Qualitative and Quantitative Comparison of Curve and Surface Skeletons – A State of the Art Review

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Introduction

- Skeletons are well-known shape descriptors.
- Applications in: shape matching, recognition, animation, etc.
- We compare sixteen skeleton methods against quality and quantitave criteria.
- Results reveal several interesting, unknown differences of the methods considered.

Methods

We had 12 skeleton methods compared, where those are mesh and voxel skeletons in curve and surface skeletons.
Mesh curve-skeletons:

Au *et al* (AU) : O. Au, C. Tai, H. Chu, D. Cohen-Or, and T. Lee, *Skeleton extraction by mesh contraction*, In Proc. ACM SIGGRAPH, pages 44:1-44:10, 2008.

Tagliasacchi *et al* (ROSA) : A. Tagliasacchi, H. Zhang, and D. Cohen-Or. *Curve skeleton extraction from incomplete point clouds*, ACM TOG, 28(3):71:1-71:9, 2009.

Cao et al *et al* (CAO) : J. CAO, A. Tagliasacchi, M. Olson, H. Zhang, and Z. Su, *Point Cloud skeletons via laplacian based contraction*, In Proc. SMI, pages 187-197, 2010.

Telea and Jalba (TJ) : A. Telea. and A. Jalba, *Computing curve skeletons from medial surfaces of 3D shapes*, In Proc. TPCG, pages 137-145, 2012.

Au *et al* improved (AUI) : We improved the re-centering step of this method.

Au *et al* using surface skeletons (AUS) : We start the Laplacian contraction from the surface skeleton, which is closer to the final curve skeleton than the input mesh.

Voxel curve and surface skeleton:

IMA : Hesselink W, Roerdink J. *Euclidean skeletons of digital image and volume data in linear time by the integer medial axis transform* IEEE TPAMI 2008;30(12):2204–17.

MS : Reniers D, van Wijk JJ, Telea A. *Computing multiscale skeletons of genus 0 objects using a global importance measure* IEEE TVCG 2008;14(2):355–68.

HJ : Siddiqi K, Bouix S, Tannenbaum A, Zucker S. *Hamilton-Jacobi skeletons* IJCV 2002;48(3):215–31.

DDS : Arcelli C, di Baja GS, Serino L. *Distance-driven skeletonization in voxel images* IEEE TPAMI 2011;33(4):709–20.

TV : Palagyi K, Kuba A. *Directional 3D thinning using 8 subiterations* In: Proc. DGCI; vol. 1568. Springer LNCS; 1999, p. 325–36.

RT : Liu L, Chambers E, Letscher D, Ju T. *A simple and robust thinning algorithm on cell complexes* CGF 2010;29(7):2253–60.

Comparison

3D shape skeletons are useful in many fields such as shape representation, shape matching and animation. Both curve and surface skeletons can be extracted by a variety of methods that work on either polygonal mesh or voxel representations. However, the latest extensive comparison of such methods dates from 2007 [1].

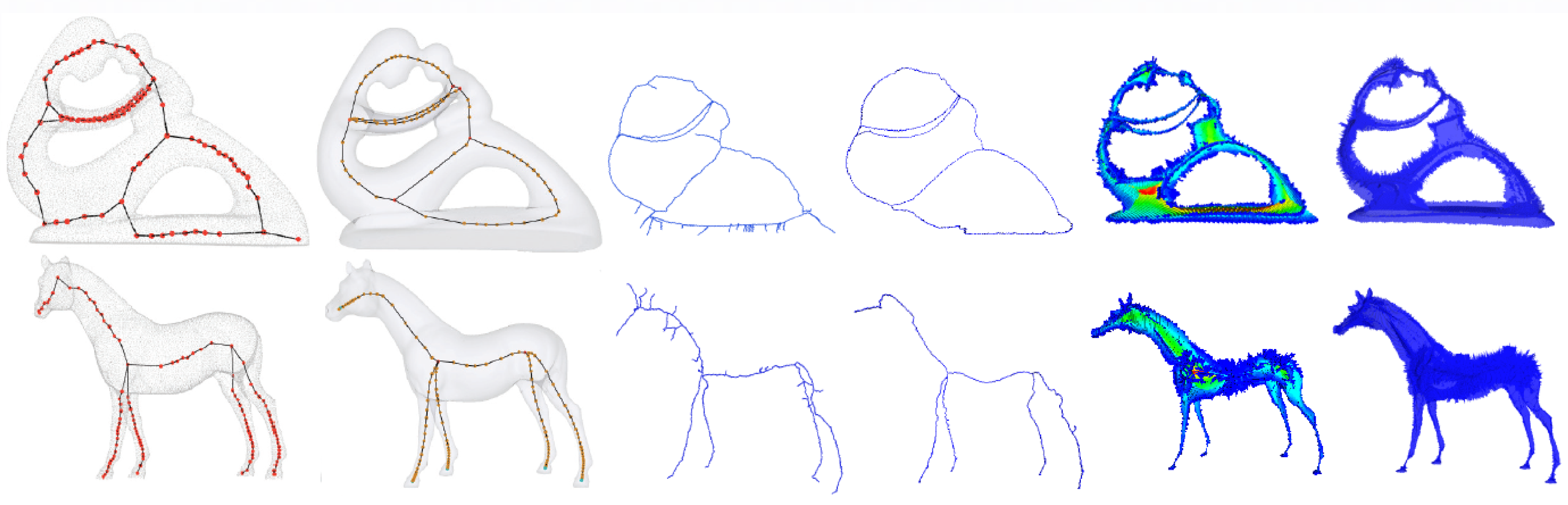

Figure 1: *Centerdeness.*

In this work, we compare six mesh-based curve-skeletonization methods and ten voxel-based curve- and surface-skeletonization methods along criteria proposed in [2]: homotopy, invariance, thinness, centeredness, smoothness, detail preservation, and resolution robustness. Most tested methods were not included in [2]. Besides this qualitative comparison, we also propose a quantitative comparison based on the Haussdorff distance. Thereby, we extend our earlier work [1] which compared only mesh-based curve skeletonization methods qualitatively. All methods were tested on the same platform, for input volume resolutions ranging from 128^3 to 1000^3 voxels, and mesh resolutions from 10K to 500K faces respectively.

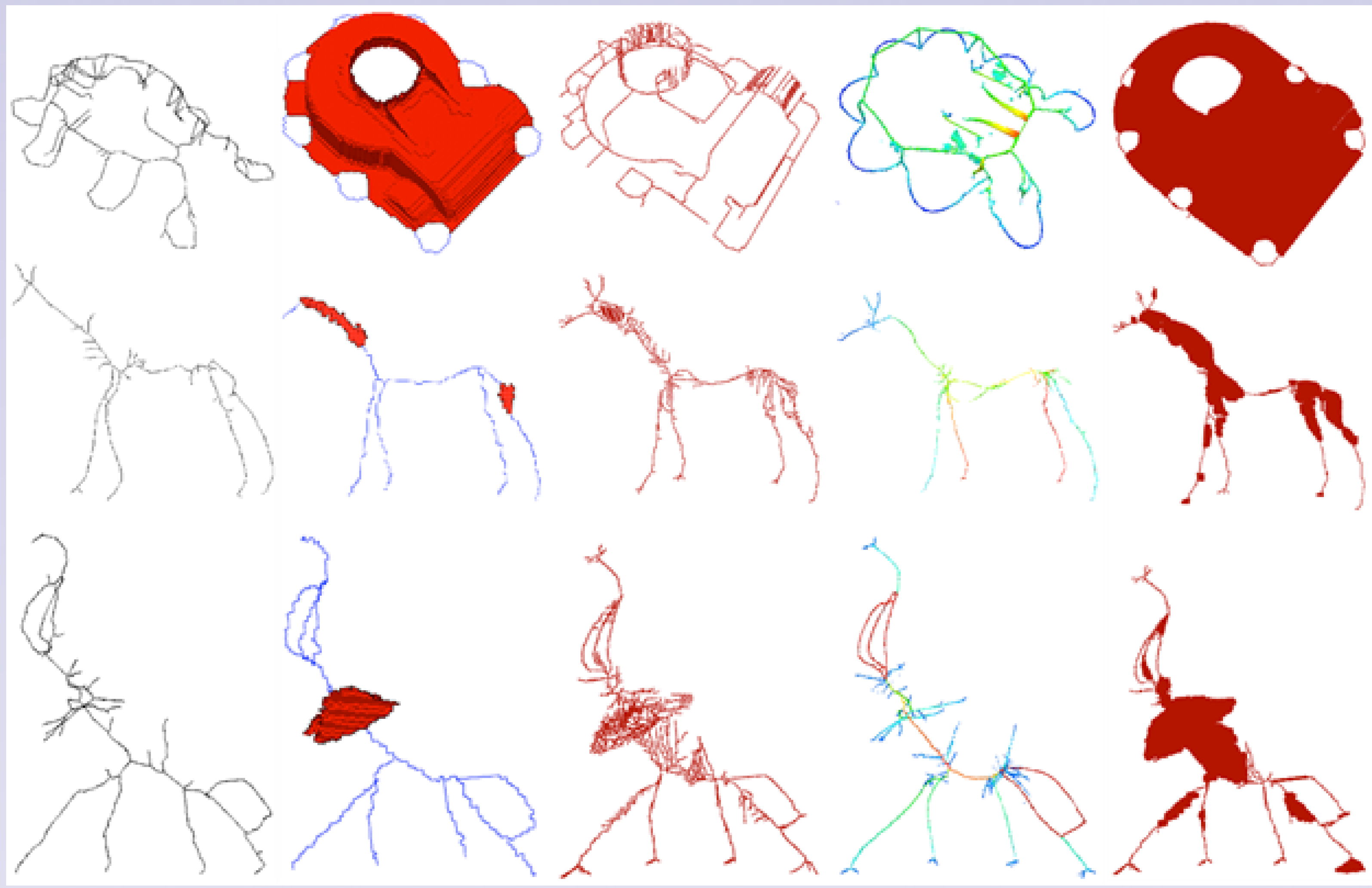

Figure 2: *Different skeletons.*

Figures 1 and 2 show a selection of our results. These show that, despite recent advances in the field, the fundamental robustness problem of skeletons is still open. Also, different methods produce significantly different skeletons from the same input. Both these observations apply to curve and surface, as well as to mesh-based and voxel-based skeletonization methods. This supports the claim that further fundamental and applied research is needed in the skeletonization field.

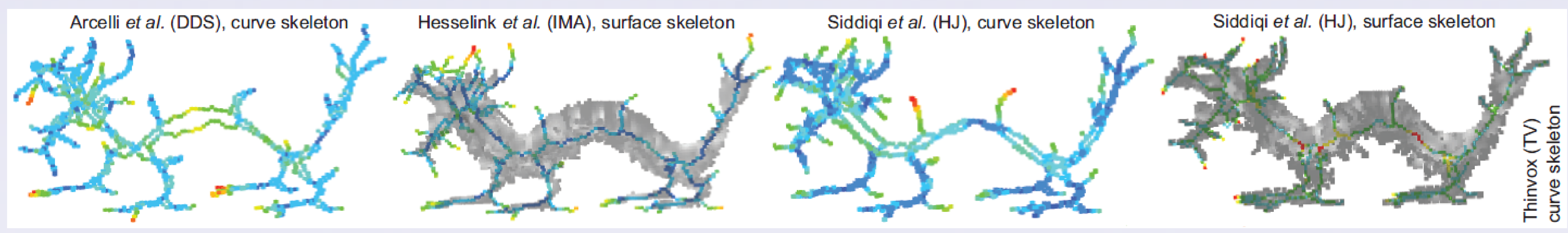

Figure 3: *Quantitative.*

Figure 3 shows Euclidiean differences between those skeleton methods. We had compared curve against curve-skeleton, curve- against surface-skeleton and surface- against surface-skeleton only in voxel dataset. In the Figure 4, we play some simplification levels for to test the noise robustness. Some methods keeps similar and some others loses information.

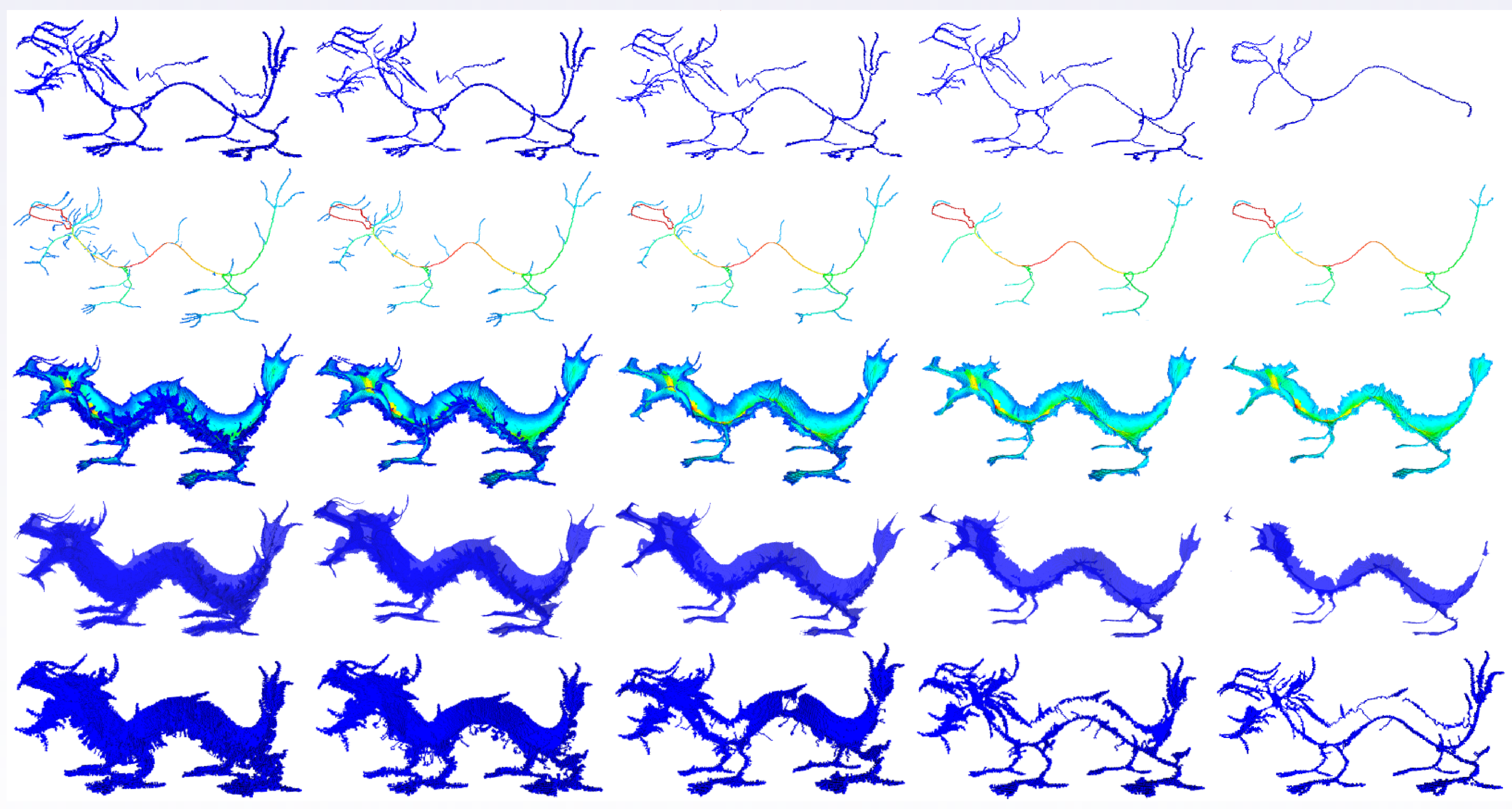

Figure 4: *Noise robustness.*

Conclusion

- We have presented a qualitative and quantitative comparison of curve and surface skeletonization methods that use a mesh and a voxel representation.
- The methods were compared from the perspective of several accepted quality criteria: homotopy, thinness, centeredness, detail preservation, smoothness, robustness to sampling.
- Skeleton methods behaves different between them, mesh methods are faster and voxel takes more details.
- There is no clear best skeletonization method. All studied methods have limitations. Further work is thus needed to design optimal skeletonization methods for real-world applications.

References

[1] N. Cornea, D. Silver, P. Min, *Curve-skeleton properties, applications, and algorithms* IEEE TVCG 2007;13(3):87–95.

[2] A. Sobiecki, H.C. Yasan, A.C. Jalba, A.C. Telea, *Qualitative Comparison of Contraction-based Curve Skeletonization Methods*, In Proc. ISMM, pages 425-439, Springer LNCS 7883, 2013.

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