Patientenindividuelle Modellierung der Geometrie der Lendenwirbelsäule aus CT-Daten

Patientindividual Geometric Modelling of the Lumbar Spine from CT Data

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Motivation

Surgery simulation in the field of spine surgery depends strongly on patient individual geometric models of the spine. However, this is a very time-consuming task consisting of segmentation, meshing and assembling of different structures. Besides this workflow requires a lot of effort by the surgeon. Our algorithm works almost automatically and it provides us with single unconnected vertebrae which is a requirement for biomechanical modeling with the finite element method (FEM).

Methods

Our approach consists of a segmentation method dedicated to segment vertebrae from CT data and a cavity bridging algorithm to generate the intervertebral discs. We implemented this software as a component of our medical simulation framework MEDIFRAME [1] and by the use of the Insight Toolkit (ITK) [2]. Starting with a single seed point, a region growing algorithm provides us with a rough segmentation of the spine. The previous segmentation result and the original image are then used as inputs for a level set segmentation to separate the vertebrae. As a result we get small gaps at the joints of the vertebrae thus we can now select the vertebrae independently. To eliminate jagged borders morphological operators are used. But the inner spongiosa is still heterogeneous which is undesirable for the later marching cubes surface generation. Therefore the outer of the vertebra is segmented through region growing. The result is the complement of this segmentation which is a homogeneous vertebra.

The intervertebral discs are still a problem to segment from CT images. Consequently we implemented an algorithm which bridges the cavity between two adjacent vertebrae. The algorithm consists of detecting the superior and the inferior contact area between vertebra and intervertebral disc and joining them to get a closed mesh.

In detail the contact areas are determined starting at a seed point, found heuristically, to collect an initial triangle area. Then the algorithm circulates the found temporary contact face and adds adjacent cells until the angle between the master normal, the normal at the seed point, and the normal of the cell undergo a predefined threshold. An important issue of this algorithm is to maintain a single connected region and to avoid protruding triangles. Afterwards the two surfaces are merged by collecting consecutive triangles which connect corresponding points.

Results

The algorithm has pointed out that automatic robust geometric modeling of the spine is possible. The performance of the segmentation algorithm strongly depends on the duration of the smoothing filters and the morphological operators and not as expected on the region growing and the level set algorithm. The intervertebral disc builder has shown robust behavior with different data sets. A problem is the predefined threshold for the angle criterion which has a big impact on the resulting mesh.

Conclusion

Automatic geometric modeling of the spine allows patient individual simulation and planning, especially with the FEM. The benefit of this approach is that computer-aided surgical planning will not last longer than conventional planning which nowadays is still an obstacle for the wide application of computer-based planning tools.