Title:
Surface detection and CAD modeling of Arbitrary Cloud of Points from 3D sketching

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Introduction:

This work aims to advance 3D-sketching-to-production capabilities. Multiple methodologies and tools exist to sketch products at their conceptual phase, amongst them CAD systems, and various 3D virtual sketching capabilities, which have emerged in recent years. However, there still exists a significant knowledge gap in transferring these initial sketches for detailed design or realizing products based on these abstract sketches. In this work an algorithm is proposed which contributes to closing this gap.

A designer may use 3D sketching as a tool in the early stages of a project, but the technology does not yet allow the user to directly bring their sketches to reality. Whether a part is to be machined or 3D printed, it is generally represented as a 3D model prior to manufacturing. We developed a solution for converting 3D Cloud of Points (COP), created by an augmented reality 3D sketching system, into an explicit 3D model – incorporating as much design intent as possible. While several algorithms exist that convert COP created by a 3D scanner to a 3D model, the challenges of converting a 3D sketch output has yet to be addressed.

Unlike the 3D sketcher, modern 3D scanners sample points from the objects envelope, largely providing an ordered COP. In the 3D sketching process, the user sketches the object in space, and not necessarily only draw the external surface of the desired object, rather, they might fill the object with internal points. However, there is no indication of whether the points lie within the body, outside the body or on the surface. The main challenge is therefore, to construct a 3D model from an unordered COP that include not only points from the envelope but internal and external (noise) points as well.

Much research has been done regarding mesh reconstruction from an unorganized COP, where the points are created from a scanner. For example, Schnabel, Wahl and Klein [8] and Kyriazis, Fudos and Palios [5] and Woo, Kang, Wang, and Lee [10] propose an algorithm using the octree-based 3D grid method to handle large amounts of unordered sets of points data. One of the existing methods to extract the surface points in a 3D COP where the points do not necessarily lie on the surface is the Alpha Shapes algorithm [1,2]. Edelsbrunner and Mucke [3] derived the use of alpha-shapes to isolate the boundary points in a COP and reconstruct the shape of the object.

Solution Approach:
The Immersive Freehand 3D Sketching on Air in Full Body Scale [9] 3D sketching system was used. The system uses a number of Vicon Cameras, set up around the room, which can capture the motion of reflective markers on the head and hand of the user (see figure 2). As depicted in the figure: A: The Room, B: Vicon Camera, C: VR glasses with reflective markers and D: Hand Glove with reflective markers. The output from the system is a COP in Cartesian coordinates. For the purpose of this project, only sample COP were taken which fit within the scope of a single body, with no holes (genus 0).

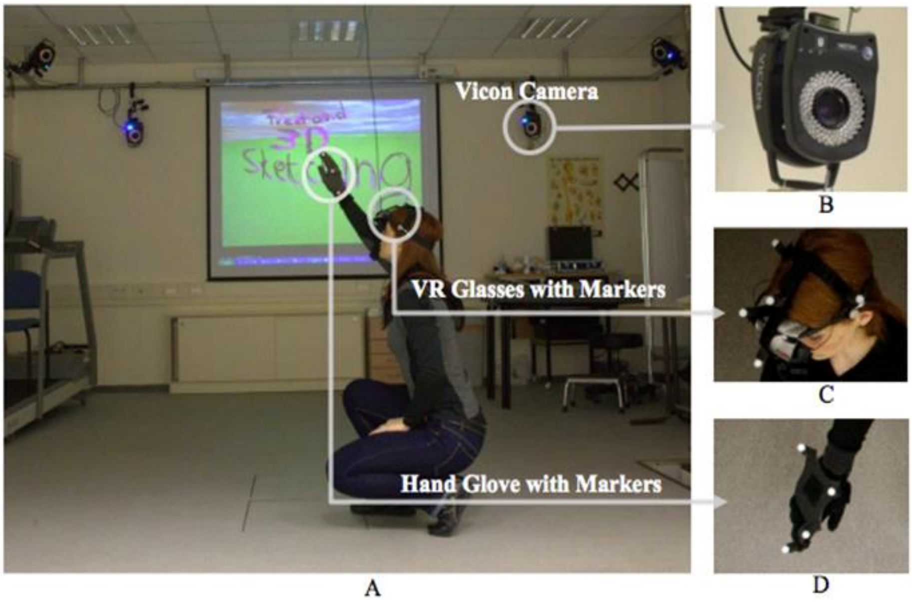

Fig. 1: 3D sketching system.

As part of our solution approach, the surface points were isolated from the COP by using and investigating two approaches: octree representation [4] and alpha shapes [3].
Figure 2 describes the breakdown of the algorithm we named Slice and Loft, into stages. At each stage, research was done to determine the best way to accomplish the task. The stages are broken down into categories by color: yellow is COP pre-processing, blue is data processing resulting in locating the edge points, pink is reconstructing the 3D model, and green is post-processing to improve model precision.

The input is a set of non-ordered points in space. The points can sit anywhere within the body (using K-means [7]), or on the surface. There is no predetermined surface defining the shape of the body.
The method begins (blue) by slicing the COP and projecting the points within a slice onto a plane. Then, it uses the 2D alpha shapes algorithm to extract the edge points. From there, a smooth spline curve through the edge points is created on each slice plane [6]. Finally, a loft is produced from the resulting curves. The algorithm successfully converts a 3D COP into an explicit 3D model.

Results:
The results of the methodology were tested in a number of manners.
Quantification: A method was developed in order to quantify the results. For the COP which were generated, the initial desired body was used as the goal surface. The error was measured as the normal distance, *d*, between the resulting surface and the goal surface. Positive and negative errors represent points lying outside and inside the desired surface respectively.

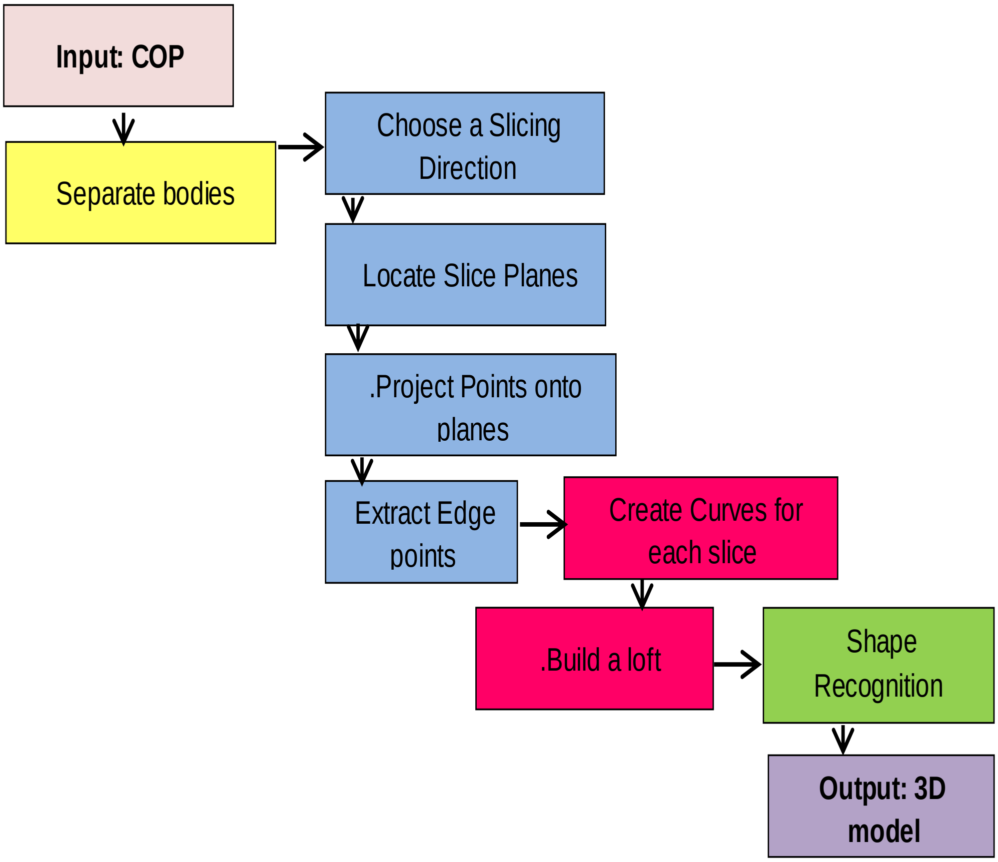

Fig. 2: Block Diagram of the solution process.

Check for distortion: The algorithm was tested on a set of data that does lie on the surface of a known shape, similar to scanned objects. COP were generated where all the points lie on the surface of a basic shape, and the slice and loft algorithm was applied. In this manner, it is possible to quantify the distortion caused by the slice and loft algorithm.

Comparison to 3D Alpha Shapes method: Two COP were generated in order to compare the results to those obtained using alpha shapes The first is a planar body in the form of a three dimensional L Shape. The second is a curved body, made of 3 overlapping spheres of different sizes. The Slice and Loft algorithm, and the alpha shapes algorithm, were applied to each COP 3 times, each with a different probe radius. Our results were, that the overall shape is preserved much better using the Slice and Loft algorithm, especially comparing the methods at a larger probe radius. (results not shown here)
Figure 3 is an example of the Slice and Loft algorithm which successfully constructed a 3D model from the COP. The loft effectively transitioned between the circular and rectangular slices. 2D shape recognition techniques were then manually applied to the slice curves, and the loft re-created.

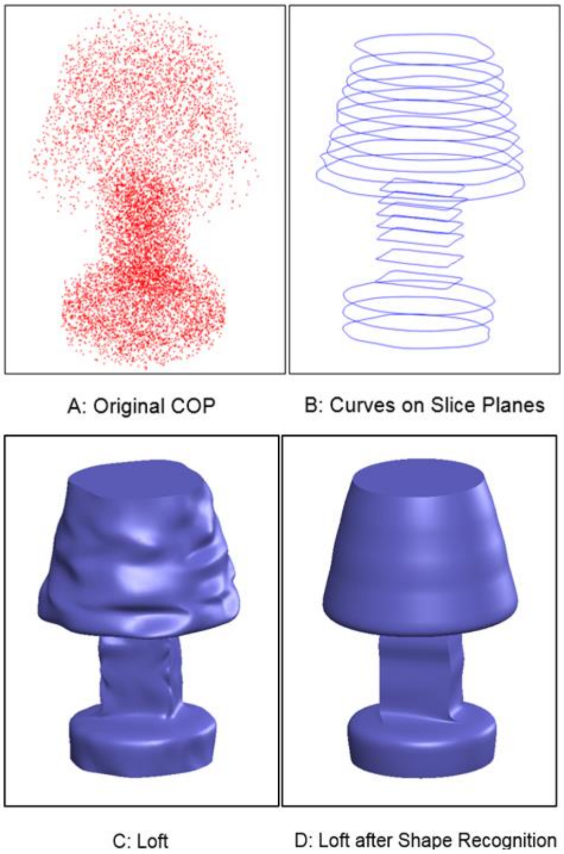

Fig. 3: Lamp Shade Example.

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