Automatic liver segmentation of 3D abdominal MR images of rodents

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Introduction

Fast and accurate segmentation of the liver from magnetic resonance (MR) images has various applications, ranging from the estimation of the liver volume before liver transplantation, hepatic tumor localization, and hepatic fat distribution. Manual segmentation is labor intensive and highly variable among raters. Existing semi-automatic and automatic liver segmentation tools have reduced both processing time and intra/inter rater variability. Nevertheless, the reliability and accuracy of these techniques can be further improved. We propose an automatic segmentation approach that integrates both a probabilistic model and an atlas-based method for utilizing both image intensity and liver shape information in order to get better liver segmentation.

Methods

MRI acquisition: All experiments were approved by local IACUC. A Varian 9.4-Tesla horizontal MRI system was used to acquire 3D gradient echo images of C57BL/6 mice (n=5, 20-25g) with the following parameters: TR/TE= 750/3.73 ms; FOV= 33 x 33 x 16.5 mm^3; matrix size= 128x128x64; flip angle= 20°. Anesthesia was induced by inhalation of a mixture of medical air and 3% isoflurane, and maintained by a mixture of oxygen and 2% isoflurane through a nose cone. The mouse was then restrained in a prone position on an acrylic stage by tape and placed in a quadrature 38-mm birdcage transmit/ receive coil. Warm air was circulated through the bore of the magnet to maintain the body temperature at 37°C by a rectal probe. TR was chosen to scan synchronously with a respiratory rate of about 80 breaths/min.

Probabilistic and Atlas-based Segmentation: A liver atlas was produced using an MR image from one subject, which was not otherwise included in the statistical analysis. The liver structure in the atlas scan was manually delineated. We introduce a region of interest (ROI) approach (Fig 1) to automatically segment the liver from an individual image based on its intensity and the liver shape of the atlas. First, a ROI containing the liver and its surrounding tissue was generated by superimposing the dilated liver atlas that has been transformed by the affine transformation [1] of the atlas scan onto the subject's image space. In Bayesian segmentation, a mixture of Gaussian distributions was used to estimate the density function of the image intensity in the compartments of liver tissue and non-liver tissue using expectation-maximization (EM) algorithm [2]. This often results in topology errors in the segmented liver volume (e.g. holes, multiple components) due to absence of spatial information. We thus incorporated the shape of the liver atlas into the segmented liver volume through large deformation diffeomorphic metric mapping (LDDMM) [3] to filter the topology errors (Fig 2).

Results and Discussions

The automatic segmentation was tested on 5 mice and validated against manual segmentation. The liver volumes were calculated in both manually and automatically segmented volumes (Table 1). The volume difference and an overlap ratio between the manual and automatic segmentations are respectively 20% and 70.3% on average among the five subjects. The variability of overlap ratio across subjects is due to the limited contrast between the liver and surrounding tissues. The result based on only 5 subjects is inconclusive. More subjects are needed to test the robustness of the algorithm. The segmentation accuracy should be further improved when using a probabilistic atlas based on a large number of subjects.

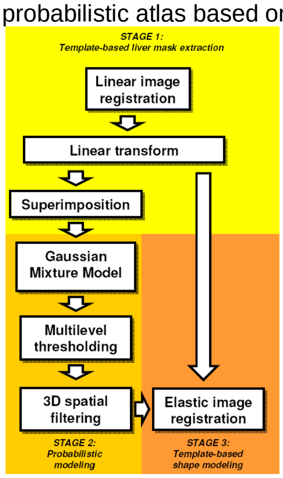

Fig 1. Automatic segmentation framework.

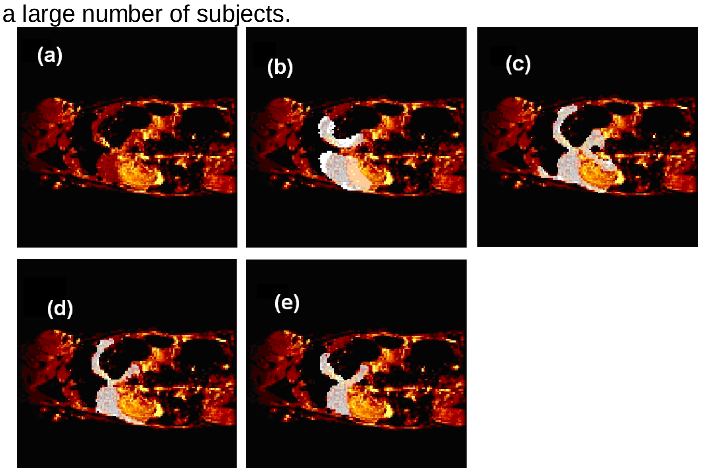

Fig 2: One example of the segmentation processing. Panels (a-d) show one coronal slice at different stages of the processing: (a) original image; b) ROI mask containing the liver and its surrounding tissue; (c) Bayesian segmented liver; (d) final segmentation of the liver after the injection of the atlas liver shape. For the visual comparison, panel (e) shows the manual segmented liver. Segmented region is highlighted in white.

Subject	Overlap ratio/ 100%	Volume / voxel count	
		Manual segmentation	Automatic segmentation
M1	66	25924	27409
M2	66.5	26094	31586
M3	74.8	21194	26875
M4	75.9	23799	28800
M5	68.4	22799	29855
Mean	70.3	23962	28905
STD	4.7	2087	1901

Table 1: Comparison between automatic and manual segmentations.

References

1. Jenkinson M, et al. Med. Im. Anal. 5:143-156, 2001
2. Tomasi C. Retrieved Jan 1 2008, www.cs.duke.edu/courses/spring04/cps196.1/handouts/EM/tomasiEM.pdf .
3. Beg MF, et al. Int. J. Comp. Vision. 61:137-157, 2005