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Virtual Open Heart Surgery Segmentation

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Abstract. We have developed a semi-automated segmentation method based on the Watershed transform [1]. The watershed transform is a fast and intuitive segmentation method. It is applied to 3D cardiac MRI to interactively produce patient-specific models for pre-operative planning and virtual heart surgery [2]. Our software offers a detailed exploration of the data-set via combination of many visualization techniques such as volume rendering, multiple overlays, and surface rendering.

Keywords. Virtual heart surgery, watershed segmentation.

Introduction

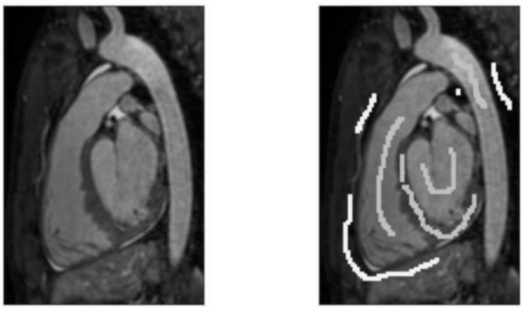
Segmentation of the heart remains a challenging task as the heart morphology is known to be very complex. Particularly in congenitally malformed hearts, where the morphology varies significantly from individual to individual, any approach relying on prior knowledge from normal morphology will fail. We propose an interactive solution to the problem of the heart segmentation: the marker constraint watershed transform. Our process needs some markers on different parts of the organ to be segmented. The markers are then growing according to the watershed algorithm [3]. These markers can be seen as patient-specific prior information that constraint the watershed transform to include some specific parts of the image.

1. Algorithm

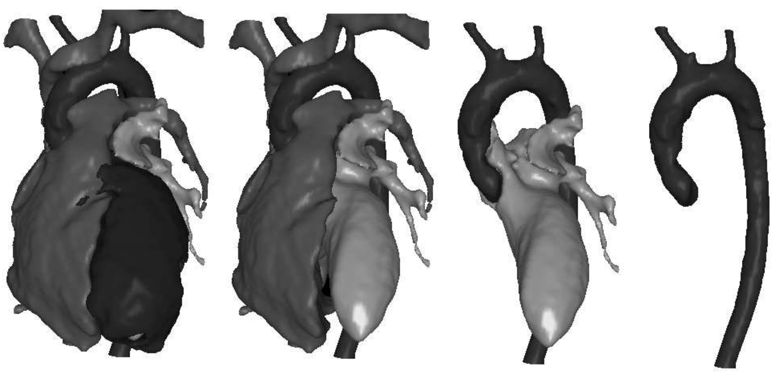
The watershed transform uses an intuitive description of boundary in an image: It considers an image as a topographic surface where the height of each point is directly related to its gray level. The algorithm then simulates a flooding of this surface from a finite set of points. To avoid mixing of water of different sources, a watershed line is constructed where they meet. The watershed line computed on the gradient of an image finds the high gradient points which are related to boundaries in the image. In cardiac MRI this corresponds to e.g. the border between the blood pool and the myocardium. To avoid over-segmentation due to noise in the images, the set of points from which the flooding process starts is defined interactively by the user [3]. Details of the implementation can be found in [1].

2. Segmentation

All models are reconstructed from 3D MRI acquired with isotropic voxels at a resolution of approximately $1.7^3 mm^3$, which forms a data-set of 256x256x100 voxels. The images are first filtered using anisotropic diffusion [4]. The user then specifies the different objects of interest in the image by inserting a few markers from which the watershed transform is invoked. The user can place markers interactively by drawing on 2D slices. This method was used to segment the blood pool and myocardium volume semi-automatically (see Figure 1). After the segmentation step, the user can add or delete markers if it is necessary.



(a) (b)



(c) (d) (e) (f)

Figure 1. (a) Original MRI Data.(b) User specifies interactively some markers by drawing on a slice. (c-f) Different parts of the segmented data. The segmented images are drawn as surfaces. The software enables the user to select surfaces to hide it or to overlay it with the original data.

3. Image Visualization

We have developed a software dedicated to heart MRI segmentation and visualization. Our software allows the user to explore a highly detailed view of the data-set for easy interpretation. This is important for validation purposes. The user can visualize the segmented image as a set of surfaces, one surface for each region. The marching cubes algorithm was used to extract detailed surfaces of the segmented image. Users can also overlay the surfaces on the original image. It is possible to view 2D slices of both segmented and original image as well as 3D volume rendering. Combination of all this visualization methods allows an easy and fast interpretation of the segmentation. Complex morphologies can therefore be explored easily and interactively.

4. Conclusion

We encounter problematic issues with the segmentation of the right ventricular epicardium due to bad contrast of the bordering tissue. The resolution of the images is often too small to distinguish clearly this part of the heart. However we have partially solved this problem via new segmentation methods based on graph-cuts and minimal surfaces [5]. Graph-cuts is a combinatorial optimization method which is today considered as a leading method for image segmentation. Its combination with the watershed transform offers a stable segmentation that can be used interactively [6].

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