to-cloud based techniques were used to register point cloud data together. These techniques were carried out in the office and did not facilitate the ability to field check the data against known monuments.

In 2005 Trimble® introduced the Trimble® GX™ 3D scanner. This system was the first to combine the technology of a dual-axis compensator and a set of survey-based field procedures that replicated the traditional survey workflows used by surveyors with a total station. This solution provides the surveyor with the ability to position the instrument accurately over a known ground point, level the instrument using a plate bubble or electronic level, measure an instrument height, accurately position and measure to backsights to orientate the survey, and to observe a foresight setting the stage for a traditional survey traverse. An accurate resection technique is also facilitated. Both techniques offer residual error results providing the surveyor with instant field feedback to ensure confidence that the station setup is reliable. Measurements to other reference monuments can be observed as additional checks during the data-collection process to provide confidence that the large amount of data captured is within the tolerance required for a specific project, (Lemmon & Biddiscombe, 2005).

The adoption of the traditional surveying techniques has lead to a confidence in the large amount of data that can be collected with a spatial imaging solution. This confidence has facilitated the ratification of the technology by many of the government authorities around the world. Therefore; today, spatial imaging technology is being adopted by surveyors as a choice for rapid, accurate, and comprehensive data collection.

3. ADOPTING TECHNIQUE TO THE APPLICATION

Adopting the most appropriate technique is important to achieve the desired result on any project site. With spatial imaging there maybe a number of techniques that can be applied to collect a complete data set. As there are a large number and varied types of application I have chosen just few as an example.

3.1 Application and Technique

3.1.1 Tunnel Inspection

Consider the construction of a two-way tunnel to alleviate the congestion in a large metropolitan city. During construction there is a fire that damages a section of the constructed tunnel and needs to be repaired quickly. There is a need to ensure that the repair work is carried out to minimize downtime while containing repair costs. A 3D scanner is selected to monitor the situation.

- Reference points are set up in order to conduct surface/volume comparison after the repair is complete.
- A scan is captured of the damaged area.
- The surface is then cleaned with high pressure water jets then a second scan is captured.
- The surface is repaired with a new concrete liner and a final scan is conducted of the repaired area.
- Using the established reference points the three data sets can be registered and compared in the office software to determine the total volume of material removed and concrete used in the repair.

The benefits of this technique provide the project manager with verification of the claims made by the contractors of the volume of materials removed or used in repair. It also guarantees the accuracy of the restoration to the original form, (Biddiscombe, 2005).

3.1.2 Roads

Spatial Imaging solutions are ideal for the quick and safe capture of data on roadways. Often the difficulty of safely capturing data with traditional survey methods is facilitated by lane or complete road closure. 3D scanning offers the surveyor with a method to capture a comprehensive data set quickly and safely. By employing a traditional traverse technique it is possible to cover a large section of road efficiently. Data density is usually determined by setting a grid-spacing at a set distance, or set an angular resolution. The resulting data set is usually very dense close to the instrument and quickly deteriorates a relative short distance along the road surface. This requires a large overlap of data collection to fill in density required. The effect of this is an increase of the number of station setups required and time consuming data processing in the office required to disseminate the data to obtain the point spacing desired. New technological advances such as Trimble® SureScan™ have been developed to allow the surveyor to obtain the data with a uniform spacing at each station across the entire scan area. This reduces the unwanted superfluous data capture in the field, (Hook and Lepere, 2007).

It is important as in all traversing methods that alternative reference monuments are observed to ensure that accuracies are maintained during the survey.

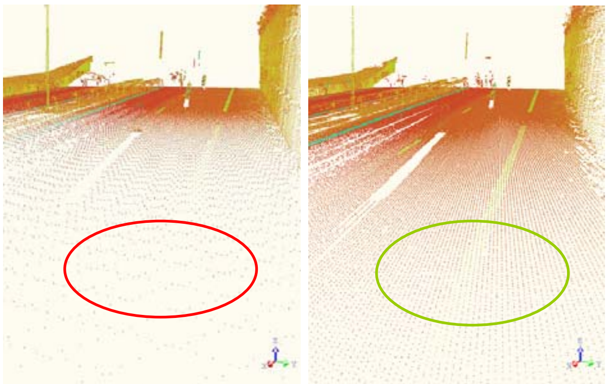

Figure 1. SureScan (right) highlights the increased coverage and uniformity of the data captured on a road surface.

3.1.3 Accidents and Forensics

Spatial Imaging solutions provide the forensic surveyor with a tool to capture a complete topographic documentation of a location and the objects present, be it a crime scene or accident site. Metric information in 3D and images in 2D can be captured safely and in a short period of time. The greater consideration at these sites is the speed and the completeness of the data capture. It is not often known what information needs to be captured, and reference to a real-world coordinate system is not required. Therefore a "free-stationing" technique is often used. That is, the instrument is set up at a convenient location allowing line of sight to the scene. Data and images are captured at the highest resolution possible in the time frame available. Results are processed in the office at a later time after it is determined what information is required.

Figure 2: Trimble S10 scanner in the hangar for rebuilding the American space shuttle Columbia" and reconstruction from point clouds.

3.1.4 Quarries

Rock-slope analysis and quantitative surveys are an everyday part of a surveyor working in the mining environment. It is important that these surveys can be carried out quickly and accurately. The stabilization of a rock face is critical to safe operation in a pit-based mining operation. Therefore it is important that a survey is as complete as possible. Traditional survey instruments can provide accurate results but can only collect enough data in the time-frame available to provide relative information. Due to the speed, density, and completeness that a spatial imaging solution can provide makes it ideal for adoption to this environment. One technique that can be employed is a "single station" setup. Based on the time available the surveyor can setup at a convenient location that allows for collection of the area of interest and also be able to reference to the known reference monuments available on the exterior just outside the current area being excavated.
Using a laptop at the site office or in the survey vehicle 2D and 3D results can be delivered to the site engineer in a matter of minutes after the data collection is complete.

3.1.5 Integrated Surveying

With the introduction of systems combining total station, imaging, and 3D scanning a greater amount of flexibility is available for the surveyor. Combining techniques simultaneously is possible. By choosing an option for an integrated surveying setup at your station, it is possible to carry out a 3D scan and GPS data capture with a rover at the same time. This technique broadens the type of information that can be captured in the field as opposed to deriving the data in the office at a later time. By having this flexibility the final deliverable can be provided to the end user of the information in a shorter time frame.

4. FOCUS ON THE DELIVERABLE

4.1 2Dimensional (2D) and 3Dimensional (3D)

Before starting any survey it is important that you have a clear understanding of the final deliverable that is required to satisfy the customer, site manager, or government authority that will be using the information you generate to as part of the decision-making process. By having a clear knowledge of the final deliverable, the surveyor can determine the type of solution and technique required to produce the result. This is specifically important for spatial imaging as the deliverables can vary from simple 2Dimensional, for example a site plan, to a complex 3Dimensional rendering or model.

4.1.1 <u>2D Deliverables</u>

What most surveyors would consider traditional style of deliverables can be categorized as 2Dimensional (2D). Some examples of these are site plans, contour maps, cross-sections, elevation drawings, and more. Most of these are delivered in paper-plan formats. With pure 3D scanners these deliverables are creating in the office with specific software that can handle large point cloud data sets. Some of the techniques used can be simple snap from point-to-point creating a polyline to semi-automated extraction tools to produce contours or other linear line features. Creating 2D deliverables from complex 3D data has some inherent dangers that should be considered. One of these is snapping on points in 3D. When attempting to produce a line that needs to be on the exact alignment as the previous point, there is a danger of snapping to an adjacent point that is not aligned in the correct dimension. Therefore, it is important that the correct perspective be presented on screen when selecting a point. More sophisticated techniques can be used to assist in accurate extraction of 2D outputs. Special algorithms have been developed over time to help the office surveyor automatically extract linear feature information such as contours, cross-sections, or break lines. Understanding these tools can help determine the density of data that is collected in the field to allow these tools to extract the information accurately. This highlights the need to understand the deliverable require so that the correct procedure can be used to collect the relevant information to generate the result. With integrated surveying techniques much of the break line information can be directly generated in the field but this is dependant on the type of job site the data is being collected on.

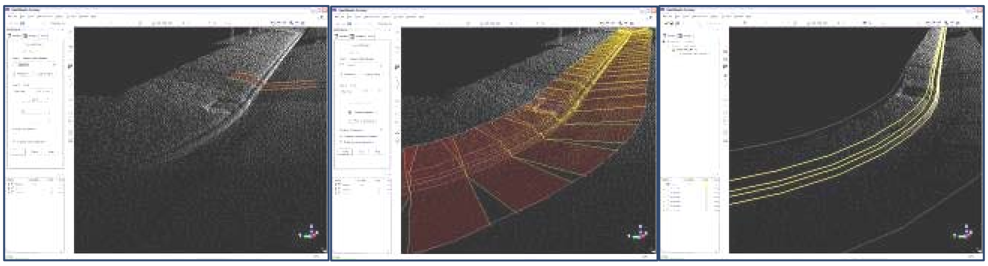

Figure 3. EasyProfile function in Trimble ReakWorks Survey assists with linear feature extraction

4.1.2 3D Deliverables

When considering providing a 3Dimensional (3D) deliverable it is important to consider the dimensions of the subject being surveyed. 3D models require that a comprehensive data set be capture to ensure that the size, shape and dimensions of each object can be determined in the office software. Creating a 3D surface is often an automated process, for example a mesh or TIN surface can be generated after some simple data editing. More complex 3D shapes may require a combination of manual and automated processes that can be time consuming. Therefore it is important to consider the time involved to prepare a 3D deliverable for presentation. Most often these deliverables are provided in a CAD file format. With the proliferated use of tools such as Google Earth presenting a deliverable via the media such as the internet is growing in demand.

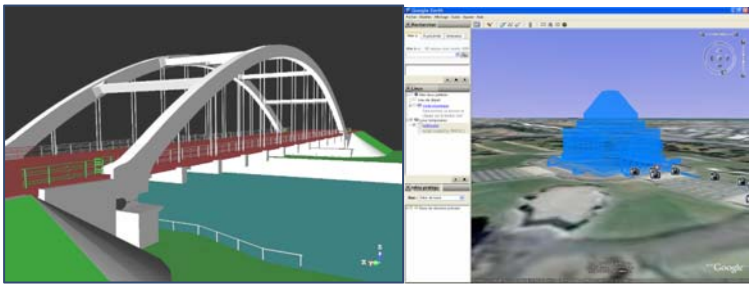

Figure 4. A 3D model of a bridge and a 3D model presented in Google Earth.

4.2 Combining 2D and 3D

There is a growing trend to provide a variety of information to be delivered for the process of making decisions on a project site. The combination of 2D and 3D deliverables is an effective way to present information and be used effectively to make important decisions.

4.2.1 Image overlay

Most spatial imaging solutions have integrated image technology. Of course it has long been known "that a picture beats a thousand words". Images are something that requires less interpretation compared with a complex series of maps and diagrams. Providing an image overlay with on a 2D or 3D deliverable enhances the deliverable for the end user of the information. Tools provide with in office software aides the creation of this compelling deliverable. It is important to keep in mind when collecting information on a project site that automated collection of images is often available within a spatial imaging system. If manual images are required with either the instrument or separately with a handheld camera keep in mind the perspective of the image capture as related to the metric data collected. Adjustment of image lighting and color matching is a feature provided by the office software to enhance the final deliverable.

4.2.2 Inspection mapping

An important influence in as-built data collection is the comparison of the existing site verses the intended design. Special tools developed in spatial imaging software, has facilitated the mapping of 3D dimension data and designs to a 2D representation to enable easy interpretation of this data.

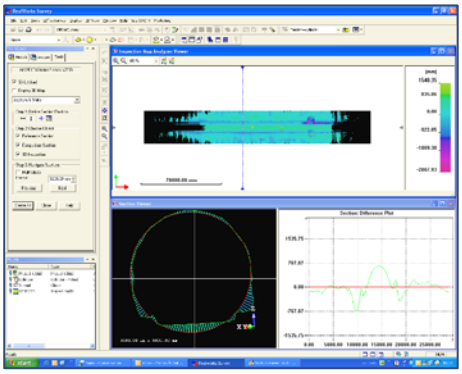

Figure 5. Inspection mapping of a tunnel comapring design vs. as-built.

5. ENVIRONMENTAL INFLUENCES

To ensure that accurate and complete data is captured with a 3D survey it is important that consideration is given the environmental influence affecting no-contact measurement as well as any limitations to the project site.

5.1 Site access

Access to a project site may be limited and thus the range and line of site will be affected. This limitation may affect the complexity of the data that can be collected and thus it may be necessary to supplement the data from other information sources or with other technologies and techniques. In some cases the site may be an environmental protected, restricted access or contaminated site in which case the limitations may be hard to overcome.

5.2 Atmospheric conditions

Many of the everyday atmospheric conditions will affect the ability to collect data with non-contact methods. Rain or ice can accumulate on a road surface that will make it act like a mirror reflecting the laser beam away and thus receive no return to obtain a measurement. Thick atmospheric conditions such as fog will refract the light and reduce the range that data can be collected from. Likewise heat shimmer will refract the laser to reduce range and accuracy capability. There are certainly other conditions such as cold temperatures that will reduce the ability for the system to produce accurate and complete results. These must be in considered when ensuring the results are possible for any given survey.

6. LOOKING TO THE FUTURE

What are some of the influencing trends that will affect the future developments of spatial imaging as a survey technology and technique?

- It is noteworthy that many high-profile projects are starting to use spatial imaging systems as a primary technology to collect valuable information and ensure a complex data set is available to make the most appropriate decisions for the future of a project.
- Many government authorities are mandating the use of spatial imaging technologies and techniques for data capture on roads and bridges where access is limited or road closures are costly for the community at large.
- Images are becoming an accepted way to document the features for land surveys and thus place a new emphasis on rich data capture.
- The use of 3D models in design is starting proliferate within the engineering community thus the demand for complex 3D data is growing.
- The collaboration of online information and real-time data updates is influencing the need for faster and more comprehensive data collection.

These market influences are driving the need for complex 3D data sets. As technology evolves further and techniques are refined the ease of which this information can be collected and processed is aiding the surveyor in becoming the primary professional to provide this information.

Continued collaboration with surveyors will ensure that spatial imaging technology is developed with the surveyor in mind. This will provide valuable information so that the automation of systems continues to provide feedback on the accuracy and completeness of the data collected. It is also essential that the technology facilitates the input from the professional surveyor to provide a value added service to the end user of the information.

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BIOGRAPHICAL NOTES

Bryan Williams has a degree in Cartography from The School of Engineering Bathurst College of TAFE, Australia. In his 24 years of work experience based in Australia and the United States of America, Mr. Williams has extensive experience as a Surveyor, GIS Consultant, Publishing Manager, IT Consultant, Sales and Marketing Manager. In his seven years at Trimble Navigation Mr. Williams has been focused on the development and adoption of spatial imaging technology.

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