Multimodal Data Fusion and 3D Reconstruction for Needle Guidance in Cryoablation Procedures

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This work presents a method to track, register and integrate preoperative images with multimodal data acquired during the actual intervention. The goal of the method is the virtual reconstruction of the operative scenario to provide the surgeon with the ability to clearly understand the spatial relation of the anatomical structures of interest even after important deformations.

The proposed method focuses on the assistance of percutaneous cryoablation of renal tumours because this procedure requires the surgeon to translate the mental plan developed on the CT images into the reality without any hint about internal structures position or with the assistance of a bare US image. The use of virtual reconstruction increases the awareness of the ongoing procedure, by providing a rendering of the different tools and structures involved in the intervention it improve the positioning of the cryoablation needle.

Along with standard CT and US images, the method exploits the data obtained by a RGBD Microsoft Kinect camera, integrated through the tracking system to monitor the breathing motion and to identify unexpected movements of the patient (or phantom in our case). The hull extracted from the reconstruction provided by the Kinect camera, is rigidly registered with the patient (or phantom) external surface obtained by CT data segmentation. This phase allows mapping the preoperative plan in the world coordinate system as defined by the tracking hardware.

The plan defines the proper entrance point and orientation for the needles (typically 3) tip to reach the target point. The user is guided during the placement and the insertion of the needle by mean of a small screen. The rendering of the US images in the virtual environment provides further assistance. US data, in fact, are mapped in the world coordinate system thanks to a calibration procedure that exploits a simple, crosswire phantom and are used intraoperatively to monitor the deformations of the needle and of the internal tissues. The Kinect camera keeps trace of the breathing movements and continuously updates the position of the target point from the preoperative image in the world coordinate system, through a surface based registration method.

Target registration error is estimated in-vitro by using an anatomical phantom that provides good contrast images in both in CT and US. The overall error of the system depends on the noise introduced by each of its components, but data redundancy can be used to reduce it. The inaccuracy introduced by the needle calibration and the needle guidance system is around 3mm. The integration of needle navigation with the US system introduces the error due to US calibration and US target identification, which is around 7 mm, the overall error of the complete system is around 10 mm.