Automatic Passive Tracking of a Prostate Biopsy Device Using Phase-only Cross Correlation

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Introduction

Prostate cancer is one of the most common tumors diagnosed in men over 50 years [1] and, despite a relatively low sensitivity, ultrasound-(US)-guided prostate biopsy remains the gold standard for a definitive diagnosis. The excellent soft tissue contrast provided by MRI has been used to improve the sensitivity of the biopsies [2], but the time needed to manually track the prostate biopsy device in the MR images imposed an important constraint to the popularization of MR guided prostate biopsies. To speed up the needle orientation procedure we propose a new fast method for tracking of passive markers attached to the biopsy device. The method uses a phase-only cross correlation algorithm for marker detection and is combined with automatic slice positioning to track the current biopsy needle position.

Materials and Methods

Theory

Phase-only cross correlation (POCC) is a very efficient method for image feature extraction [3]. Let *I(x,y)* be a measured image of a given object (e.g., the cross-section of the prostate biopsy marker) located at (x_0,y_0), and let *M(x,y)* be an artificial image (e.g. a circular ring) representing a digital model of the object in the image center. Using the k-space representation of *I* and *M*, the POCC is computed:

$$POCC(k_x,k_y) = \frac{I(k_x,k_y)}{\left\|I(k_x,k_y)\right\|} \cdot \frac{M^*(k_x,k_y)}{\left\|M^*(k_x,k_y)\right\|} = \frac{I(k_x,k_y)}{\left\|I(k_x,k_y)\right\|} \cdot \frac{I^*(k_x,k_y)}{\left\|I(k_x,k_y)\right\|} e^{i2\pi(k_x x_0 + k_y y_0)} = e^{i2\pi(k_x x_0 + k_y y_0)}$$

The position of the object can then be extracted by applying the inverse FFT to the POCC image, which ideally has a maximum at the location of object.

Prostate Biopsy Device

The prostate biopsy marker (PBM) [4] was developed at MRI Devices/Daum, Schwerin, Germany, in cooperation with Charité, Berlin. It consists of a cylinder filled with a contrast agent solution (Gd-DTPA/water: 1:100). The central opening of the cylinder is used to insert the biopsy needle. In a T1-weighted MR image acquired orthogonally to the needle axis the marker appears as a ring. During the procedure the marker is connected to a holder at the patient table which can be locked for needle positioning (fig. 1).

Fig. 1: *Experimental setup showing the prostate biopsy device and the PBM.*

Pulse Sequence

A dedicated tracking sequence was implemented on a clinical 1.5 T MR system (Siemens Magneton Symphony, Erlangen, Germany) for automatic detection of the PBM. Using an initial localizer two parallel tracking slices are positioned orthogonal to the PBM axis. Two strongly T1-weighted tracking FLASH images are acquired (TR/TE=4.5/3.0 ms, FOV=256x128 mm², α=45°, partial Fourier = 4/8, slice thickness=5.0mm) and the position of the PBM is calculated in the standard image reconstruction environment (ICE, Image Calculation Environment) with the POCC algorithm. After a short pause of 100 ms, the position information is sent to the gradient hardware to align a third slice with the needle axis in real-time. In this orientation a trueFISP image is acquired with the same parameters of the previous FLASH images. Marker and trueFISP images are continuously re-acquired and displayed in real time (Fig. 2).

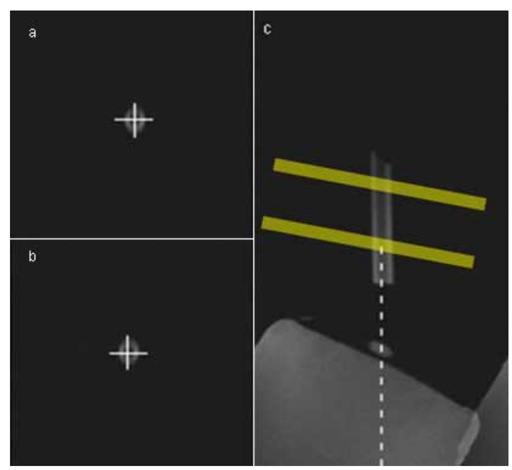

Fig. 2: *a and b) Two initial FLASH images are positioned in a localizer image and used to estimate the position of the object (cross). Finally this information is used to prepare the next slice position / orientation and in c) a TrueFISP image shows the biopsy device (two parallel lines) being aligned with the vitamin E capsule (doted line).*

Precision Estimation

To measure the precision of the needle positioning, a target phantom was developed with a set of five vitamin E capsules that were placed over a layer of gelatin. The prostate biopsy device was attached to the patient table and the biopsy needle was inserted into the targets, using both the automatic tracking sequence and the manual slice positioning. A reference grid was placed over the targets so that every time the needle was positioned, it would leave a mark showing its distance to the center of the vitamin E capsules. The experiment was repeated three times and the errors of the needle position were measured.

Results and Discussion

The average error of needle positioning for the manual/automatic tracking was 3.6±1.7 mm / 2.1±1.41 mm. The detection algorithm was robust even under initial misalignments (cf. Fig. 2a/b). The passive automatic tracking can be easily integrated into any MR pulse sequence, allowing operators to navigate instruments near the prostate in real-time using the PBM as a pointer (similarly to an US probe). The algorithm exploits the fact that only minor changes of both orientation and position are present when the operator reorients the biopsy device in the rectum to target the suspect lesion. The use of POCC to track the PBM could provide a simple and cost-efficient alternative to existing tracking system which might help to increase the precision and patient throughput in MR-guided prostate biopsies.

References

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