TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics and Mechanics
Vol. 55, Issue II, 2012

REPLICATION OF AN EXISTING MODEL SHAPE USING LASER SCANNING – A CASE STUDY

Corina-Mihaela MATEI, Ioan BLEBEA

Abstract: *Sometimes designers wish to use exact replicas of specific shape and configuration within their designs. In such reverse engineering situations, it is necessary to scan the existing shape as a first step. Once the shape is scanned, the data is used as input to the CAD/CAM system for generating a necessary tool path in duplicating the shape. This paper describes the requirements to complete the cycle from the original shape to the duplicate shape and illustrates the entire operational process with an actual example.*

Key words: *Reverse Engineering, 3D scanning, point cloud, mesh generation, surface reconstruction, CNC machining*

1. INTRODUCTION

Reverse Engineering is the process of generating a Computer Aided Design (CAD) model from an existing model. It enables the reconstruction of an object by capturing all of the object characteristics such as shape and dimensions.

Reverse engineering is widely used for various reasons.

First of all, in some situations, designers give a shape to their ideas by using clay, plaster, wood, or foam, but a CAD model is needed to enable the manufacturing of the part. Reverse engineering provides a solution to this problem because the physical model is the source of information for the CAD model [1]. Furthermore, how efficient will be for designers to re-create what only nature can provide, through its exquisite biodiversity for which no software have an efficient solution. This technology enables designers to use exact replicas of specific surfaces and configuration within their designs.

Another reason is that of creating replicas for replacement of sculptures and monumental works of art, in open spaces in case their presentation requirements do not allow them to remain in their original place [1].

This paper is only concerned with reverse engineering of a mold shape, in order to obtain an exact model but from a different material than the materials that can be cast.

Reverse Engineering process begins with the acquisition of a point cloud from the surface of an existing model. There are many different methods for acquiring data shape and each of these uses some mechanism or phenomena to collect the information from the existing object surface.

Essentially, two methods [2] can be used: touch-probe or laser scanning.

The touch-probe method is a precision method, mostly used in manufacturing, generally realized with a CMM (Coordinate Measuring Machine).

When comparing laser scanner with touch-probe, the first presents the advantages of high scan speed and can be used to measure surfaces with soft or flexible materials.

The disadvantage of CMM having contact to the surface of an object can damage the object. The reason being is if the surface texture is soft, holes can be inflicted on the surface.

Flexibility of parts makes it very difficult to contact the surface with a touch probe without creating an indentation that detracts from the accuracy of the measurements.

The most used technology to build soft or flexible shapes is laser scanning.

The drawbacks of this system is related with missing data points, namely, where the laser pattern is occluded and erroneous reconstruction data due to potential diffraction resulting from a shiny or mirror object surface.

The purpose of a 3D laser scanner is usually to create a point cloud of geometric samples on the surface of the subject.

Point cloud, lacks topological information and is therefore often processed and modeled into a more usable format such as a triangular faced mesh, a set of surfaces or a CAD model.

The basic steps for a computer aided engineering process are [3]:

1) data acquisition;
2) data processing; and
3) creating useful CAD model.

2. CASE STUDY

2.1 Scanning preparation

The object under study is a mold for casting gypsum forms, plaster, modeling paste, wax or soap (fig. 1, a). To avoid any possible errors in data acquisition because of the mold`s shiny and white surface, the mold exerior surface was coated with a matte spray to prevent unexpected reflection of the laser beam.

For the data acquisition, Kreon Zephyr KZ 50 laser scanner, mounted on an articulated arm, Romer Stinger II, is used.

The scanner was installed in a controlled environment. The whole measuring system was calibrated by scanning a calibration ball from several viewpoints.

The mold is positioned so that the measuring arm can include it in the scanner's field of movement, resulting thus a correct scanning.

2.2 Acquisition of raw point cloud

All captured geometry data was transferred to display to Polygonia software, for real time monitoring, editing and saving under different files format.

The saving procedure is necessary in order to make the transitions from the scanning software to model reconstruction system software to be transformed in a conceptual model supported by a triangular surface geometry or by a CAD surfaces.

2.3 Application of CATIA Reverse engineering tools

CATIA Reverse engineering tools aim to convert the raw point cloud into a digital model with desired accuracy and detail. CATIA V5 Shape workbenches were used to transform the point cloud into a mesh of triangles and to generate surfaces from a triangle mesh.

The computer aided reverse engineering process done for our object is shown in fig.1 and involves the basic three steps presented in introduction.

The captured data was imported in CATIA V5 Digitized Editor workbench for processing.

The initial point cloud contained a great deal of noise and redundancy produces by the laser scanning technology. This results in enormous data size. For easier mesh generation (triangulation of points) unnecessary points were removed or filter out without losing the original shape. The refined point cloud (fig. 1, b) is used to generate the mesh thought

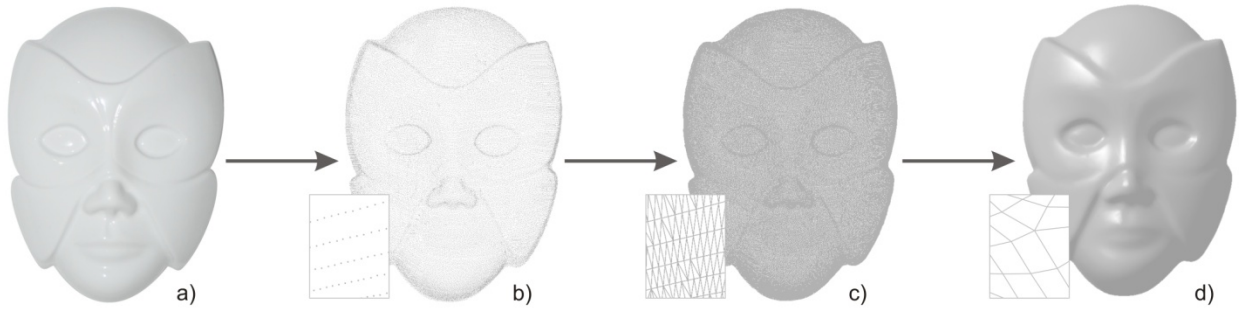

Figure 1. Physical to digital process:
a) physical object, b) point cloud, c) triangular mesh and d) CAD surface model

triangulation of points. Mesh generation is an automated process of connecting the closest three points to form a triangle [4]. Problems may occur in the generated mesh due to irregularities in the imported data, such as non-manifold vertices and edges redundant and acutely angled triangles, triangles with inconsistent orientation, etc. Similar to the point cloud, the mesh needs to be clean-up and refined. The work done to remediate these problems on the mesh was one of cleaning the

defects, filling the holes and smoothing the mesh. Smoothing the mesh aims to improve the quality and accuracy of the reconstructed surface.

The obtained clean and smooth mesh (fig. 1, c) is transformed in a CAD surface model (fig. 1, d) in CATIA Quick Surface Reconstruction workbench - Automatic Surface.

2.4 Machining (CAM – Computer Aided Manufacturing)

CATIA Surface Machining workbench is used in order to generate the NC program files for 3-axis CNC Milling of the mask virtual model.

For the machining operation it is necessary to build the material stock for the mask model.

The machining technology for this model has the following successive operations:

- Roughing operation – to remove as much stock material as quickly as possible to reveal a stepped form (fig. 2, b);
- Sweeping operation – to remove the stock material left on from the roughing;
- Sweeping operation with opposite tool path direction – to achieve a smoother, more accurate surface finish (fig. 2 c).

For all operations it is necessary to specify the geometric elements that enter in operations definitions and the tool path strategies.

When setting up a project for CNC milling it is of crucial importance to relate setting in the digital file to the physical setup of the CNC machine. Aspect such as the dimension of the material, position and tools properties need to correspond to the setting in CATIA Machining.

A special attention is placed upon the setting of the machining parameters for all operations. Setting them in a correct way is important to ensure good results. These parameters are generally selected from machining handbooks, experience, tool tables etc. Good results can only be achieved with well-balanced settings of these parameters according to cutting tool for each operation and workpiece material.

For each operation a material removal simulation can be performed. The simulation makes it easier to visualize the exact tool path and to evaluate finished surface quality, allowing a fast and easy problem identification and change opportunity.

Generate the operation file is the final step that translates the generated tool paths into a correct format file understood by the CNC machine controller. Because the Fawoo 700 S CNC machine doesn't have a tool changer, the tool paths for a series of cutter can be put into one large file, or in separate files for each tool.

A modelboard material (chemiwood) is use for machining the mask shape replica. It is a solid resin based material with no grain, with excellent machine processability that can replace the wooden materials.

The machined result - replica of the mask shape is shown in figure 2, d).

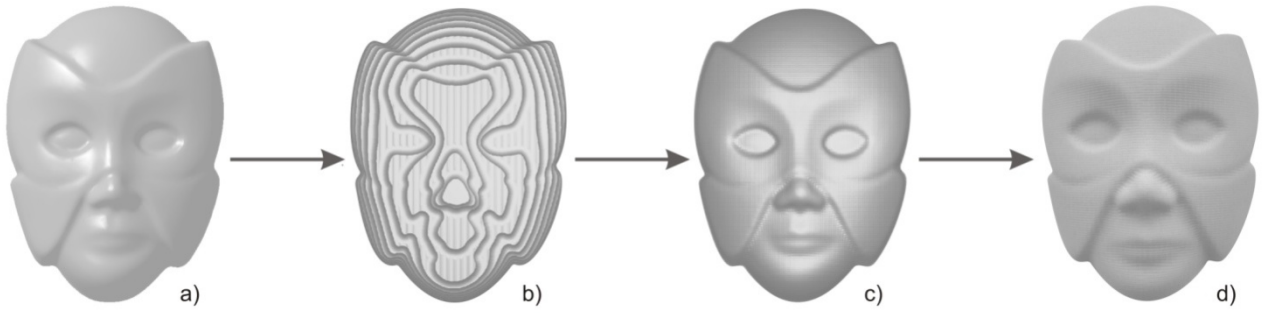

Figure 2. Digital to physical process:
a) CAD surface model, b) roughing operation, c) finish operation and d) replica of the mask

3. ACKNOWLEDGEMENT

This paper was supported by the project "Doctoral studies in engineering sciences for developing the knowledge based society-SIDOC" contract no. POSDRU/88/1.5/S/60078, project co-funded from European Social Fund through Sectorial Operational Program Human Resources 2007-2013.

4. CONCLUSION

The methodology presented in this paper consist in 3D scanning of a shape, processing of the scanned result by reverse engineering and obtain a digital model for conducting to its manufacturing. This methodology can be successfully applied in the design process, especially for objects with organic shapes for which designing in CAD may be challenging or impossible.

5. REFERENCES

[1] G. Tucci, V. Bonora, *Application of high resolution scanning systems for virtual mould and replicas of sculptural works,* XXI International CIPA Symposium, 01-06 October 2007, Athens, Greece

[2] C. Relvas, A. Ramos, A. Completo and J. A. Simões, *Accuracy Control of Complex Surfaces in Reverse Engineering,* International Journal of Precision Engineering and Manufacturing, vol. 6, No. 6, 2011

[3] C. Bradley, B. Currie, *Advances in the Field of Reverse Engineering,* Computer Aided Design and Applications, 2(5), 2005

[4] K. Soni, D. Chen and T. Lerch, *Parametrization of prismatic shapes and reconstruction of free form shapes in reverse engineering,* International Journal of Precision Engineering and Manufacturing, 2009

REPLICAREA UNEI FORME EXISTENTE UTILIZÂND SCANAREA LASER – UN STUDIU DE CAZ

Rezumat: Uneori designerii doresc să utilizeze în proiectele lor replici exacte ale unei forme specifice sau configurații. În astfel de situații de ingineria reversibilă, primul pas, este acela de a scana forma existentă. O dată ce forma este scanată, datele sunt folosite ca date de intrare pentru sistemul CAD/CAM pentru generarea traseului sculei necesar în replicarea formei. Acest articol descrie cerințele pentru a finaliza ciclul complet de la forma originală la forma replicată şi ilustrează întregul proces operațional cu un exemplu real.

Corina-Mihaela Matei, PhD, Student Dipl. Eng, Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, e-mail: Corina.Matei@muri.utcluj.ro.com, Office phone: 0264-401664.

Ioan Blebea, Prof. Dr. Dipl. Eng, Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, e-mail: blebea@muri.utcluj.ro.com, Office phone: 0264-401664.