A Method for ultrasound navigation using image data

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Abstract

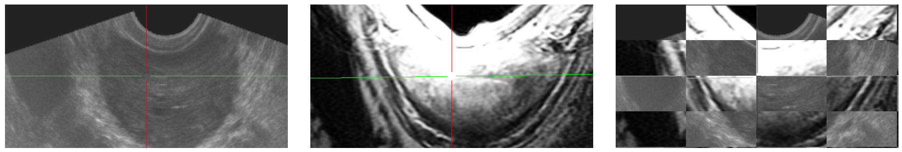
This document describes a method for tracking-based fusion imaging of real-time ultrasound and computed tomography/magnetic resonance (CT/MR images. It is unique in the sense that no absolute positioning system is required for the fused CT or MR images to show the same plane and move synchronously while performing the real-time ultrasound acquisition.

1 Background

Ultrasound is widely used for interventional procedures for the lives due to a number of advantages; it is non-invasive, easy acessible at a low cost and most importantly, its real-time capability. Without a tracking system, the operators need to mentally register previously acquired CT or MR images to the live ultrasound image. This mental registration is quite difficult and the situation is further complicated by the fact that it is often impossible to scan patient with orthogonal, sagittal or coronal planes, which are used for interpretation of CT or MR images in the clinic. Due to recent advances in the CT and MR imaging technologies small target lesions are often visible only using these modalities and it is of great interest to fuse the preoperative images with the live ultrasound images. Using fusion image the operators can conduct interventional procedures with high confidence and accuracy for challenging target lesions. Tracking-based image fusion can be realized using an optical or electromagnetic tracker, where the tracker is responsible for the absolute positioning after an initial alignment. Fuision imaging has gained considerable attention and in the BK Medical portfolio of products we offer a fusion solution for prostate surgery using an electromagnatic tracker.

2 Contribution

The initial alignment of tracker is quite difficult for a number of reasons. The patient is positioned differently for ultrasound and CT imaging, e.g. for prostate surgery, the patient is positioned in Lithotomy, whereas the preoperative CT and MR images are all acquired while the patient is in Supine position. In general, the different positioning of the patient results in a deformation and displacement of organs and it is quite difficult to



(a) (b) (c)

Figure 1: (a) Ultrasound prostate image. (b) MR prostate image. (c) Checker pattern demonstrating correct registration.

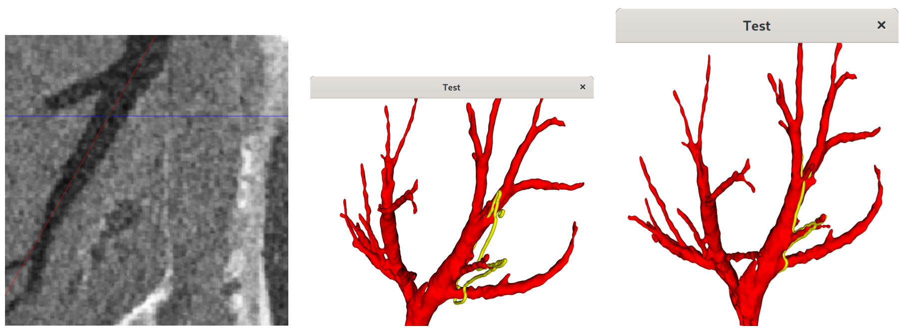
perform the initial alignment using image information. This alignment procedure leads directly to the method that we would like to protect. Real-time tracking of ultrasound images to preoperative images using image content. The preoperative images can be MR og CT images but it is not limited to these modalities. It can even be used for fusing live ultrasound to previously acquired 3D ultrasound volumes. A situation where this is useful is for liver tumors requiring overlapping ablations.

2.1 Alignment

The alignment of the live ultrasound image to the preoperative content can be made using algorithms operating directly on the image data. Such algorithms are very accurate and for registration between different image modalities, mutual information can be used as a criteria for correct registration. On a modern desktop computer, 2D registration using image data can be performed with datarates of more than 50 frames per second. Volume registration is much slower and a couple of seconds is usually required for registering two volumes to each other. In Fig. 1, the result of a registration process between ultrasound and MR is shown for a 2D prostate image. Methods using image data are very well suited for registering 2D to 2D or 3D to 3D, but they are not applicable for registering 2D to 3D.

Another option is to apply some segmentation for automatically extracting features present in both the live ultrasound images and the volume data and perform a registration of the features instead of the image data. The registration is usually less accurate when compared to methods using image data, but it is much faster and accuracy can be acquired by performing multiple registrations and some filtering of the results. Good features for registration must be visible in both the preoperative 3D volume and the real-time ultrasound image.

For liver surgery, the vascular tree can be used for registration. In Fig. 2, a 2D image showing a bifurcation in the liver is shown together with a 3D visualization of the features before and after the registration has been performed. The registration is made using a simple point-cloud registration algorithm [] and on a modern desktop computer such registrations can be performed with datarates of more than 100 frames per second.



(a) (b) (c)

Figure 2: (a) 2D image used for detecting contours of vessels. (b) Features visualized in 3D for the vascular tree and the contour before registration is performed. (c) Features visualized after registration.