# Interactive Volumetric Segmentation through Least-Squares Optimization of Local Hessian-constrained Implicits

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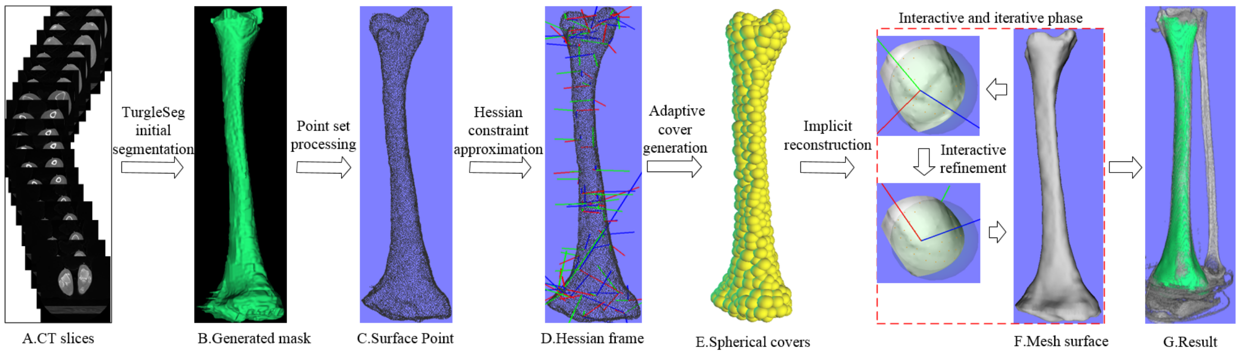


**Figure 1:** *Flow chart of our method. (A) Original CT slices. (B) The segmentation mask generated by TurtleSeg. (C) The extracted surface points. (D) The Hessian frames. (E) Spherical covers. (F) The reconstructed mesh surface. (G) The finally-segmented mesh surface, which is visualized via hybrid rendering together with original volume data.*

## 1 Motivation

A great number of volumetric datasets have been routinely acquired everyday and their qualities are varying tremendously, without proper processing they could not be directly utilized. Specifically, volumetric segmentation plays a vital role in many downstream applications, including geometric modeling, scientific visualization, and medical diagnosis. So far, many volume segmentation methods have been proposed, Top et al. [2011] designed an interactive segmentation tool by interactively contouring on some sparse slices and Ijiri et al. [2013] developed a system to extract contours and evaluate the scalar field in spatial domain.

This paper systematically advocates a novel framework for volumetric image segmentation by way of iteratively optimizing local implicit surfaces with Hessian constraints based on least squares fitting. The key idea lies at the incorporation of contour based interactive segmentation into the generalized least squares Radial Basis Function (RBF) based local implicit surface reconstruction.

## 2 Our Approach

Our interactive volumetric image segmentation framework aims to provide a way for users to edit the intermediately-segmented surface by adjusting the eigen-system of Hessian matrix. Fig.1 shows the pipeline of our method. Given original volumetric image slices (Fig.1A), we use the TurtleSeg software to generate a rough segmentation mask (Fig.1B), which can help improve the accuracy compared with other interactive image segmentation methods. Since the mask is just a rough segmentation result, it may contain errors. To edit the point set (Fig.1C) which is extracted based on the mask at the volumetric resolution via intuitive interaction, we resort to placing contours on the cross-sections locally, which is simple and does not require much expert knowledge.

Due to the jagged boundaries, we apply the Weighted Locally Optimal Projection (WLOP) operator to handle noises and outliers, and employ an existing method to estimate the normal directions of the point set. We conduct local quadric least squares fitting to approximate the Hessian matrix, and Fig.1D demonstrates the frames of Hessian matrix on some points. In order to speed up the segmentation, we adopt the strategy that firstly approximates the implicit reconstruction locally and parallelly, and then blends such local implicits together. So, we propose an adaptive spherical cover generation method to decompose the original volume domain into overlapping regions (Fig.1E) based on the importance sampling of Gauss curvature. The red box in Fig.1 illustrates our interactive and iterative manipulation procedures, and we can locally edit the Hessian constraints and update the scalar field until we become satisfied with the results (Fig.1G). Currently, the method of RBF implicits with Hessian constraints guarantees the high-order requirements, and our prototype system provides an intuitive and simple interface to edit a point set and fine-tune Hessian constraints. To better utilize the system, the novice user may still need to get familiar with the basic structure of Hessian matrix and receive a brief training.

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## References

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