Automatic 3D Non-rigid Registration of Whole Body Serial MR Animal Images

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Introduction

Registration of serial images is critical for detecting or measuring changes such as variations in tumor size, shape, or physiological characteristics in response to therapy. A number of automatic methods have been proposed to address this problem, which have been successfully applied to the registration of head images. However, the automatic registration of whole body MR images, which requires non-rigid registration techniques, remains a challenge. Recently we proposed a novel registration method that permits the automatic registration of CT images [1, 2]. In this study, this algorithm is extended and applied to small animal MR images.

Methods

To test our algorithm, we require high resolution MR images without motion artifacts. To achieve this, a mouse was first sacrificed and imaged in a Varian 7.0T scanner equipped with a 38mm quadrature birdcage coil. An SPGRE sequence was employed to obtain MR images with a spatial resolution of 0.176x0.25x0.25mm^3. Next the mouse was imaged within the same holder using an Imtek MicroCAT II small animal scanner to generate the CT images with a resolution of 0.2x0.2x0.2mm^3. The mouse posture was then changed arbitrarily and a second set of MR and CT scans were acquired. This process was repeated in five mice.

The registration method is a four-step process and each step is automatic: (1) each MR scan is registered to its corresponding CT scan. Because the same holder is used to acquire MR and CT images and assuming minimal motion between modalities, registering the CT volume with the MR volume can be done with a rigid body transformation. (2) Longitudinal CT scans are registered to each other using the method we have previously proposed [1]. This method is itself a two-step process in which the skeletal structures are first registered using a robust point matching algorithm [3]. This is followed by the registration of the entire CT volumes using an intensity-based non-rigid registration algorithm we have developed [4]. (3) The transformation computed in step 2 is applied to the corresponding MR scan. (4) Finally, the registrations are adjusted by applying the intensity-based algorithm to the MR images obtained after step 3. In our experience, following this approach produces better results than those obtained by applying the intensity-based algorithm to the original MR images directly.

Results

Figure 1 shows results we have obtained. The panels show the skeleton in the first CT scan registered to the skeleton in the second with the method we propose (left), when applying only the intensity-based method to the CT images (middle) and when applying only the intensity-based method to the MR images (right). Clearly the method we propose permits deformations of the skeletons (especially ribs) without introducing unrealistic distortions, while the other methods do not. Figure 2 shows registration results we have obtained for the entire MR image volume. In this figure, the left panel is a coronal slice in one volume. The middle panel is the corresponding slice in another volume. The third panel shows the volume on the left registered to the volume in the middle using the method we propose. The green contours have been drawn on the middle image and copied on the others to show the type of accuracy we are able to achieve. The red arrows show the most noticeable differences between reference and target volumes.

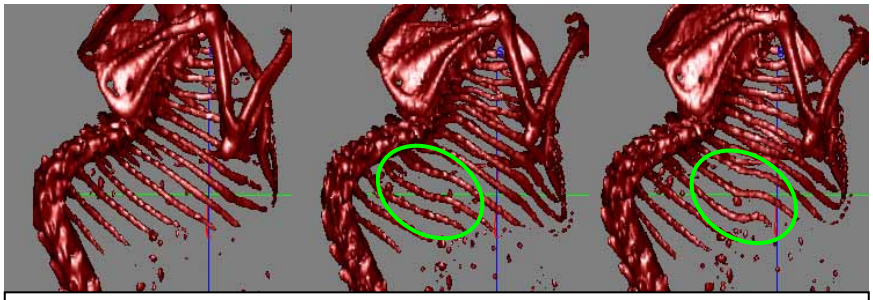

Figure 1: the skeletons with the proposed method (left), when applying only the intensity-based method to the CT images (middle), and to the MR images (right).

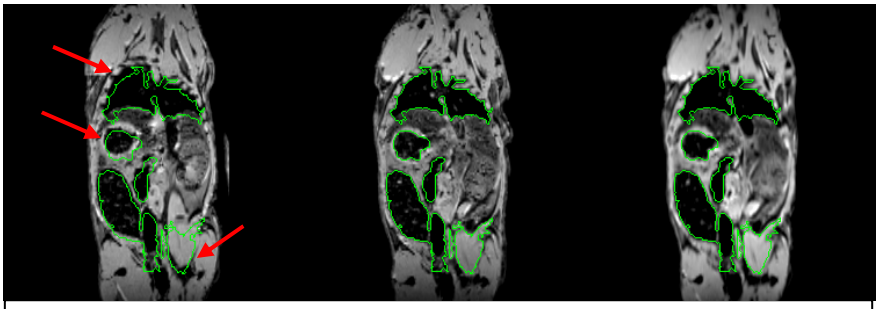

Figure 2: the coronal MR slice in the reference volume (left), the target volume (middle), and the deformed reference volume using the proposed method (right), respectively.

Conclusions

We have developed a novel method for the automatic registration of serial whole body MR images. The results we have obtained show that our approach leads to better results than those obtained with only CT or MR images. All the steps in our approach are automatic. Regularization constraints imposed in our registration algorithms also lead to smooth and invertible transformations. Ongoing work includes quantitative validation of our approach.

References

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