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Liver image registration with constraint applied for accurate tumor localization

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Abstract The main purpose of liver image registration of 3D ultrasound and XCT images is in accurate tumor localization in an US image by fusing the corresponding XCT image. The existing approach for US-XCT liver registration aims to align visible anatomical structures such as vessels and diaphragm between two images. In this paper, we try to improve the performance of non-rigid registration for accurate tumor localization. By examining the motions of tumors, vessels, and diaphragm and adopting thin-plate spline modeling of vessels, we apply a constraint to the non-rigid transformation. Experimental results show the improvement of registration accuracy in tumor area.

Key words: Liver, ultrasound, XCT, non-rigid registration, tumor localization

1. Introduction

The registration between 3D ultrasound (US) and XCT images of the liver is an essential step in various applications such as diagnosis, surgical planning, and US guided intervention for radio frequency ablation (RFA) and biopsy. Due to the limit of poor quality of US images, there were several trials to display a high quality XCT (or MR) image which corresponds to an US image. In this case, registration is to be performed for accurate alignment between US and XCT images with different respiration phases.

Several algorithms have been suggested for registering 3D US and XCT/MR images of the liver. The algorithms can be categorized into two approaches, or global registration which adopts semi-affine transformation [1] and local registration which adopts non-rigid transformation [2], [3]. These algorithms use visible anatomical structures such as vessel and/or diaphragm of the liver for correlating a XCT/MR image with an US image, and try to align those structures.

One of the benefits of liver image registration of 3D US and XCT images is in accurate tumor localization. Since tumors in US images do not appear clearly in most cases, the transformation for a tumor area is approximated by using those for the anatomical structures. Hence, the registration result may not be accurate.

In this paper, we try to improve the registration performance for more accurate tumor localization. As a preliminary research, the proposed algorithm is applied to the simulated US and real XCT images.

2. Method

The diagram of the proposed algorithm is given in Fig. 1. We first perform a global registration using affine transformation. A local registration using non-rigid transformation is then performed based on the initially transformed result obtained from the global registration. For accurate tumor localization, we refine the transformation by using a thin-plate spline modeling of vessel correspondences. Finally, the local registration is performed again with the refined transformed result.

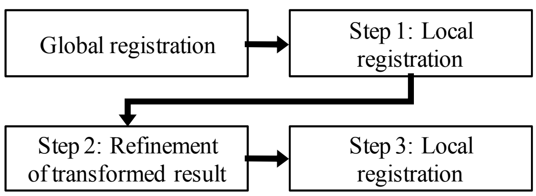

Fig. 1. The registration process

The adopted local registration algorithm is described in detail in [3]. In the algorithm, a B-spline free form deformation model is adopted as a non-rigid transformation. For precise registration, an image-based similarity measure is used to correlate an XCT image to an US image. The similarity measure is based on the information of intensity, gradient magnitude, and gradient orientation.

Through the global and local registration, we can obtain a precise transformation between the two images. However, this transformation may not guarantee the accuracy in the tumor area if the tumor information is not used in the registration process. For refining the transformation in the tumor area, we examine the motion of liver and find that tumor and vessels near tumor have similar motions. Based on this examination, the transformation from the registration is constrained by using thin-plate spline modeling of vessel correspondences between US and XCT images. The transformation based on a thin-plate spline modeling is given as

$$\mathbf{T}_{\mathrm{TPS}}(\mathbf{x}) = \mathbf{A}\cdot\mathbf{x} + \sum_{i=1}^{n}\{\mathbf{b}_i\theta(|\boldsymbol{\varphi}_i - \mathbf{x}|)\} \quad (1)$$

where $\mathbf{A}$ is an affine matrix, $\mathbf{b}_i$ is a non-affine coefficient, $\boldsymbol{\varphi}_i$ denotes the vessel corresponding point in the US image, θ represents a radial basis function, and n is the number of vessel correspondences. The refinement of transformation is then calculated as

$$\mathbf{T}_{\mathrm{refine}}(\mathbf{x}) = \mathbf{T}_{\mathrm{TPS}}(\mathbf{x}) - \mathbf{T}_{\mathrm{reg}}(\mathbf{x}), \quad (2)$$

where $\mathbf{T}_{\mathrm{reg}}$ is obtained from the global and local registration.

Based on the refinement, we perform the local registration again to improve the registration accuracy in the region far from vessels.

3. Experimental result

For the simulated experiment, XCT images with a tumor are acquired at inspiration and expiration and used. The image at expiration is set to a target and is converted into a simulated US image in order to apply the registration algorithm. In the experiment, the global transformation is calculated by using an NMI-based affine registration scheme. Tumors in both images are interpolated with its neighbor's intensities.

Fig. 2 shows the experiment results. We select one of axial slices from the volume for demonstration. In order to observe the correspondences of tumor and diaphragm between two images, we use arrows which are located at the same position in the image. The proposed result in (d) shows a good correspondence for a tumor.

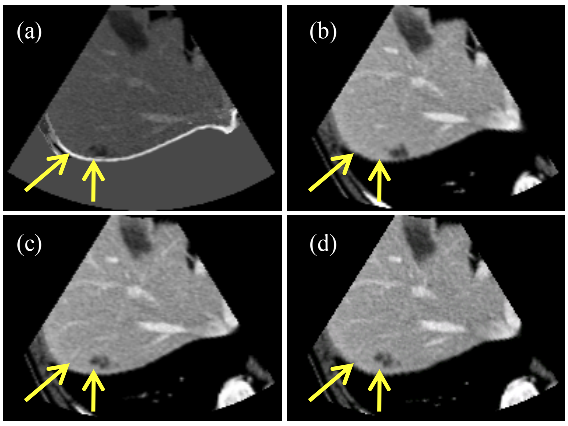

Fig. 2. Registration results; (a) simulated target image, and registered XCT images of (b) step 1, (c) step 2, and (d) step 3

4. Conclusion

In this paper, we propose an algorithm for improving tumor localization in the liver image registration. For accurate tumor localization, the transformation is constrained on the basis of the motion of vessels. Through the simulated experiment, we verify the performance of the algorithm. For further work, experiments for real data will be conducted.

References

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