

MR-US Fusion for Targeted Prostate Biopsy

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Introduction:

In men with suspected prostate cancer, ultrasound-guided prostate biopsy is a standard diagnostic procedure. This is a relatively inexpensive, safe and straightforward procedure, which is typically performed in < 20 minutes in the urologist's office. However, ultrasound provides only gross targeting for prostate biopsy, as it is unable to distinguish malignant tissue from healthy prostate tissue. Because of ultrasound-guided prostate biopsy's low sensitivity (as low as 40%), repeat biopsy is frequently required [1]. On the other hand, multi-parametric MRI is able to distinguish malignant or suspicious prostate tissue from benign prostate tissue, with a sensitivity up to 96% [1]. Because of this, prostate MR is being used more routinely to solve these dilemmas in prostate cancer, both as purely a diagnostic tool and for MR-guided biopsy. Although highly sensitive and specific, MR-guided prostate biopsy is typically only performed in academic centers due to procedure length, cost and discomfort for both the patient and operating physician.

One potential solution to this problem is to take pre-acquired diagnostic MRI images, and to actively fuse them to the real-time ultrasound acquired during the urologist's typical in-office biopsy procedure. In this way the diagnostic power of prostate MRI could be married to the flexible, rapid and inexpensive ultrasound guided procedure.

Some existing solutions for targeted prostate biopsies based on 3D ultrasound have on-going research regarding fusion with MRI. Those systems do to date not provide deformable registration in the mobile prostate, and have static probe-holder designs – which are somewhat antithetical to the current normal urologist workflow.

We propose a system based on a magnetically tracked freehand ultrasound probe, combined with a novel powerful deformable registration workflow that effectively compensates prostate organ deformation between the two modalities.

Materials and Methods:

The fusion system uses a Siemens Sequoia 512 ultrasound system with an EV-8C4 end-fire transrectal ultrasound (TRUS) probe. A magnetic position sensor (Ascension Tech.) was affixed to the probe and calibrated. A PC workstation receives both the live ultrasound images and tracking information, and runs our fusion software, visualizing the patient's MRI spatially aligned with TRUS.

Subjects: 19 middle aged men, with elevated PSA and suspected prostate cancer were enrolled in the study. Each patient underwent a T2-weighted 3D-SPACE MRI exam acquired with an isotropic resolution of 0.9 mm. The measurement was performed on a Siemens Magnetom Verio equipped with body array and endo-rectal coil. The MRI data was then transferred onto the fusion workstation in the urology room.

Planning: The prostate was segmented using a semi-automatic Random Walker segmentation, initialized with one stroke across the organ. If necessary, corrections could be made using nudging tools and re-segmentation based on further fore- and background seeds. Suspicious masses within the prostate were marked as targets for MR-US guided biopsy.

Registration: Next, the patient was set up in the urology chair and the magnetically tracked TRUS probe inserted. The physician maneuvered the probe into an axial plane, which was used to initialize the MRI orientation with respect to the tracking coordinate system. Henceforth, he quickly marked the left and right side, as well as the base and apex of the prostate both in TRUS and MRI in a side-by-side visualization. Then a 3D freehand sweep was recorded in coronal orientation, covering the entire prostate, serving as input data to a novel automatic registration algorithm, comprising the following steps. The 3DUS sweep is compounded into a rectilinear volumetric grid, the MRI prostate contour transferred onto it, and the Random Walker segmentation executed using this contour as initialization. The physician quickly reviews and, if necessary corrects, the prostate contour on the ultrasound volume. Afterwards, a deformable boundary-based registration step warps the MRI contour to exactly match the one on 3DUS, using a variational registration approach on a distance volume representation of the contours. The target markers are warped according to the registration result.

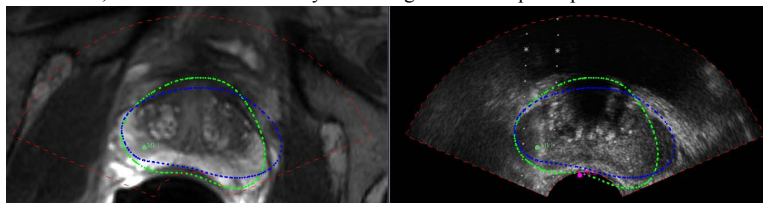


Figure 1: MRI and TRUS live view, just after targeted puncture. The target is shown as green point, contours used for registration are also depicted (MR green, US blue).

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Results and Discussion:

The entire registration workflow as described above, was usually executed in 1-2 minutes (of which ~20 seconds is computation time). We retrospectively evaluated the registration accuracy by carefully annotating anatomical targets within and at the border of the prostate in both modalities. The average RMS landmark error after registration is 3.1 mm. Compared to rigid pre-alignment, suspicious targets in the vicinity of the TRUS probe significantly improved in terms of alignment with MR, since the deformable registration compensates for probe compression (on average 1.2mm reduction of RMS error, up to 6.3mm for individual targets).

Towards the end of this first patient population, the study protocol was in place allowing us to evaluate the described methods including fusion guided actual biopsies, and comparison to pathological findings. At the time of writing, three patients have been successfully diagnosed using our system.

The proposed system and methods allowed for a relatively straight-forward fusion of tracked freehand ultrasound and a designated MRI SPACE sequence, increasing the confidence of targeted prostate biopsy. Still, it retains the flexibility of using a freehand ultrasound system with MRI fusion as opposed to a designated, mounted 3DUS guidance solution.

References:

- [1] Pondman KM, Fütterer JJ, ten Haken B, Schultze Kool LJ, Witjes JA, Hambroek T, Macura KJ, Barentsz JO. MR-guided biopsy of the prostate: an overview of techniques and a systematic review. Eur Urol. 2008 Sep;54(3):517-27.