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METHODOLOGY AND CASE STUDY IN THE FURNITURE INDUSTRY USING PHOTOGRAMMETRY AND 5 AXIS MACHINING

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Abstract: *This paper presents a digital close range photogrammetry method as an inexpensive digitization technique used for abstract shaped real objects, having as ultimate goal unique or mass production of the object using CNC machining. The growing need to digitize real objects for manufacturing in the shortest time and at a price as low as possible, such as ornamental objects or various components of furniture where the precision of the resulted 3D model is less demanding, has been the premise of this study. The methodology that the authors propose consists in the following steps: acquiring the images of the object, cloud processing using specialized software, 3D model editing, elaborating the manufacturing technology, CNC code generation and CNC machining. A comparison of the most recent software packages that can be used for digitization of real objects has been undertaken and a detail study case with the digitization of a real object is presented.*
Key words: *close range photogrammetry, 2D images, 3D model, CAD/CAM, 5 axis CNC machining.*

1. INTRODUCTION

Multi-image photogrammetry or Structure from Motion is a relatively new technique for accurate digital capture of three-dimensional objects and surfaces [1]. Digital close-range photogrammetry is practically a digitization technique, in which, using a digital camera and some complex algorithms, one can generate a tridimensional model of a real object, which can be exported in various file formats.

Digital close ranged photogrammetry was successfully used in cultural heritage preservation and created very high level detailed tridimensional models as shown in [2-6].

The 3D reconstruction of an object from a set of 2D images, using different techniques and equipment, is a complex process that can be used for models of different sizes and configurations. From existing small objects to buildings, provided that the precision of the resulted tridimensional model is not a concern, photogrammetry can be a low cost digitization technique which smaller manufacturing companies can afford.

The premise of this study started from the growing need to digitize real objects from manufacturing, such as ornamental objects or even various components of furniture, where the precision of the resulted 3D model is less demanding, all this in the shortest time and at the lowest costs.

Therefore, this paper presents a simple and effective approach of digitization of a real object, with use of inexpensive equipment that is available to all users, with the ultimate goal being unique or mass production of the object using CNC machining.

In the case of abstract sculptures, for example, a computer model is usually very hard to be generated. In these cases the sculptures are usually handmade and then digitized with laser scanners. Laser scanning has been successfully used in several cases to generate a tridimensional model for CNC machining [7]. In this article, the authors want to show that digital close ranged photogrammetry is a viable solution in digitization of real objects, in order to be reproduced on a CNC machine.

2. METHODOLOGY AND OBJECTIVES

The main objective has been to develop and test a methodology by which the best possibilities of digitization of a real object by photogrammetry can be highlighted, using dedicated free software packages available on the internet. Based on the 3D generated model, the item in question can ultimately be manufactured.

There are several softwares that have been developed in the recent years and are free to use. Therefore, we reviewed the most recent ones and compared their features and capabilities together with the resulted 3D model within a case study. The final goal was to generate the manufacturing technology for the object in question using a dedicated CAD/CAM solution.

In order to reach the upper mentioned objectives, the authors followed the steps:

- **photo shooting:** the subject has to be photographed from different angles and heights in order to capture every detail of the object. Each picture must have at least a 60% overlap of the previous picture in order to recognize the algorithm and the similarities. To achieve a complete mesh of the model, photographs must be taken not just from the side of the object, but from the top of it;
- **cloud processing:** after the picture set is taken, the photographs are processed using specialized software like *PhotoModeler* [8] or on a cloud based system like *Autodesk 123D Catch* [9], *Autodesk ReCap* [10] or *Autodesk Memento Project* [11]. The cloud based systems are free of charge and they generate the 3D meshes fully automatically. The PhotoModeler software is not free of charge, but has a manual method of creating the tridimensional meshes, which sometimes can lead to better results;
- **3D model editing:** the generated mesh usually contains noises from the background of the object; these must be removed before the model is processed further. To remove the background noises, a mesh editing software is used. A free source software may be MeshLab [12];
- **CNC code generation and manufacturing:** by using Catia V5 solution, the manufacturing technology for the considered object was designed and different types of strategies were discussed depending on the chosen material;

3. CASE STUDY

For the case study, the authors chose as an object for digitization an alabaster statue, which represents a scale replica of Venus of Milo, which was a Greek goddess (Fig. 1). The statue was made by Ifestos firm (www.ifestosart.gr).

First of all, we aimed to identify and compare the best free software possibilities of digitization of a real object by photogrammetry, and we proposed the best one, based on the generated 3D model of the statue. The chosen software's to be studied are some of the most common ones and all three are free: Autodesk 123D Catch, Autodesk ReCap and Autodesk Memento Project.

Fig. 1: Replica statue used for the case study

In order to do that, in the first stage the statue was photographed from several angles all around with a Canon EOS 500D DSLR camera, which had Sigma 17-70 mm f/2.8-4 DC Contemporary lens mounted. After the photo shooting, 50 images were selected to be uploaded on Autodesk's free photogrammetry cloud applications. The reason for selecting this number of images is that Autodesk ReCap is limited to a number of 50 uploaded images. Since we have the same number of photographs, we can study the three different image processing applications (123D Catch, ReCap, Memento).

123D Catch and Memento use a downloadable software in which the photographs can be uploaded and the virtual reconstruction edited after; ReCap uses a web interface instead.

In figure 2 the resulted tridimensional model of the statue in 123D Catch application can be seen. This application also shows where the camera was placed at the moment of the photo shooting.

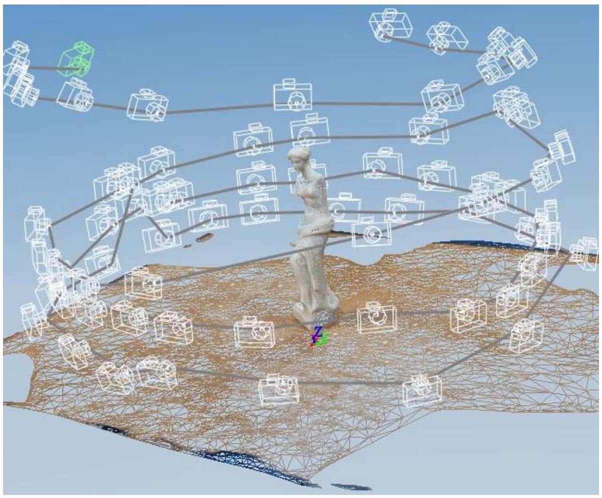

Fig. 2: Resulted 3D model from 123D Catch

Figure 3 ilustrates the resulted 3D model from Autodesk ReCap software.

The resulted 3D model from Autodesk Memento can be seen in figure 4. It is visible that this model has no background noises, unlike the models above. Memento has an option which automatically erases the background noises.

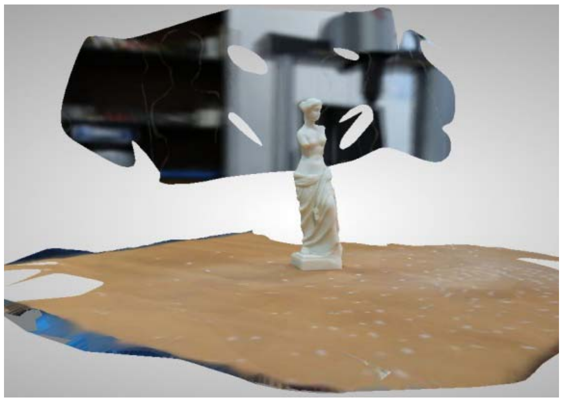

Fig. 3: Resulted 3D model from ReCap

Fig. 4: Resulted 3D model from Memento.

The generated 3D models were imported into a mesh editing software in *.obj format. In this case, the authors used Autodesk 3DS Max aplication. In this software the model is cleared of all unnecessary vertices and it is analyzed. Table 1 presents the number of polygons of the generated 3D models and their size.

Table 1 Comparison of the resulted 3D models

Application	Number of polygons	File size (MB)
123D Catch	17,083	4.92
ReCap	26,234	5.72
Memento	152,574	34.4

Since these models are generated with random dimensions (each model differs in size), the best comparison method is a visual comparison of the level of detail. Figure 5 shows a visual comparison of the resulted 3D models, from left to right: 123D Catch, ReCap, Memento. The level of detail is increasing.

Some differences and informations about the cloud based applications used to generate the 3D models are presented in Table 2.

Table 2 General information about the used cloud based applications.

	Software		
Feature	*123D Catch*	*ReCap*	*Memento*
Maximum pictures that can be uploaded	70	50	Above 70
Processing time	30-45 minutes	30 minutes – 1 hour	1-2 hours
Interface	Stand-alone software with cloud processing	Web-based	Stand-alone software with cloud processing
File format	*.dwg, *.fbx, *.obj	*.obj	*.obj
Automatic background removal	No	No	Yes

a) 123D Catch b) ReCap c) Memento

Fig. 5: Level of detail of the resulted 3D models

After the best variant was selected, the resulted 3D model was exported as an *.stl file, and it was imported in CATIA V5 to create a solid body of the 3D model, on which the CNC code for machining can be generated.

The material of the final statue was intended to be wood, so the manufacturing technology for the statue was made for a BMG 311 VENTURE 316 M 5 axis center machine, equipped with a maximum spindle speed of 24000 rpm and with 10 KW spindle motor power. The technology was also made for plastic material, where we used a Challenger Microcut 2418 milling center, with automatic tool-change capabilities (max number of tools = 16), equipped with a maximum spindle speed of 10000 rpm and with 7.5 KW spindle motor power.

Further on, the manufacturing technology will refer only to the wood version, where the initial work-piece was a wood plate, sized 90mm × 90mm × 340mm. The desired final statue was scaled in Catia so that its final height be about 250 mm.

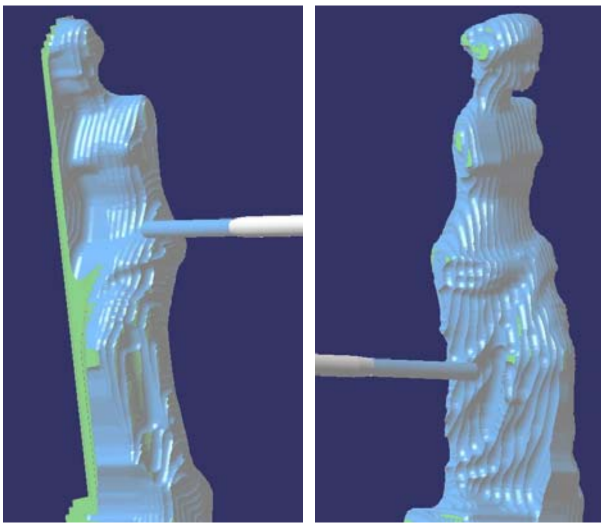

Fig. 6: Roughing simulation in Catia

Figure 6 presents a sequence from the roughing simulation operation in Catia V5R21, and figure 7 illustrates a sequence from the finishing phase, where 5 CNC axes were used simultaneously. The total machining time was approximately 5 hours and 20 minutes with all the tools, parameters and strategies that have been adopted.

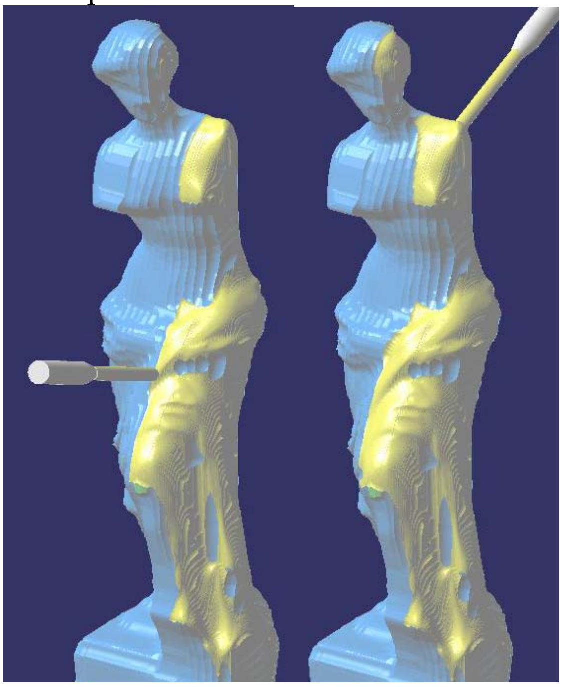

Fig. 7: Finishing simulation in Catia

4. CONCLUSION

Photogrammetry is a viable solution for digitizing abstract objects and can be combined with CNC machining to create affordable reproduction of real objects, provided that the precision of the resulted tridimensional model is not a concern.

The main advantages of photogrammetry may be the use of inexpensive equipment, that is available to all users. This can lead to a 3D model of a real object, whether we speak of ornamental objects or even of restoration of antique furniture components.

The best cloud system for photogrammetry resulted from the case study was Autodesk's Memento, which generated by far the most detailed 3D model of the studied object, with over one hundred fifty thousand number of polygons.

The main disadvantages of photogrammetry are that you cannot create models at their real scale, which result in insufficient precision that in some cases can generate anomalies.

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De la imagini la produs utilizând tehnici de fotogrametrie si prelucrari în 5 axe CNC. Metodologie si studiu de caz in industria mobilei

Rezumat: Această lucrare prezintă o metodologie prin care au fost evidențiate posibilitățile de digitizare a unui obiect real prin fotogrametrie, utilizând softuri dedicate de pe internet, astfel încât pe baza modelului 3D generat, la final să fie posibilă prelucrarea pe maşini unelte CNC a reperului considerat. Nevoia tot mai mare de a digitiza diferite obiecte reale, pentru fabricarea lor în cel mai scurt timp şi la un preț cât mai scăzut posibil, cum ar fi obiectele ornamentale sau diverse componente de mobilă, unde precizia modelului 3D rezultat este mai puțin exigentă, reprezintă premiza acestui studiu. Metodologia propusă de autori constă în următoarele etape: achiziționarea de imagini/poze a obiectului, procesarea lor utilizând software specializat, editarea modelului 3D rezultat, elaborarea tehnologiei de fabricație, generarea programului de comandă numerică şi prelucrarea pe maşini unelte CNC. Un studiu comparativ al pachetelor software gratuite cele mai uzuale, care pot fi utilizate la digitizarea de diferite obiecte şi componente de mobilier a fost realizat, precum şi un studiu de caz detaliat cu metodologia propusă.

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