Title:
Improving Medial Surfaces for Reverse Engineering

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Introduction:
The goal of this research is to compute CAD models of thin-plate objects (like automobile bodies, plastic injection mold components, sheet metals or welded parts etc.) from their CT images by using medial axes. Medial axis (medial surface in 3D) is a shape descriptor of the solid models by the center-line of the object [1]. The medial axis has various applications including shape animation, shape analysis and so on. Created CAD models of "real objects" are useful in reverse engineering applications including product quality control and shortening development time. It will also be helpful in dimensional reduction, reducing computational complexity in finite element analysis, and other analyses and simulations.

We can find several work on medial axis transform (MAT) in 2D and 3D images [1, 5], however these approaches have two issues for the applications to reverse engineering. First issue is the medial axis is shrunk at the end point. Second issue is that dents appear at the junctions. These problems are due to the definition of the medial axis and they should be resolved for reverse engineering applications. For CAD models, mid-surface [4, 6, 7] introduced to resolve these issues, however it is difficult to apply them to the polygonal meshes from CT images.

This paper presents a method for improving medial surfaces created from CT images for reverse engineering applications. Our goal is to create mid-surfaces from CT scanned mechanical objects. Our method is based on medial surface extraction scheme proposed by Michikawa and Suzuki [3], and apply some optimization methods including: Extension of shrunk medial surface and Removal of dent at junctions.

Methods:
Our method consists of two optimization methods: extension of the medial surfaces and dent removal. Extension step is applied to the binary volume data, and the dent removal method is applied to the medial surface polygons. In their computation, we combined with the medial surface computation method proposed by Michikawa and Suzuki [3]. Note that the proposed method can be combined with other medial surface extraction schemes.

Extension of medial surface is achieved by introducing spherical virtual voxels to the endpoints (Fig. 1). We first compute medial voxels by the method proposed by [5] (Fig. 1(b)). We next apply clustering surface voxels by types of the closest medial voxel (the endpoint or others) as shown in Fig.1 (c). Segmented surface voxels are labelled by connected components and we apply region growing on surface voxels and the endpoint on the surface voxels are found (black dots in Fig. 1 (d)). Once the endpoints are found, we add spherical volumetric voxels to the points (Fig. 1 (e)) and the extended medial surface is obtained by applying medial voxel extraction method to the updated voxels (Fig. 1(f)).

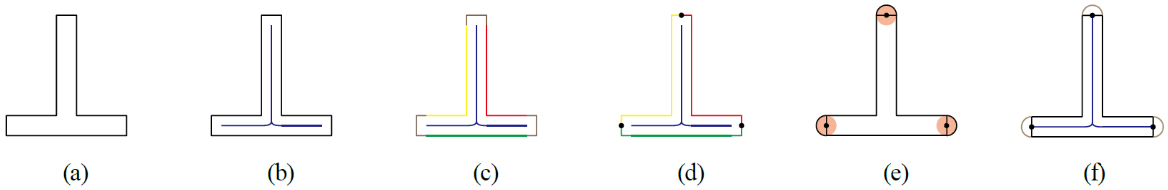

Fig. 1: An overview of extension of medial surface (2D example).

Dent removal is achieved by updating the positions of the junction points. Basic idea is to update the points so that they are projected on the planes neighboring to the points (Fig. 2). $\hat{\mathbf{x}}_i$, the new position of the vertex $\mathbf{x}_i$ can be computed by minimizing quadric error-based function inspired by QEM-based simplification [2] as shown in Equation (1) :

$$E(\hat{\mathbf{x}}_i) = \sum_j \langle \mathbf{n}_{i,j}, \hat{\mathbf{x}}_i - \mathbf{p}_{i,j} \rangle^2 + \|\mathbf{x}_i - \hat{\mathbf{x}}_i\|^2, \tag{1}$$

where $\mathbf{n}_i$ and $\mathbf{p}_i$ denote the normal vectors of the neighboring triangles and points in the triangle respectively.

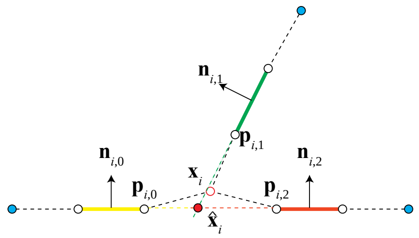

Fig. 2: Removing dents at the junctions.

Results:

An experimental result (240x240x140 voxels, 7,461 faces) is shown in Fig. 3. Computational time of the example is 1,190 seconds on a desktop PC with 3.0GHz CPU. The main bottleneck of this is computing medial voxels twice.

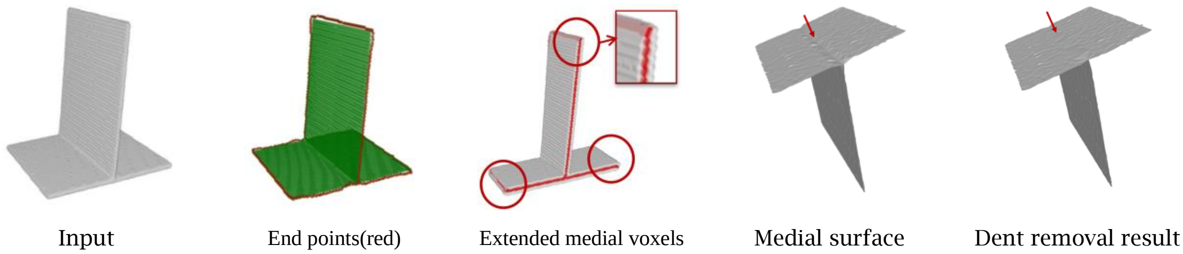

Fig. 3: Some results of the method presented.

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