PHOTO-TEXTURED BUILDING MODELS

LUIGI COLOMBO AND BARBARA MARANA ON 3D PHOTO TEXTURING AS USED AT THE GEO-TECHNOLOGY LABORATORY (GEOLAB) AT THE UNIVERSITY OF BERGAMO, ITALY

Documentation of ancient buildings is more and more frequently performed nowadays through virtual modelling and spatial relationship with web geo-visualization systems, like Google Maps, Microsoft Live Maps, and Yahoo Maps.

Geometric and thematic description is a need for monitoring, diagnostics, maintenance and recovery interventions, involving structures and materials; this approach could be the basis for the construction of an Information System devoted to building conservation during its life-cycle.

A point model can be created thanks to well-known *non-contact* techniques, both passive (image based) like close range photogrammetry and active, such as laser scanning; if object points are connected via software according to small planar elements, the final product is a model of surfaces (meshed model).

Spatial visualisation can be achieved, in the best way, with *photo-realistic rendering* which requires the projection (pixel by pixel) of digital images over a point or a meshed model.

Point density and model precision are strictly related parameters: only a small sampling step of an object can properly describe it, supplying a correct shape reconstruction.

Survey remarks

The scheduled scanning locations have to provide a wide visibility of the area to be collected, for instance by selecting panoramic scanners with large FoV (Field of View) and optimizing overlapping areas so as to limit occlusions and shadows, due to morphology, light conditions, etc.

Visibility and occlusions are the major cause of information loss: in enough complex buildings it becomes really impossible or impractical to

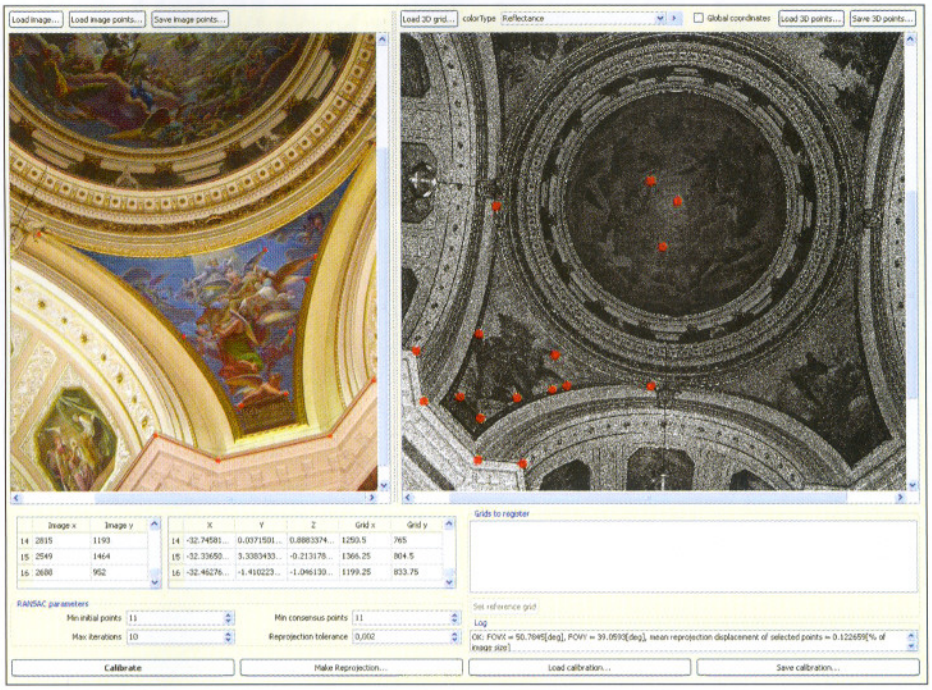

FIG. 1 - Tie points for manual image reprojection over a model: the process of point selection.

FIG. 2 A-B-C-D - St Maria Maggiore's Cathedral (a-b) and Grazie's Church (c-d) in Bergamo.

obtain a complete model, even if performing more scans around and close to the building surfaces.

To overcome a little this problem, it is useful to get on-line fast registrations for point clouds, so as to preview the complete model and perform, if requested, further acquisitions.

This point model can be submitted, via software, to a LoD (Level of Detail) simplification process (over points, triangulation and texture), to keep in memory only what is needed and visible.

Continuous LoD is a known technique adopted in photo-texturing for a view-dependent reduction of mesh number and of texture resolution; this can improve the ratio between visual quality and rendering-time. The level of detail is calculated dynamically, referring to surface complexity, viewer distance and viewing angle; the maximum loss in quality is controlled by pre-selected threshold values.

Building photo-texturing

Photo texturing needs a set of images for describing material, color or decay information to be superimposed on point or meshed models.

Image taking has to exclude over-exposition or under-exposition; besides, because windows and glass surfaces can cause undesired reflections and shadows for indoor survey, a solution could be the acquisition of photos only in diffused artificial light.

Images can be stored simultaneously while scanning (on-line or *direct* acquisition), if the instrument is equipped with a digital photo-camera connected to the laser sensor (internal and external orientation are known). If it is advisable to take images in different time, the object has to be photographed (off-line acquisition) from locations close to scanning positions and with the same point of view, so as to avoid perspective splitting and inconsistencies.

Besides, when package allows the following process, it is useful to take photos from *selected* points and then ad hoc *virtual scans* can be created, via software, from the same positions.

Image reprojection

The reprojection of each photo over a point model or a meshed model involves the knowledge of internal orientation and the estimate of external orientation of the photo-camera; if the camera is built inside the laser sensor or it is jointly connected to it, the external orientation is already known: so, one can speak about *automatic* (or *direct*) *reprojection*, while scanning. On the contrary, when a photo-camera is used over a tripod, external orientation is unknown and it has to be estimated (together with the internal one, if the camera is not pre-calibrated) through suitable tie points (*manual reprojection*).

Automatic reprojection is a difficult step while texturing, since a built-in camera usually records images at low resolution, while a connected one sometimes provides an unsteady asset over time and images are often collected in not suitable light conditions. On the contrary, manual reprojection requires the selection of a large set of tie points, between model and each image, which have to be well distributed over the scene.

Anyway, it seems that the best solution could be the use of both automatic and manual reprojection.

Figure 1 shows the step of tie point definition, for a dome-intrados texturing (Grazie's Church in Bergamo), inside the package 3D Reconstructor.

Texturing problems and remedies

In case images for texturing should be at a higher resolution than point cloud density, and the scale of visualization should be large, they have to be projected over a meshed model to preserve the quality.

Many problems in this approach are still to be solved: radiometric discontinuities among adjacent meshes and loss of information for occlusions and geometric distortion produced by camera calibration-orientation effects.

Remedies are both *colour balancing*, which optimises RGB colour levels, and *blending*, namely colour interpolation for smoothing radiometric differences among images, based on image-object spatial relationship.

Balancing and blending are applied at first to each cloud and then, after connecting adjacent clouds, to the whole model.

Finally, the model and its textures can be exported to 3D visualisation environments, thanks to proper interchange graphic formats, like the standard VRML 1 or 2 or 3DS format by AutoDesk.

Experiences developed at GeoLab

In Italy, the preservation of *sensitive* buildings has become a relevant task for the scientific

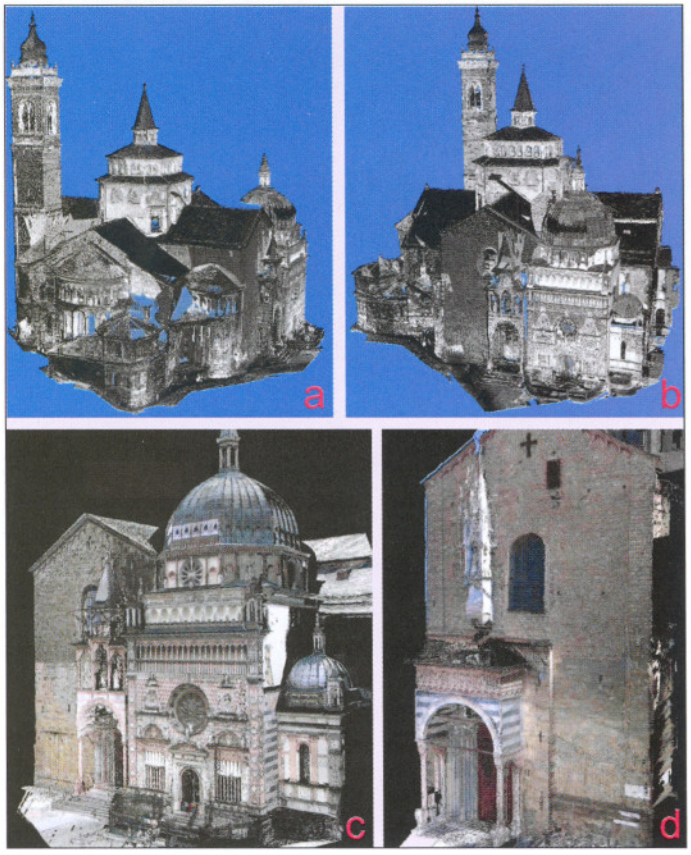

FIG. 3 a-b-c-d - Point model for St Maria Maggiore exteriors (a-b) and two prospects with texture(c-d).

community and for the institutions devoted to Cultural Heritage.

In Bergamo, city of ancient traditions, the fourteenth-century Church of St Maria Maggiore, located on the city hill and surrounded by Venetian walls, is of great significance for the local community.

For some years, this sandstone monument has been object of documentation analysis by the Geo-technology Laboratory (GeoLab) at the University of Bergamo, faculty of Engineering; surveying measurements and a complete scanning survey were carried out both for the interiors and the exteriors (Figure 2 a-b).

In particular, for the exteriors, a Riegl scanner (with a connected photo-camera) was used, in order to provide a spatial model with direct photo-texturing.

Another religious building, the eighteenth-century Grazie's Church (Figure 2 c-d), is now under survey for the interiors (with stone walls and marble coating), which have been degraded by remarkable humidity and capillary ascent phenomena.

The technologies employed are both surveying instruments and laser scanning; image acquisition, for decay texturing, was collected while scanning (performed in night time for diurnal impracticability, due to daily religious services) and then integrated by a further off-line photographic documentation.

Field experiences performed in Bergamo during these years have pointed out that automatic photo-texturing approach presents meaningful advantages in regular working situations but in bad light condition, manual photo-texturing is more versatile and effective; however, in this case reprojection process is more difficult because several tie points have to be selected manually.

Besides, the quality of photo-textures can be better preserved if their mapping is carried out over meshed models instead of point models.

Some examples

The following figures deal with these topics in detail; in particular, Figure 3 a-b highlights the point model reconstructed for St Maria Maggiore exteriors, while Figure 3 c-d shows some perspective views of the same model, with photo-textured superimposition.

Figure 4 a-b compares two examples of image reprojection (Grazie's Church interiors), respectively over a point model (at medium density), with poor results, and over the meshed model (with a good visualization).

At last, Figure 5 underlines the photo-texturing process, for interiors of the same church, based on a very dense point model.

Acknowledgements

Thanks are due to the GeoLab team at University of Bergamo.

References

[1] Y. Alshawabkeh, N. Haala (2005) - Automatic multi-image photo-texturing of complex 3D scenes - XVIII CIPA International Symposium, Turin - ISPRS - Vol. 34-5/C34, pp. 68-73.

[2] A. Baumberg (2002) - Blending images for texturing 3D models - Proc. of the British Machines Vision Conference- pp. 404-413.

[3] F. Bernardini, I.M. Martin, H. Rushmeier (2001) - High-quality texture reconstruction from multiple scans - IEEE Transactions. Visualization and Computer Graphics. 7 (4), pp. 318-332.

[4] L. Colombo, B. Marana (2007) - Camera laser scanner - GIM International, 21 (8), pp.15-17.

[5] E. Petsa, L. Grammatikopoulos, I. Kalisperakis, G. Karras, V. Pagounis (2007) - Laser scanning and automatic multi-image texturing of surface projections - XXI CIPA International Symposium, Athens, 1-6 October, pp. 579-584.

Article by Luigi Colombo and Barbara Marana. Luigi Colombo is a professor of Surveying & geomatics and Building monitoring geo-techniques at the faculty of Engineering - University of Bergamo; Barbara Marana works as researcher at the same faculty. Contact: luigi.colombo@unibg.it

FIG. 4 A-B - Grazie's Church interiors: comparison between photo-texturing over a point model (a) and over a meshed model (b)

FIG. 5 - Grazie's Church interiors: the photo-rendered dense point model.