VERIFYING TERRESTRIAL LASER SCANNER QUALITY

Leica HDS 3000 in the Lab

To the user the terrestrial laser scanner (TLS) is a black box; measurement procedure and data processing are treated as classified. Vendor provided technical specifications are reliable but may be inadequate, while verification is complicated. Using Leica HDS 3000, the authors developed and tested a new method for verifying the quality of TLS data. Surprisingly, the angular accuracy of the system appeared ten times better than specified.

One of the most used measurement principles for terrestrial laser scanners (TLS) is the spatial polar method: distances are measured by a pulse or phase distance meter and the two perpendicular angles determined by reading position of oscillating plane mirrors, prisms, or from rotation of the scanner-head. From this information and the coordinates of the position of the TLS, coordinates of points are calculated. Certain factors significantly determine the quality of TLS data:

- measurement accuracy of the scanning system

- registration accuracy and transformation of individual measurements

- geometric configuration

- physical characteristics of measured surface and environment.

Distance Accuracy
The quality of the distance measured between TLS system and object depends on how much of the reflected signal will reach the TLS sensor. This mainly depends on angle of incidence and physical characteristics of the surface, in particular reflectivity, absorbency and permeability. Absorption and permeability do not cause problems, but reflectivity does; its is the way in which a surface reflects the signal that determines how much radiation falls on the TLS sensor. The main types of reflection are diffuse and specular. A diffusion surface, such as chalk, reflects radiation proportionally in all directions. An ideal specular surface, such as polished silver, reflects radiation according to the law of reflection and little or no radiation in other directions, including in the direction of the TLS.

Test and Results
Forty-six materials were selected on the basis of their reflectivity diagram, and tested. The materials included shiny colours, dead colours, emery papers, metals, stones and bricks. The surfaces of size 200mm x 200mm were placed on a plane on several desks made of chipboard and covered with white lamina, and measured under incidence angles of 0, 30, 50, 55, 75 and 90gon at distances of 15m and 25m. The results confirm that the most suitable are surfaces with diffuse reflection. Surfaces with specular reflection cause multiple reflections for steeper angles of incidence, resulting in distances too long and thus incorrect. Consequently, difficulties may arise when, for example, scanning chemical plants constructed from highly shiny metals. On surfaces with specular reflection and high absorbency, especially black shiny surfaces, the radiation reaching the sensor was so little that no distances could be determined.

Angle Accuracy
There are few publications on the angle accuracy of TLS systems, and the methods described deal only with assessment of transverse error between measured and modelled object. These methods can be used only for relative accuracy assessment between different TLS systems. We therefore developed a new method that enables direct determination of standard deviations of horizontal directions and zenith angles. The method is based on a modified photogrammetric approach using direct linear transformation (DLT) in 2D. A plane calibration field is placed across the measurement direction and photogrammetrically measured. After switching off the lighting, the calibration field is measured with the TLS, during which procedure it is simultaneously photogrammetrically measured with an accuracy of approximately 0.1mm for each coordinate. The method is thus suited for scanners with standard deviation in direction from 1.3mgon on, since this is a ten times lower accuracy than can be achieved with the photogrammetric method. After transformation of the measurements from the TLS system into the plane system of the calibration field, errors are assessed as differences between photogrammetric coordinates and TLS coordinates.

Results
This method can be used for all TLS systems emitting radiation in the visible part of the electromagnetic spectrum, as the digital camera is sensitive only to this radiation. The method assesses interior accuracy of the TLS system within a small field of view (1x1gon) and therefore the results are not influenced by systematic errors such as collimation error and index error. On the other hand, the method shows real measurement accuracy for modelling of smaller objects. The angle standard deviation specified by the manufacturer is 60 micro-radians, or, expressed in mgon, 2.7mgon, while we found standard deviations in horizontal direction and also in zenith of between 0.2 and 0.3mgon, roughly ten times more accurate. It is surprising that the accuracy of the HDS 3000 scanner is much better than

specified by the vendor.

Further Reading

Kremen, T., Koska, B., Pospíil, J., 2006; Verification of Laser Scanning Systems Quality, in XXIII International FIG Congress, Shaping the Change [CD-ROM]. Munich: FIG, ISBN 87-90907-52-3.