Frontiers of High-Definition Surveying Using 3-D Laser Scanning Systems

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Traditional means of measurement in civil engineering applications are rapidly being enhanced by laser scanning systems that gather millions of points from the surfaces of visible objects in a scene at ranges up to around 100 meters. The resulting density of position information is transforming many civil applications, and many historical field issues like missed measurements or incorrect recording of measurements disappear when using high-definition data sets.

Available scanning systems vary in a few key parameters. The quality of data is largely characterized by the range accuracy, angular accuracy, and spot size of the laser beam at range. In addition to affecting the accuracy of measurements, the spot size affects the resolution of the unit, in terms of the smallest features that are detectable by the scanning system. Similarly, the range and angular resolution, as well as other mechanical characteristics of the system, control the maximum density at which data points can be sampled on the surface and therefore also define the resolution of the scanning system. In addition to accuracy and resolution issues, there are many other important factors that affect the convenience of collecting data. These factors include: range, usually specified in terms of accuracy achievable and how much light the surface reflects; field of view, which varies from camera-like to full-dome visibility; and speed, which ranges from a thousand to many hundreds of thousands of points per second. Finally, there are other convenience characteristics such as size, weight, and battery life that affect the usability in the field. There are also numerous software solutions for gathering and processing data, some provided by the same vendor that manufactures the scanner and others by third-party software companies.

The applications areas of scanning solutions to date are quite varied. Several of the early systems initially focused on documenting the as-built environment, often for process plant applications. In this area there is often geometric modeling involved, where walls and pipes are extracted from the point cloud data, allowing retrofit activities to occur with very accurate as-built models. It became apparent that these as-built models were rather expensive in terms of office time, and there were many cases where the entire model wasn't needed. In these cases either selective modeling of required elements, or simple interference detection of new objects compared to existing point clouds provided all the needed functionality. Scanning systems are also being used in construction monitoring, to see that the new objects are being properly placed, and to allow adjustments to subsequent construction in the event deviations are found. Scanners are also being used to gather data from a scene to allow later measurement as needed. For example, a region can be scanned at high density with less pre-planning of which measurements are required, and then the measurements can be taken from the scan data as needed, with little fear of missing some measurements that will be needed later on in the engineering process. Finally, scanners are being used in a wide variety of traditional survey applications, to draw 2-D plans of surface features, sometimes with elevation contour information. In this respect,

scanners compete directly with traditional point-at-a-time surveying instruments that are used to measure the terrain surface. These traditional survey applications also include mapping hardscape such as roads and bridges.

The application of point cloud data to civil projects is really in its infancy, although the industry is now ten years old. There are many interesting technical problems that must be addressed along the way to broader use, in addition to the feature sets needed for each particular application. Among the interesting technical issues are the size of data sets, which have rapidly increased with increasing scanner speed. While five million points was large in the early days of the industry, it is now commonplace to have single projects with hundreds of millions of points, and billions of points are expected in the near future. Working with this many points, and making them available to do engineering, is a challenge on PC-class machines. Other interesting topics include: surface reconstruction, since the scanner measures points but does not say how they are connected; the registration of data sets taken from different positions; and the correct handling of scanner error and noise characteristics to make best use of the resulting data. These technical challenges, and the vast opportunities in potential application areas, will make scanning an active development area for some time to come.