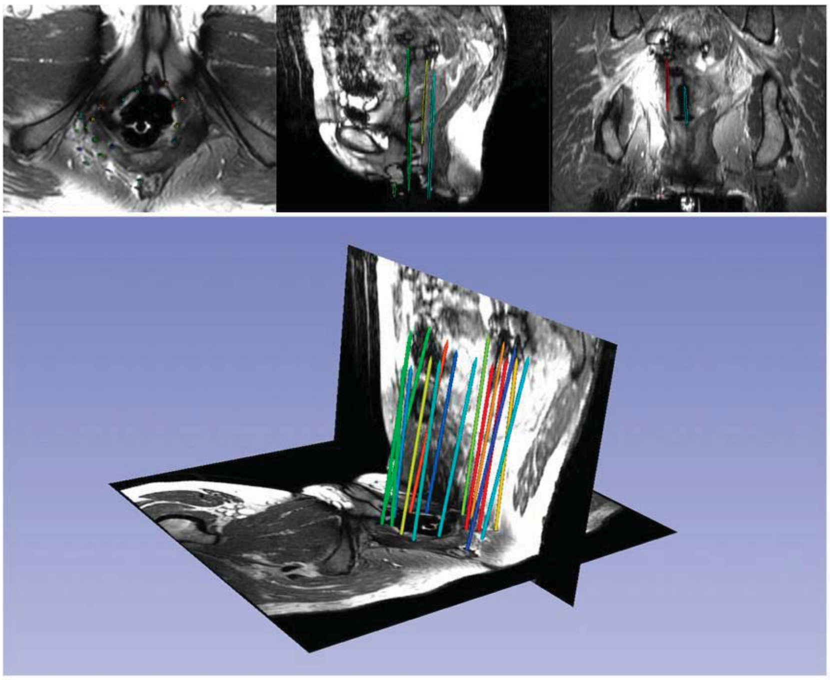
Needle Labeling for Interstitial Gynecological Brachytherapy

Yi Gao[1], Nabgha Farhat[1], Neha Agrawal[1], Guillaume Pernelle[1], Xiaojun Chen[1], Jan Egger[1], Tyler Blevins[1], Sylvain Bouix[1], Allen Tannenbaum[2], William Wells[1], Ron Kikinis[1], Ehud Schmidt[1], Akila Viswanathan[1**] and Tina Kapur[1**]
[1]Brigham and Women's Hospital, [2]Boston University, **Joint Senior Authorship

Purpose – During the process of needle insertion for interstitial gynecologic brachytherapy, the needles may bend secondary to tissue deflection. Variability in tissue resistance may arise from fat, water, bone or muscle coursed through in the path of the needle. 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. First, the user is asked to draw a region in one of the transverse slices where all the needles pass through. 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. The algorithm then takes over to extract the needles in the image. Mathematically, we 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 $B = \{b_i \in \Omega;\ i = 1, \dots, N\}$ and the voxel positions for the needles as $D = \{d_i \in \Omega;\ i = 1, \dots, M\}$. Then, the Hessian image $H: \Omega\rightarrow S^{3\times3}$ 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 $d_{1,\dots,M}$, 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.

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. The figure on the right shows the results of the needle extraction algorithm on three cross-sections (top), and rendered in 3D (below). Results have been visually compared very favorably to manual needle extraction by a physician, and will be quantified in future work.



Conclusions – 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.

Acknowledgements
This work was supported by NIH grants R03EB013792, P41EB015898, U54EB005149, and members of the AMIGO and Slicer communities.

References
[1] Kapur, T., Egger, J., Damato, A., Schmidt, E.J. & Viswanathan, A.N., 3-T MR-guided brachytherapy for gynecologic malignancies. Magnetic Resonance Imaging, Elsevier, in Press, 2012.
[2] Kichenassamy, S., *et al.*, Arch. Rational Mechanics and Analysis, 134(3):275–301, 1996.