

DIGITIZATION OF THE COLLECTION OF MOLDINGS OF THE UNIVERSITY MARC BLOCH IN STRASBOURG: A STUDY CASE

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ABSTRACT:

3D digitization of middle size objects of cultural heritage is a problem that has been investigated many times for almost two decades. Recent works, for instance, have emphasized the complementarity of close range photogrammetry and terrestrial laser scanning. The goal is to generate a nice 3D model by realizing a feasible method which can be successfully applied regardless of the cost and sharp equipment needed. However, as soon as one wants to process a large collection of objects, the question of the standardization of the equipment as well as of the software becomes crucial. In the ideal case, one unique equipment and a small set of standardized treatments available in the commercial software should suffice to reach the goal at least for a category of objects. The museum of moldings of the University Marc Bloch in Strasbourg would like to digitize a significant set of statues that represent well classical Greek sculpture. In this paper, a method based on a terrestrial laser scanner designed to standardized software treatments is described. It is shown, in particular that the noise range that affects the measurement accuracy makes it impossible to obtain a correct surface triangulation. Thus, a method of spatial filtering is proposed. Its originality lies in the fact that it brings the problem back to the world of image processing. One can then envision to use the standardized image processing software to process the point clouds before surface triangulation. The work proposed in this paper shows that it is possible to obtain 3D models at reasonable cost which makes it possible to envisage semi-industrial production.

1. INTRODUCTION

The collection of moldings of the University Marc Bloch in Strasbourg, created at the end of the nineteenth century, originated from the desire to compile this unique set into some kind of virtual museum, an ideal collection of classical Greek sculpture. The moldings have been built in the workshops of Berlin, Dresden, Frankfurt, London, Munich, Paris, Rome and Vienna and originated from prestigious sculptures discovered from archaeological excavations which were then led in Greece and in East: Olympia, Delphi, Samothrace, Delos, Pergamon. The aim of the collection was at first educational, but it has also served as a laboratory to experiment with several restorations of groups or antique statues: the group of the Tyrannoctones, the Aphrodite of Cnide, the Victory of Samothrace, etc. The collection of Strasbourg quickly became a leading scientific and educational instrument. At the end of the 19th century, the collection was considered one of the most brilliant collections in Europe. It is also considered the second biggest molding collection in France as well as the best university collection. Additionally, its specificities make it one of the most remarkable collections of Europe.

As a reminder of its initial educational and scientific aim, the Marc Bloch University aspires to value the collection by carrying out a 3D digitalization of a selection of particularly representative pieces of the history of Greek art. Furthermore, the university hopes to upload the 3D models to the web in order to make these models easily accessible to everyone. In particular, college students in subjects such as history, art history and archaeology would benefit from these models to develop and enhance on the fundamental knowledge of these topics. Besides the very classic advantages offered by the digitalization of works of cultural heritage, the nature of the collection offers two supplementary advantages. From the point of view of 3D modelling, it is of little importance whether the

model has been digitized from the original work or from a quality molding. Moreover, the collection offers a vast selection of works of famous artists in the history of Art whose original works are spread all over Europe. Since the entire collection is located in the same place, it allows relatively few expenses for the digitization of the entire collection. In order to take advantage of such rich collection to achieve substantial results in terms of quantity as well as quality, the question of the cost of the operation becomes crucial. Since the collection is composed by several hundred sculptures, varying in size, shape and complexity, it is not possible, at a reasonable cost, to use different equipment and methodology for each particular sculpture. In order to process even a consequent subset of the collection within the limits of a moderate cost, it is necessary to select the equipment and the optimal method which allow to obtain the best trade-off between the quality of the results and the complete cost of the operation (from handling the moldings to the post-processing calculation time on a computer). Although the choice may have been done somehow arbitrarily, it has been decided to use Terrestrial Laser Scanning rather than photogrammetry. It is beyond the scope of this paper to investigate whether one should use photogrammetry rather than laser scanning or even the combination of both techniques. A lot of academic research has already been done on that subject and surely will be done in the future since the subject is constantly renewed by technological improvements. The reader may turn his attention to some recent works or review papers that may be considered as the standard literature. The following references though not exhaustive give a reasonable idea of the state of the art (Bernardini, 2002; Blais, 2006; El-Hakim, 2004; Guidi, 2004; Guidi, 2006; Remondino, 2006; Taylor, 2003; Bitelli, 2002; Hanke, 2004; Heinz, 2005). Besides, there are so many different parameters that are susceptible to influence the final decision (precision, accuracy, cost, algorithm complexity,

physical characteristics of the surface, etc.) that it seems useless to give general ideas that could only lead to choosing one technology somehow on a dogmatic basis. Thus, one good practice, when one faces the need to make a choice, is probably to investigate experimentally whether the foreseen technology may be suited.

Naturally, the foreseen technology is not determined entirely by chance. In this particular case, the size of the works (statues of about two meters high), the physical characteristics (the statues are plaster moldings that would require structured light) have led to try laser scanning to find out whether this technology could be well suited. On the other hand, the objective of this statue digitization is semi-industrial (digitization of a large number of statues), the question of finding out whether simple and well identified schemes with a unique equipment will be capable of managing the task, arise and will be the aim of this paper.

2. THE STANDARD CHAIN: FROM ACQUISITION TO THE 3D MODEL

The standard chain from the acquisition of the data to the final 3D model consists of various stages whose order may often be changed as many variants exist. In the same way, each stage may be realized by a wide variety of algorithms more or less automatically and is in itself a subject of research. The scope of this paragraph is to describe the general idea of the standard chain which has been tried as a first attempt to process the point cloud acquired on a statue.

The acquisition provides the raw point clouds, i.e. sets of points given by their X, Y, Z coordinates and usually the intensity of the laser pulse which, however, will not be used in this paper. Each point cloud corresponds to one position of the laser scanner, called a station, several stations being necessary to define the whole volume of the statue.

Then, the different point clouds are registered and a unique point cloud is obtained for the whole object.

The next step consists in isolating the object of interest in the segmentation step.

Lastly, modeling or surface triangulation can be applied to obtain the geometrical model of the statue. Further processing like texture mapping can still be applied depending on the final result one wants to obtain. Since the statues of the collection of moldings are made out of plaster (sometimes painted), the question of texture mapping is not central and will be neglected. Hence, the standard chain in this paper will be defined until the geometrical model obtained by surface triangulation.

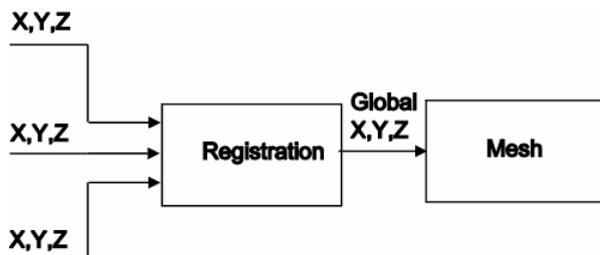


Figure 1. The standard chain

Since the Museum of Moldings has the objective to digitize a significant subset of its collection, as an industrial or at least semi-industrial task, it is important to define a standardized equipment and method including software processing that may

be applied without adaptation in the production stage. Thus, it is quite natural to try the commercial tools because they are optimized among others in terms of processing time.

The following lines describe the results obtained on the point cloud acquired on a statue of an Amazon (type "Mattéi" 440/430 B.C.) The statue is about 1.8 metres high.

The TLS used was a LS840 from FARO. The range is measured by means of phase shift. The maximum sampling rate is 120 000 points per second with an accuracy of 3 mm at 25 m. The maximum angular resolution is 0.009°. The statue has been scanned from three stations at this maximum resolution resulting in a total amount of points of about 2 millions.

Figure 2 illustrates the digitization at the museum of moldings.



Figure 2. The TLS and the statue to digitize.

Figure 3 shows the raw point cloud obtained.



Figure 3. The Raw point cloud of the "Amazon"(left).

The three stations have first been registered by means of spheres that have been placed close to the statue. Then, the raw point cloud showed points on the edges of the statue with very high reflectivity which were in fact, mixed pixels: these points

obtained by the laser beam which hits the edge of the surface and divides into a direct reflection on the statue itself and another reflection on the background (which was very reflective compared to the dark surface of the statue) have been removed by thresholding the intensity information to obtain a sharp edge on the object. Lastly, the segmentation has been done to isolate the region of interest, i.e. the statue itself. Then, 3DReshaper has been used for surface triangulation including the smoothing utility but with very poor results as suggested by figure 4.

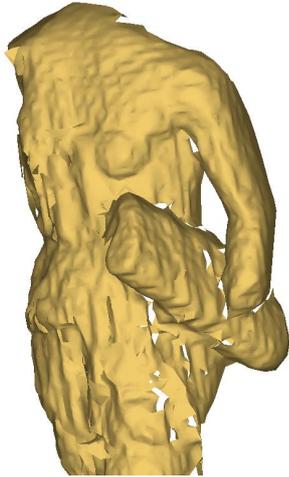


Figure 4. Best surface triangulation applied on the point cloud of figure 3

Despite the different algorithms provided by the software as well as the enhancements like model smoothing, the final 3D model remains very chaotic exhibiting roughness even on the smoother parts of the statue. The result is quite easy to interpret by the random range noise, the measured points oscillating randomly back and forth around the true surface of the object. Hence, the raw point cloud is improper to surface triangulation because of the range noise. This result suggests the use of a spatial filtering scheme to reduce the range of noise as much as possible.

3. SPATIAL FILTERING OF THE POINT CLOUD: THE MODIFIED PROCESSING CHAIN

Spatial filtering is a very classical issue that has been studied deeply by the signal and image processing community. However, in this particular case, the situation is different because the data is a point cloud, each point being given by its three (X,Y,Z) coordinates. Some research has been done to investigate the possibility of working directly on the global point cloud or on the surface mesh. The following paragraph gives a non exhaustive idea of what has been done in the recent years.

3.1 State of the Art

Yagou et al. (Yagou, 2002) use frameworks to extend the mean and median filtering schemes in image processing into smoothing noisy 3D shapes given by triangle meshes. The frameworks consist of the application of the mean and median filters to face normals on triangle meshes and the edit of mesh vertex positions to make them fit to the modified normals. Mashiko et al. (Mashiko, 2004) introduce an effective mesh smoothing method for 3D noisy shapes via the adaptive MMSE (minimum mean squared error) filter. The adaptive MMSE

filter is applied to modify the face normals of triangle meshes and then mesh vertex positions are reconstructed in order to satisfy the modified normals.

Fleishman et al. (Fleishman, 2003) have developed an anisotropic mesh denoising algorithm that is effective, simple and fast. This is accomplished by filtering vertices of the mesh in the normal direction using local neighbors. Motivated, as they say, by the impressive results of bilateral filtering for image denoising, they adopt it to denoise 3D meshes addressing the specific issues required in the transition from two-dimensions to manifolds in three dimensions.

Fournier et al. (Fournier, 2006) propose their scheme which is applied on the global point cloud after registration and their method is based on the so-called Distance Transform (DT).

3.2 The image approach

In the state-of-the-art methods briefly described above, the input data is either a global point cloud or a surface mesh. The methods developed, though successful, are not standardized yet and not easy to implement. The approach that has been developed for this paper consists in coming back to the standard chain at the point where one does not have to deal with 3D data, i.e. on the very basic principle of laser scanning. The scanning consists in sweeping both the horizontal and vertical angle called respectively θ and φ : for each position of the laser beam, the range called R is measured. Hence, the coordinates of the measured point is given in the spherical frame tied to the laser by the triplet (R, θ, φ) . It may thus be considered that the data obtained by the laser for one station is a 2D function $R = f(\theta, \varphi)$. If the scanning is rectangular, then this 2D function is nothing else but an image in the very classical sense with the exception that the intensity information (being function of two space variables) is replaced by range. Thus, the spatial filtering of the point cloud may be processed as a mere image filtering with all the methods that have been developed within the image processing community. As a first step, a simple low-pass filter may be applied since the range noise contains, among others, high frequencies. But in further steps, one can imagine to find out what kind of filter has to be used depending on the statistics of the surface to be digitized.

The standard chain exposed in figure 1 is then preceded by the one shown on figure 5.

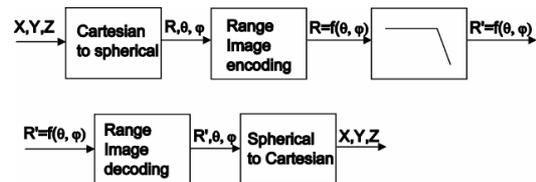


Figure 5. The filtering chain ahead of the standard chain of figure 1. The chain is applied for each station before registration.

The raw point cloud from one station given by the (X,Y,Z) coordinates is first transformed into the (R, θ, φ) triplet (the laser scanner measures directly these values but transforms them into their X,Y,Z equivalent and outputs them in the output file). Then the (R, θ, φ) set is transformed into an image with a rectangular grid by exploiting the $\Delta\theta$ and $\Delta\varphi$ information of the scan. The low-pass filters is applied and the inverse transformations are applied to come back to the X,Y,Z space. Then, these modified (X,Y,Z) clouds may enter the standard chain described on figure 1, i.e. the individual clouds that have been the objects of the former filtering are registered, the

registered cloud is segmented and finally enters the surface triangulation step.

3.3 Result on a plane

In order to validate the principle exposed in the former paragraph, the modified chain has been applied on a basic and well known surface, a mere plane. Four stations have been acquired. Because of the raw clouds being affected by the range noise as explained above, the direct surface triangulation does not give a satisfactory result since the model shows roughness that does not exist on the real surface (figure 6). The spatial filtering scheme has been applied on each point cloud before registration with a simple averaging filter (the range of the central point is replaced by the average of the point itself and its eight nearest neighbors). One can show that this averaging scheme is equivalent to a low-pass filter. Then, the four individual clouds are registered with the three points method (ICP algorithm) and, finally, the final cloud may be modelled by surface triangulation. Figure 7 shows the object after processing.

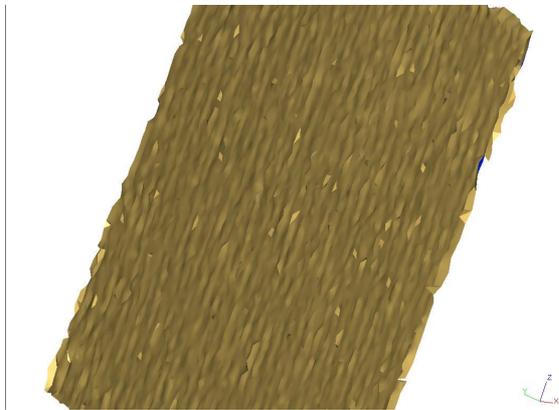


Figure 6. Surface mesh applied on a point cloud representing a mere plane.

One can notice that there still remains some roughness. Though part of it may be natural since the digitized plane was made out of wood, the poor performances of the mere averaging filter explains that the final surface is not as smooth as the real one. One can expect to obtain better results with more sophisticated filters. On the other hand, it could also be interesting on a quantitative point of view to calculate the noise reduction by calculating the difference between the point cloud and the average plane obtained by least squares for instance, before and after filtering.



Figure 7. A better triangulation of the plane.

4. RESULTS

The method has then been applied on part of the point cloud of the “Amazon” shown above. One leg has been chosen because the surface does not exhibit too high spatial frequencies. Hence, the case is rather favourable for a first try.

Figure 8 shows the surface mesh obtained directly by the standard chain on the raw point cloud. The smoothing utilities of 3DReshaper have been used and still the result is quite poor, the software having difficulties to fill holes for instance. To conclude with this try, one can affirm that the standard tools are not sufficient for correct surface triangulation and for obtaining a result which is satisfactory even on a purely visual basis.



Figure 8. Surface mesh of the “Amazon’s” leg.

Figure 9 shows the result obtained after filtering with the same mere averaging filter. Although it looks better, the result is still insufficient.

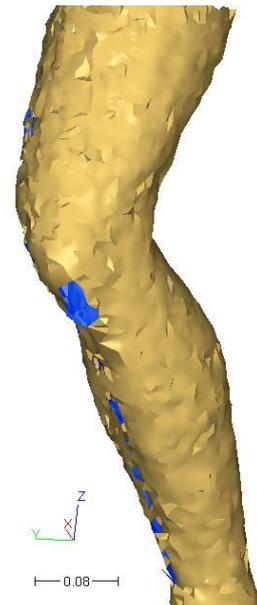


Figure 9. Better but still insufficient mesh obtained after filtering.

Lastly, figure 10 shows the obtained model after having applied the smoothing algorithm of 3DReshaper.

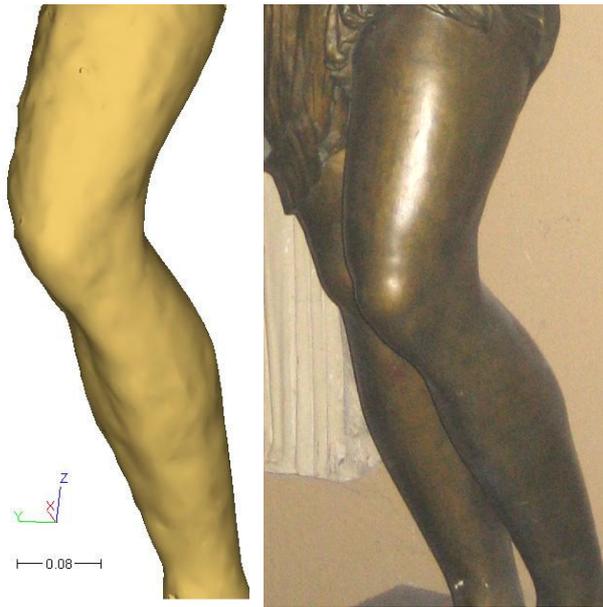


Figure 10. Model after smoothing the mesh (left) compared to the original image (right).

One can conclude that the filtering scheme, though insufficient in itself, allows one to obtain a satisfactory result by applying the standardized smoothing algorithm of a commercial software.

5. CONCLUSION AND FURTHER WORKS

Though 3D digitization of cultural heritage objects and particularly middle size or large statues has been a well studied area, the question of defining standardized and affordable methods in the perspective of semi-industrial production still remains. The first results obtained in this paper in the context of the digitization of the mouldings of the museum in Strasbourg suggests that a standardized equipment like a TLS associated with standardized software from acquisition to surface triangulation may be efficient. Though, range noise prevents the direct application of surface triangulation on the global point cloud obtained by the standard chain, it has been shown that a mere filtering scheme in the sense of image processing and as an intermediate step would perform the task and make it possible to obtain a nice result.

Certainly, much is still to be done before starting production. First, it is important to find out what kind of TLS is the most suited: phase shift or Time Of Flight?

Furthermore, the attention should also be drawn on the nature of the filter that should be used depending probably on the statistics of the surface to digitize. An other important question is about the robustness of the filter with respect to the registration. So far, it has been noticed that filtering each individual station is not without consequence on the quality of the registration. Further studies will have to quantize the effect in order to maintain it as low as possible by choosing the right filter.

Last but not least, quantitative procedures could be defined to measure the improvement in the signal to noise ratio as well as measures on the accuracy and precision of the final model.

Although these tasks are still to be accomplished, we hope that the simplicity of the method opens a nice perspective in the subject of generalization of cultural heritage digitization.

REFERENCES

References from Journals:

Bernardini, F., 2002. Building a digital model of Michelangelo's Florentine Pieta. *IEEE Comput. Graph. Appl.*, 22(1), pp. 59-67.

Blais, F., 2006. Recent developments in 3D multi-modal laser imaging applied to cultural heritage. *Machine Vision and Applications*, (17), pp. 395-409

El-Hakim, S., 2004. Detailed 3D reconstruction of large scale heritage sites with integrated techniques. *IEEE J. Comput. Gr. Appl.*, pp. 21-28

Guidi, G., 2004. High-accuracy 3D modelling of cultural heritage: the digitizing of Donatello's "Maddalena". *Image Proc. IEEE Trans.* 13(3), pp 370

Guidi, G., 2006. Three-dimensional acquisition of large and detailed cultural heritage objects. *Machine Vision and Applications*, (17), pp. 349-360

Remondino, F., 2006. Image based 3D modelling: a review. *The Photogrammetric Record*, 21(115), pp. 269-291

Taylor, J., 2003. NRC 3D technology for museum and heritage applications. *J. Vis. Comput. Anim.*, 14(3)

References from Other Literature:

Bitelli, G., 2002. Digital photogrammetry and laser scanning in surveying the « Nymphaea » in Pompeii, *ISPRS Commission V, Symposium 2002*, September, 1-2, 2002, Corfu, Greece

Bonaz, L., 2004. Terrestrial Laser scanner data processing, *ISPRS Commission V, Congress 2004*, July, 12-23, Istanbul, Turkey, pp 514-519.

Fleishman, S., 2003. Bilateral Mesh Denoising. *International Conference on Computer Graphics and Interactive Techniques, ACM SIGGRAPH 2003 Papers*, July, 27-31, 2003, San Diego, California, USA, pp. 950-953.

Fournier, M., 2006. Filtrage adaptatif des données acquises par un scanner 3D et représentées par une transformée en distance volumétrique. *19èmes journées de l'Association Française de l'Informatique Graphique (AFIG) et de l'Association, Chapitre Français d'Eurographics*, 22-24 novembre 2006, Bordeaux, France

Hanke, K., 2004. Recording and visualization of the cenotaph of German Emperor Maximilian I, *ISPRS Commission V, Congress 2004*, July, 12-23, 2004, Istanbul, Turkey, pp. 413-418.

Heinz, G., 2005. Surveying of Pharaohs in the 21st Century, *Proceedings of the FIG Working Week 2005*, Cairo, Egypt, April 2005

Mashiko, T., 2004. 3D triangle mesh smoothing via adaptive MMSE filtering. *Proceedings of the Fourth International Conference on Computer and Information Technology (CIT'04)*, September 14 – 16, 2004, pp. 734 – 740

Yagou, H., 2002. Mesh smoothing via mean and median filtering applied to face normals. *Proceedings of the Geometric Modeling and Processing – Theory and Applications*, IEEE, pp. 124 – 131

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