

Three-Dimensional Focal Spot Tracking based on Portal Vain Tree Structure

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Introduction The target tracking technique to “lock on” the focal spot is important for MRgFUS for the abdominal organs such as the liver. The technique based on relative displacements of blood vessels using sagittal MR images was effective for translational motion and deformation in superior-inferior (SI) and anterior-posterior (AP) directions [1,2]. The analysis of three-dimensional transformation and deformation of the hepatic tissue using image sets of multiple slices under slow free breathing led the deformation in left-right (LR) direction was negligibly small[3]. In this study, we proposed two three-dimensional tracking methods based on portal vain structure.

Methods and Materials Multiple sagittal plane images of healthy volunteer’s liver were acquired by 1.5T MRI (Signa Excite 11, GE Healthcare UK Ltd.) with Fast Image Employing STeady state Acquisition (FIESTA). Imaging conditions were as follows: TR/TE, 3.8/1.3 ms; slice thickness, 5mm; pixel size, 0.78 x 0.78 mm²; field of view, 400 x 400 mm²; spatial matrix, 512 x 512; flip angle, 90 degrees. 65 image sets of interleaved four slices were acquired under slow pace respirations that cycle was 20 seconds per a breath.

First, each image set was arranged to the isotropic voxel images by a linear interpolation method. Next, the portal vessel structures were extracted with following steps: 1) Correct magnetic field inhomogeneity by least square approach. 2) Smooth the images with moving average filter. 3) Extract the vessels by thresholding from the smoothing images. 4) Apply three-dimensional region growing process. 5) Smooth the images with the three-dimensional Gaussian filter. 6) Extract the skeleton of the vessel structure using the Euclidean distance transformation.

The branching vessel v_1 for interesting was shown in Figure 1. Figure 2(a) shows branching point P_1 and branch vessels P_2 and P_3 . The target point O was set on the other branching point of vessel v_2 . **Method 1:** On the assumption that the relative positions of the target and $\Delta P_1 P_2 P_3$ were held after motion, the distance between the target of after motion O' and $\Delta P'_1 P'_2 P'_3$ would be $d' = S' * d / S$, where S was the area of $\Delta P_1 P_2 P_3$ as shown in Figure 2(b). **Method 2:** The other method is as shown in Figure 2(c). The target before motion O was projected onto a sagittal plane. The target after motion $O'(y'_o, z'_o)$ projected on sagittal plane was obtained by a following relational expression; $(y_3 - y_2) / (y_o - y_2) = (y'_3 - y'_2) / (y'_o - y'_2)$, $(z_3 - z_2) / (z_o - z_2) = (z'_3 - z'_2) / (z'_o - z'_2)$. $O'(y'_o, z'_o)$ was back projected to LR direction. The distance of back projection was the translational distance of the branching point P_1 along LR direction.

Results The skeleton of the branching vessel of 35 image sets were successfully extracted from original MR images. The image processing operation from step 3) to step 6) were applied to the selected area which included the branching vessel for interest. The coordinate of P_1 and O were extracted as branching points of the extracted skeletons. The vessels P_2 and P_3 were extracted from the image that was 9 slices away from the slice of the branching point P_1 . The errors between the estimated target and branching point O are shown in Figure 3 and Table 1.

Discussion and Conclusions

The results demonstrated the target could be tracked with the proposed method. The feasibility of the proposal method was demonstrated under the condition that deformation in LR direction was negligibly small and rotation of branching vessels was not considered. In the future, we sophisticated the proposed method will be applied for complicated deformation of portal vain.

Table 1 Average and standard deviation of estimate error [mm].

	SI	AP	LR	Euclidean distance
Method 1 Ave.	3.18	2.16	0.99	4.28
S.D.	1.20	1.10	0.60	1.07
Method 2 Ave.	3.21	2.76	2.41	5.58
S.D.	2.64	1.73	1.46	2.60

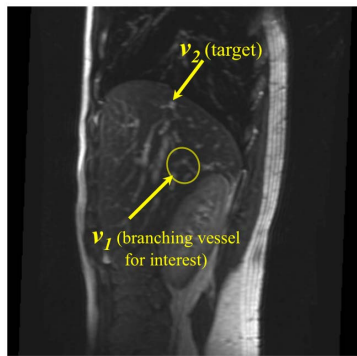


Figure 1 Three-dimensional MIP image reconstruct from isotropic voxel images (26 slices). v_1 is a branching vessel for interest and v_2 is a branching point (target) for tracking.

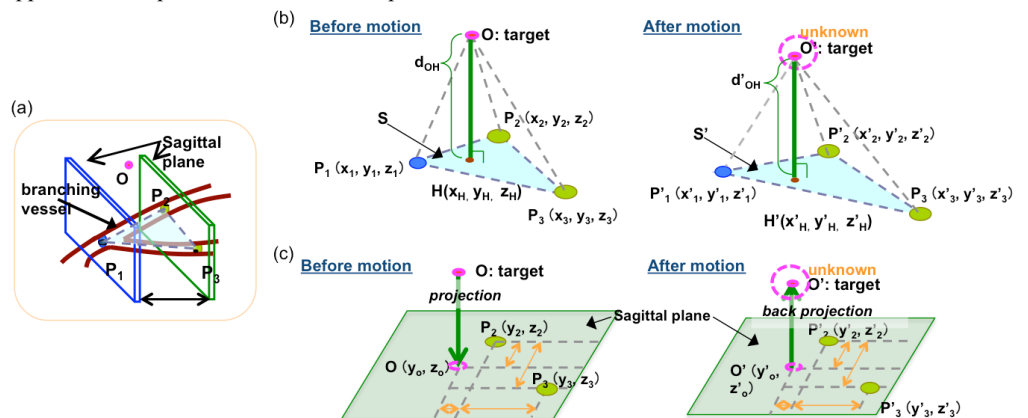


Figure 2 (a) P_1 is branching point and P_2 , P_3 are branch vessels divided from P_1 . (b) Method 1: A target point and the plane S constructed from P_1 , P_2 and P_3 before motion and after motion. (c) Method 2: A target was projected on sagittal plane and after motion the target would be back-projected onto estimated target.

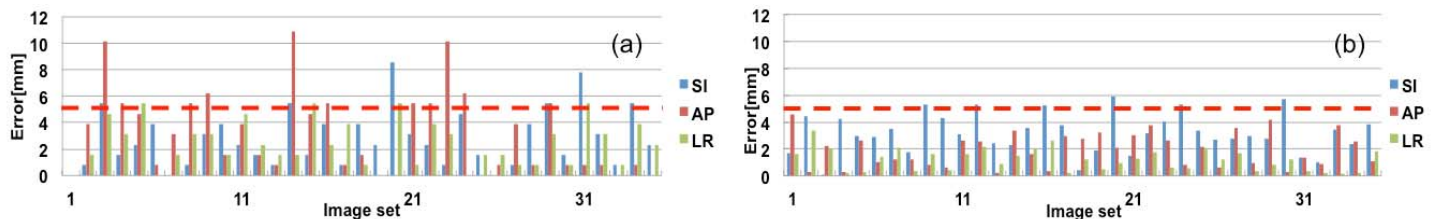


Figure 3 Error between the estimated target point and the branch point O of each image set. The purpose of tracking error is under 5mm (red dotted line).

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