# Needle Labeling for Interstitial Gynecological Brachytherapy

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Purpose

In interstitial brachytherapy for gynecological cancer, radioactive seeds are delivered to the target tissues using multiple hollow needles. However, due to tissue resistance, these needles may not follow a trajectory that can be accurately predicted using dead reckoning. In this work we provide a fast and accurate method to extract and display needles from MR images acquired during MR-guided gynecological cancer brachytherapy. Compared to CT, needle artifacts are less easily identifiable in T2w MR, the sequence of choice for visualizing gynecologic cancer. In previous work [1], we introduced the use of a customized SSFP MR sequence to enhance needle artifacts in these procedures, and in this work we provide a post-processing method that reliably and accurately extracts the needles from images acquired using these SSFP MR images.
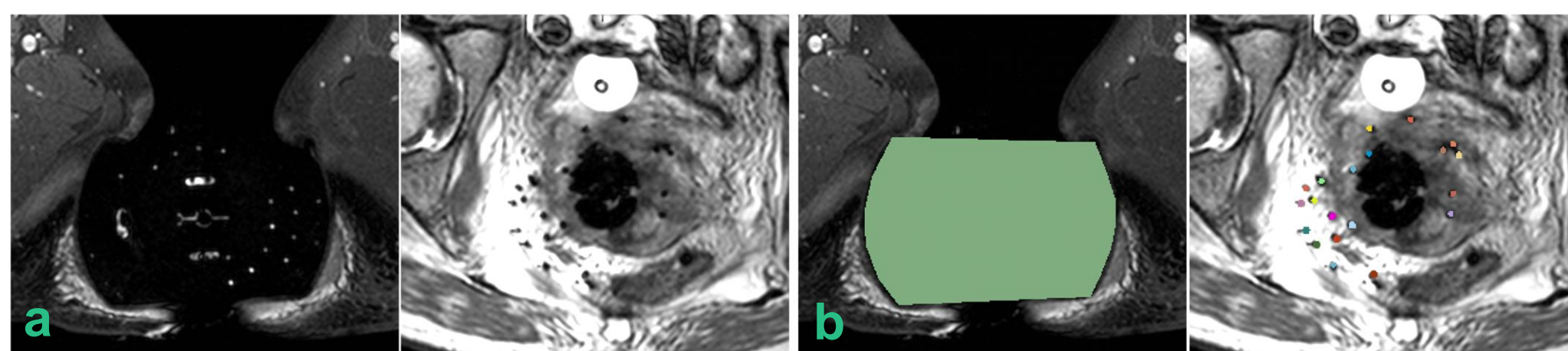
Methods

The user is asked to provide two pieces of information in order to initiate the needle extraction tool (Figure 1). The algorithm then takes over to extract the needles in the image. Mathematically, denote the MR image as a function $I:\Omega \rightarrow R$ where Ω is the field of the view of the image. Accordingly, denote the voxel positions drawn by user for the template as $B = \{b_i \in \Omega; i = 1, \ldots, N\}$ and the voxel positions for the needles as $D = \{d_i \in \Omega; i = 1, \ldots, M\}$. Then, the Hessian image $H: \Omega \rightarrow S^{3 \times 3}$ is computed. The eigen system of the 3×3 matrix defines a Conformal Euclidean metric on Ω [2]. A straight line is then computed from each needle label region among $d_{1,\ldots,M}$, to the template region B. By doing this, an optimal line is obtained for each needle, which is regarded as the needle. The algorithm is implemented in C++ language.

Figure 1: User Input
First, the user is asked to draw a region in one of the inferior most transverse slices through which all the needles pass. For example, when a Syed Neblett template is used and is visible in the scan, this region can be the approximate outer boundary of the template. Then, the user is asked to scroll to a superior transverse slice close to the tip of the needles, and identify the cross sections of the needles.
(a) Shows the unmarked scan and (b) shows a typical initiation marking.

Results

This needle extraction tool has been used to segment needles on 6 SSFP MR images. The running time, from user input to final results, is less than one minute to extract up to 20 needles. Results have been visually compared very favorably to manual needle extraction by a physician, and will be quantified in future work.
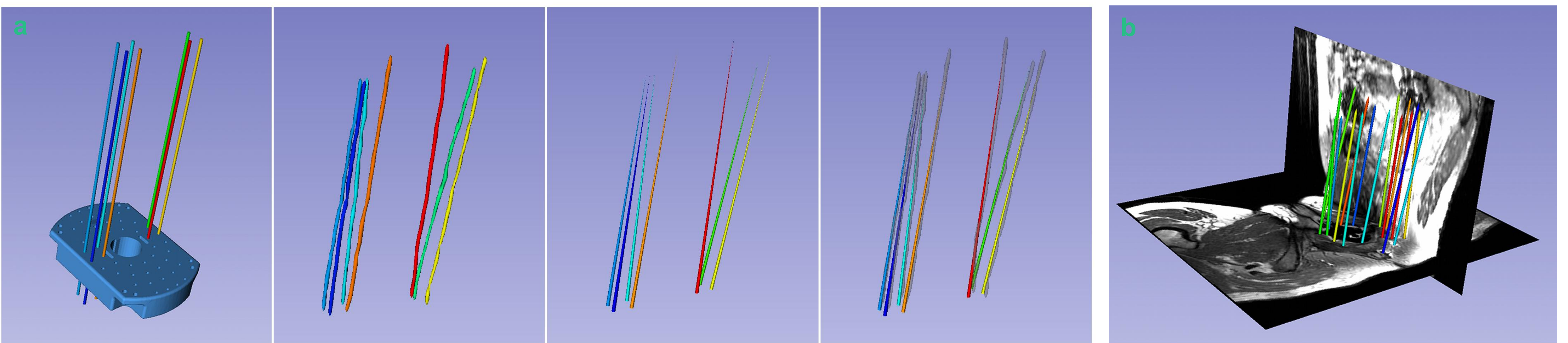
Figure 2: Results
(a) Left to right: CAD model of Syed Neblett template and ideal needle positions assuming no tissue resistance; Manual segmentation of needles from MR image; Automatic needle extraction from MR; Overlay manual and automatic.
(b) Results of needle extraction from Figure 1 rendered in 3D
(c) Results of needle extraction from Figure 1 in three cross-sections

Conclusion

In this work we have a novel algorithm to extract gynecologic brachytherapy needles from SSFP MR imagery. The algorithm requires simple inputs from the user based on which 3D models of the needles are constructed in a time frame that is acceptable for intra-procedural guidance. Future work includes (1) modeling the bending of needles (2) quantitative comparison of results to manual extraction of needles from MR, as well as to CT images.

References

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