A New Technique for the Registration of 3-D Ultrasound to CT or MR Images in Image Guided Surgery

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Registering intraoperative ultrasound (US) to preoperative images like computed tomography (CT) or magnetic resonance (MR) remains a challenging problem in the field of image guided surgery. For many surgical applications ultrasound provides adequate clinical information to carry out the required intervention. There are some applications, however, where being able to interpret the ultrasound images in the context of the higher quality preoperative imaging has been shown to be helpful.

In this presentation, we explain a new rigid registration technique that aligns volumetric US and CT or MR images by systematically applying linear transformations in order to minimise the Kullback-Leibler distance (KLD) between the observed joint intensity distribution of the linearly transformed images, and a reference distribution representing the a priori knowledge about the expected joint intensity histogram when the images are aligned properly.

We calibrate our KLD registration by taking an ultrasound scan, and manually aligning that with a CT scan to establish the fixed reference distribution. Once done, as more 3D ultrasound acquisitions are acquired over the course of the surgery this calibration does not need to be repeated - so the cost of the calibration is amortised over all the follow up scans during the procedure. If there are many scans, the calibration cost is a small percentage of the total effort.

We study the effect of image variability of the US image with respect to small geometrical deformations, US scanner settings, and noise level on the performance of the registration method using the following criteria:

1. Accuracy; with what precision is the correct alignment found?
2. Speed of convergence; how many iterations are needed?
3. Robustness; how sensitive is the method to noise and the geometrical differences between the images that are being aligned and the images used for the calibration?

We conclude that the proposed technique succeeds in successfully aligning the images. Perturbing the images on the aspects mentioned above has no effect on the accuracy of the registration, and very little effect on the speed of convergence and robustness.

Our test set consists of clinical data and phantom data.
To generate our test set of phantom data, we used a 3D abdominal phantom (CIRS, Norwalk, VA). Two 3D US images of the liver (left lobe, right lower lobe) were generated using the Stradx software (Cambridge University, Cambridge, UK). The CT and US images were manually aligned using the Slicer software (Brigham & Women's Hospital, Boston, MA).
As clinical data we had an US-MR pair of a neonate brain at our disposal. For the manual alignment we used the registration tool in the Image Processing Toolbox in Matlab.