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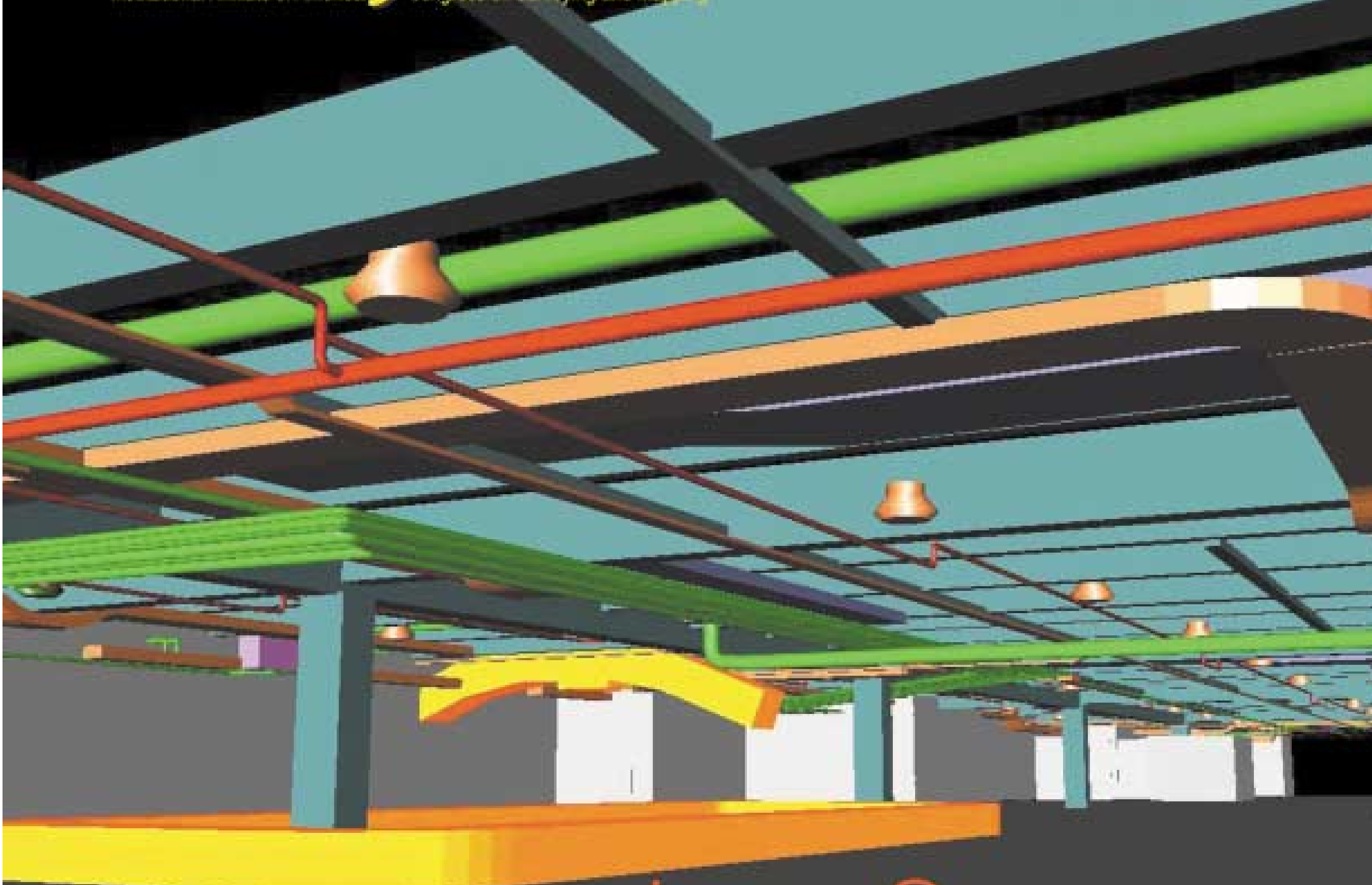

Laser Scanners

A Working Guy's Experience

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The California Surveyor
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Laser Scanners

A Working Guy's Experience

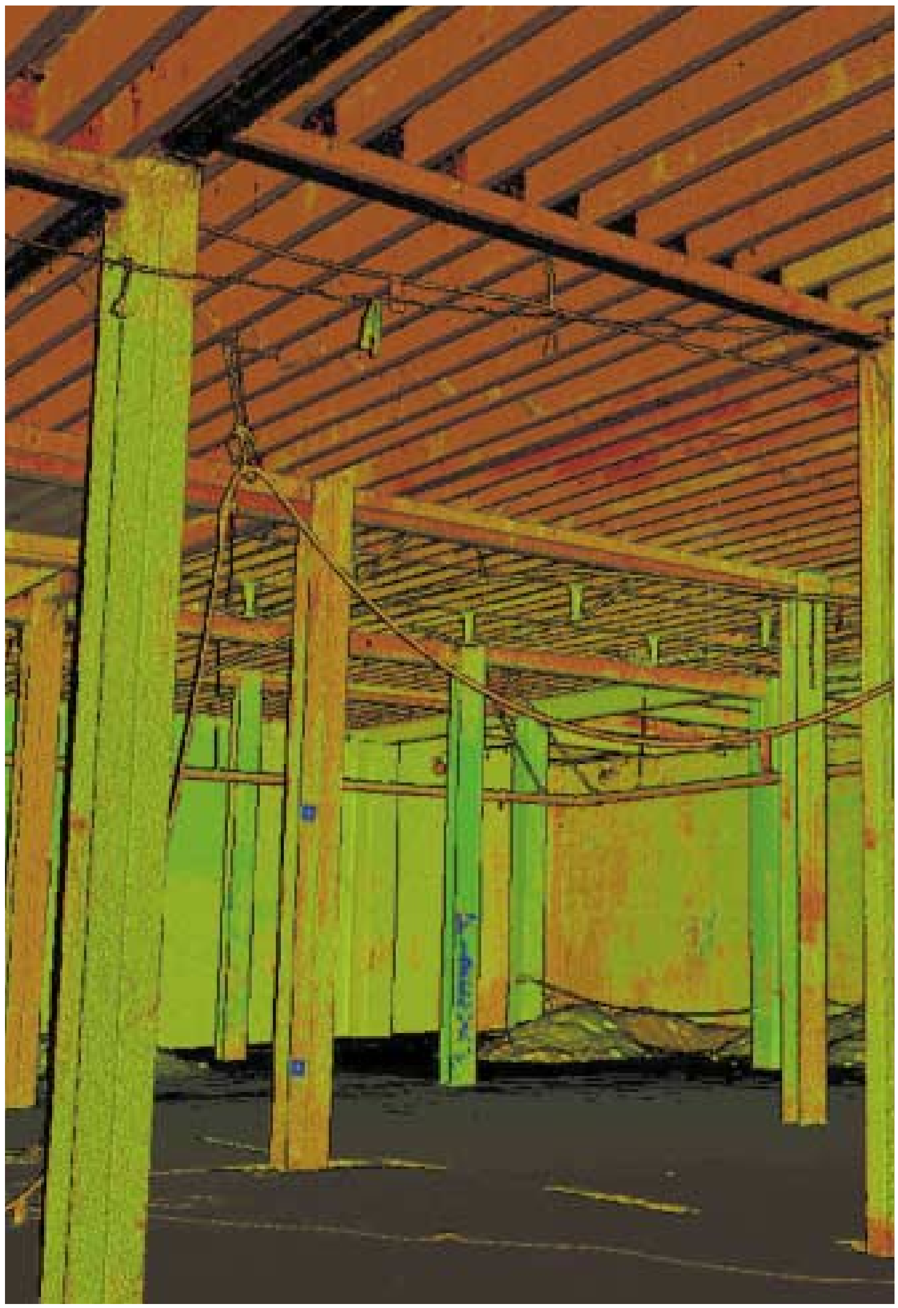
Many of us have been witness to the changes in surveying in the last 15 years, largely due to technology. Many of our younger surveyors do not recall a time when we did not have GPS, personal computers or data collectors. Each has vastly changed the way we practice surveying.

It seems that the next "big" thing working its way down the pike is laser scanning. I have been interested in scanning and following the development thereof for the last three years. I can draw many parallels with the advent of GPS. For instance, laser scanning is simple enough to operate and to get information (lots of information). But, the determining of the quality of the information, the adequacy of information and the making a deliverable product for a client are a few of the challenges.

Our company has completed several scanning project this year. We have partnered with a company, Inovx Solutions, on these projects. Inovx Solutions has been the scanning business for the past seven years. Their copious experience (over one-hundred and twenty projects) in laser scanning exceeds that of most companies working in the United States. Their experience and work has been primarily in the oil refinery business. For Inovx, scanning is actually a component of their software business. Their primary business is development of PlantLinx software used throughout the world by petrol-chemical companies.

In writing this article we are going to run through what we have learned about laser scanning to date.

Scanning in short, is collecting millions of X, Y, Z points configured in point clouds. These points are then modeled, which are mapped, into 2D and 3D drawings. In addition to mapping, the modeling is required to make the information manageable in standard CAD programs. On an average size project, it is not uncommon to have gigabytes of information; the raw data cannot be loaded into the CAD package.



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Our intention is to give our brethren some real world considerations based on our experience. Each topic we highlight could have an entire article written. We have chosen to touch on some the major components of scanning equipment and add in some considerations for the user of the equipment.

Phase based scanners:

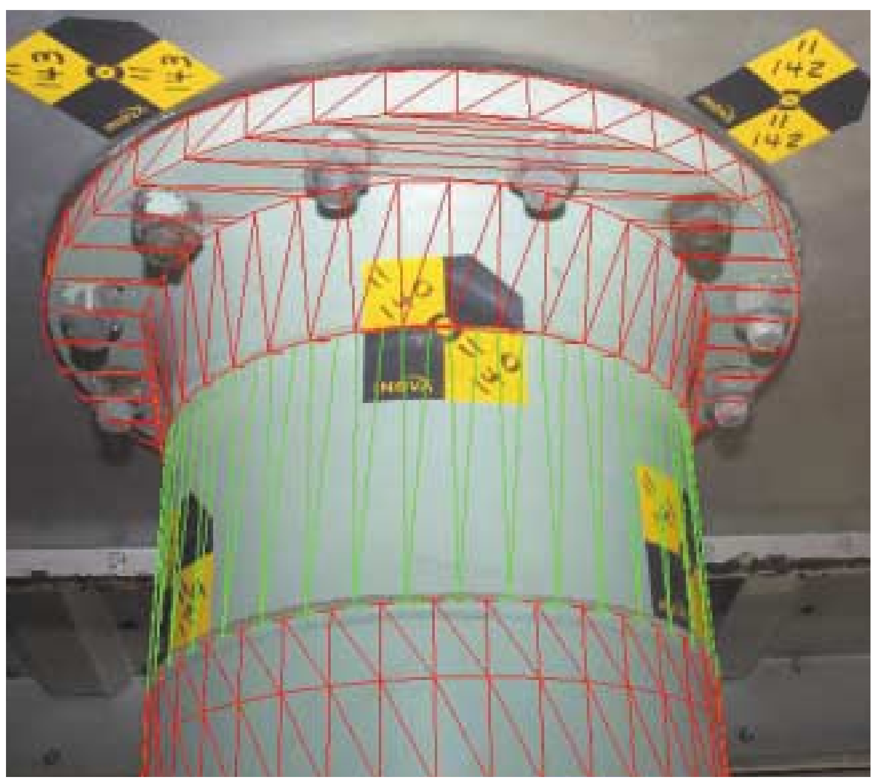
Phase based laser scanners deploy the same technology as used in theodolites and interferometers. Phase based scan technology may also be referred to as 'amplitude modulation continuous wave (AMCW)' or 'phase-difference' methods. The methodology deploys a continuously emitted laser signal that is intensity modulated in amplitude by a sinusoidal frequency. Comparing the emitted and returned signal, a phase difference can be measured, which is directly proportional to the range (or distance) from the measured object. In addition, the reflectivity of the object can be measured directly, resulting in a black and white photograph like reflectance image.

Since the measurement depends on a phase measurement, only measurements within a 180 degree phase shift can be resolved unambiguously. Outside of this so called ambiguity interval, a phase and therefore range wrap-around occurs. Sophisticated phase based scanners employ dual-frequency modulation, where a lower modulation frequency is used to resolve the ambiguity over a certain range interval, and a higher modulation frequency is used to achieve accuracy, just like on a vernier scale.

Since phase based scanners are modulating and digitizing a continuous beam millions of times per second, many of these scanners have the capability of capturing measurements at speeds up to 625,000 points per second.

(If we run into each other, don't ask me about the previous section, it came from a vendor and makes as much sense to me as does to you. D.W.)

The scanners available have varying ranges of 20 meters to 100 meters. Equally, the speed of the scanners can vary greatly. The key to the scanner is the ability to integrate into a software package. It is similar to the differences between our vendors of conventional survey equipment i.e. Geodimeter/Trimble, Leica, Topcon etc. each has something to offer based on given criteria.



Software:

OK, so now you have millions of point accurately representing in 3-D your scope of work. Now what? Today it is rare that a building survey or topographic survey will be satisfied with a gigabyte of pixels. Many clients like the idea of the 3-D data but want or need 2-D plans and sections. The programming is continuously being developed to enable AutoCAD and Microstation users to generate useful and familiar drawings and models. Users of CAD integration software can work directly in their familiar CAD software programs using plug-in applications like CloudWorx™ from Leica to extract points, measurements, surfaces, features, line work, and models from point clouds. These add on programs allow the users to manage the large amounts of data collected.

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We have all been privy to the many "field to finish" programs presented through the years. As with any other software, the user needs to evaluate their individual needs and choose the package that will best fit. For those of us that use automated line work in our topographic mapping, the ability to do the same is available in scanning software programs. But, most of us did not start out using that functionality; we loaded our points into our CAD program and connected the dots. The same will hold true with scanning software.

The real learning curve in mapping/modeling is working in 3D. Most surveyors and engineers have traditionally worked in 2D. The tools used in 3D are unfamiliar to many of us. Navigation of a 3D model allows us to look at data from many different perspectives and is required to accurately map the data. Viewing and mapping the data from a typical plan view is nearly impossible. For example, we will typically collect cross section data i.e. top of curb, flowline, lip of gutter, and have text data overlapped in the drawings.

In scanning, we have much more data and the differential data, in plan view, is stacked vertically. For example, when scanning a building, the CAD file has the upper building corner, the building edge, the bottom building corner and any ornamental information. This may be represented by a few thousand points. The procedure is to rotate the drawing on an axis and identify the points needed to map. These not only present challenges for the surveyor, but equally for the client.

When evaluating software packages, we recommend that the users ask the vendors about their client base. Who uses their packages? By in large, the petroleum industry and the architects have spearheaded the development market. Therefore, these packages specially cater to their needs. Think about this, when looking at scanning ads, how many pipe ways, tanks and buildings have you seen? How much of your business is surveying pipe ways? That is not to say that scanning of a conventional project is not practical, it surely is, but how the software handles the information is very key.

Power requirements and Laptops:

Most laser scanners available today can run on either DC battery power or 110/220 volt AC power. When operating from external battery power, most laser scanning systems can be equipped with enough battery power (2 or more external batteries) to facilitate a complete shift (8 hours or more). For many civil applications this scenario is ideal. However, it is important to keep in mind that many scanners are controlled by either a Laptop PC or PDA devise. These are either linked by a physical network line or wireless connection. Most PC's today are not capable of running 8 hours or more remotely and therefore may require some added power considerations. It is not uncommon for service providers to require some AC power or utilize vehicle DC power to get through the day collecting data. This is an important consideration when planning a project as sometimes it may not be possible to gain vehicle entrance or AC power may not be readily available. To assure a smooth project start and timely execution – be sure to consider your actual power needs up front. Don't be caught powerless!

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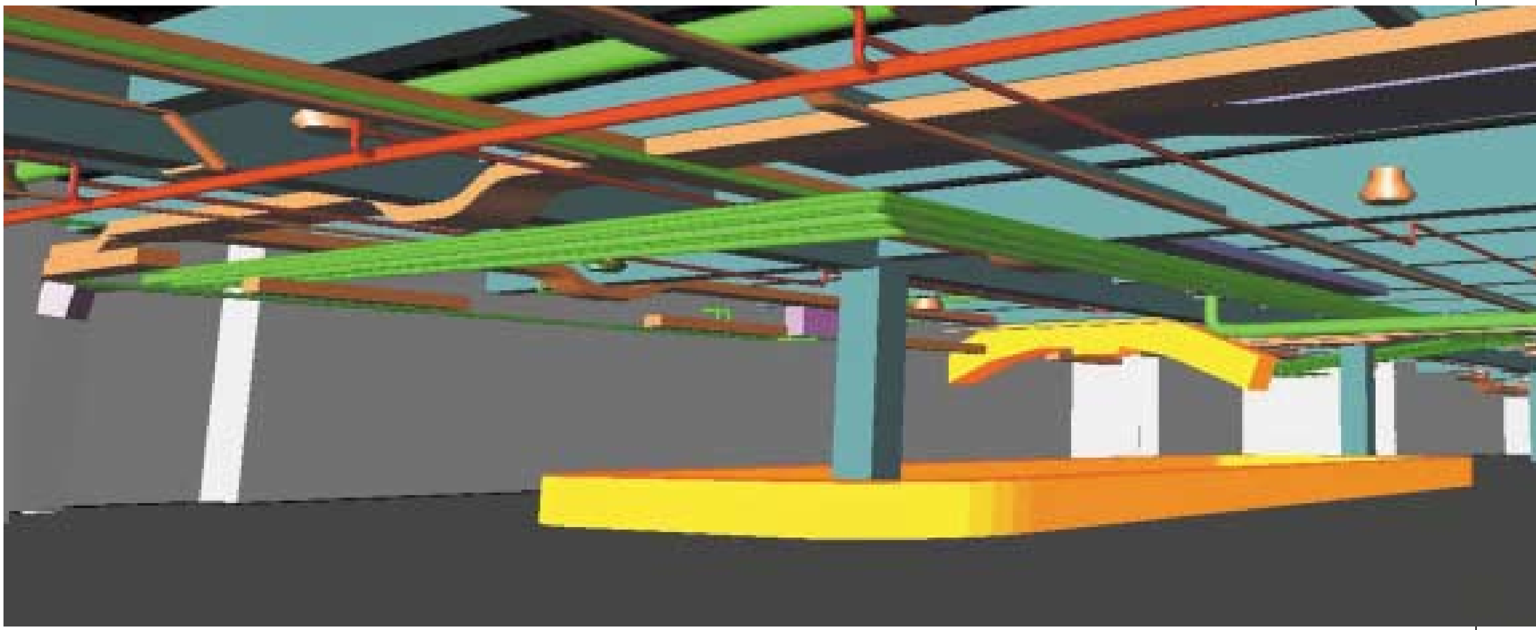

Work hours and project logistics:

Scan anywhere any time? Maybe… When planning a laser scanning project – remember – unlike discrete survey where one point is targeted and then collected, the scanner is basically taking a 3-D photograph of everything around it. A tremendous benefit clearly is that this is a non-contact non-disruptive method of obtaining large volumes of accurate and localized data. By the nature of the way in which data is collected – laser scanning can acquire positional data in places where a person does not need to or can't gain access to, e.g., streets, highways, and bridges can be fully documented without the need for costly and dangerous lane closures.

On the other hand, it is still important to consider the activities that take place in or around your scope of work. Take into account the actual environment in which you will be collecting data. Though laser scanning is a non-contact rapid data collection technology – remember, you can only scan what the scanner can see. If the area you are documenting has heavy traffic during certain times of day, extreme temperatures, excessive noise, vibration, or any extended activity or disruption, we suggest it may be worth considering an off-hours data collection schedule for some or all of your project. Even working a premium time schedule (evenings and weekends) may prove to be more cost effective. For example, our team recently completed a project for a commercial airport where certain times of day employees and vehicles were continuously moving through the area. These activities significantly hampered our ability to document the areas of interest and sometimes blocked our access completely. We coordinated our activities with our client and the terminal representative and ended up collecting the data at night. Though night data collection was not our first choice – it did prove to be the most efficient and ultimately saved time and money for the project.

As an aside, the scanners are their own light source, which means it works the same in light as in the pitch black of night. Recently we surveyed the interior of an old gutted out hotel. Being gutted, means that we did not have much in the way of lighting. We were running three scanners on one floor at 9:00 PM, we could not see each other unless we had our flashlights on, but the place looked like a disco with thin green scanning lights crossing in all directions.

Control Surveying for Scanning:

Horizontal and vertical control for scanning employs the principles we have learned in photogrammetry. The scanner collects X, Y , Z, but it has little sense of where it is from scan to scan or within a given coordinate system. The mating of the scans are called cloud registration. The coordinate system is introduced in the office procedures. As with conventional survey control, there are varying schools of thought and procedures. We employ a method that requires us to use 3-5 targets per scan; similar to a fully controlled model in photogrammetry. As in photogrammetry, it is best not have the targets in a straight line, horizontally or vertically. The control should envelope the scan.

As a matter of efficiency, we have developed some procedures. A million point scan takes roughly 12 minutes and often times we are scanning several views from the same position, we are only rotating the scanner horizontally (using a Cyra 2500). That being the case, we perform our horizontal and vertical control simultaneously. We set up the survey instrument, out of the scan view (incidentally, the scanner scans up and down as opposed to left to right) and position the targets while the scanner is scanning. The control and scanning are completed at the same time. This assumes employing a two man crew. We like the idea of our people keeping busy, if they are not doing control, they are standing around waiting for the scanner. It becomes a little more complicated when running multiple scanners.

Now understand scanners position points relative to each other within 2-4 millimeters. Most of our standard conventional survey equipment is capable of positioning within 8-10 millimeters. I am sure you see the problem.

Early on, we would double determine our control, process the data through Star*Net (using good procedures) and the folks doing the modeling would tell us that our control was not good. Our typical conversation went like this; "Dave, we have a problem with your control." By how much I ask? We have "6mils." Well guys, it doesn't get any better. What do you want us to do about it?

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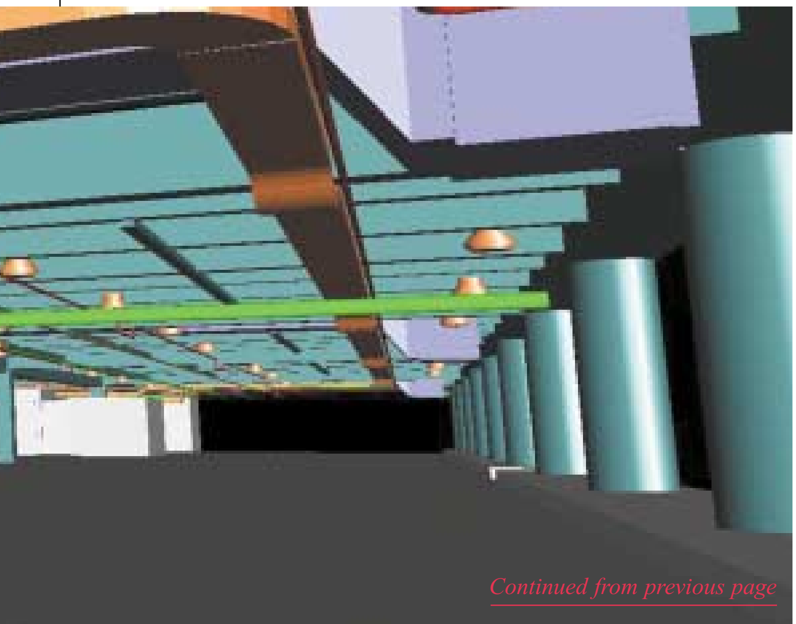

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We could write an entire article on precise control, so we will limit it a couple of tips. Set the control points on the face of a structure i.e. wall, tank, etc. enough control so that at any given time you can have 3-5 points. Understand that when scanning, you most often are not doing large areas and that scanner has a limited range. We use targets with a sticky back and a 1/16th" hole in the center. Record and horizontal and vertical angles directly to each of these points, then place a precise prism on the point. We use the standard peanut prism fitted into sleeve about 4" in length, (the exact offset is calibrated), sight the target and guide the glass on line for a distance. These simplified procedures eliminate our largest sources of error; height of instrument measurement, tribrach bubbles, optical plummets and staff bubbles. We seldom set or occupy a known point on the ground; the error is in transferring it to the instrument.

By the way, we have a Leica TCA2003, which is a arc second, 1 mm, 1 ppm instrument which has eliminated the troublesome "We have a problem with your control" calls.

Another control procedure is known as Cloud to Cloud Registration; this is the transferring known points in one scan to another scan in the overlap areas (similar to photo identification in photogrammetry.) We utilize this procedure when doing the exterior of high rise building, as it is not possible to set targets on the face the building on the 8th floor. Cloud to Cloud eliminates the need to set targets in each scan scene. But, it does make the office work a lot more labor intensive. It becomes a matter of managing resources and schedule. We prefer our field guys to control the model while waiting for the scanner, as opposed to tying up our CAD operators for a few extra days. One word of caution with Cloud to Cloud Registration, the conventional control is being pushed out; therefore, any inherent error is magnified. Remember Survey 101, the short back sight to a long foresight lesson? Be careful to look at the control from a survey stand point, sure the software will produce an answer, but how good is it? If all of our control was at the base of a 15 story building and we produced it up 150' feet vertically and 250 feet horizontally, we have found errors in excess of 0.5' feet. To eliminate this potential problem, build redundancy into the scan scene and position easy identifiable points with conventional methods.

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Deliverables:

One of the most challenging aspects of the data is presentation. How do we present this data in a hard copy format that is intelligible? As surveyors, the closest standard experience is plotted cross sections or contours. Our plans to date have several different orthometric and elevation views complete with dimensions and callouts.

When the CAD user looks at the digital drawings (for example; looking at a building from the front) the user also sees through the building and the features in the back. It is difficult to differentiate features in a 3D wire frame. So, our answer is to shade and render the drawing, set cut off planes horizontally and vertically. Once we have crossed that hurdle, can the client read and understand the plans? We are constantly evolving and developing hard copy plans that serve the client and as provide detailed information not presented in the past. The mechanical and architectural professions undoubtedly have something to offer us.

Final Thoughts:

The technology is available and the demand is growing. Currently, we know of four other firms in Southern California using scanners. We are entering the next phase of technology that is going to change the way we do business. It will undoubtedly have growing pains. But, how many of those reading the article could go back to the days before GPS? The market for this equipment will develop and the clients will be asking for this technology. ❖

If you have any questions about scanning, please feel free to contact us at:

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