A Reverse Engineering method for 3d parametric modeling of geometries based on processing of laser scanning data and a sweep technique

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Abstract. A Reverse Engineering (RE) method for parametric modelling is presented in this paper. According to this method laser scanning data are processed by means of an algorithm and a parametric geometry is produced. The algorithm generates a spline used as a driving curve for a 2D profile, both approximated from the point cloud data, with the final geometry being produced through with a sweep based technique. The method was applied to digitize a commercial product, a bottle, and the geometry was reconstructed at high accuracy and surface quality. Finally the results of the proposed method were compared with auto surfacing from *.stl files and with surfaces generated by means of sweep commands without converting curves to splines.

1. Introduction

For decades reverse engineering methods have been used for direct and accurate geometry reconstruction, without contacting the real object. Reverse engineering is suitable for remodeling objects with complicated geometry e.g. archaeological objects (1) or biomedical applications (2,3,4). In this circumstances the obtained point cloud could, after smoothing and local operations processes, produce surface geometry with high accuracy.

The instant remodeling method of reverse engineering is also very useful for geometry reconstruction of specimens used in industry or industrial design consumer products. The electronic file in these circumstances could be used for mold creation (5) and G code generation or for better design optimization as well as changing product dimensions. Changes in dimensions length and smooth surfaces are great advances or surface representation with parametric modeling.

On the other hand modeling of a real part in a parametric CAD software like Autodesk Inventor, SolidWorks, Creo parametric, could be a complicated and time consuming processes. In some cases is necessary for the user to have expert knowledge of advanced CAD modeling techniques like sweep, loft or boundary. Moreover even if the user has the appropriate knowledge it is likely that he will have to try many of these techniques in order to find the most appropriate one.

Finally point cloud processing software’s produce small surfaces with non-uniform area curvature and continuity with local inaccuracies, when auto generating surfaces. Such surface generation are not...
suitable for applications such as G code production. The more suitable process of converting areas of point cloud to planar or b spline surfaces, requires surface modeling techniques with trimming and knitting functions, in order to produce the final object. This is in some circumstances not accurately enough done automatically, as shown in the present paper.

All the aforementioned reasons necessitate parametric modeling of object surface with automatic functions able to circumvent these problems, especially for applications involving industrial use.

In this paper an automatic method is presented for parametric generation of object surface through laser scanning data. The processes is based on an algorithm which converts point cloud data to a sweep based feature when the application has the suitable form.

2. Proposed method
According to the proposed method, employing data derived from a laser scanner, two 2D curves are produced. A 2D profile and a guide curve. The algorithm approaches the 2D profile with an ellipse and the guide curve with a spline curve.

Initially a plane is defined where the 2D profile will be produced and the ellipse’s axis is modelled based on the min and max distances of the points in this area. The ellipse adjusts to the length of the two axes driven by the guide curve.

The guide curve represents a spline approximation with a max. of four polynomial points, a start point an endpoint and if necessary, two polynomial points in between to maintain a simple formulation of the curve. A point on the major axis of ellipse is considered as the start point for guide curve generation, whereas the endpoint of the spline is projected in the far opposite area of the scanned object. The shape of the spline is generated and controlled from the algorithm described in previous papers (6,7) and verified in papers (8,9). The accuracy of the sketch profile and guide curve are controlled from distance measurements of point cloud and curves.

Once the curves are imported into a parametric CAD Software, a Sweep function is used to generate the desired surface.

3. Application of the proposed method
The proposed method was applied to a commercial bottle shown in Figure 1. This product, modelled in a parametric CAD software with sweep based techniques, represents a characteristic example of geometries for which the proposed method could provide accurate results.

Figure 1. Specimen.
The specimen was measured by a laser scanner. The result of the measurement, after an automated smoothing processes, is shown in figure 2. The proposed method produced two 2D curves, an ellipse and a spline, which are shown in figure 3 in relation to the point cloud.

In a following step, the ellipse, curve and point cloud were imported into a parametric CAD software and a surface was generated with sweep based technique. In figure 4 the resulting surface and zebra strips are shown. The shape of strips are optimized to geometry smoothness and continuity.

Finally the distance deviation between point cloud and surface was measured and is shown in figure 6. The overage deviation is less than 0,03mm and the maximum is below 0,1mm.

![Figure 2](image2.png)  **Figure 2.** Polygons.

![Figure 3](image3.png)  **Figure 3.** Spline (in red) and ellipse (in blue) used to generate the final surface.

![Figure 4](image4.png)  **Figure 4.** Sweep surface resulting from the proposed method.

![Figure 5](image5.png)  **Figure 5.** Zebra strips of the generating surface.
Figure 6. The overage deviation is less than 0.04 mm

To provide a reference to the above technique, the object’s surface was also created with an automated process provided by the point cloud processing software. The produced surface is shown in figure 7 and the corresponding zebra strips in figure 8. It is obvious that the surface is not smooth enough.

Figure 7. auto creation surface  Figure 8. Zebra stripes of the auto creation surface.

The third method used to generate the surface, was based on a guide curve, produced within the point cloud processing software, through the projection of points in a reference plane. The produced curve consist of small line segments. The geometry of the object for the final method is produced once again with a sweep technique, as shown in figure 9, whereas the corresponding zebra strips are demonstrated in figure 10. In this case, similar to the one above, the produced zebra strips are not satisfactory.
4. Conclusions
In this paper a method for reverse engineering an object with parametric surface characteristics is presented. More specifically, any industrial type specimens or consumer products can be reconstructed with sweep based techniques. The proposed method automatically extracts a 2D sketch profile of ellipse and a spline curve (used as a guiding profile for the sweep function) consisting of a maximum of four polynomial points to maintain a simple formulation at a smooth enough representation. The final geometry is produced instantly and in easily, without the need of experienced user involvement or any manual intervention (e.g. curve design). The final geometry is superimposed onto the initial point cloud data and the overage deviation was below 0.04mm. Moreover the geometry of the specimen is produced with two alternative methods and compared to the aforementioned one. An auto surface creation inside the point cloud processing software and a method where the guide curve was produced by projecting points onto a reference plane. The Zebra strips are investigated and the results of the proposed methodology compared favorably to the latter two scenarios.

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