

CONVERTING 3D POINT CLOUDS TO PLANAR SHAPED SOLIDS

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Abstract: 3D point clouds can be easily turned to meshed surfaces or solids, but still they have to be processed to be useable as 3D models for Reverse Engineering. A main drawback of such a conversion is that the file the part is saved to is very big, even if the shape is in fact a simple one. Finding in the point cloud planar shapes, which could be converted to primitives, is very useful. The paper presents an algorithm and some pieces of software designed in VisualLISP for AutoCAD that aid user in converting point clouds in solid primitives if the original shape of the part allows that.

Key words: Reverse engineering, 3D scan, Points cloud, Planar shaped parts, Surface fitting, CAD/CAM.

1. INTRODUCTION

Reverse Engineering (RE), one of the most innovative techniques in engineering, is usually used to reconstruct a damaged object, or to redesign one. A specific feature of RE is that although the material object exists, there is no available technical documentation for it. The main problem of RE is gathering the data that reconstructing the 3D model of the part to be based on. Among the methods to gather input data for part reconstructing process, 3D scanning is the most important one.

The main drawback of 3D scanning is it's (still) low precision. That is even the dimensional precision is usually accurate enough, the shape precision is most times unsatisfactory. Even very simple shapes, the regular ones, like planes, boxes or rotational shapes are rather poorly copied by 3D scanning: the point cloud, the output of 3D scanning, contains many points that deviate significantly from the original shape.

Even if the dedicated software can convert accurately point clouds to meshed surfaces or solids, this is not the best solution. That is because the accuracy of the conversion reveals a good similarity between the mesh and the point cloud, but not always between the point cloud and the original shape. That is why a tool that aids the engineer to find geometrical primitives that best fit to the original shape of the part is a must.

The present paper presents a way to identify the planar shapes that fit acceptable to the original shape in order to replace (at least partially) the point cloud. So, the problem is to find the description by any means of the plane(s) that can be used to build solid primitives that replicates the original shape of the part.

2. PREVIOUS APPROACHES

The most previous approaches of the problem point to large objects, namely, buildings (Peternella & Steinerb 2004). The two main features of the solving already proposed are:

- Data used are from airborne laser scanner data;
- Precision required for such purposes is not very high.

To reconstruct the shape of the body (usually a roof) some further data are required: the plan of the building (Vosselman & Dijkman 2001), or specific methods are used – statistical method (Huang H., et al. 2011). Some works present the way the primitives can be merged to get the final output (Huang 2011).

Processing primitives resulted from point cloud, in terms of removing the internal common faces is discussed in (Liu et al. 2011).

Geometrical and technological features of the part are used as well as input data to reconstruct the 3D model (Thompson et al., 1999).

3. SOLVING THE PROBLEM

In order to reconstruct the 3D model of the part using the point cloud, an original method was developed. It operates in AutoCAD, and the engineer's work is aided by several pieces of software which solve some different stages of the process.

In few words, the method consists of making some steps: separate the planar sector of the point cloud and insulate each of the planar faces, in order to process it. Processing the insulated face is done by whittling the point cloud until it becomes precise enough. After the unacceptable deviated points are removed, the median plane of the point cloud can be used as the theoretical surface of the scanned body. At this point the

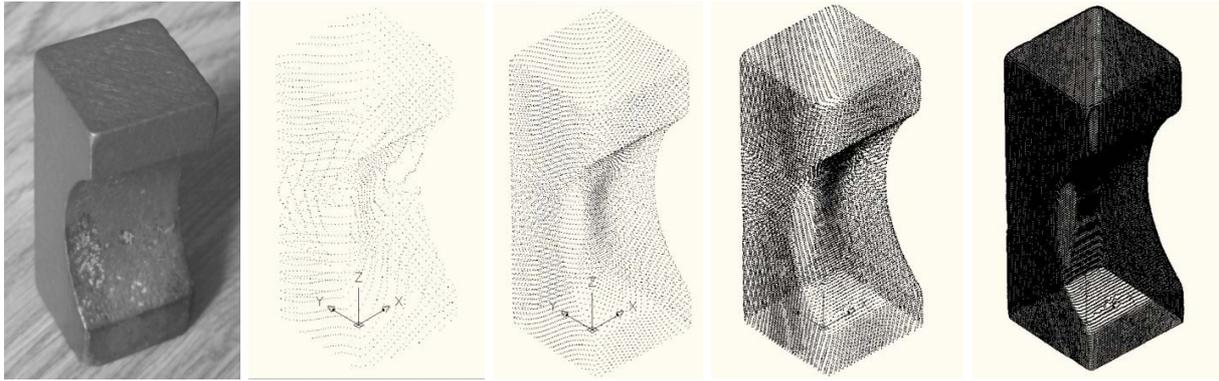


Fig.1. The part and the point cloud in for presentation (point densities)

plane can be mathematically described for later usage.

When all the sectors of the point cloud corresponding to the planar faces of the scanned part are processed, the data required to reconstruct the plan faceted primitives are available.

3.1 The part and the point cloud

The part processed is presented in Fig. 1. The point cloud is shown in four point densities, controlled by the piece of software used to import the STL file in AutoCAD.

Conversion of the STL file to an AutoCAD drawing was performed using a piece of software that reads line by line the STL file, cuts out from each line the strings corresponding to X, Y and Z coordinate and converts these strings to numbers used to build point entities in the drawing.

The four samples show the point cloud in 1%, 5%, 10% and 100% of the total number of points.

Apart studies revealed that the point density is not relevant for the accuracy of part reconstructing process by means of primitives in the case of study on planar faceted parts.

The density of 10% was considered to be appropriate for the study, both in terms of visualization and of handling the point cloud.

To ease the process of finding the plane corresponding to a face of the part, if necessary, the whole point cloud may be rotated, so the

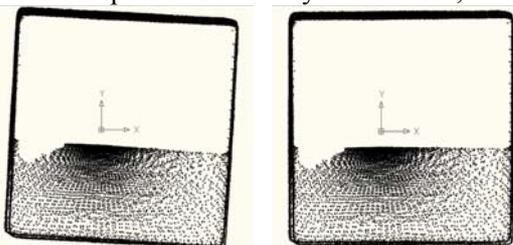


Fig.2. Aligning the point cloud to the UCS

studied face to come parallel to one of the UCS planes. Rotation is easier performed in a plan view. This is shown in Fig. 2 (before and after rotation).

3.2 Processing a face of the part

In order to get the parameters that describe the primitive to reconstruct the part, depending on the complexity of it, some faces should separately be processed. Since the studied part is a box shaped one, processing three faces perpendicular to each other might be enough. If more accuracy is wanted, the more faces processed, the better the results are.

Processing a face consists first of insulating the sector of point cloud it is represented by. This can be done either by removing the rest of point cloud, or better, create a copy of the wanted sector to a separate layer.

The face of the part is represented by – let us say – a point *film* instead of point *cloud*. The thinner the film, the better approximation of the face is. First, the thickness of the film has to be computed, and then must be found the median of the film. The median is the imaginary plane that divides longitudinally the film into to equal parts, having each the same thickness. This imaginative plane is the theoretic side of the primitive that models the scanned part.

3.3 Finding the median of the point film

Take into consideration the sample of a point film parallel to ZX plane of the UCS. The Y coordinate of every point is examined, and the minimum and maximum values are stored. Their difference is the thickness of the point film, and their mean value is (at least for now) the Y coordinate of the median ZX plane.

Since the number of points that deviate from the median on its two sides is not balanced, the position of the median must be refined. That is done by removing the points placed in a certain

depth (20% of the thickness of the film) on the

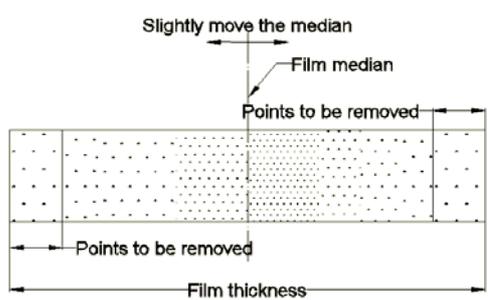


Fig.3. Finding the median of the point film (cross section through the point film–sketch)

two sides of the film, as depicted in Fig. 3. Afterwards, the correct position of the median is checked: the number of points from one and the other side of the median must be balanced. If it is not, the median is slightly moved along the thickness of the film towards its most populated with points side. The process is iteratively performed, until the wanted balance is achieved. Another way to find Y coordinate of the median ZX plane is to average the Y coordinate of all points in the cloud film.

At this stage, either store the coordinate of the median plane of the point cloud, or select three nearest points to the median in order to define mathematically the plane. For parts that have not the faces perpendicular to each other, solving the problem is a little more complicated. In such case the UCS should be aligned successively to each face, determine the median plane of the point film, and then transfer the wanted coordinates from the current UCS to WCS.

After process all the needed sectors of the point cloud (a sector for each face of the scanned body) the model of the part can be reconstructed.

3.4 Reconstructing the 3D model of the scanned part

Depending on the shape of the part to be reconstructed, two paths can be followed to do the job:

- A box shaped part can be directly built as a primitive using two opposite corners. Their coordinates are taken from the appropriate median planes of the point films.
- For any other type of planar faceted part, the 3D model can be reconstructed from a large enough rough box. It should be sliced by the median planes of each sector of the point cloud. Of course, to/from such bodies can be added/subtracted other primitives; finding rotational patterns in point clouds has been approached by the author in another research

(Drăgoi, & Navalusic 2013 - publishing in progress).

The main steps of the algorithm here presented have been modeled in some pieces of software developed in VisualLISP. However, the main decisions have to be taken by the user, so the process is not yet fully automated. Since the means to align a planar sector of point cloud to UCS and to check the correctness of such an alignment are not very precise, the user’s intervention is compulsory.

4. CASE STUDY

To check the validity of the algorithm and of the new developed software, several parts have been scanned and their point clouds processed.

For the part in Fig 1, the result of reconstruction is presented in Fig. 4: the 3D model along with the points that remained outside the solid.

The output was good, inside the solid being 26179 points of the total of 51475 (remember, the sample point cloud for this study case has only 10% of the total points gathered by scanning). 50.8% and 48.2% of the points are inside and respectively outside the solid, that means the model is correct positioned related to the point scan. Another good indicator is that the points remained outside the 3D model are relatively uniform distributed around the solid: the 3D model is both correct sized and well aligned related to the point cloud.

The precision of the method is satisfactory: the dimensions of the 3D model deviate from the real ones with 0.21 ... 0.32 mm.

Replacing a point cloud with geometrical primitives brings many advantages. One of those refers to the size of files that store in fact the same data, but in different formats. The sizes of files that store the point clouds in the four versions mentioned at paragraph 3.1 are presented in table 1.

Table 1. File sizes

File	1%	5%	10%	100%
Size [MB]	104	448	1326	8000

The size of DWG file that stores only the reconstructed 3D part is 62 KB, while that of the STL file generated by the 3D scanner is 81121 KB. That is the file size decreases more than 1000 times when saving the 3D model instead of storing the same data as an STL file.

Related to the size of the file that stores the full point cloud, the 3D model file size is almost 130

times smaller. The 3D model file size is even smaller than that of the file containing only 1% of the original point cloud.

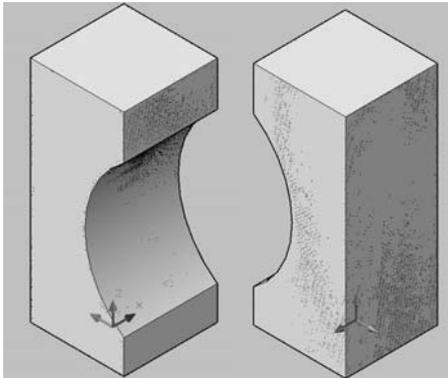


Fig.4. The output of part reconstruction

The density of the points in the cloud is not relevant for the accuracy of part reconstruction. Anyway a too crowded point cloud is slow processed and is hard to be handled. In the case of planar sectors of a point cloud, more points do not bring more pieces of information, as happens in the case of complex surfaces with many details.

5. CONCLUDING REMARKS

The novelty of the method is that it works with optimized sectors of the point cloud. Each sector corresponds to a planar face of the part. The optimization consists of removing a thin film at the both sides of the sector of point cloud. In this manner, the most deviated points from the theoretic shape are eliminated. The thickness of this optimized film can be selected by the user. The median plan of the remained film can be moved inner or outer in order to find the best fit to the real part.

All the main operations are performed by means of some pieces of software. These tools are not yet integrated in order to give the user the liberty to make choices and decisions. Furthermore, some tasks cannot be fully automated, e.g. aligning the film to the UCS or vice versa.

The new method to reconstruct plan faceted parts has a main advantage – it gives the user the chance to use primitives instead point clouds, with many subsequent benefits: easier handling the object, the ability to edit it, smaller files.

The big disadvantages of the method are that the process is slow, and it is not yet fully automated. In fact, a balance between the user's freedom to

make decisions, and the fastness of the process has yet to be found.

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