PhD thesis topic proposal
Tool Localization and Tracking from 3D Medical RF Ultrasound

Supervisors (PhD in European co-agreement):
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Context
Minimally invasive surgery, biopsy and direct neuronal cortical recording are three examples of medical tasks in which it is necessary to precisely localize the respective tool (scalpel, needle, electrode) with respect to the organ to be examined. Ultrasound seems to be particularly suited for this task for its comparatively low cost, non-invasiveness, no harmful radiation, real-time speed, and ability to image both the soft tissues and the usually metallic tool. In particular, modern 3D ultrasound machine allows tracking in all axes and access to the RF signal potentially permits us to achieve localization accuracy better than the wavelength.

Goal
Design, implement, and test methods for precise and robust real-time localization of metallic tools in tissues from 3D ultrasound RF sequences.

Method
Existing methods developed during two previous PhD theses on the subject will be used as a reference and adapted to the extended possibilities of our new research ultrasound scanner Ultrasonix 500 RP.
Specifically, we will tune the excitation sequence and the reception filters to maximize the localization accuracy. This will require theoretical modeling of the interaction of the ultrasound impulse with the tool. The precision will be further increased by an adaptive tool-specific denoising and deconvolution procedure. Temporal prediction will increase tracking robustness. Multiresolution should bring further acceleration. In the experimental part, we shall evaluate the benefit of using the RF signal directly. The performance and usefulness of the proposed approach will be evaluated in collaboration with our clinical partners.

Partners and equipment
The thesis work will be part of the Early Stage Training Marie-Curie project WARTHE (Wide Area Research Training in Health and Engineering), sponsored by the European Union. It will be done in collaboration of three partners: the group CREATIS that has an ample experience in ultrasound imaging and has access to a well-equipped laboratory and modern 3D ultrasound scanners. The ``Institute of Cognitive Science'' in Lyon will provide us with the clinical knowledge. Finally, the ``Center for Machine Perception'' at Czech Technical University in Prague, specializes in signal and image processing, optimization and pattern recognition.

Benefits
We expect to help to develop tools and techniques permitting accurate in-vivo real-time localization of surgical tools. This should lead to faster and more precise surgery, biopsy, or measurements,

accelerating the procedure and reducing the likelihood that it needs to be repeated