DTU Compute
Image Analysis and
Computer Graphics

Finding Space-Time Boundaries with Deformable Hypersurfaces

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Abstract

Object segmentation and tracking in 4D (3D+time) images is challenging, especially when objects split/merge. Current methods do not handle splits/merges or are infeasible for large data sets. We propose to fit a hypersurface in the 4D domain to the evolving object boundaries. This gives a compact representation of the objects at all times, and allows objects to split/merge.

Method

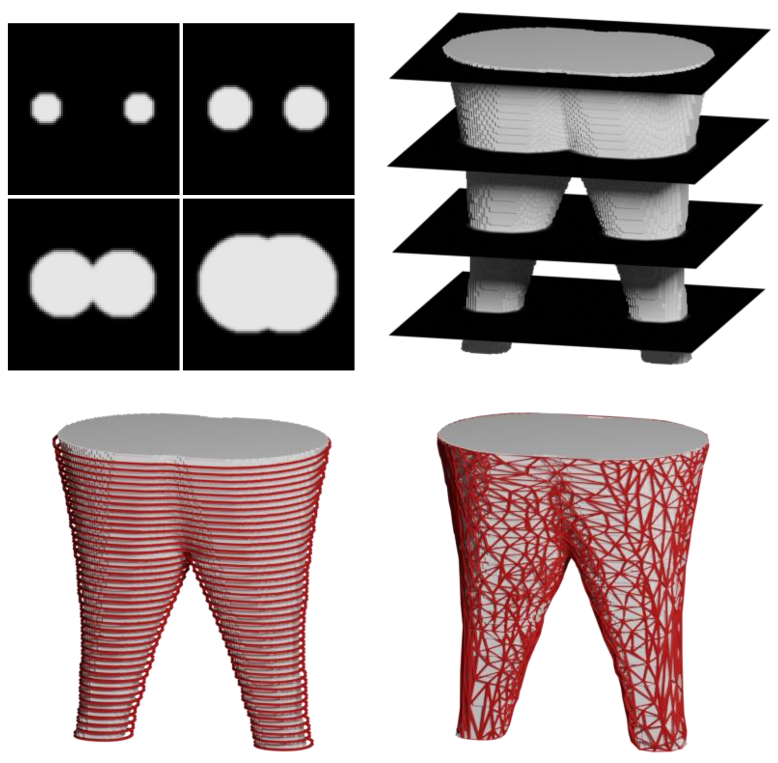

Fig. 1: Basic idea of the method for a 3D (2D+time) example. Two disks grow over time until they merge, which forms a single conn. comp. in 3D. Instead of segmenting in each 2D slice (bot. left), our method segments the 3D conn. comp. with a single mesh (bot. right).

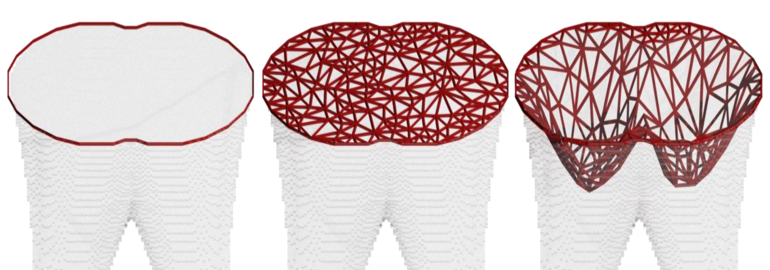

Fig. 2: General method pipeline. Left: outline of object in the last slice is detected. Middle: object interior is tetrahedralized. Right: Tet. mesh is deformed to segment conn. comp.

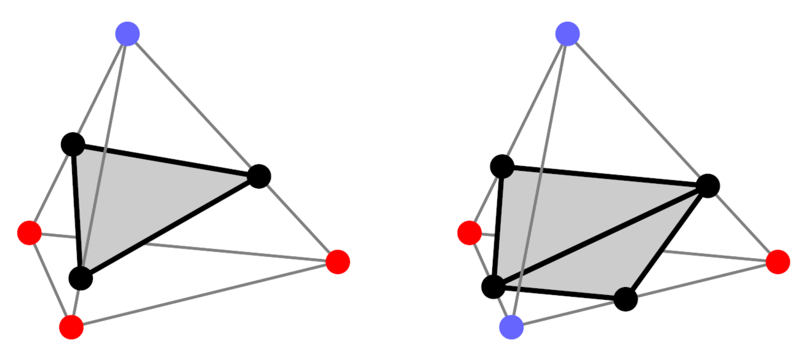

Fig. 3: Extracting 3D segmentations. After fitting, a 3D segmentation can be extracted as a triangle mesh giving the object boundary. This is done by intersecting each tet. with an xyz-hyperplane.

Application to Evolving Metal Foam

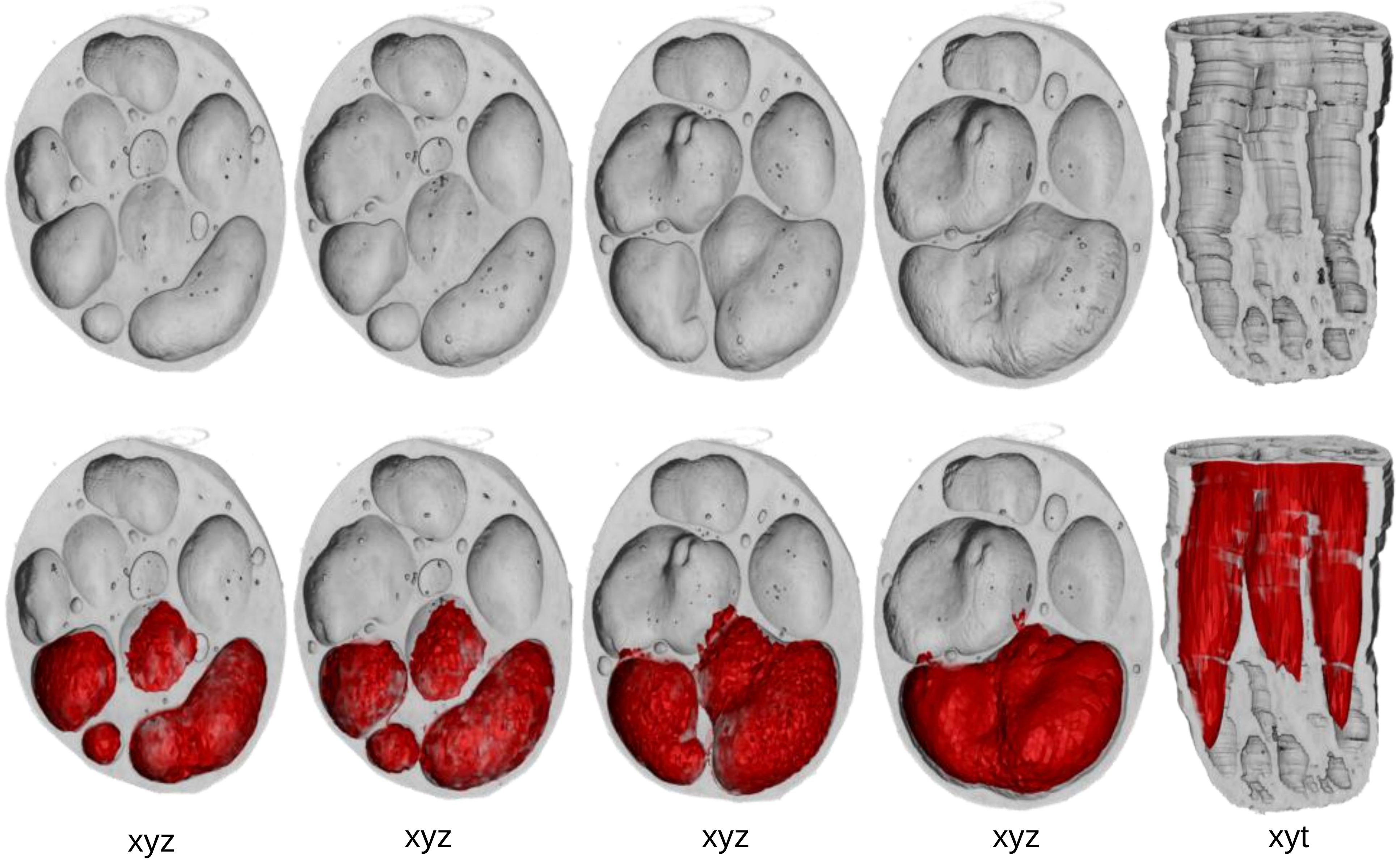

Fig. 4: 3D renderings of data with tet. mesh cross sections overlaid on image data. Columns 1-4 show xyz-slices and column 5 shows xyt-slice. Note that all columns show a cross section of the same tet. mesh.

Numerical Experiments

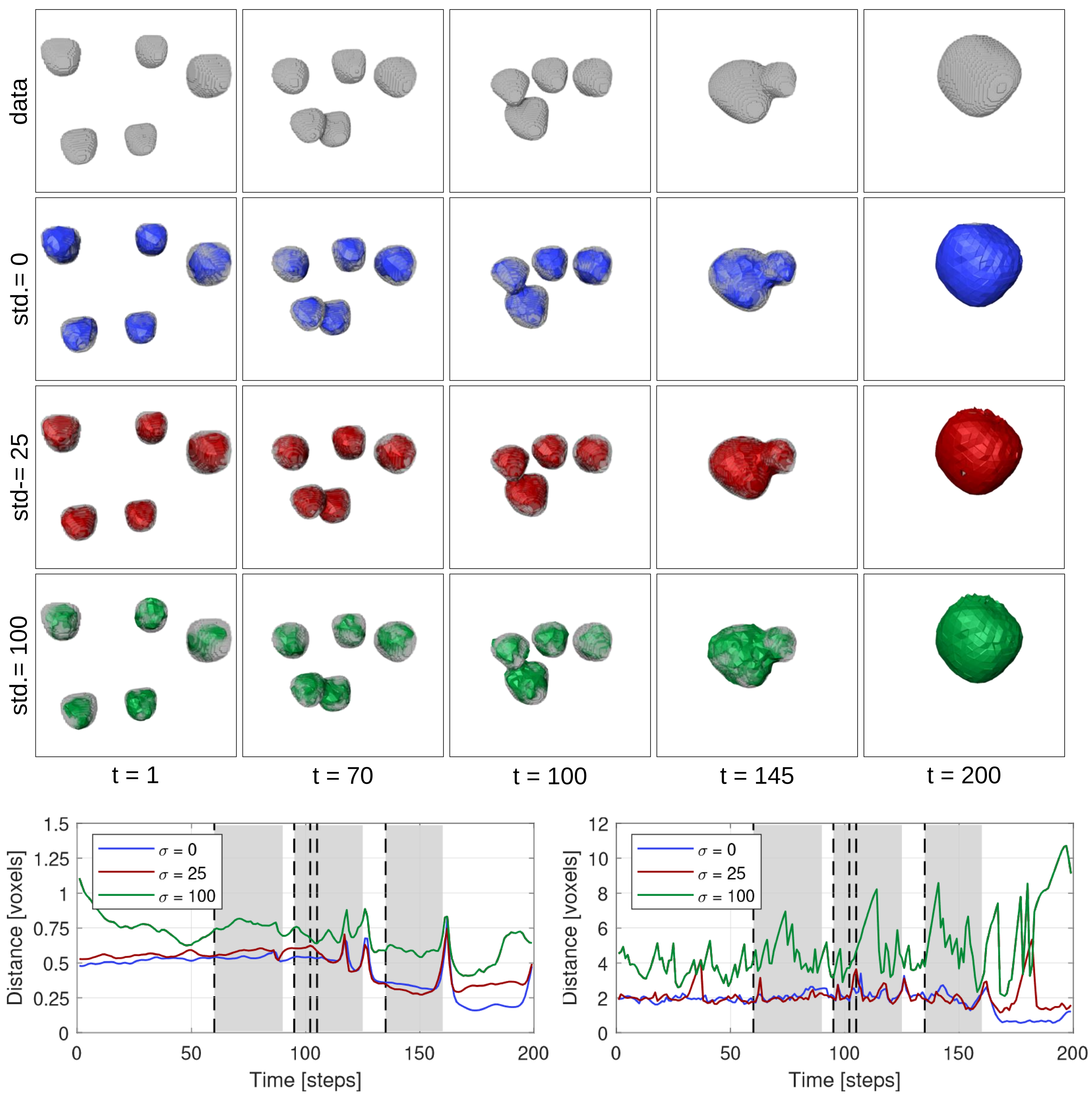

Fig. 5: Top: 3D renderings of artificial data with tet. mesh cross sections overlaid on image data for different noise levels. Bot. right: mean distance to true object boundary over time. Bot. left: max distance to true object boundary over time. Bot: Gray regions mark object merges.

Comparisons

Tab. 1: Methods used for comparison w.r.t. segmentation accuracy, run time, and memory use.

Method	Full name
3D MRF	6-connected Markov random field
4D MRF	8-connected Markov random field
GC/2	Surface fitting with graph cut (Δ=2)
GC/8	Surface fitting with graph cut (Δ=8)
Ours	Deformable hypersurface
Ours (s.t.)	Deformable hypersurface (small tets.)

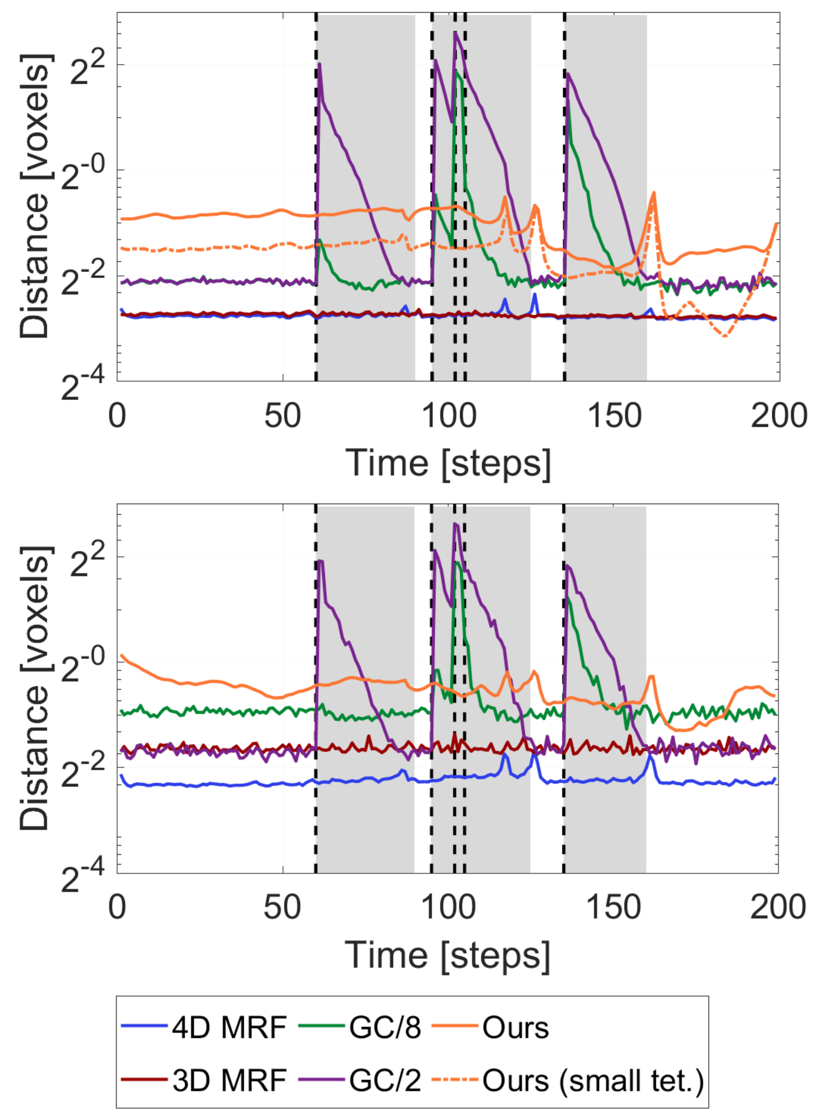

Fig. 6: Mean distance to true object boundary over time for all methods. Gray regions mark object merges. Top: std. = 25. Bot: std. = 100.

Tab. 2: Resource use for all methods at the two noise levels. Mem. use does not include the size of the image (200 MB).

Method	Time [s]	Mem. use (peak / seg.)
std. = 25		
3D MRF	53	428.0 MB / 200 MB
4D MRF	115	57,500.0 MB / 200 MB
GC/2	49	48.6 MB / 9.2 MB
GC/8	50	47.3 MB / 9.2 MB
Ours	72	84.9 MB / 2.3 MB
Ours (s.t.)	149	270.9 MB / 5.1 MB
std. = 100		
3D MRF	65	421.8 MB / 200 MB
4D MRF	238	57,500.0 MB / 200 MB
GC/2	62	46.9 MB / 9.2 MB
GC/8	57	46.9 MB / 9.2 MB
Ours	90	137.7 MB / 3.5 MB