# Graph-Based Vertebra Segmentation Using a Cubic Template

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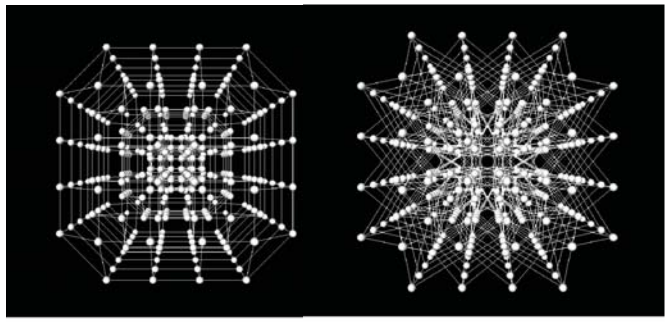
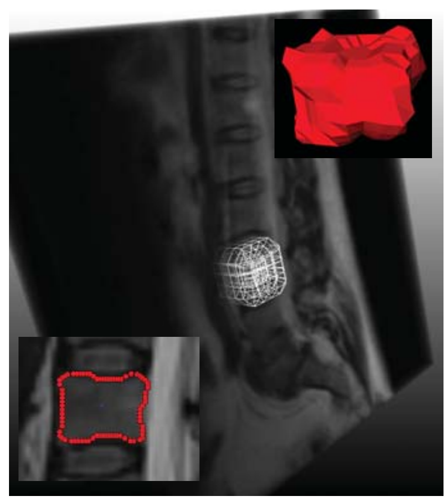
**Purpose** – The current development of the population's structure leads to a growing part of older patients with a more frequent insistence for surgical treatment like lumbar spinal stenosis (LS), which is the most common cause of spinal surgery in individuals older than 65 years of age [1]. For the assessment of spinal structures such as nerve roots, intervertebral discs and ligamentary constitution, Magnetic Resonance Imaging (MRI)-imaging is in general suitable. However, certain changes of the vertebra due to osteoporosis, fractures or osteophytes, require an evaluation of the bone structures via Computed Tomography (CT)-scans, which include radiation exposure [2]. In this contribution, we want to illustrate the capability of MRI-segmentation to reconstruct the vertebral body without x-ray examination, leading to less pre-operative examinations and therefore affecting radiation exposure costs and time-management.

**Methods** – The presented approach is an extension from our recent articles [3, 4] to a third dimension and it starts by setting up a directed 3D graph from a user-defined seed point that is located inside the vertebra. To set up the graph, the method samples points along rays, which are distributed on a cube's surface. The sampled points are the nodes $n \epsilon V$ of the graph $G(V,E)$ and $e \epsilon E$ is a corresponding set of edges. Besides, there are (inter-) edges between the nodes and there are edges that connect the nodes to a source $s$ and a sink $t$. An additional delta value determines the construction of the *xy*-edges and therefore the smoothness of the segmentation results, like shown in the image on the right side. After the graph has been generated, the minimal cost closed set on the graph is calculated via a polynomial time *s-t*-cut [5], creating the 3D segmentation of the vertebra.



XYEDGES DELTA = 0 XYEDGES DELTA = 1

**Results** – For testing the presented segmentation algorithm we used a C++ implementation within the medical prototyping platform *MeVisLab* (http://www.mevislab.de). The overall segmentation – sending rays, graph construction and *mincut* computation – in our implementation took about twenty seconds on an Intel 2.1 GHz CPU, 4 GB RAM, Windows 7 Home Premium, x64 Version, SP 1. The image on the right side shows a 3D graph that has been constructed around a vertebra inside an MRI dataset (white, with a delta value of zero). Thereby, the center of the graph is located at a user-defined seed point inside the vertebra. The zoomed view in the upper right corner of the figure shows the segmentation result of a vertebra as a triangulated surface (red) and the zoomed view in the lower left corner shows the segmentation result on a sagittal slice (red).



**Conclusions** – In this contribution, we presented the initial results for a novel 3D vertebra segmentation method. The method is an enhancement of an algorithm we recently developed in a previous work from 2D to 3D. Thus, it is now possible to calculate the volume of a vertebra instead of the area. For vertebra segmentation, the 2D scheme was enhanced, by creating a directed 3D graph within a cubic-shaped template. Thus, the center of the cubic template was user-defined and located inside the vertebra. Then, the minimal cost closed set on the graph has been computed via a polynomial time *s-t-cut*, creating an optimal segmentation of the vertebra's boundary and volume.

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**References**

[1] A.F. Joaquim, et al. Degenerative lumbar stenosis: update. Arq Neuropsiquiatr 67(2B): 553-8, 2009.

[2] P.J. Richards, et al. Spine computed tomography doses and cancer induction. Spine (Phila Pa 1976) 35(4): 430-3, 2010.

[3] J. Egger, T. Kapur, T. Dukatz, M. Kolodziej, D. Zukic, B. Freisleben, and C. Nimsky. Square-Cut: A Segmentation Algorithm on the Basis of a Rectangle Shape. In: PLoS ONE, 2012.

[4] J. Egger, B. Freisleben, C. Nimsky, and T. Kapur. Template-Cut: A Pattern-Based Segmentation Paradigm. In: Nature - Scientific Reports, Nature Publishing Group (NPG), 2(420), 2012.

[5] Y. Boykov and V. Kolmogorov. An Experimental Comparison of Min-Cut/Max-Flow Algorithms for Energy Minimization in Vision. IEEE Transactions on Pattern Analysis and Machine Intelligence, 26(9), pp. 1124-1137, 2004.