Retrospective Registration of Heptic MR Images

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Introduction:

Imaging the liver is an important and challenging radiological task. Hepatocellular carcinomas, a primary liver cancer, is the single most common intraadominal tumor world wide primarily due to hepatitis B virus and hepatitis C virus. The liver is also a frequent target of metastatic tumors. With increasing demands for early detection of disease or assessment of response to therapies, being able to provide quantitative information from images of the liver either over time or across modalities is desirable. Quantitative analysis of the liver is difficult due to the inherent motion of the liver within the abdominal cavity with respiration. Hence, a successful image registration strategy is essential for any image quantification. We present our preliminary results addressing the feasibility and efficacy of a head and hat (surface-based) and mutual information (voxel similarity-based) registration schemes for intrasubject MR-MR intramodality registration of the liver.

Materials & Methods:

Image Acquisition: We retrospectively collected contrast enhanced MR images of the liver from five subjects. Because of our institution's large liver transplantation service, we focused on images of the cirrhotic liver. These cirrhotic liver evaluations typically consist of three volume images: 1) pre-contrast images, 2) hepatic phase contrast images and 3) portal phase contrast images. Because the cirrhotic liver becomes quite stiff from scaring, we assumed for our first effort that the liver is a rigid body. Because the data was collected retrospectively, the images were not ideally suited for image registration. In particular the images all use rather thick slices (10 mm) with modest in-plane resolutions (1.1mm-1.5mm). Series consisted of a pre-contrast image, an hepatic phase image, a portal phase image and in some subjects late portal images. For each data set the liver was segmented from the image by hand by manually outlining the liver in a slice by slice manner. The hand segmentation approach was validated by ensuring the volume of the liver of each image from the same patient was consistently within ±7% of one another. An experienced abdominal radiologist also reviewed the segmentation.

Heat and Hat Algorithm: A multi-scale surface fitting technique was implemented based on the Head and Hat algorithm proposed by Pelizzari and colleagues [1]. Surfaces were taken from the hand outlining of the liver described above. The target image is denoted as the head, and the registration transformation is determined by iteratively transforming the second surface (the hat) with respect to the head surface, until the closest fit of the hat onto the head is found. Optimization of the hat to head transformation was done using a Powell's minimization scheme. We chose the hepatic phase images as the targets.

Mutual Information Algorithm: We used a multi-resolution mutual information [2] scheme distributed with the ITK Insight software package (National Library of Medicine, Bethesda, MD). We registered unmasked images of the liver to the masked image of the hepatic phase liver.

Registration Validation: As an independent measure of registration accuracy, the mean displacement of automatically selected point landmarks was evaluated [3]. This is a gradient based approach where landmarks in the first image are identified from locations with strong gradients. Matching locations in the second image are identified by examining the correlation between the gradient shape in small neighborhoods in the vicinity of the first image landmarks. We computed displacements between images using the 20 points with the highest matching criteria.

Results:

Mean displacement ($\sqrt{dx^2 + dy^2 + dz^2}$ for registration performed using the mutual information approach was 8.2 mm, whereas mean registration for registration performed using the head and hat surface registration technique was 9.2 mm. Example registered images are shown in FIG. 1 and plots of misregistration by subjects are shown in FIG. 2 for each of the hepatic-pre, hepatic-portal, hepatic-late poral cases.

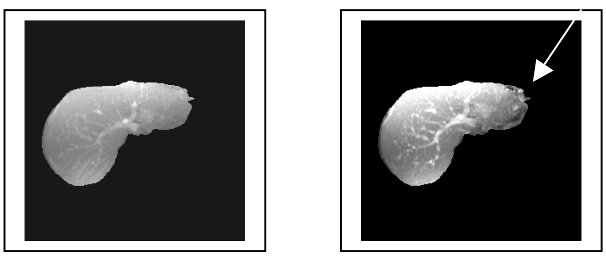

Figure 1. Example images showing registration effect for portal phase images registered to hepatic phase images. On the left we have the registered (mutual information) source image multiplied by the target mask. On the right we have the registered (head-hat) source image multiplied by the target mask. Note the increased amount of non-hepatic structures within the masked region of the head-in-hat image (arrow).

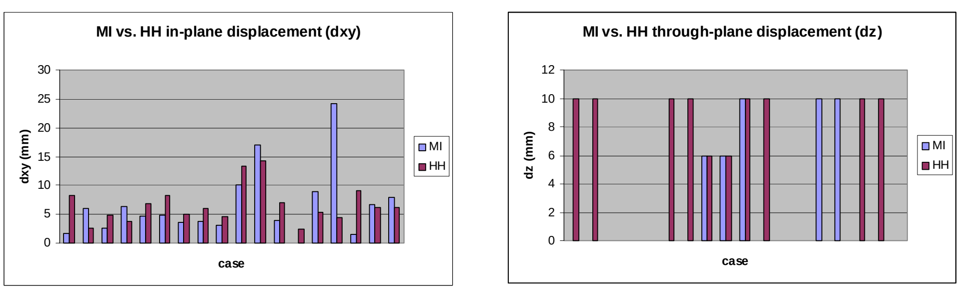

Figure 2. Mean in-plane displacements (left) and through-plane displacements (right). Mean displacements of zero are not plotted.

Discussion:

The superiority of a voxel similarity-based over a surface-based approach for intramodality MR-MR registration has been shown in this study. Since the images had 10 mm thick slices, we believe that we should not expect much lower displacements. These results also indicate that a 3D, nearly isotropic resolution would most likely greatly improve the registration. For most of the cases examined, both registration methods had a mean through-plane displacement equal to the slice thickness. In addition to a slightly better performance, the MI approach has the advantage of requiring that we segment only one image volume for a set of images to be registered.

References:

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