Automated Measurement of Kidney Volumes for MRI Based Whole Mouse Screening

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Introduction:

The increasing use of MRI for small animal imaging results in a large number of images to be screened for analysis of anatomical data but the technology for rapid analysis is lacking. Techniques such as multiple mouse imaging [2] can potentially generate many high-resolution whole body images, from which any number of internal organs such as the kidney maybe segmented for further quantitative analysis. However, it is very time consuming and hence inefficient to manually segment a large number of organs. We describe here an automatic technique to segment kidneys from whole body MRI scan. We validate its accuracy by comparing the measured kidney volumes to that determined by manual segmentation.

Methods:

The essence of our method is to combine a registration algorithm with a deformable model segmentation algorithm. The use of registration as a preliminary step helps automate the segmentation. Sixteen C57Bl6 wild type mice were perfused with Gadolinium (Gd-DTPA), formaldehyde fixative and scanned postmortem. All sixteen images were acquired simultaneously on a Varian 7.0T/40 cm bore animal system using a T1-weighted 3D spin echo sequence with TE=16 ms, TR=650 ms, and isotropic voxels of 100 µm. The images were then linearly registered to a reference mouse using AIR (UCLA). The initial surface model was created by manually segmenting the right and left kidney from one mouse using AMIRA (TGS, CA). This kidney model was used as the initial state of the deformable model algorithm [3] for all mice. The position of vertices evolves iteratively under the influence of forces derived from the edges in the image and elastic constraints on shape regularity. To keep the results consistent, we kept the parameters that control the algorithm constant for all kidneys. The volume enclosed by the deformable surface was taken as an estimate of kidney volumes [1]. For comparison all images were manually segmented (3D data) using AMIRA and the corresponding volume was compared for each kidney.

Results:

Of the sixteen images, one was excluded since that mouse was lacking one kidney. Figure 1 shows the result in one slice of the 3D segmentation on one of the mice. Over all fifteen mice, the mean and standard deviation were 187±8, 168±7 for manually segmented and 184±7, 161±2 mm^3 for automatically segmented right and left respectively. A pairwise t-test comparing automatic versus manually measured volumes found no difference for either right or left. Pearson's correlation between manual and automatic measurement was highly significant ($p < 0.01$) for both right and left kidneys. Manual segmentation accounts for $R = 0.72$ and $R = 0.37$ of the observed variance in the automated measurement for right and left respectively. (see Figure 2)

Discussion and Conclusion:

We have demonstrated the ability to segment multiple kidneys using the deformable model algorithm with constant parameters and one initial model. This approach is conditional on being able to pre-register the individual datasets before segmentation. It may not be appropriate when the images can not be pre-registered. We anticipate that this approach can be used to detect abnormalities due to genetic and environmental factors. We also anticipate that a similar technique can be used for segmentation of heart and other organs.

References:

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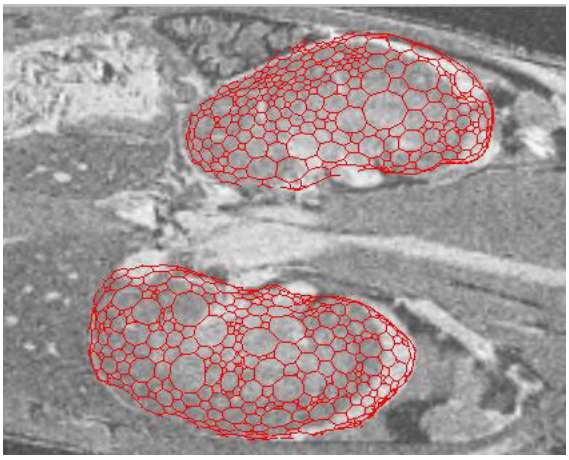

Figure 1: Sagittal MRI section with deformable surface.

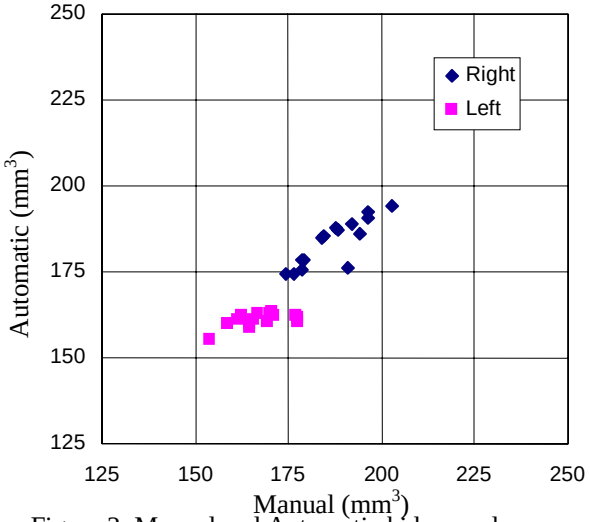

Figure 2: Manual and Automatic kidney volume measurement