RETURN

3D MODELING OF REAL ARTISTIC OBJECTS WITH LIMITED COMPUTERS RESOURCES

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ABSTRACT

Modeling real life objects, although at reach of current technology, is confined to a niche of sophisticated industrial applications because the high equipment costs involved. The costs of 3D imaging devices are substantially coming down, furthermore 3D modeling, within certain object complexities, is becoming feasible with limited (and inexpensive) computer resources.
This work reports on modeling complex real life objects with small computer resources. Practical provisions and clear examples of the object complexity at reach of the resources of this league are presented. Our considerations hold general validity but are demonstrated by examples pertaining to the field of artistic objects. This area is representative of both the typical difficulties encountered in practical 3D modeling and of the great opportunities offered by these techniques once production costs will be substantially lowered.

1. INTRODUCTION

The interest towards 3D object modeling is growing outside traditional areas of applications such as car and movies, industries, reverse engineering for precision mechanics or medical imaging, but it is becoming popular in a variety of new fields such as anthropometrics, volume monitoring and many others (see [1]).
An interesting area where 3D modeling can be profitably employed concerns with cultural heritage. 3D models in this field can be used as conservations records, their large information content may allow a virtual representation of the object by suitable CAD/CAM equipment for restauration and monitoring purposes or for interactive visualization in computer graphic applications.
Cultural heritage objects, such as statues, bas-reliefs and architectonic decorations, are rather articulated so that the required spatial resolution/object dimensions ratios typically lead to large amounts of data. Furthermore since the objects in most practical cases cannot be moved, a portable acquisition system is often needed. These issues point out that 3D modeling of cultural heritage objects involves the hardest difficulties of real life objects modeling.
Another important question is related with the detail level of the 3D reconstructed object model: high accuracy means high resolution (i.e. millimetric) and this can easily lead to models made out of hundreds of images. In these cases the time spent for data acquisition is typically a small fraction (e.g. 10%) of the total time spent for the 3D model building: indeed the major part of processing time is employed for properly assembling the data into the full model. Many tasks involved in this step can be only partially automated, so they still require considerable human intervention. Furthermore, building complex 3D models needs high computer resources, available until recently only with very expensive platforms. Current technology advances make now feasible 3D modeling tasks also on personal computer , potentially with enormous savings with respect to the traditional costs of 3D modeling. It seems realistic to think that these advances and savings will make the use of 3D modeling more and more attractive for applications in the field of cultural heritage.
However, building 3D models of complex objects, such as those typically encountered in cultural heritage, cannot be styraight-forwardly approached with limited computer resources. This work reports about our experience in coping with these difficulties and presents a number of procedures and provisions of general uselfuness in modeling complex real life objects. Our hardware equipment consists of a PC Pentium II, 350 MHz, equipped with 256 MB of RAM and 1 GB of free hard disk. These computer resources will be referred in the following as “the reference computer”.
In order to build a reliable 3D object model, many images taken from various points of view, are needed. This arises by the requirement to avoid some occlusions, which could hide parts of the object in a single scanned image, and to acquire a full object view from different sides (front, rear and lateral). During the image acquisition step there is no constraint between two consecutive snapshots, the ordering depends only upon the succeeding processing strategy. Since the geometric relationship between consecutive camera stations is unknown, we have to face with the aligning of a large number of images in order to recover the full information about the object. This involves the computation of the roto-translation between the two camera stations points, in order to correctly “paste” two adjacent images. As final step, prior to generate the complete 3D model, we have to remove the redundant information represented by the overlapped regions between two consecutive images, that is anyway needed for the aligning process.
In next section we provide a brief description of the employed object scanning device, based on a laser camera by which the data are acquired in the form of range and intensity images, while in section 3 we consider the alignment of a large sets of these range data with small computer resources. Then in section 4 we introduce practical methods to merge large sets of range images into surface models and finally in section 5 we report the conclusions. The results are exemplified by various applications concerning cultural heritage ,the field of our interest, but clearly they apply to general 3D modeling and can be used also in many other applications.

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The procedures that we will describe in following sections refer to a concrete example, namely a bas-relief by Donatello, located in the main altar of the Church of Sant'Antonio in Padova (Italy).

2. THE BIRIS CAMERA

In order to generate highly accurate 3D model we have employed a laser scanning sensor, e.g. the range camera Twinline Vitana, developed by the laboratories of National Research Council of Canada (NRCC), which is able to acquire in the same time the object shape and the information contained in the reflected intensity. In this way it was possible to acquire very detailed 3D images of the object, although this has involved a great effort to process the consequently large amount of range data.
The 3D sensor is based on a laser source, a CCD camera and a Bi-iris mask located in front of the diaphragm. The system provides range data through a combination of two optical principles: *triangulation* and *defocusing*. In the first task the depth information is recovered detecting the pixel position where the laser beam, reflected by the object, hits the CCD image. In order to improve this detection and to reduce the amount of noise due to the environment light conditions, a defocusing is performed (fig. 1), separating the laser beam in two different rays through a two aperture mask (which gives the name Biris to the laser sensor).

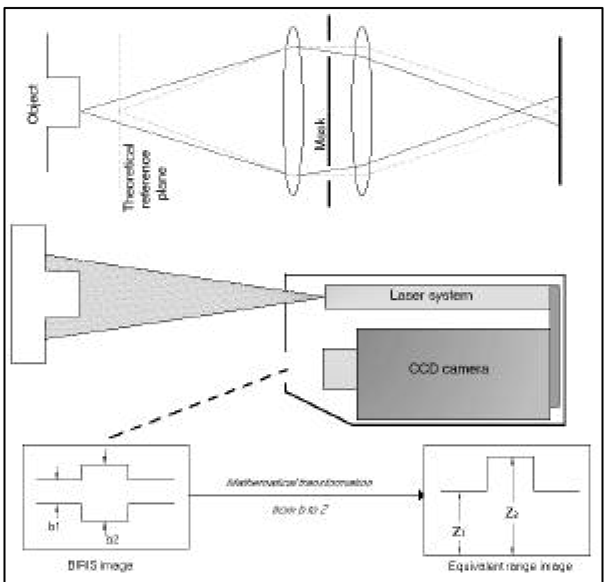


Fig. 1: The BIRIS laser range camera

In this way it is possible to obtain another range measurement: the redundancy of the acquired range data allows a robust estimate of the Z coordinate. Then scanning the whole object with a pan & tilt unit, we obtain a set of vertical profiles images, by which the full object surface (e.g. the object points coordinates X,Y,Z) can be recovered. Obviously as we deal with a non metric CCD camera, in order to reduce the error on the range and intensity data due to the lens distortions, a camera calibration has to be performed anyway. The full data acquisition step is depicted below in fig. 2 .

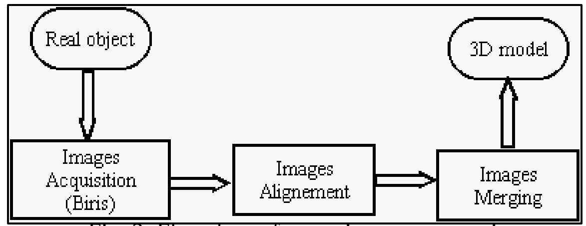


Fig. 2: Flowchart of range images processing

3. THE IMAGES ALIGNEMENT

Once the object is fully scanned by the laser sensor, we have to deal with a large number of 3D images, acquired in some order, which have to be aligned each to other. This operation requires on one hand that the views are taken with some degree of supeirmposition and on the other hand the computation of the 3D rototranslation matrix bringing to coincience the common region of two partial views. This last task can be performed by a variety of numerical methods as the Iterative Closest Point (ICP) algorithm [2] or the more recently technique, described in [3], working in the frequency domain.
The alignement of more than two images can be profitably approached as proposed in [4], which method is also supported by a commercial product. Given a set of N partially overlapping images, in principle we can obtain the full alignement adopting an iterative procedure, in which the (i+1)-image is aligned with a group of i already aligned images, for i=1,2,….,N-1. If the range images are of size 256x256 pixels, as in our case, the memory occupancy with a block of N=20 is around 15 Mbytes and the procedure of [4] for N≥20 becomes considerably slow in our reference computer.
Another important issue to cope with, regards the alignement of open 3D objects (such as a bas-relief) that is intrinsecally more difficult than that of all-round objects (such a sculpture) because of the lack of any alignement reference, and the minimization procedure [4], when N increases becomes very sensitive to starting points.
In our case the bas-relief of Donatello was imaged at a distance of 30 cm, resulting in a spatial resolution of half a millimeter and an object surface represented through 270 images. Fig. 3 shows a partial set of these sub-images.

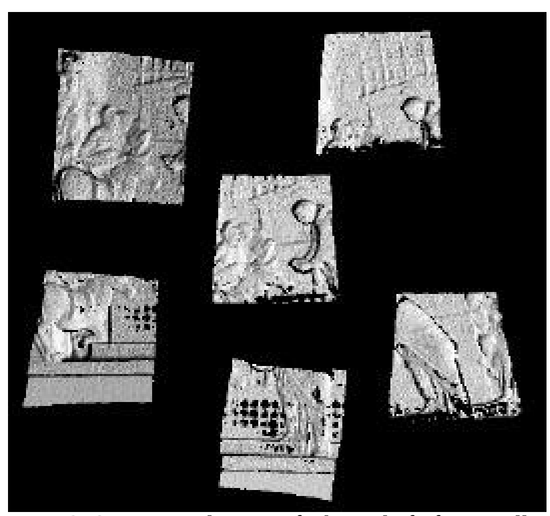
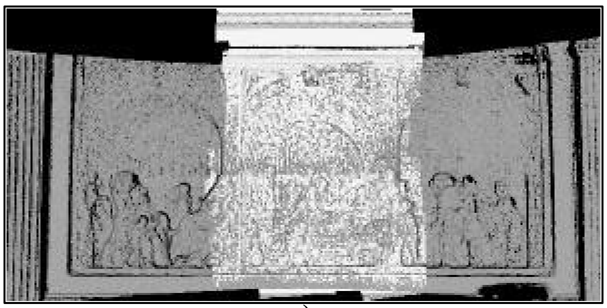
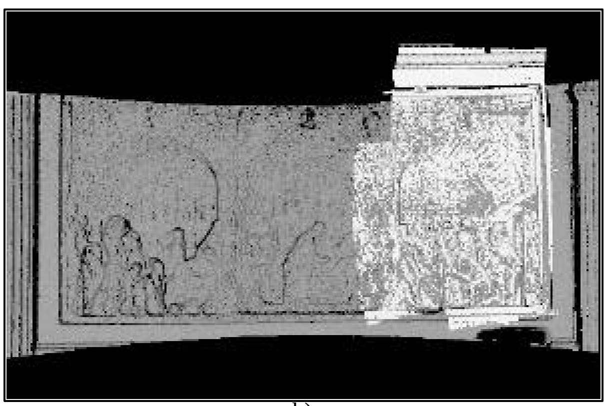


Fig. 3: Some partial views of a bas-relief of Donatello

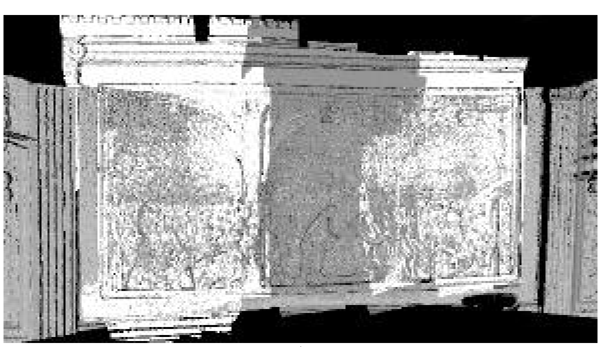
Given limited computer resources, in order to perform effectively the alignement of this large amount of 3D images, we have adopted a hierarchical approach. The original set of 270 images was subdivided in three macro-blocks, each of 90 images, which were further grouped in sub-sets of 20 images. The alignement was carried out between the images of the same sub-group and then between the sub-groups of the same macro-block. In order to avoid the divergence of the algorithm, proposed in [4], as N becomes greater than 100, which is a problem essentially related to the need of starting the alignement procedures from good pre-alignements, we used a low resolution target-image of the whole object as alignement guide. The three macro-blocks of around 90 range images can be separately pre-aligned with this low resolution image, as depicted in fig. 4.
As final step of our procedure, the original (14) sub-groups of approxima-tely 20 range images, forming all the three macro-blocks can be realigned. The final result is shown in fig. 6.



a)



b)

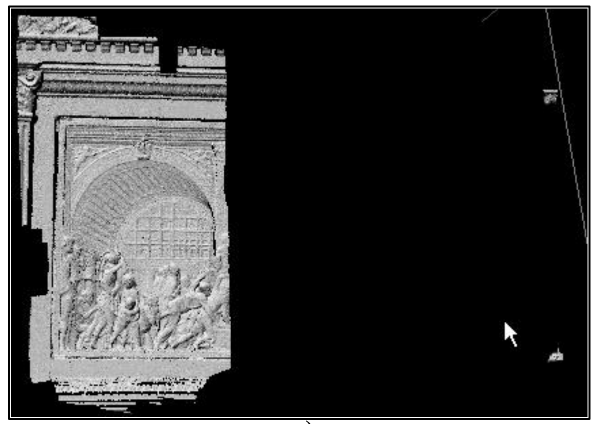


c)

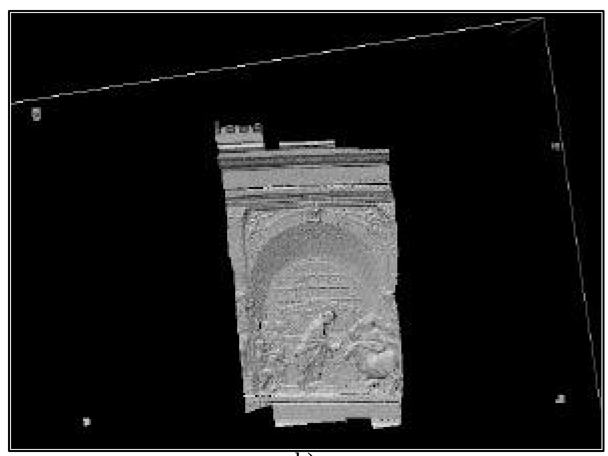
Fig. 4a),b): two macro-blocks aligned with the low resolution image. c) Final alignement of the three macro-blocks.

4. MERGING THE 3D IMAGES

In this last processing step the previously aligned images are merged together to generate the surface models, with consequent data reduction. An efficient merging technique, also supported by a commercial package, is described in [5].
According to this method, the merging of N images requires the subdivision into sub-sets up to 2^N, which leads easily to explosion of computation and memory requirements. In practice the procedure works safely, with our reference machine, for the merging of up to 100 range data images, each of size 256x256: as the number of images increases over 100 the memory quota is usually exceeded. As example fig. 5a) and 5b) show two surface modesl, of 951066 triangles, derived by the 90 range images macro-block of fig. 4: Note that the latter occupies about 80 Mbytes, while the former only about 20 Mbytes.



a)



b)

Fig. 5a),b): two surface models each composed by 90 aligned range images, with four corners of the bas-relief.

In order to overcome the great memory requirement for the merging operation, we have adopted the following strategy to generate the surface model of the whole object:

a) Split the previous alignement of all the macro-blocks in N parts, each of them containing also the images of the 4 corners of the bas-relief and save them separately;

b) Generate the surface model of each part, the software removes automatically the redundant information represented by the overlapping regions between the images;
c) Load into software package the models one after the other and *past* them manually, using the saved corners as reference points to preserve the original alignement of the macro-blocks.

The whole procedure is depicted in fig. 6. Various views of the 3D model are also shown in fig. 7, the visual quality of the whole model is very high. Of course, the advances of computer technology (Pentium III is already on the market) should soon move the area of the 3D models feasible with inexpensive resources beyond this complexity level.

Fig. 6: The final model of the bas-relief

5. CONCLUSIONS

In this work we have presented a procedure to build 3D model of complex real objects with limited computational resources, corresponding to a Pentium II (300 MHz) provided with 256 MB of RAM and 1 GB of free hard disk.
As result of the method we have reported our experience for building a 3D model of a bas-relief of Donatello located in Sant'Antonio church in Padova (Italy). It was scanned with the laser range camera Biris, developed at NRC of Canada, in order to generate an high detailed model.
The large amount of range data resulting from scanning step has lead to difficulties for succeeding data processing, in terms of computational and memory requirements. Therefore to overcome these problems we have adopted some effective techniques for aligning and merging of a large number of range images. The considered example pertains to modeling of cultural heritage objects, however the presented procedure is of general validity.
Cultural heritage is one of the many fields where 3D modeling could be profitably used if its production costs were drastically lowered. An important step in this direction is the fact that 3D modeling in this application field can be done today with computer resources of the order of a few thousands US dollars, rather than of a few hundred thousands dollars. Nevertheless it should be not forgotten that the costs of these models cannot still be lowered beyond a point , as the amount of human interaction currently needed for building 3D models of articulated objects is quite relevant. Fully automatic 3D modeling is the exciting challenge, that will decide the practical impact of these techniques in many fields, among which cultural heritage applications.

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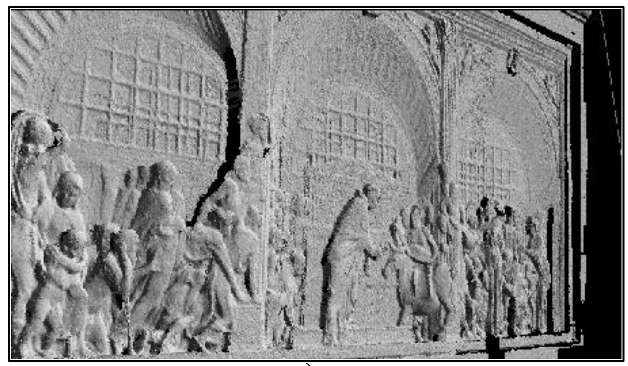
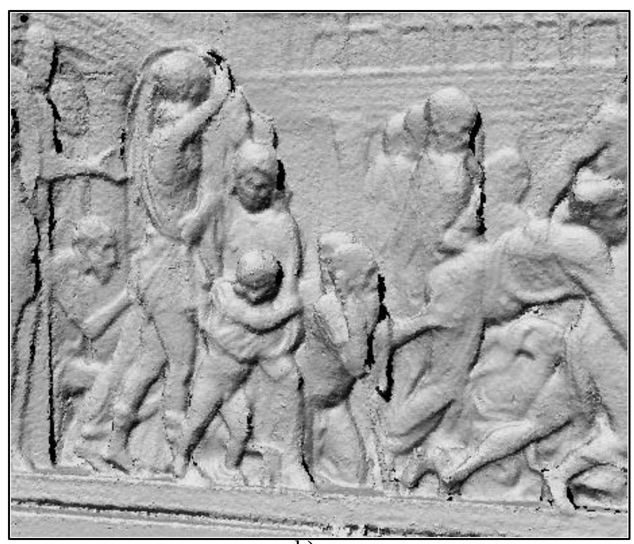


a)



b)

Fig. 7a): A perspective view of the bas-relief model; b): A particular of the right side of the bas-relief model.