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EVALUATION OF A PHOTO BASED SCANNING AND 3D RECONSTRUCTION TECHNIQUE APPLIED IN MEDICAL ENGINEERING

BY

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Abstract. A case study of using a photo based 3D reconstruction technique is carried out in this paper. An object and an anatomic surface were scanned and reconstructed in order to evaluate the accuracy of reconstructed indentations. The results show that the blind holes, the threads and the small indentations are not well reconstructed, objects appearing incomplete. The 3D models are discussed and some solutions for the improvement of reconstructions are presented.

Key words: photogrammetry, single camera, 3D reconstruction, indentations, evaluation.

1. Introduction

The increase of interest in scanning and in generating digital reconstructions using digital cameras and increasing capabilities of processing software has expanded the range of domains to which photo based technique or

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photogrammetry may be applied. This tendency permitted simultaneously the decreasing of the costs of acquisition, processing, and analysis.

A variety of specialists such as engineers, archaeologists, paleontologists, hydrologists, bioengineers etc. can benefit from 3D products derived from modern photogrammetric techniques. Industrial photogrammetry has been described as application of photogrammetry in civil engineering, mining, vehicle and machine construction, metallurgy, etc. (Chang, 2008), (Heuvel, 2000).

Photogrammetric techniques can be usefully and feasible for industrial measurements and inspection applications. There are known applications in some industries where components or objects of a complex surface configuration are to be manufactured, which would be time consuming to measure with conventional commercial measuring devices. A systematic approach to implementing such applications is necessary to investigate the effects in the reduction of operating time, operating costs and equipment costs.

Generally, photogrammetry is the technique of measuring objects from photographs. Photogrammetry has been used to produce topographic maps which remained the most requested photogrammetric product except photographic reproductions.

Photogrammetry has as basic procedure the assembling of an overlapping pair of photographs taken to simulate the perspective view of the centers of human stereoscopic vision (Curless, 2000), (Jin *et al.*, 2006).

Photogrammetry can be classified after camera position during photography. On this classification there are:

- Close-range photogrammetry (with camera distance settings to finite values);
- Aerial photogrammetry (or remote sensing with camera distance setting to indefinite).

Close-range photogrammetry is the technology of obtaining information about objects and the environment by recording, measuring, and processing photographic images. Taking photographs is a process that transforms the 3D real objects into flat 2D images. In this case, the digital camera is the device that transforms 3D objects to 2D objects.

Photogrammetry or more precisely stereophotogrammetry may be considered the reverse of the normal photographic process transforming 2D images into 3D models.

Photogrammetry, involves determination of the three-dimensional coordinates of points on an object by means of processing software. Common points are identified on each image and using triangulation the three dimensional position of the points is computed. The photogrammetric surface reconstruction technique is able to recover almost the complete geometry of an object but reported some errors limiting the use in precise applications (Pollefeys *et al.*, 1999).

In this study, an object with simple geometry and having holes, blind holes and thread (equivalent to helicoidally indentations) and an anatomic surface were scanned using single camera photogrammetry technique and finally 3D reconstructed and the results were discussed. Reconstruction was performed using commercial photogrammetric software.

The reconstruction furnished details about the limits of the 3D modeling of some types of peculiar geometrical shapes and especially of small indentations.

2. Method and Material

Commercial 3D scanning and reconstruction packages do not produce correct meshes without dense point clouds and as a result, a lot of time is consumed in mesh generation and editing. The existing problems of converting a point cloud into a realistic 3D model that can satisfy high modeling demands have not been completely solved (Remondino, 2006).

Reliable commercial software packages are now available and they are based on manual or semiautomatic measurements: ImageModeler, PhotoModeler, 3DSOM etc. These packages permit, after an adjustment phase, to obtain sensor calibration data, three dimensional point coordinates and 3D models from a set of images.

In this approach, in the first stage, an object with simple geometry was scanned using a commercially conventional available digital camera (Cannon SX 200 IS) and a photogrammetry technique. Reconstruction was performed using the commercial 3D photogrammetric software package 3DSOM.

An anatomic surface (ear in this case) was scanned and reconstructed in the second stage using the same photogrammetric technique.

The studied objects furnished details about the characteristics of the reconstruction of some types of peculiar geometrical shapes.

3. Results

3.1. Reconstruction of a Hexagonal Object with Screw Thread

A hexagonal object with a screw thread as in Fig.1 was scanned with single camera photogrammetric technique and reconstructed in three final forms using 3DSOM software.

When picturing an object, the number of required photos should be between 20 and 40 and the surfaces should be permanently in focus and lit with a diffuse illumination

The 3DSOM scanning software used in this study compares images patch by patch to find the matches and when these matches are found, the position data of the photos is used to automatically assemble the patches in the 3D space.

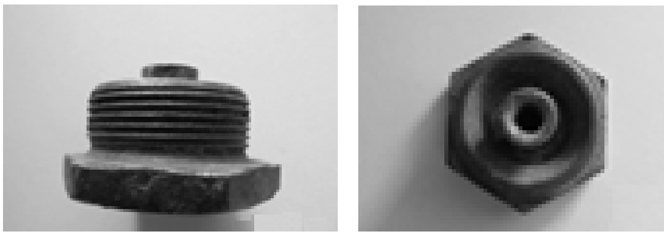

Fig. 1 – Front view (left) and top view (right) of a threaded object used during scanning.

The object was pictured using a single digital photo camera during scanning. A hand held digital camera was moved around the object, step by step, after trajectories like in Fig. 2. The steps between camera positions were about 15 or 30 degrees. A calibration grid printed on a paper was positioned under object in order to permit the 3D reconstruction. A commercial digital camera was used (Cannon SX 200 IS) with 12.1 Megapixels and 12x optically stabilized zoom. During scanning, the digital camera had next parameters: exposure time 1/40, aperture value 3.40, focal length 5.00, digital zoom ratio 1.00x, ISO speed rating 100, and resolution 180x180 DPI.

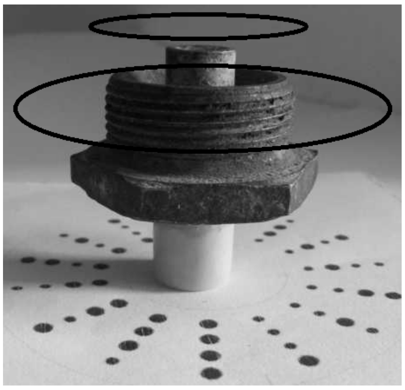

Fig. 2 – The scanned object, calibration grid and camera trajectories.

This technology has some limitations in the kind of objects that can be digitized. Shiny, mirroring, transparent and moving objects are very difficult to be scanned and 3D reconstructed. Also, the 3DSOM software rejects all photos with imprecise focalization and without visible calibration grid.

After scanning there are next phases in connection with 3D reconstruction:

1. Introduction of all photos in the reconstruction software;
2. Automatic selection of compatible photos;

3. Manual or automatic elimination of background details;
4. Automatic 3D reconstruction.

Fig. 2 shows some pictures of the studied object, from different positions and with a uniform background after a manual elimination of details. Software has tools for manual elimination of background details.

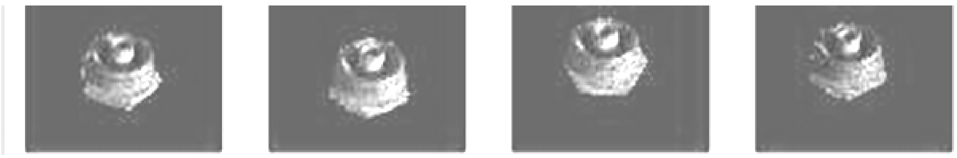

Fig. 2 – Elimination of background details

The main phase is the automatic reconstruction of the 3D model. Software reconstructs three types of models: 3D mesh models, 3D shaded models and textured models. Fig. 3 shows the 3D models after reconstruction.

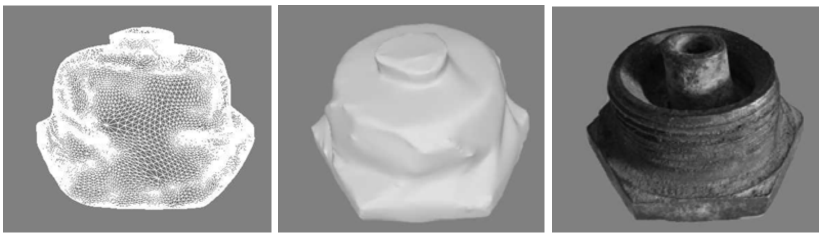

Fig. 3 – The mesh model (left), shaded model (center) and textured model (right) after 3D reconstruction

Results show that the 3D reconstructed textured model (Fig. 3 right) looks very impressive being very close to the object from Fig. 1.

Analyzing the 3D mesh model and the 3D shaded model from Fig. 3 it is obvious that the reconstruction does not reveal:

- The inner cylindrical tube;
- The hole of cylindrical tube;
- The larger blind hole;
- The screw thread.

As can be seen in Fig. 3, some geometric forms are not reproduced correctly. There are also a lot of surface irregularities which depend upon the number of photos and upon the quality of the 3D reconstruction.

Also, all 3D commercial software different some tools to improve the geometry of scanned surfaces.

3.2. Reconstruction of an Anatomic Surface

Another approach was the scanning of the human ear as in Fig. 4 using the same software and the same calibration grid. The ear was scanned and 3D reconstructed as in Fig. 5 in order to understand how the 3D reconstruction works in the presence of indentations.

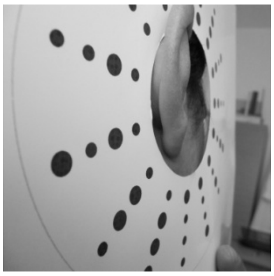

Fig. 4 – The scanning of the ear with the calibration grid

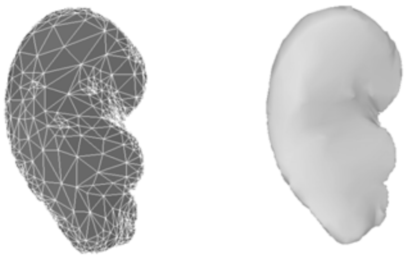

Fig. 5 – The 3D mesh model of the ear (left) and the 3D shaded model (right)

As can be seen in Fig. 5, some geometric forms (indentations) are not reproduced correctly. Surface irregularities depend upon the number of photos and upon the quality of the 3D reconstruction.

In this case, surface indentations are too complex to be repaired using the 3DSOM software tools.

4. Discussion

Each 3D scanning technology has its advantages, limitations, and costs. According to some scientific papers about photogrammetric scanning, this technology has some limitations in the kind of objects that can be digitized.

The results of this study on a small object and on an anatomic surface with indentations show that the indentations are not revealed directly.

The object studied in Fig. 1 is not well determined. The reconstructed 3D mesh and the shaded model have some imperfections, as in Fig. 3 left and center and do not reveal the inner holes and the thread.

The raised helical rib, going around a screw, studied in Fig. 1 is impossible to be revealed directly. The reconstructed 3D mesh and the 3D shaded model show no thread. But the 3D textured model shows the blind holes and the thread being very close to real model. In this case, the texture creates the illusion of the presence of the blind hole and of the thread.

The anatomic surface with indentations from Fig. 4 is reconstructed without indentations. The 3D mesh and shaded models from Fig. 5 are not useful in medical applications. The 3D model needs more details in the case of the fabrication of an artificial ear.

There are some options: to use another scanning technique or to carve the 3D mesh using specific tools. In the case of indentations there are necessary some image processing techniques (surface carving with Boolean tools) from reconstruction software or eventually, using other 3D CAD or computer graphics software to create the existing indentations or holes in the mesh model.

In medical applications, the reconstruction of an artificial ear is performed by an interdisciplinary bioengineering team filled with an anaplastologist. An anaplastologist is a person who has the knowledge of customizing a facial, craniofacial or somato prosthesis. Using the 3D single camera photogrammetric technique the 3D mesh models of the unaffected ear is copied and then mirrored. Finally the 3D model is sent to a Rapid Prototyping machine in order to be manufactured an artificial ear.

5. Conclusions

Photogrammetric scanning technique became one of the most cost-effective solutions for the 3D modeling of small objects and surfaces. During the 3D reconstruction, there been observed some difficulties in reproducing the exact details: some indentations will not appear on the 3D model

A lot of photo-based software has a number of manual and automatic tools to modify and to improve the 3D model. Using these tools or other software for editing it is possible to push the surface inwards in order to create an indentation or to pull the surface out to create a bump.

All these supplementary tools or additional processing software have as effect the extent of reconstruction duration and the cost of 3D modeling.

Despite these disadvantages, the photogrammetric scanning technique, with its low cost, noninvasive character and ease of use make it useful for different medical applications (Remondino, 2006), (Sequeira, 1999).

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O EVALUARE A UNEI TEHNICI DE SCANARE ŞI RECONSTRUCŢIE 3D CU AJUTORUL FOTOGRAFIILOR APLICATE ÎN INGINERIA MEDICALĂ

(Rezumat)

Lucrarea prezintă o evaluare a unei tehnici de scanare fotogrammetrică şi de reconstrucţie 3D cu posibile aplicaţii în ingineria medicală. Este prezentat un studiu de scanare şi reconstrucţie 3D făcut asupra unui obiect cu diverse indentaţii şi asupra unei suprafeţe anatomice (ureche). Rezultatele indică faptul că reconstrucţiile 3D făcute cu această tehnică nu pot modela anumite indentaţii de suprafaţă. Sunt prezentate şi comentate unele soluţii de îmbunătăţire a calităţii reconstrucţiilor 3D în aceste cazuri.