Robust automated Navigator tracker positioning for MRI liver scans

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PURPOSE: The Navigator Echo sequence is widely used in abdominal MRI scans to compensate for respiratory motion effects. However, the navigator signal may be contaminated by signals from the heart, large lung vessels, and fat containing parts of the body due to inappropriate positioning of the Navigator tracker; thus, resulting in the degradation of image quality caused by miss-triggering of the Navigator. Accordingly, the positioning of the Navigator tracker is a troublesome process, and worsens the workflow. In an earlier study, we proposed a method of automated navigator tracker positioning[1] to improve the process, and we obtained successful navigator positioning in volunteer subjects. In a subsequent study with additional volunteers and patients, several cases displayed inappropriate positioning due to false edges on non-liver tissue. The purpose of the present study was to demonstrate that our method of automated navigator tracker positioning was robust for a variety of images, including post-surgical deformed liver and diseased liver with cysts.

METHOD: Fig. 1 shows the block diagram of our proposed method. First, 2D scout scan images are acquired by a Single Shot Fast Spin Echo (SSFSE) three-plane localizer, which is usually run at the beginning of a MRI exam. The 2D scout images consisted of five axial slices, one sagittal slice, and seven coronal slices. The scan parameters were given as TR/TE: 1100/80 ms; Scan matrix: 320×192, Slice thickness: 8 mm, Slice spacing: 5 mm, NEX: 0.54, FOV: 400×400 mm or 480×480 mm. The total scan time was 20 s. No intensity correction was applied, and subjects did not hold their breaths during the scan. The five axial images were used to extract the maximum length of the right/left (R/L) and anterior/posterior (A/P) direction in the body by the morphology process which consists of erosion and dilation using a 5×5 structuring element following binarization by image noise. Similarly to the previous method, the rough location of the boundary between the lung and the liver was identified by template matching, and the derivative points near that boundary and inside the body were extracted from each coronal image. As shown in Fig. 2, a 19×19 kernel is used to detect the boundary of the lung and the liver. AdaBoost[2] (6 Haar-like features and 955 weak Classifiers) was applied to further refine the edge detection. Finally, minimum covariance determinant (MCD) estimation[3] removed outliers in the detected edges of the images, using the location of the edges from coronal images as the input vector. This process allowed us to remove the false edges more effectively than the previous method. Dynamic programming (DP) was applied to extract the curve of the liver dome from the edges. The center of the Navigator tracker was placed on the liver dome peak, as in the previous method, while the A/P location was defined as the A/P location of the coronal plane closest to the center of the body (shown in Fig. 1). We used 3578 positive samples and 7120 negative samples from both 20 volunteers and 15 patients for the learning step of AdaBoost. Apart from these learning datasets, our method was tested on other 118 volunteers and 53 patients (mean age = 64 years; age range = 24 – 85 years) following institutional review and approval.

RESULTS: Fig. 2 shows the box plot of the difference between the expert user- and automatically- selected navigator position in test datasets. The negative values of the R/L and S/I (Superior/Inferior), indicate that the detected location was offset in the right and superior directions, respectively. The error in R/L was more than twice as larger than S/I error. Error in A/P was ±1 slice shift (10-15 mm) in the worst case. Fig. 3 shows the two cases of automated tracker results. Fig. 3a is a case of multiple hepatocellular cancer and Fig 3b is a case of giant cyst. In these cases, the livers were much deformed by surgery (3b) and disease (3a). However, our algorithm worked properly. As for 29 cases of the patients, the automated tracker results were actually applied to slice tracking technique in dynamic study with breath holding scans and we confirmed the all of slice locations were fairly matched by Navigator echo technique. The computation time of the automated tracker was 10 s on a laptop with a Core i5 processor and 2 GB RAM. The program was written in Matlab R2012a.

DISCUSSION: The shape of liver dome showed various changes since the scout scan images were acquired without breath hold, resulting in much larger error in R/L direction than S/I. Breath holding scout scan will be helpful to obtain more consistent results although the number of slices will decrease due to the limitation of the breath holding time. Despite the error variations, all navigated scans completed successfully for auto-tracker placement case. From a clinical standpoint placement variations vs expert user did not cause any failures.

Conclusion: We have demonstrated the effectiveness of the proposed method on a group of 118 volunteers and 53 patients. Our practical approach is expected to help the operator and will improve the workflow.

Reference

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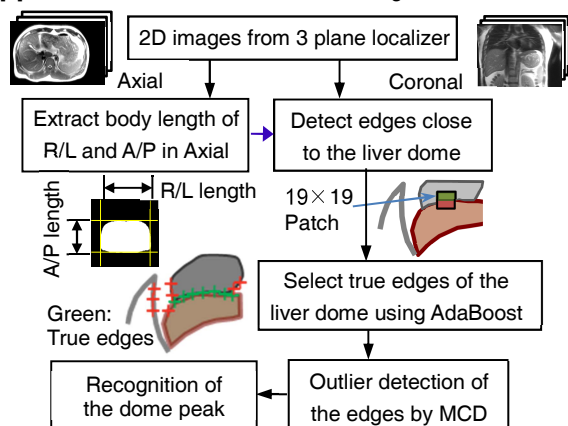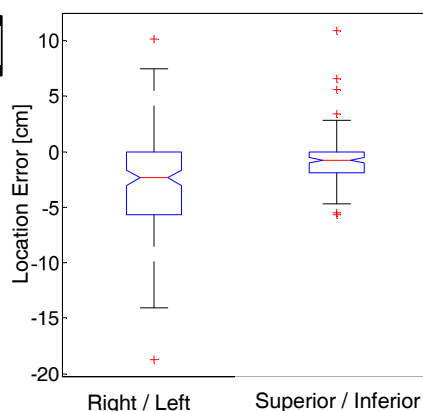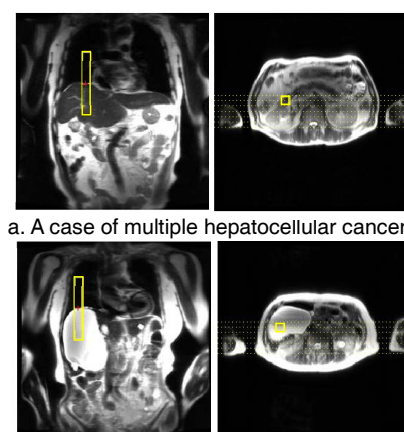
Fig. 1 Block diagram

Fig. 2 Navigator tracker positioning error

a. A case of multiple hepatocellular cancer

b. A case of Giant cyst

Fig. 3 Automated Navigator Tracker results in patient data