A New System for Passive Tracking of a Prostate Biopsy Device with Automatic 3D Needle Position Estimation

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Introduction

Recently a new sequence for passive tracking of an MR compatible prostate biopsy device was proposed [1]. With this tracking approach the direction of the biopsy needle was obtained in real-time by extracting the position of the prostate biopsy passive marker (PBPM) using phase-only cross correlation (POCC) [2]. In this tracking sequence one degree of freedom was not determined and the position of the biopsy needle tip could not be obtained. Furthermore, the system could not track movements of the PBPM in the direction of its main axis. In this work, an additional small marker was integrated into the PBPM and the real-time tracking sequence was modified to allow for 3D device tracking with the same temporal resolution.

Materials and Methods

Prostate Biopsy Passive Marker

The prostate biopsy passive marker (Invivo, Schwerin, Germany) [1] consists of a cylinder filled with contrast agent solution (Gd-DTPA/water: 1:300). 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 intervention a holder is used to align the PBPM with a suspect lesion in the prostate. Once the device is aligned the biopsy needle is inserted and a sample is retrieved. To estimate the penetration depth, an additional toroidal marker was attached co-axially at the distal end of the PBPM, forming the PBPM3D. In a slice oriented parallel to the PBPM3D main axis, the marker system appears as two parallel lines and two circles (fig 1).

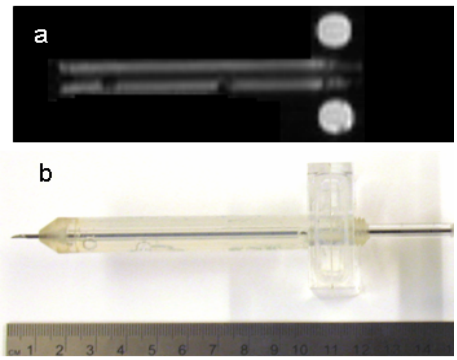

Fig. 1: *The PBPM3D: a) cross-sectional MR-image, b) photograph showing the passive marker with the biopsy needle.*

Passive Tracking Pulse Sequence

A dedicated pulse sequence was implemented on a clinical 1.5 T MR system (Siemens Magneton Symphony, Erlangen, Germany) for automatic tracking of the PBPM3D. Using an initial localizer two parallel tracking slices are positioned approximately orthogonal to the PBPM3D axis. Two strongly T1-weighted tracking FLASH images are acquired (TR/TE = 4.5/3.0 ms, FOV = 256x128 mm², α = 35°, partial Fourier = 4/8, slice thickness = 5.0mm) and the direction of the PBPM3D is calculated in the standard image reconstruction environment (ICE, Image Calculation Environment) by extracting the position of the center of the PBPM3D in two different slices with the POCC algorithm (Fig. 2). 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 as the previous FLASH images, but with α=70°. During a second pause, the position of the circle markers is extracted from the trueFISP image using POCC algorithm. This information is used to reposition the next tracking slices and to show the estimated position of the needle tip. Tracking (FLASH) and trueFISP images are continuously re-acquired and displayed in real time (Fig. 3). To improve the robustness of the sequence, an automatic loss of tracking detection system was implemented based on the maximum speed of device reorientation. In case of incorrect tracking, an error message is displayed and the last valid tracking slice orientation is used until the correct device position is found.

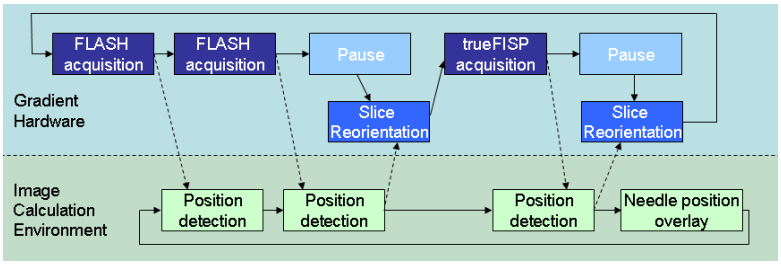

Fig. 2: *Schematic view of the tracking system showing information flow between the gradient hardware and the image calculation environment.*

Phantom Experiment

The precision of the needle tip positioning was measured in a prostate biopsy phantom (CIRS, Norfolk, USA). The tracking sequence was used to guide the PBPM3D until it was aligned with an embedded lesion. The needle tip position was estimated for two situations: before and after release of the biopsy gun (150 mm, Invivo, Germany). Afterwards, the biopsy needle was inserted and a TSE image with the same orientation was acquired before/after shooting the biopsy gun. The position of the needle was measured for both situations and the errors of position estimation were obtained. This procedure was repeated 10 times and the average errors were calculated.

Results and Discussion

The error of needle position estimation before/after shooting the biopsy gun was 1.5±0.7 mm / 1.8±1.1 mm. With a refresh rate of about 1 image/s the 3D tracking system enables a robust and safe method for targeting of suspect prostate regions in real-time. Compared to manual slice alignment, which is currently used during MR-guided prostate biopsies, this technique is expected to decrease the intervention duration significantly. Furthermore, with its precise estimation of the biopsy needle position this system could help improving the precision and sensitivity of MR-guided prostate biopsies. Since no extra hardware is necessary, the 3D tracking system can be easily be integrated into any MR scanner thus providing a simple, cost-effective and safe alternative to other more hardware-dependent systems. The proposed concept is flexible and, with some minor modifications, this tracking system could be used to target other organs.

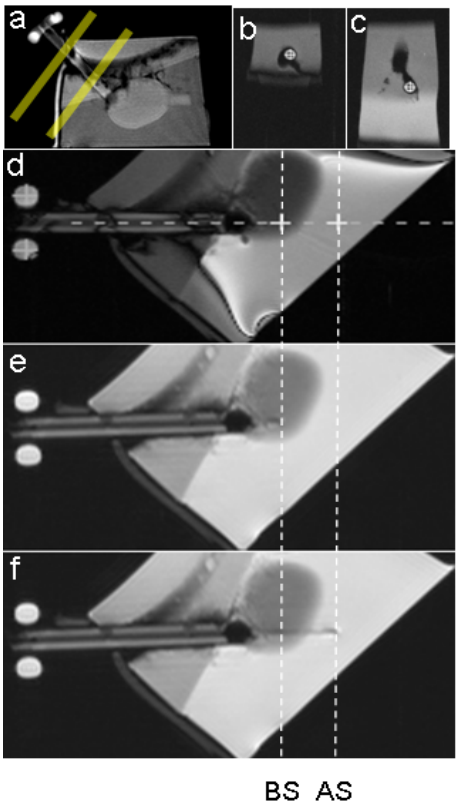

Fig. 3: *(a): Localizer image showing the initial tracking slices position. (b,c): FLASH images with the estimated device position (white crosses). (d): TrueFISP image showing estimated needle trajectory and position before (BS) and after (AS) shooting the biopsy gun. The estimated position of the PBPM3D circles is also overlaid on the images. (e): TSE images show the needle inserted before shooting and (f) after shooting the biopsy gun.*

References

[1] De Oliveira et al, MRM : 2007,59, in press.

[2] Chen Q, et al. IEEE Trans Pattern Anal Mach Intell : 1994,16(12):1156-1162.