ACADEMIC AND MANUFACTURER FACE CHALLENGES

Laser-scanning and Heritage

The March issue of GIM International carried the response of manufacturers of laser-scanning sensors and software to remarks made in the Insiderâ€™s View column on shortcomings of this technology in the spatial documentation of heritage sites. Based on his long-term experience in capturing heritage sites in Africa, Professor RÃ¼ther explains there is still ample room for development, a challenge for both academic and manufacturer.

Judging from the responses to my original column, it appears some manufacturers interpreted my observations as rejection of laser scanning as a tool for heritage documentation. The opposite is true. Without doubt, laser scanning has high potential in a wide range of established and yet to be explored applications, heritage being one of the more complex. The fact that the Aluka Heritage Documentation Group at the University of Cape Town (UCT) has completed more than 1,500 scans, and plans many more for the future, proves how much we value laser scanning (Figure 1). Nevertheless, expectations are sometimes unrealistic, while, more importantly, processing software needs further development. And my observations referred primarily to terrestrial scanning of heritage sites in difficult physical environments.

Documentation
Spatial documentation of heritage can be roughly broken down into two principal areas of application. In one, domain buildings and manmade structures are captured and presented in generalised forms, walls being represented by planes, edges as straight lines and curved surfaces as simple or sometimes complex mathematical functions. In this form the record can serve as a basis for architectural, cultural and similar studies, and here I agree that watertight models are not always required and 2D ground or façade plans or simple 3D-models may well suffice (Figure 2). However, in the second and possibly more important area of application, heritage documentation aims at the acquisition of a fully realistic record with maximum detail. In this form the data can be used for conservation, restoration and monitoring purposes, as well as for research. Both approaches, but especially the second, differ significantly from industrial and other applications.

Watertight
In most cases the surfaces of heritage sites should ideally be ‘watertight’; that is, fully covered and without scan holes. In practice it is often highly impractical and in principle impossible to fill all of these holes by scanning from different positions. Heritage sites are typically complex and full of detail, with numerous occlusions such as windowsills, portions of wall decoration and parts of concave features. These areas are often very small and numerous and an additional set-up for each is simply not justifiable. In some cases potential scan positions are in precarious locations, and in others it is physically impossible to find a vantage-point from which missing surfaces can be seen. A further complication arises from ‘alien’ objects in the scan field of view, such as vegetation in the form of small tufts of grass or bushes growing from cracks in walls, or random objects such as benches for visitors, or signposts (Figure 3). Some heritage-sites, especially mosques or churches, are still in use and people coming from or going to their place of prayer may walk through the scans. Also birds, cats, dogs and donkeys frequently appear in our raw data! In such cases two manual operations are required: cleaning, that is removal of unwanted objects, and filling of holes combined with modelling occluded areas. These processes are manual and highly time-consuming, and a few three-minute, all-round scans with a phase-based scanner may well require hours of registration, cleaning, creating a surface model and filling of holes in the processing phase.

Scan Holes
A real-world example may serve to underline the 1:10 ratio; that is, one day data capturing in the field resulting in ten days data-processing in the office. Typical for a single member of the UCT team are thirty to fifty all-round scans per day, using a phase-based scanner at a complex heritage site. These scans will generate around 100 million scan points. To register, clean, create a triangulated model, complete (by filling holes) and texture will take a single operator at least ten days, probably many more. It is irrelevant, for obvious reasons, in industrial applications if the back of a pipe or strut is captured or not, and primitives and components of known dimension can be used to replace point-clouds. Industrial environments are also possibly easier to control and keep free of ‘alien’ objects. For industrial applications a 1:1 field to processing ratio may therefore represent a realistic scenario. I must, however, categorically reject the statement of one correspondent who claims that the presence of scan holes is due to the shortcomings of the service provider. For all but the simplest structures, and especially in heritage site documentation, scan holes are absolutely unavoidable with any form of terrestrial laser scanning.

Aesthetics
The Great Mosque of Djenne in Mali provides a good example of how unavoidable are scan holes, and the associated processing workload. More than five hundred wooden beams of different sizes and shapes protrude from the mud walls of the building (Figure 4). As the mosque is the highest structure in the area it is impossible to find vantage-points from which the upper surface of these beams can be scanned, and scaffolds or mobile, raised platforms are clearly impractical in so remote a place. This meant manually completing the upper surfaces of more than five hundred beams of differing dimensions during processing. If one adds to this the interior of the mosque with its

some 120 pillars and hundreds of roof beams, again impossible to scan from all sides, one easily arrives at a field-to-office ratio of one to ten. It is possible to reduce the number of holes by adding scan positions, but this quickly becomes uneconomical, and in many cases impossible due to physical limitations. The filling in of holes and occluded areas may well raise the eyebrows of conservators and researchers, and rightly so. The African Heritage project addresses the conflict between objective documentation and complete and aesthetically appealing models by providing two models of each structure, one cleaned but not otherwise modified and thus objective, and one more subjective model with holes filled and some ‘cosmetic’ corrections.

Enhancement

There is a need for the enhancement of software for modelling, feature extraction, texturing and presentation to the end-user. The latter is an important issue that appears largely solved in industrial applications but which needs considerable attention in heritage work. Surface texturing also differs significantly in industrial and heritage applications. Heritage documentation requires realistic, high-quality colour imagery; high-resolution and taken under ideal light conditions, something not required in industry. This ideal scenario is generally unachievable with a built-in camera and scan-simultaneous photography. A 360o scan will necessarily cover part of a building/structure in sunlight while the opposite side is in shadow. Photography relies on ideal lighting conditions, which is not the case for scanning, thus the criteria for good photo–graphy and suitable scan times will often differ, as will optimum positions for camera and scanner. So additional photography with independent cameras is required, and texturing of models based on orientating individual photographs is time-consuming, difficult and, with some of the scanner software packages, extremely cumbersome. Edges and corners on heritage sites are not simply the intersections of two or more planes and cannot be represented by geometric primitives. Rather, these features are often irregular and complex (see Figure 5), as are many other features on sites, especially if structures are in ruins. There is a need for software for the automated extraction of irregu–lar features and the intelligent decimation of points on the basis of detected features. Photogrammetry would appear to have the answers to some of these issues. Indeed, photogrammetry should not be written off as having been replaced by laser scanning, and hybrid photogrammetry-laser-scanning systems should be considered to provide solutions for feature extraction and texturing.

Data Volume

A further area that needs and already holds the attention of software developers is optimisation of manipulation of large datasets. In the UNESCO World Heritage site at Lalibela we have acquired more than 1,000 million points for a cluster of four churches, some 250 individual scans using one phase-based scanner and one time-of-flight scanner having been taken in seven days of fieldwork. Even after breaking up the data into still meaningful subsets, the volume of data makes processing impossible for most software packages while it causes others to crash. The team’s policy is to capture high-resolution point-clouds as a record for the future and in anticipation of future hard and software developments but to work with drastically reduced point-clouds for the creation of models for presentation on the Aluka web page or other practical applications.

Expertise

The notion that money can solve scan-hole and other problems, as suggested by one correspondent who claims that a ‘well-experienced and well-paid service provider will produce error-free data within processing ratios 1:0.75 to 1:3’ is, according to my experience, unrealistic. The UCT/Aluka team comprises four experts, two computer scientists, one visualisation and media expert, and two Geomatics professionals, one specialised in photogrammetry. In completing more than 1,500 scans and working with more than twenty individual models of complex heritage sites (Figure 6 shows an example) this team has gained huge expertise and practical experience (Figure 7).

Concluding Remarks

The participation of members of the manufacturing/software development community in one of our field campaigns in Africa would be most welcome and might create valuable co-operation and interchange required for optimal future development of this technology.