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32nd Annual Symposium of the German Association for Pattern Recognition (DAGM)
September 22-24, 2010, Darmstadt, Germany

Nugget-Cut: A Segmentation Scheme for Spherically- and Elliptically-Shaped 3D Objects

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Introduction:

Gliomas
- most common primary brain tumors
- evolving from the cerebral supportive cells

Glioblastoma multiforme (GBM)
- therapy contains maximum safe resection, percutaneous radiation and chemotherapy
- survival rate is still only approximately 15 months

Clinical follow-up
- evaluation of the tumor volume is essential in the course of disease
- volumetric assessment of a tumor using manual segmentation is a time-consuming process

Methods:

Novel segmentation scheme for spherically- and elliptically-shaped objects
- sending rays through the surface points of a polyhedron
- sampling the graph's nodes along every ray

Graph construction
- sampled points are the nodes $n \in V$ of the graph $G(V,E)$ and $e \in E$ is a set of edges
- edges between the nodes and edges that connect the nodes to source s and sink t
- polynomial time s-t-cut delivers optimal segmentation of the tumor

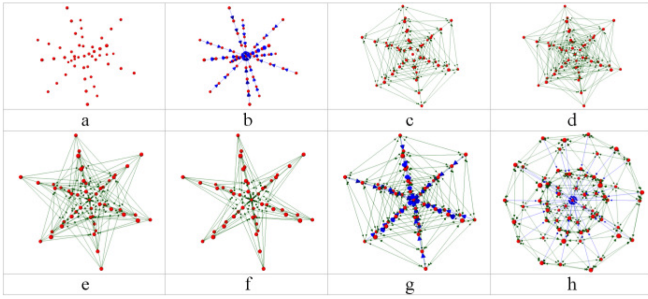

Figure 1: Principle of graph construction. a) five sampled points (red) along each of the 12 rays that provide the nodes for the graph. b) edges between the nodes belonging to the same ray. c) edges between nodes of different rays for Δ_r=0, d) Δ_r=1, e) Δ_r=2 and f) Δ_r=3. g) complete graph for Δ_r=0. h) complete graph with 32 surface points, 3 nodes per ray and Δ_r=0

Results:

The presented methods were implemented in C++ within the MeVisLab platform and applied to magnetic resonance imaging (MRI) datasets with GBM

One click tumor Segmentation
- 50 clinical datasets were used and manual slice-by-slice segmentation was performed by experts (neurosurgeons)
- the overall segmentation (sending rays, graph construction and min-cut computation) took less than 5 seconds in our implementation
- the average Dice Similarity Coefficient (DSC) for all datasets was 80.37±8.93%

	Volume of tumor (cm³)		Number of voxels		DSC (%)
	Manual	automatic	manual	automatic	
Min	0.47	0.46	524	783	46.33
Max	119.28	102.98	1024615	884553	93.82
$\mu \pm \sigma$	23.66 ± 24.89	21.02 ± 22.90	145305.54	137687.24	80.37 ± 8.93

Table 1: Summary of results: min., max., mean μ and standard deviation σ for 50 gliomas

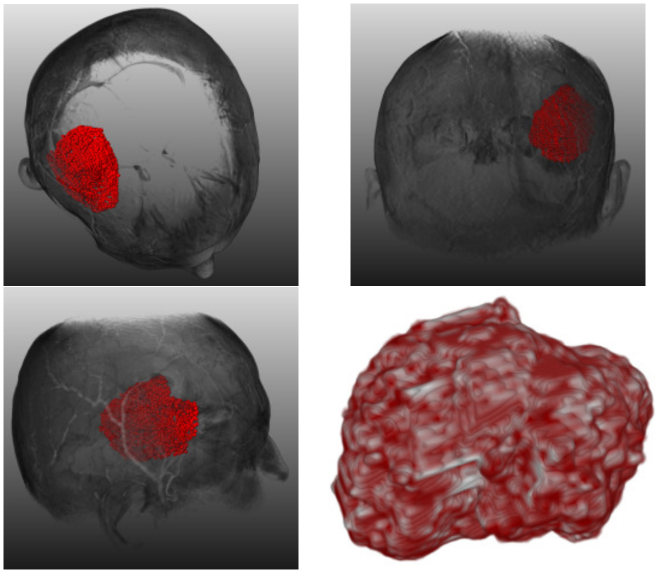

Figure 2: 3D views of an automatically segmented tumor and the voxelized tumor mask

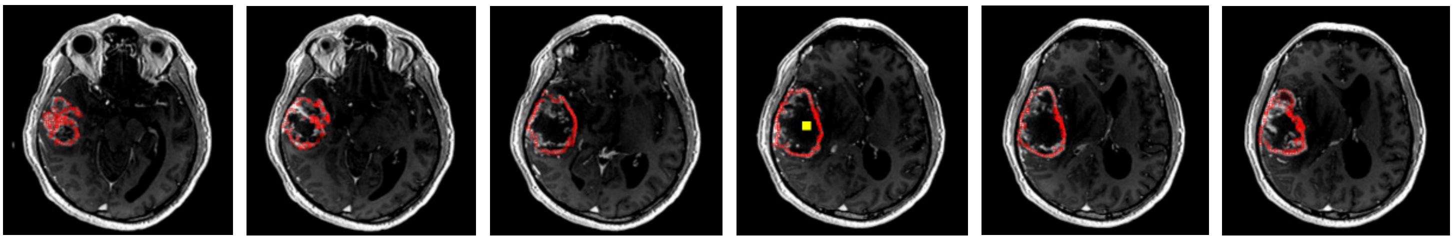

Figure 3: Result of automatic tumor segmentation (DSC=81.33%). The yellow point (inside the tumor) in the fourth image from the left side is the user-defined seed point. Manual segmentation performed by a neurological surgeon took 16 minutes for this dataset

Conclusion:

In this paper, a graph-based segmentation scheme for spherically- and elliptically-shaped objects was presented. The introduced method uses only one user-defined seed point inside the object to set up a 3D graph and to perform the segmentation. Therefore, rays are sent out radially from the seed point through the surface points of a polyhedron to generate the directed graph. After graph construction, the minimal cost closed set on the graph is computed via a polynomial time s-t cut, creating an optimal segmentation of the object. The presented method has been tested on 50 MRI datasets with World Health Organization grade IV gliomas (glioblastoma multiforme). The ground truth of the tumor boundaries were manually extracted by three neurological surgeons with several years of experience in resection of gliomas and was compared with the automatic segmentation results.

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