Skeleton extraction by point cloud contraction

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1 Introduction

Curve-skeleton is a kind of high-level representation of complex shapes. It benefits lost of applications, such as virtual navigation, shape understanding and shape registration. Most of curve skeleton extraction algorithms depend on a voxelization, which may lead to loss of details and numerical instability. Only a few literatures are devoted to handle the problem directly. The design of a simple and robust algorithm remains a research challenge, because of the absence of the connectivity information.

We present a simple and robust algorithm to tackle the problem: given a generous noisy point cloud model even with moderate portion of data missing, our method automatically compute a good quality curve-skeleton preserving the original topology. The algorithm is similar to [Au et al. 2008] as it performs two successive operations: implicit Laplacian contraction and topological thinning, shown in Fig.1. The main challenge is to achieve this using fewer robust parameters with noise, missing data and without connectivity information. We illustrate how the extracted skeleton can be used to animate the point cloud directly, without needing to perform high quality mesh reconstruction or creating a deformation cage. We show how to perform a fast, topology aware hole-filling and we show many other skeleton based applications like consistent segmentation and retrieval.

2 Method Overview

Given a point cloud model, we first smooth and contract it iteratively by minimizing an energy balanced by two terms: a contraction term based on Laplacian operator and an attraction term using the points as anchors. The main challenge of this contraction is the choice of the discrete Laplacian-Beltrami Operator (LBO), which is not an issue for mesh model. The choice dramatically affects whether the contraction will result in a zero volume skeletal shape as well as the number of iterations required. There are many ways to define Laplacian operator on point cloud, such as [Floater and Reimers 2001; Belkin et al. 2009; Luo et al. 2009]. After various tests, we finally chose to alter one approach defined in [Floater and Reimers 2001]. For each point, we triangulate the projections of its K-nearest neighbors (KNN) in the tangent plane, then construct a Laplacian operator using the 1-ring neighbors of the local Delaunay triangulation with the famous cotangent weights. This, combined with updated contraction and attraction weights in each step, leads to great contraction in only a few iterations (usually four iterations in most of our tests). Furthermore, the KNN solves the non-uniform sampling problem in some degree (the right two of Fig.2). Our algorithm also is capable of handling of generous noisy, since the contraction process iteratively solves a global equation (the left two of Fig.2).

To convert the contracted point cloud into a 1D curve-skeleton, we sub-sample the contracted skeletal cloud using furthest-sample and a ball of radius R. Two sub-samples will be connected by an edge (red in Fig.1-c) if and only if they are associated with a pair of surface samples which belong to the same 1-ring. The set of edges so created is then topologically thinned using the approach in [Li et al. 2001], which performs edge-collapses until no triangles exist, resulting in locally 1D graph. The process preserves genus in most of our tests, and may introduce additional genus such as near the hand of the Neptune in the middle column of Fig.3.

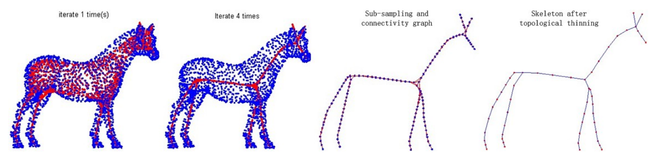

Figure 1: *Pipeline*

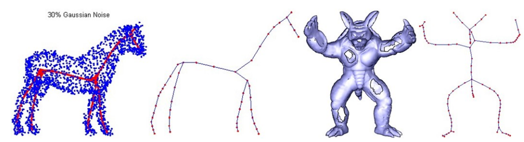

Figure 2: *Our method is noise insensitive and can deal with moderate missing data.*

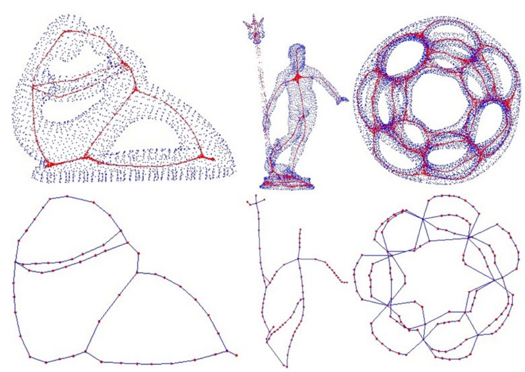

Figure 3: *Our method is almost genus preserved.*

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[1] We are planing to implement applications mentioned above, especially animation.

[2] More results about segmentation can be find in a supplement.