Semiautomatic random walk segmentation of medical tomographic 3D image data

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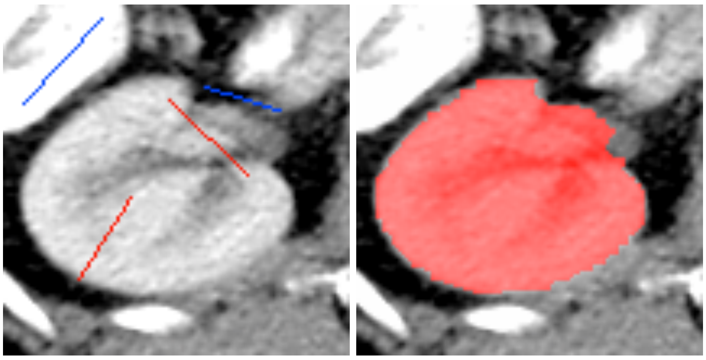
Abstract
Image segmentation is the process of separation an image into different classes. In medical applications segmentation is a fundamental step for advanced 3D-visualization methods, pattern matching or qualitative measurements [2]. The random walk algorithm published by Leo Grady in 2006 [1] is a semi-automatic image segmentation algorithm and has been implemented in Java as part of the bachelor thesis. The main goal is to analyze the user-dependence of a semi-automatic segmentation algorithm. The semiautomatic algorithm is able to segment two dimensional and three dimensional problems with two classes. In medical applications the tool can be used to segment organs, tumors or tissues in MRI, CT or sonogram data, among others.



(a) (b)

Fig.1: This figure shows (a) the input of the program random walk for image segmentation and (b) the output of the algorithm. You can see one of 25 slices of a 3D CT data in soft tissue window. The kidney is segmented.

The random walk for image segmentation works with user-defined labels visualized as colored markings (seed points or seeds) in the image sequence, shown in Figure 1. Based on seed points the segmentation for each pixel is calculated. The general approach of this algorithm is to consider a graph where each vertex corresponds to a pixel / voxel in the image data. On every node a random walker starts a path across the graph. Every random walker has a certain probability to reach a seed of class 1 on this walk and another probability to reach a seed of class 2. The pixel belonging to the walker´s start node is assigned to the class with the higher probability.
To analyze the user-dependence, seven tests with medical image data are performed and evaluated. We studied the user-dependence by using three different case studies. First the segmentation of the eye in a T1-weighted transversal MRI image sequence, second and third a kidney and the femoral head in a transversal CT image sequence.
In order to systematically analyze the robustness of this algorithm, we used a synthetic approach where the user is substituted by a random generator, that draws colored lines with specific characteristics. The lines are created with the Bresenham algorithm [3]. Variable parameters are the number of seeds, the line width, the margin between the seeds and the object border and the number of slices with seeds.

The resulting segmentation is evaluated against a gold standard segmentation provided by a clinical radiologist.

The first test analyzes the influence of the seeds localization. Our evaluation shows, that the position of the marked pixels influences the Dice coefficient and the Hausdorff-distance [2, pp. 153-154] of the segmentation. The quality of the segmentation depends on the distribution of the seed points. If the seeds evenly spread over the image sequence, the segmentation has a higher quality. If all seeds are concentrated on a small area, the segmentation will be poor.

The second experiment analyzses if the number of seed points has an influence on the segmentations quality. It shows, that more seeds tend to yield segmentations with better quality.

Another set of experiments examines if the number of slices with seeds influences the quality of segmentation, even if the number of seeds stays the same. If more slices contain seeds, the Dice coefficient rises and the Hausdorff-distance decreases.

In a further test it is shown that thinner lines of seed points indicate results in higher quality than a thicker line with the same number of marked pixels.

In the next experiment it is tested if a margin between the seeds and the object border influences the result. It is shown, that a distance up to six pixels does not influence the results of the Dice coefficient and the Hausdorff-distance.

Especially when dealing with CT images the windowing [4] is an important step of preprocessing that influences the result of the segmentation. With one experiment it was worked out that the windowing affects the Dice coefficient and the Hausdorff-distance. There is no best windowing. In some cases, the bone window and in other cases the soft tissue window yields a higher Dice coefficient. In some of the case studies the non-windowed raw data has the best result, even if the seeds localization and number of seeds is the same in all window settings. This experiment shows that the user needs to consider the special characteristics of the algorithm and windowing.

In the bachelor thesis, user guidelines for the application of the algorithm for medical image segmentation are summarized as a result of the experimental evaluations. In addition, some necessary tools for the application in clinical treatment are given.

References

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