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The Reverse Engineering of a Spring Support using the Noomeo Optinum 3D Scanner and the Rapidform XOR3 Software

The paper presents an application of the Reverse Engineering technology using a Noomeo Optinum 3D scanner to read the complex shape of the spring support and generate the geometry in a computer file that can be processed by Computer Aided Design software. Rapidform XOR software was used to convert the scanned data into a solid model.

Keywords: *Reverse Engineering, 3D Scanner, spring, Rapidform XOR3*

1. Introduction

Reverse Engineering is the technology to reproduce numerically a physical object, by 3D scanning. After scanning result one or more "point clouds" composed by three-dimensional coordinates, which, by means of specific applications, can be transformed into a polygonal network (mesh) and then in NURBS surfaces [1] or solids. Finally a file that can be processed by CAD software, will be obtain. Equipment performing the scan is called generic 3D scanner. Reverse Engineering process must be used for the following reasons [2]:
- the original manufacturer no longer exists;
- the original product has became obsolete;
- the original design documentation is missing;
- inspection of the product compared with CAD data;
- reverse engineering of the objects for FEM calculus [3].

2. The description of the 3D Scanner

The Noomeo Optinum 3D Scanner (www.noomeo.eu), figure 1, is a portable scanner that connects to the acquisition system via USB 2.0 with autonomy offered

by the battery included in the configuration. The scanner uses technology "Vision based self positioning", the point cloud acquisition is performed by successive multiple photographic images, through a CCD sensor with resolution 1024x768 pixels, which can take up to 500,000 points/image.

The scanner dimensions are 230 mm x 230 mm x 80 mm and the weight is less than 2 kg. The volume of the scanned objects fall in 10 $cm^3 \div 1m^3$, the minimum purchase size is 1 cm.

Noomeo Optinum scanner technology combines structured light, which allows instant capture of the geometry through the deformation analysis of repetitive light projected onto the object, with 2D image processing, leading to the scanner position to the object concerned and capture its texture. Thus, by 2D image processing, the autoposition is calculated, which eliminates the need for markers and the light flow provides additional information for taking geometry as a cloud of points.

Technical characteristics of the scanner are: accuracy +/- 100 mm, spatial resolution 300 mm, the acquisition distance 400 mm, A4 FOV (field of view - the extension of observable space at a time), 150 mm DOF (depth of field - distance the objects closest to and farthest from a scene that clearly appear acceptable in an image). The recommended acquisition system configuration is: CPU Core i7 Quad, 8 GB RAM, NVIDIA FX3800 with 1GB memory OS: Win 7 64bits. The scanner system does not require preparation of items scanned, their installation in a reference system or reference markers.

The scanner comes with dedicated NumiSoft software, which conducts the whole process of acquisition and 3D model reconstruction of the cloud of points. Also, the NumiSoft include the driver communicating with the hardware and algorithms for point cloud processing: alignment of 3D cloud of points, automatic 3D model reconstruction, cleaning capabilities of the points, sharp edges refining, optimization point, export cloud points and XYZ ASCII format, compared with STL-CAD geometry at points level, strategy alignment type for the geometry and/or texture.

Figure 1. The Noomeo Optinum 3D Scanner

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3. The Reverse Engineering Process

According with [2] "*Engineering is the process of designing, manufacturing, assembling, and maintaining products and systems. The process of duplicating an existing part, subassembly or product, without drawings, documentation, or a computer model is known as Reverse Engineering. Reverse Engineering is also defined as the process of obtaining a geometric CAD model from 3-D points acquired by scanning/digitizing existing parts/products.*"

The Reverse Engineering process consists of:

- **scanning phase**: three-dimensional scanners are used to scan the part geometry, producing clouds of points, which define the surface geometry; 3D scanners can operate with or without contact;

- **point processing phase**: this phase involves importing the point cloud data, reducing the noise in the data collected and reducing the number of points; the output of the point processing phase is a clean, merged, point cloud data set in the most convenient representation;

- **generate geometric model**: the goal of this phase is to generate CAD models from previous representation; the generation of CAD models from point data is probably the most complex activity within Reverse Engineering because complex surface fitting algorithms are required to generate surfaces that accurately represent the three-dimensional information described within the point cloud data sets.

4. Software for generate the geometric model

Some commercial software that is able to generate geometric models are:

- Geomagic Wrap software (www.geomagic.com) is a software tool for the cloud point transforming of the scan result into a 3D polygonal network (mesh), which can be used in the design, analysis and manufacturing. Geomagic Wrap can process large data sets, collected from different types of scanners, provides opportunities to optimize the scanned data (using remove outliers, reduce noise and other available tools), align and merge multiple scan data sets, create polygon mesh from point cloud data, automatically detect and correct errors in the polygon mesh, detect and create features in the model, repair and sharpen boundary edges, 3D model export in different formats: STL, OBJ, VRML1/2, DXF, PLY and 3DS.

- RAPIDFORM XOR3 software (www.rapidform.com) is an "Reverse Engineering" application that combines CAD with 3D scan data processing, to create parametric, editable solid models of virtually anything scan data sets. Because RAPIDFORM XOR3 is based on Parasolid kernel, it can generate history-based CAD models with feature trees and export the geometry into the SolidWorks, Pro/E, AutoCAD, CATIA and others native format. The steps to generate geometric model in Rapidform XOR3 software are [4], figure 2:
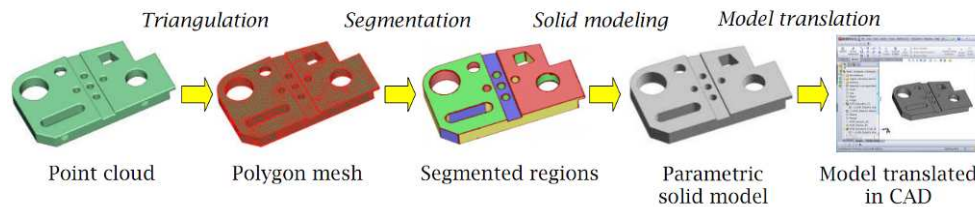
Figure 2. The steps to generate geometric model in Rapidform XOR3 software

- Rapidform Explorer software (www.rapidform.com) is a "free" application that allows the user to view the 3D models and specific files generated by scanners, in 40 formats, enables measurement of geometry and generate reports. The software can open files Rapidform native files (xrl, xdl, mdl), which include entity type: points cloud, polygon mesh, curves, surfaces, solids, notes, annotations, reference geometry, tolerances, scan-to-CAD comparison plots. There are tools for measuring distances, angles, sections, areas, volumes and deviations of 3D mesh and for reports in PowerPoint, Excel, PDF or TXT.

- GOM-Inspect software (www.gom.com) is a "free" application for inspection and processing of the 3D polygonal mesh, analysis of dimensional data sets of cloud-point type. Capabilities of the application: import of CAD models (IGES, STEP, etc.) and points cloud scanned data (STL, ASCII), alignment (automatic, 3-2-1, best-fit), mesh processing (mesh generation, filling holes, mesh refinement, extraction curve, export STL, ASCII), CAD comparisons (surfaces, section, points), CAD primitives generation (lines, planes, circles, cylinders, cones, etc.), 3D and 2D analysis inspection tools (dimensions, angles, diameters), report (tables, images, PDF) and export data.

The mathematic theory and computational algorithms for triangulation have been well developed in the past few decades. A polygon mesh can be automatically and efficiently created for a given set of data points. The fundamental concept in triangulation is Delaunay triangulation. One of the most important steps in shape engineering is mesh segmentation. Segmentation groups the original data points or mesh into subsets each of which logically belongs to a single primitive surface.

Solid modelling is the least developed in the overall shape engineering process. Boundary representation (B-rep) and feature-based are the two basic representations for solid models. There have been some methods proposed to automatically construct B-rep models from point clouds or triangular mesh. A B-rep model can then be created by stitching together the faces, edges, and vertices; this operation is commonly supported by most solid modelling kernels. B-rep models are not feature-based. In order to convert a B-rep model into a feature-based solid model, the embedded solid features must be recognized, and a feature tree that describes the sequence of feature creation must be created.

The Rapidform XOR3 software can operate in the followings workflows:

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- **Scan-to-Mesh** - for archiving, animation, measurement, 3D printing and other polygon-based applications, Rapidform XOR includes a full suite of mesh processing tools. With the Mesh Buildup Wizard™, it is possible to go through the entire scan alignment merging and mesh optimization processes. Steps: Mesh Optimization, Mesh Modelling, Export.

- **Scan-to-Surfaces** - Rapidform XOR also supports NURBS surface fitting, which is useful for creating an identical copy of scan data that does not need editing. Steps: Mesh Optimization, NURBS Surfacing, Export.

- **Scan-to-CAD** - to make a CAD model suitable for manufacturing, Rapidform XOR employs a straightforward workflow that parallels today's well-known solid modelling processes. Instead of modelling from scratch, Rapidform XOR's feature wizards and other automated tools help to build the features directly from 3D scan data. Steps: Mesh Optimization, Solid Modelling, Export.

5. The spring support geometry

The spring support geometry is shown in figure 3. From a 3D scanning point of view, the difficulty of this part is given by its thin thickness and the complex surfaces of the umbrella.


Figure 3. The spring support geometry

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6. The Reverse Engineering of the spring support

The following steps are required to obtain the final CAD file of the spring support:

- scanning of the geometry with the Noomeo Optinum 3D Scanner; to obtain a great level of accuracy 35 point clouds and 7.437.988 points are acquired by the scanner, figure 4;

- reduction of the noise in the collected data and of the number of points with NumiSoft software;

- creation of the one merged point cloud with NumiSoft software;

- exportation of the merged cloud into a XYZ ASCII file;

- importation of the the the XYZ ASCII file in Rapidform XOR3 software, figure 5;

- creation of the mesh representation in Rapidform XOR3 software, figure 6;

- creation of the mesh sections in Rapidform XOR3 software, figure 7;

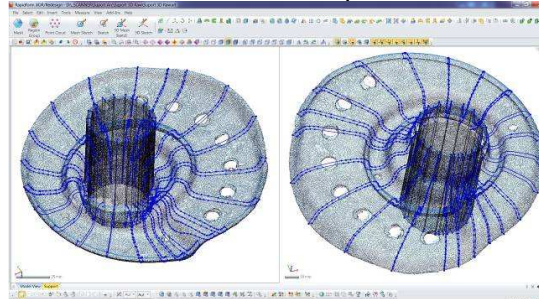- creation of the solid geometry in Rapidform XOR3 software, figure 8.
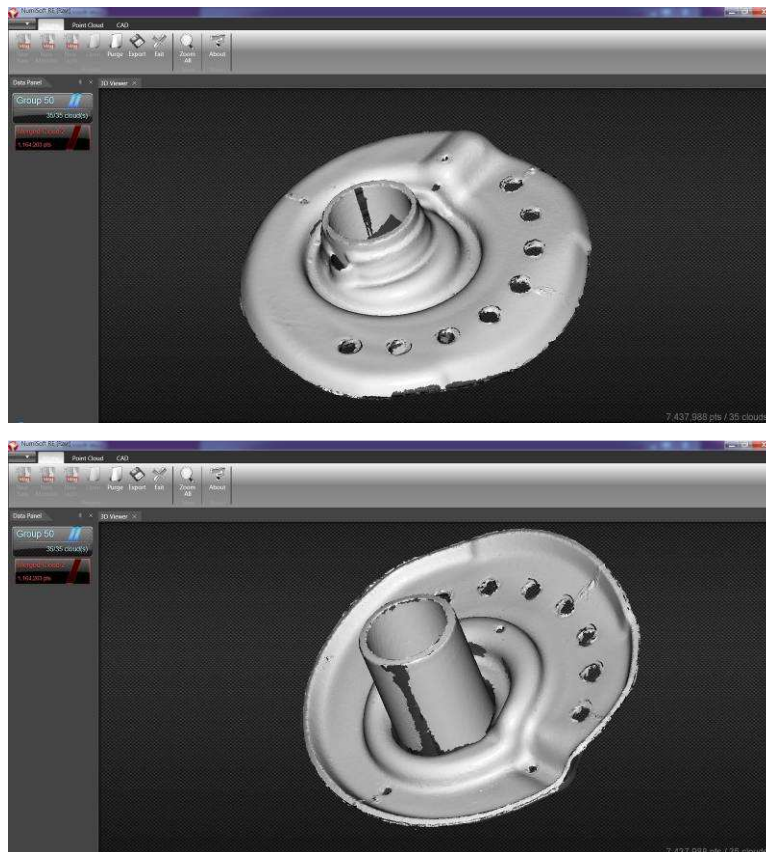
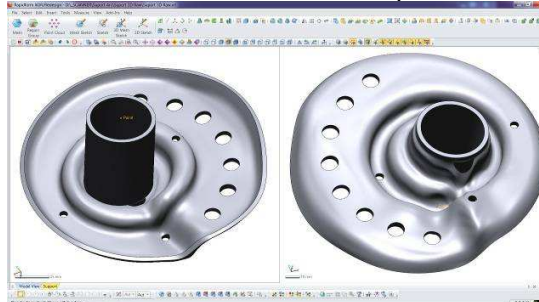**Figure 4.** 35 x Point Clouds scanned with Noomeo Scanner
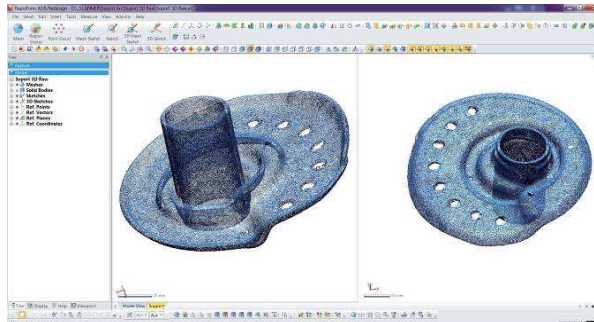
Figure 5. Merged Point Cloud loaded in the Rapidform XOR3 software
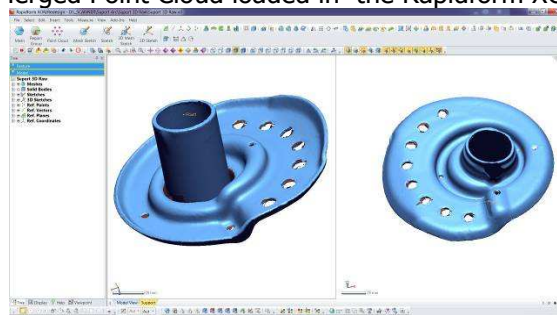
Figure 6. Mesh created in the Rapidform XOR3 software

Figure 7. Mesh sections created in the Rapidform XOR3 software

Figure 8. Spring geometry recreated as solid in the Rapidform XOR3 software

5. Conclusion

The Reverse Engineering Technology was used to recreate the spring support geometry using the Noomeo Optinum 3D Scanner and the Rapidform XOR3 software. Some general considerations about the Reverse Engineering process and commercial software that is able to generate geometric models from scan data are presented, with an accent on the Rapidform XOR3 software.

References

[1] Yongmin Zhong, *Processing of 3D Unstructured Measurement Data for Reverse Engineering*. 42 International Journal of Intelligent Mechatronics and Robotics, 1(2), 42-51, April-June 2011.
[2] Vinesh Raja, Kiran J. Fernandes, *Reverse Engineering. An Industrial Perspective*. Springer-Verlag, London, 2008.
[3] Cernescu A., Bortun C., Faur N., *Reverse Engineering and FEM Analysis for Mechanical Strength Evaluation of Complete Dentures: A Case Study.*, InTech Publishing, Croatia, 2012.
[4] Kuang-Hua Chang, Chienchih Chen, *3D Shape Engineering and Design Parameterization*, Computer-Aided Design & Applications, 8(5), 2011, 681-692.

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