GEO-KNOWLEDGE FOR PRESERVATION OF ST MARIA MAGGIORE, ITALY

Camera Laser Scanner

Image-based modelling is still the most widely used approach in building documentation and 3D investigations, but panoramic camera laser scanners are gaining in importance. They offer large fields of view, good accuracy and direct photo-texturing. The authors have tested the information content and performance of such systems in 3D modelling of St Maria Maggiore, the ancient church in Bergamo, Italy.

Technology is moving towards the development of an automated hybrid measurement system that may be called the "panoramic camera laser scanner", consisting of a Lidar device solidly integrated with a calibrated digital camera. Such new devices collect spatial point-clouds and, simultaneously, digital images of the same object. These systems are useful both for measuring 3D building points and for directly rendering 3D-models with high-definition photo-texture. They thus integrate surveying with photogrammetry and imaging. Beam divergence in these Lidar systems is very small (spot diameter of about 0.025m at 100m) and deflection is effected by two rotating devices, an optical one in the vertical plane and a mechanical one in the horizontal. The resulting field of view (FoV) is 360° in azimuth and up to 320° in elevation, which reduces the number of data acquisition locations.

Point Cloud to CAD
We used three terrestrial Lidar devices: Z&F (FoV: 360° x 310°) and FARO (FoV: 360° x 320°) for indoor survey, and Riegl (FoV: 360° x 80°, pulsed) for outdoor acquisition. The data resulted in a geo-database for the ancient building of St Maria Maggiore in Bergamo. Vector plots with plans, vertical cross-sections and elevations were directly extracted from the point-clouds using EU-JRC 3D Reconstructor, and these files then imported into AutoCAD for drawing refinement. Depending on the degree of detail in the walls, scales of 1:50, 1:100 or 1:200 were selected. EU-JRC is an advanced software package well suited for building modelling and cultural heritage survey; it is able to import a large number of scanning file formats and enables users to export processed data and images to well-known CAD environments.

Direct Photo Texturing
Orthophotos were created by superimposing digital images on the surface model of the building and then projecting this textured model over different planes of view. The calibrated digital camera enables online image acquisition. Its external orientation with respect to the scanner reference system has been determined with photogrammetric precision. Application of co-linearity equations via software enables automatic creation of correspondence between model and photo. Without calibration the operator has to identify manually a set of homologous points between model and each photo-texture: at least eleven tie points are required for this aim in 3D-Reconstructor. “Direct photo-texturing” is promising because it enables reduction of processing time and improvement in accuracy. On the other hand, more effort is required in the scanning planning and preparation stage: light conditions have to be optimised for taking photos and the differences in FoV between scanner and camera require precaution to allow later collating of point-clouds and images.

Discontinuities
An interesting feature of 3D-Reconstructor is the direct extraction of raw edges through automated detection of linear and angular surface discontinuities that mark, respectively, sharp changes in survey distance and large angular differences to the surface normal. After 2D projection of these drawings onto reference planes they can be processed within a CAD environment. Raw edges are often integrated with graphical information produced by applying progressive cross-sections: cut-plane procedure. Unfortunately, discontinuity lines are generally incomplete, uncertain and irregular because they are extracted from different point-clouds acquired at multiple locations and with differing orientations. Therefore the automatically generated 2D-vector drawings require manual editing.

Geo-knowledge
“Know to manage” should always be a must for every application in engineering and, if as Sir Francis Bacon proclaimed in 1597 “knowledge is power”, certain–ly geo-knowledge will become the core for building preservation and digital archiving. Geo-knowledge has been traditionally visualised by 2D vector drawings such as plans, cross-sections and elevations, integrated with 2D-raster plot, such as orthoimages, and DEM. In contrast, 3D textured modelling, which represents the first product of range-based collection, may be considered an important challenge to more general building documentation. Figure 3 demonstrates the point-clouds of the interiors (above) and two orthographic views of the finely decorated stucco ceilings of the dome and vaults, with the extracted vector drawing in overlay (below right). Figure 4, in contrast, presents a detail of the reconstructed surface model for exteriors, many point-clouds were collected from different locations to create the final model, and a 3D-wireframe view of Colleoni’s Chapel together with an orthophoto of its main facade. One may see the failures due to occlusions, perspective effects and structural overhangs of this complex and stately building. Figure 5 shows vector CAD drawings of the main facades of St Maria Maggiore, graphically refined in AutoCAD by manual editing and tracing work over the extracted discontinuities.

Concluding Remarks
Significant differences in levels of quality and detail emerge when comparing discontinuity lines extracted from the point-clouds acquired

by the three systems used, although the survey was done under the same geometrical conditions. Certainly the present manufactory standards for scanners have to be improved. In addition, the processing software needs the attention of scientists so as to develop plug-in modules for well-known CAD packages, and to carry out accurate 2D-line drawings and more reliable virtual-reality models.

Acknowledgements
Thanks are due to the team at Geolab, University of Bergamo, and Inn.Tec. (Brescia-Italy), commercial reseller, EU-JRC 3D Reconstructor.

Further Reading

- Boehler W. et al, 2004; The Potential of Non-contact Close Range Laser Scanners for Cultural Heritage Recording, Proceedings of the 18th
CIPA International Symposium, Potsdam, Germany.

- Bonora V., Colombo L., Marana B., 2005; Laser Technology for Cross-section Survey in Ancient Buildings: a study for S. M. Maggiore in Bergamo, Proceedings of the 20th CIPA International Symposium, Turin, Italy.

- El-Hakim S.F., Remondino F., 2006; Image-based 3D Modeling: a review, The Photogrammetric Record Journal, Volume 21, No 115.

- Froehlich C., Mettenleiter M., 2004; Terrestrial Laser Scanning. New perspective in 3D-surveying, Proceedings of the ISPRS working group VIII/2, Freiburg, Germany.

- Ullrich A. et al., 2001; Time-of-flight-based 3D Imaging Sensor with True-colour Channel for Automated Texturing - Optical 3-D Measurement techniques V conference proceedings, Vienna, Austria.