Segmentation of sparse volumetric images with non-overlapping surfaces

Patrick M. Jensen*, Camilla H. Trinderup, Anders B. Dahl, Vedrana A. Dahl

Department of Applied Mathematics and Computer Science, Technical University of Denmark, Kgs. Lyngby, Denmark

*patmjen@dtu.dk

Abstract

Multi-object segmentation with explicit surfaces is challenging as object boundaries may not be visible in volumetric images. Here, we extend the graph cut method by Li et al. to detect the boundaries of multiple distinct objects while enforcing no inter-object overlap. Application to a sparse volumetric image shows significant improvement.

Method

The graph cut framework as presented by Li et al. [1] allows the fitting of arbitrary surfaces to volumetric image data and is the basis for the proposed method.

To prevent two surfaces from overlapping, a separating plane is positioned between them, see Fig. 1.

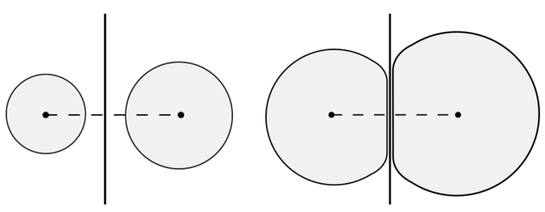

Fig. 1: Surfaces separated by a plane.

The position of the plane is determined dynamically. This is done by augmenting the graph construction from Li et al. as shown in Fig. 2. See [2] for details.

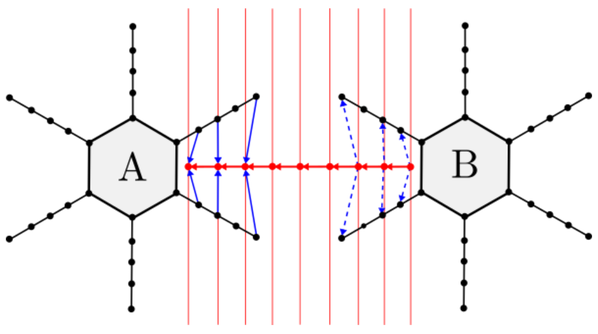

Fig. 2: Augmented segmentation graph. Black nodes are from Li et al. and red nodes are candidate plane positions. Solid arcs force nodes to have equal assignment and dashed arcs force nonequal assignment. Arcs from Li et al. are omitted.

The graph cut method from Li et al. cannot be applied to the augmented graph. Instead, we use the technique from [3] which is based on quadratic pseudo-Boolean optimization (QPBO).

Application to Liquid Foam

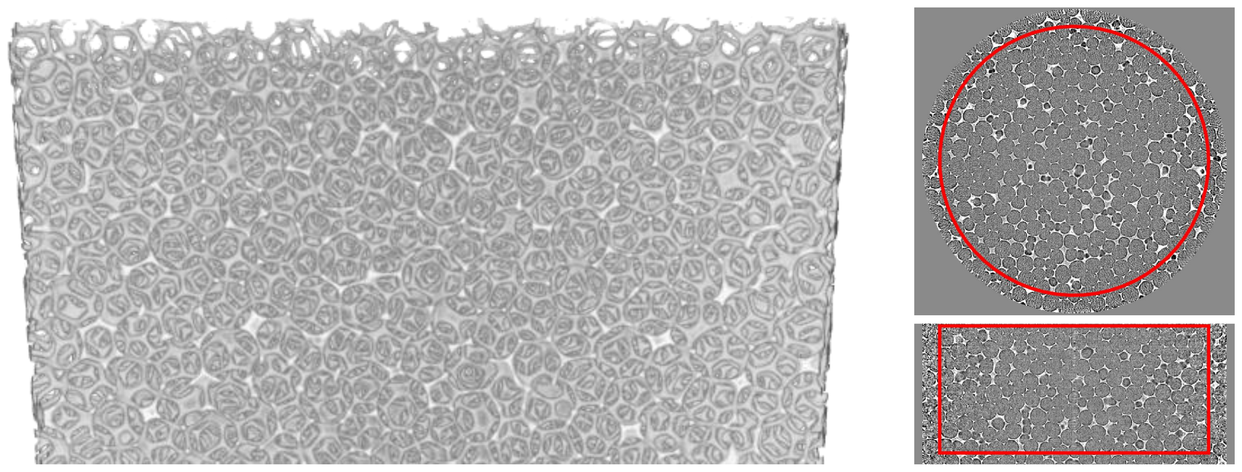

Fig. 3: (Left) 3D rendering of 3D X-ray computed tomography (CT) scan of a liquid foam. The objective is to segment every bubble in a cylindrical region of interest (right). Note that many bubbles have no visible separation.

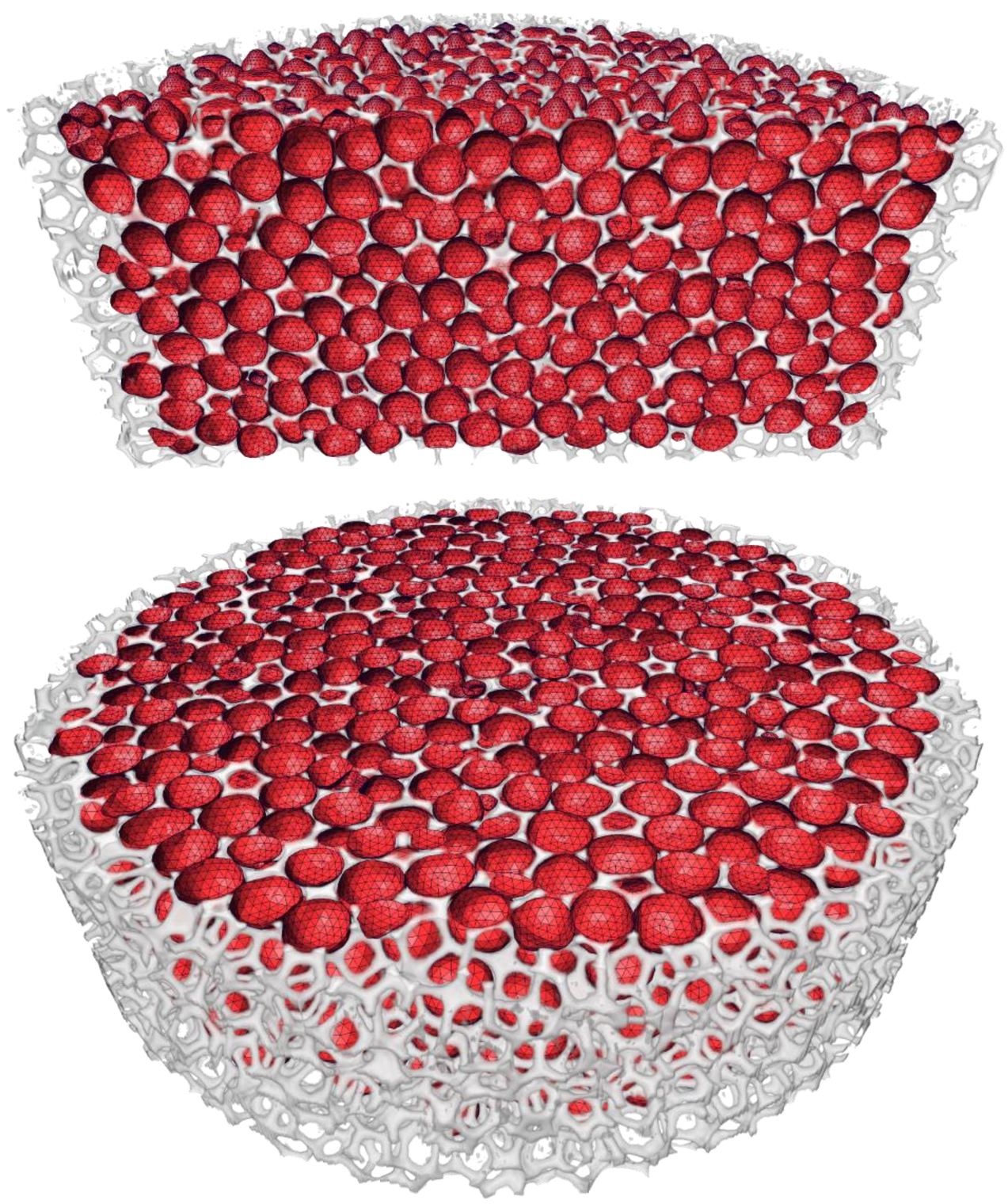

Fig. 4: 3D rendering of segmentations overlaid on image data.

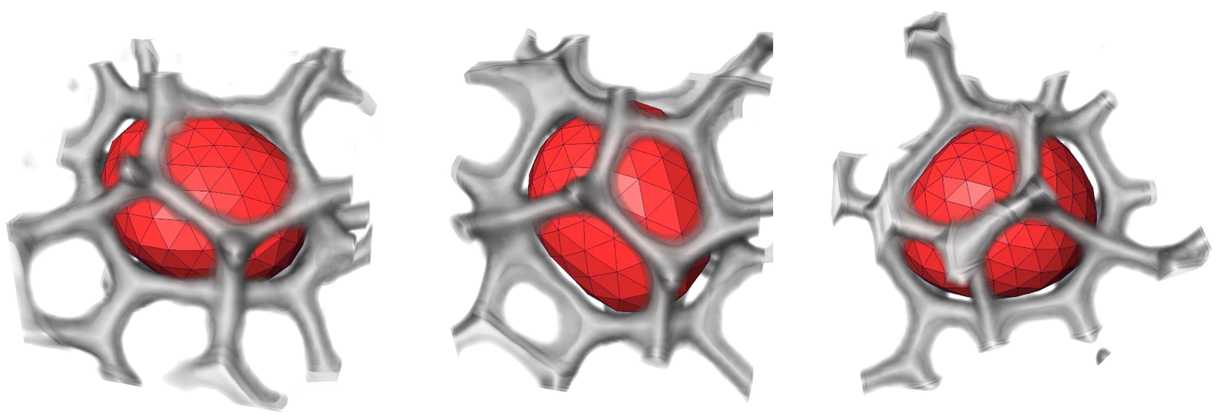

Fig. 5: Examples of individual segmentations.

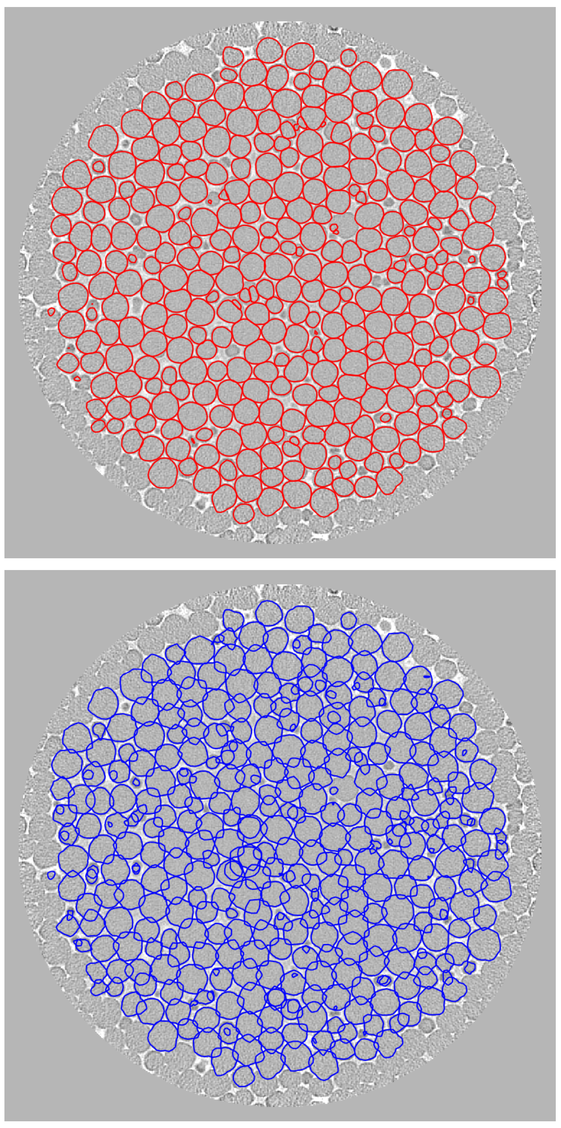

Fig. 6: Comparison of segmentations using the proposed method (top) and the original method (bottom). Note that the proposed method has prevented overlap, which results in an improved segmentation.

Further Work

- QPBO may not assign values to all graph nodes. When and why this occurs is currently not fully understood and should be studied.
- It may not always be possible to separate objects using planes. Thus, the method should be extended to work with general surfaces.
- The performance of the method depends on manual parameter selection. A more automated and robust method would be beneficial.

References

[1] Li, K., et al. *Optimal surface segmentation in volumetric images – a graph theoretic approach.* IEEE Trans. Pattern. Anal. Mach. Intell. (2006).

[2] Jensen, P. M., *Volumetric Segmentation using Deformable Meshes.* M.Sc. Thesis (Technical University of Denmark, 2019).

[3] Kolmogorov, V. & Rother, C. *Minimizing nonsubmodular functions with graph cuts – A review.* CVPR (2007).