

MULTI-RESOLUTION MODELLING FROM MULTIPLE RANGE VIEWS: THE LASER SCANNER SURVEY OF PORTA PORTELLO, PADUA, ITALY

G. Salemi ^a, F. Liberi ^a, S. Mischi ^a, V. Achilli ^a, G. Artese ^b

^a Dipartimento di Architettura, Urbanistica e Rilevamento – Facoltà di Ingegneria, Università di Padova
Via Marzolo, 9 – 35131 Padova – Italy - giuseppe.salemi@unipd.it

^b Dipartimento di Pianificazione Territoriale, Università della Calabria, Cosenza - Italy – g.artese@unical.it

Commission V - WG V/2

KEY WORDS: Laser scanning, Point cloud, Nurbs, Mesh, Resolution

ABSTRACT:

In this paper, the authors present an experiment performed in Padua, Italy to model a cultural heritage object from multiple range views. This object is Porta Portello, an old monumental door near the University, and has been scanned using the laser scanner Cyrax 2500 from Cyra Technologies. A multi-resolution approach was carried out: 1 cm and 2 cm grids were used to acquire laser data for the front and the back sides; instead, 0.5 cm grid was used to acquire more detailed scenes of some artistic features. A typical approach is based on the closest point caching to minimize the computational resources. In order to develop an unique multi-resolution model, two registration techniques were taken in account: the point-to-point alignment and the point-plane alignment. First of all, the pair-wise registration has been performed using some high resolution range views. After this phase, a global registration was produced using all the 11.000.000 of the acquired cloud points. Some patches were also used to minimize the noise of the acquired data, when “moving” objects have been scanned together the “stable” surfaces. Furthermore, the LOD (Level Of Detail) approach was used to simplify the 3D scenes to reach a good compromise among accuracy, topology and data decimation.

1. 1. INTRODUCTION

The cultural heritage documentation is today well performed using the laser scanner methodology. In Padua (Italy) there is an old monumental door (Figure 1) near the University, which was scanned using the Cyrax 2500 from Cyra Technologies. The main goal was the multiresolution documentation of this historical access door (Figure 2) using 1cm, 2cm and 0.5 cm grids acquired from multiple range views for, respectively, the front side, the back side and some artistic scenes like the Venice lion and a castle (Figures 4 and 5).

The regular and irregular surfaces were worked at long-range, medium-range and close-range scale.



Figure 1. Porta Portello, Padua.



Figure 2. A. Canal called Canaletto, “Porta Portello e la Brenta a Padova”, (1735-40), National Gallery of Art, Washington DC.

2. MONOGRAPHY

The data collection is very large, including 6 Scanworld with a total number of 30 scans ranging from 45000 up to 2 millions of acquired points for each scan. The acquisition time is, of course, related to the previous dimensions and it ranges from 4 to 38 minutes. The Cyra targets have been also acquired using a 48 x 48 matrix with 1444 points in about 1 minute from a 25 m distance.

All this data has been organized in a special monography, where some kinds of metadata related to each scan are provided; of course, all the data useful for the final registration are included.

An example of monography is reported in Figure 3, where is included the ID of scan in the designed Scanworld, the planimetry of the area with the field of view (yellow), the digital image of the scene. In the same “space” a table is added which includes the scan Id, the distance from the laser to the object, the grid resolution, the acquisition matrix dimensions, the number of acquired points and the required acquisition time.

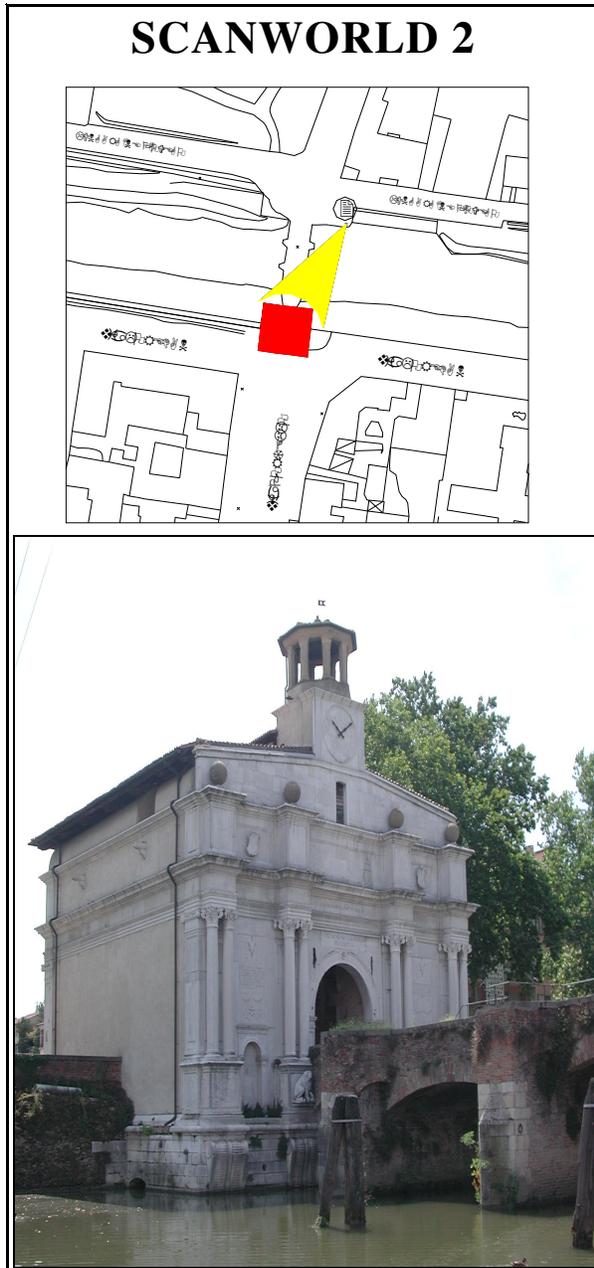


Figure 3. Monography for the laser scanner survey (partial; the data and metadata table isn't included).

2. 3. LEVEL OF DETAIL

Some architectural features are acquired with different resolution. The aim is to perform a multiresolution survey where the most interesting features are “included” in a general view. About this monumental door, two particulars are chosen: the so called “Venice Lion” (Figure 4) and the castle with tower (bass-relief in the Figure 5).

Both are quite simple figures, but the acquisition isn't so simple; in fact, is very difficult to complete the acquisition from different points of view. In the first case, also the visual inspection shows important height variations in the low part of the figure. A different resolution grid (0.5 cm) was chosen and

the related point cloud is presented in Figure 6. The figure 7 shows the partial reconstruction of the holes in the low part of the bass-relief, using a segmentation procedure and, after, the reconstruction.



Figure 4. Lion (bass-relief).



Figure 5. Castle with tower (bass-relief).

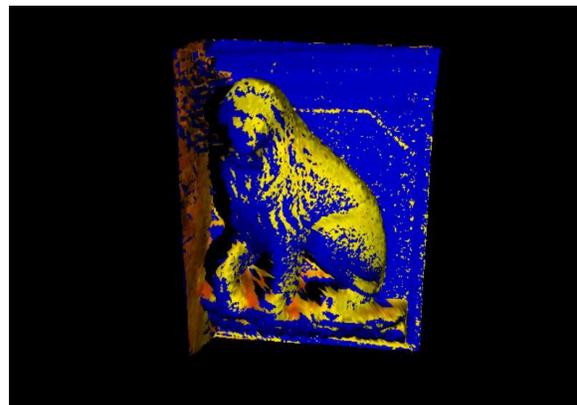


Figure 6. Lion meshes.

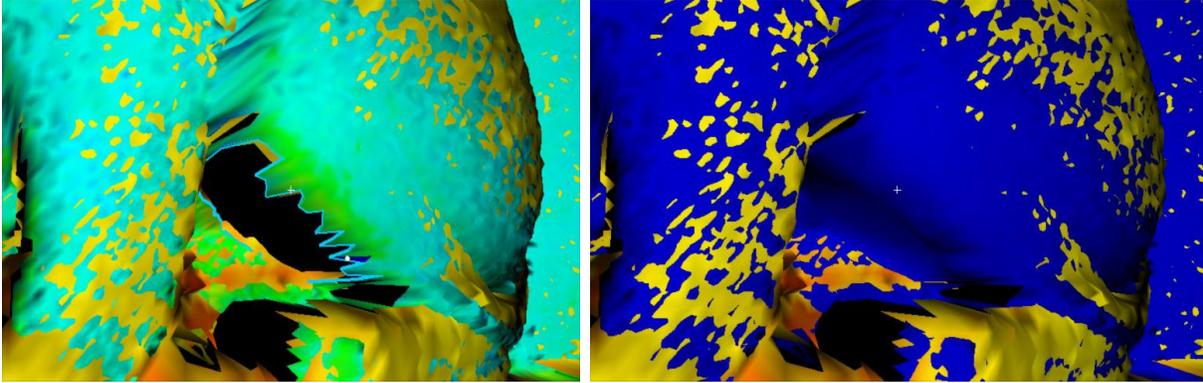


Figure 7. Partial reconstruction of the holes in the low part of the bass-relief: lion meshes (left: segmentation; right: reconstruction).

4. DATA ELABORATION

The first operation is the data decimation (Figure 9) and it is the most time consuming, also using special frames to delete points which are in or out the frame. Some patches can be created, using a defined layer where to interpolate some points; after the layer is removed with a simple operation (on/off). Also, a uniform decimation is possible when the data points density seems to be very high in that context.

In the Table 8, some results are reported about the decimation phase (DEC), where the number of points before and after decimation is reported.

Scanworld	# before DEC	# after DEC	% removed
1	3.590.766	2.780.590	22,6%
2	3.832.514	3.257.452	15%
3	402.780	273.292	32%
4	432.376	315.352	27%
5	259.573	235.605	9,2%
6	2.531.445	2.101.389	17%

Table 8. Decimation phase and % of removed points.

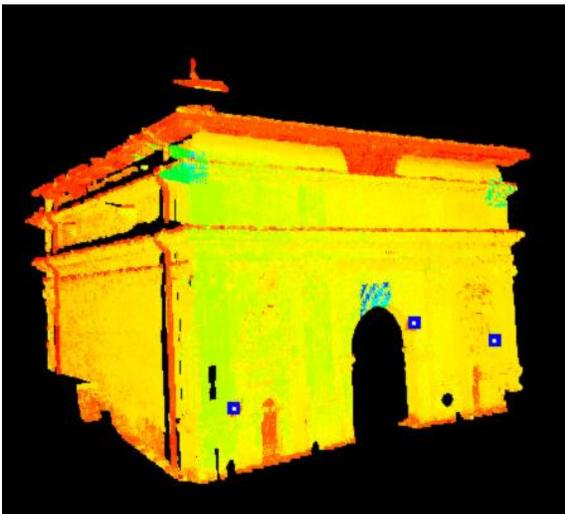


Figure 9. Example of decimated view (Scanworld 4).

The second phase of the data elaboration is the so called Registration. This is a mosaic process where more Scanworld are “registrated” in the same coordinate system, using couples of homologous points.

Two kinds of registration have been used for this acquisition:
 - the target registration (point to point or sphere to sphere)
 - the cloud point registration (cloud to cloud).

In the first case, the Cyra Tie-point and natural points (well visible architectural features) have been used. In the second case, the target aren’t needed and two Scanworld must be aligned using some points chosen by the user.

An example of alignment optimization is shown in Figure 10, including the related error histogram at the first iteration

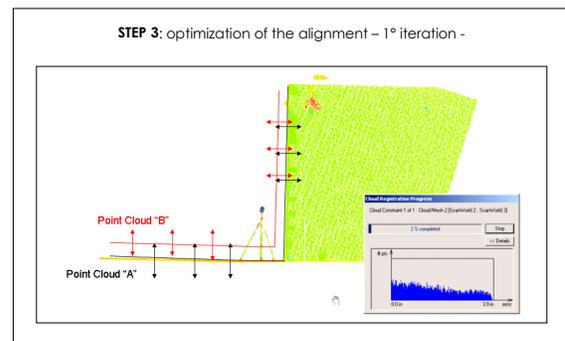


Figure 10. Example of alignment optimization.

5. CONCLUSIONS

Different registration procedures are used for the laser scanner survey of the monumental door called “Portello” in Padua. Also the CloudConstrainWizard has been used to create some cloud constraint in order to register more Scanworld. In the same time the minimization of single procedures is performed. Finally, the global registration can be operated. In this survey the error, after the global registration, appears quite good in the range of 1 cm; in only one case this value is exceeded. Probably, this fact is due to a lightly different acquisition mode for the lateral prospects. The Table 11 reports the results of the final alignment with the associated RMS between the Scanworld SW (RMS, Min

and Max error).

SW	SW	RMS (cm)	Min (cm)	Max (cm)
1	4	1.416	1.5e-006	9.750
1	6	0.821	1.5e-006	9.801
2	3	0.954	2.1e-007	9.692
2	6	0.688	3.8e-006	9.488
3	5	0.987	1.2e-004	9.213
4	5	0.957	1.2e-004	8.554

Table 11. Final result of the alignment

The Figure 12 shows the laser scanner survey obtained after the global registration for all the "Portello" including a small outline of the related bridge in front of it.

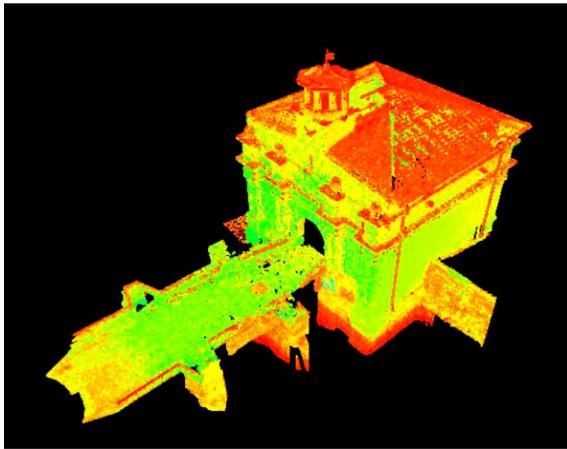


Figure 12. Final result of the global registration obtained with the Cloud Constrain Wizard

3. SELECTED BIBLIOGRAPHY

6.1 Registration

Pullin K., Multiview Registration for Large Data Sets in 3D Digital Imaging and Modeling'99 Conference proceedings, NRC, Ottawa, ottobre 1990, pp. 160-168

Besl P., McKay N., A method for registration of 3-D shapes, in IEEE Transactions on Pattern Analysis and Machine Intelligence, 14(2), 1992, pp. 239-256

Potmesil M., Generating models for solid objects by matching 3d surface segments in Proc. Int. Joint Conf. on Artificial Intelligence, IEEE, Los Alamitos CA:Computer Society Press, Ottawa, agosto 1983, pp. 1089-1093

El-Hakim S.F., Beraldin J.-A., Godin G., e Boulanger P., Two 3-D sensors for environment modeling and virtual reality: calibration and multi-view registration, in Proc. Int. Arch. Of Photogram. and Remote Sensing, Vol. XXXI, Part. B5.140-146, Wien, 1996
 Godin G., Rioux M., e Baribeau R., 3-D registration using range and intensity information, in Videometrics III Proc. SPIE 2350, 1994 pp. 279-290;

Dorai C., Wang G., Jain A. K., Mercer C, From images to models: Automatic 3D object model construction from multiple views, in Proceedings of the 13th IAPR International Conference on Pattern Recognition, 1996, pp. 770-774;

Johnson A., Hebert M., Surface registration by matching oriented points in Proc. Int. Conf. on Recent Advances in 3-Digital Imaging and Modeling, maggio 1997, pp. 121-128;

Blais G., Levine M. D., Registering multiview range data to create 3d computer objects, in IEEE Trans. Patt. Anal. Machine Intell., 17(8), agosto 1995, pp. 820-824;

Masuda T., Sakaue K., Yokoya N., Registration and integration of multiple range images for 3-D model construction in Proc. IEEE Conf. on Computer Vision and Pattern Recognition, giugno 1996, pp. 879-883;

Weik S., Registration of 3-d partial surface models using luminance and depth information, in Proc. Int. Conf. on Recent Advances in 3-D Digital Imaging and Modeling, 1997, pp. 93-100;

Faugeras O.D., Hebertand M., The representation, recognition, and locating of 3D objects, in International Journal of Robotic Research, 5(3), autunno 1986, pp. 27-52;

Kanatani K., Geometric Computation for Machine Vision, Oxford University Press, 1993.

6.2 Merge or fusion

Boissonnat J.-D., Geometric structures for three-dimensional shape representation, in ACM Transactions on Graphics, 3(4), ottobre 1984, pp. 266-286;

Hoppe H., DeRose T., Duchamp T., McDonald J., Stuetzle W., Surface reconstruction from unorganized points, in Siggraph'92 proceedings, luglio 1992, pp. 71-78;

Bajaj C.L., Bernardini F., Xu G., Automatic reconstruction of surfaces and scalar fields from 3D scans, in Siggraph'95 proceedings, agosto 1995, pp. 109-118;

Soucy M., Laurendeau D., Multi-resolution surface modelling from multiple range views, in Computer Graphics, Proceedings of IEEE CVPR'92, luglio 1992, pp. 348-353;

Turk G., Levoy M., Zippered polygon meshes from range images, in Computer Graphics, SIGGRAPH'94 Conference Proceedings, 1994, pp. 311-318;

Curless B., Levoy M., A volumetric method for building complex models from range images, in Siggraph'96 proceedings, agosto 1996, pp. 303-312.