Towards higher precision in instrument guided liver surgery: Automatic alignment of 3D ultrasound with pre-operative MeVis-CT

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Introduction:
Progress in computer sciences enables the use of instrument guidance systems for open liver surgery by providing improved orientation and guidance support during planning and intraoperative realization. Precise alignment between preoperative image data and the intraoperative situation remains challenging as the liver deforms during the surgery. We present a framework to allow for such alignment using intraoperative ultrasound imaging (US) and preoperative computed tomography (MeVis-CT) data.

Method:
A total of 14 corresponding CT and US datasets (both in 3D) were collected during open liver surgery of 9 patients (58±28 yrs, 3 males, 6 females) using the CAS-One liver navigation system (CAScination AG, Switzerland). The following protocol was performed: 1) Pre-alignment of the MeVis-CT model with the real patient using manually selected landmarks 2) Acquisition of 3D volumes of B-mode navigated US images on a desired site of interest (SOI) (e.g. around tumours). 3) Segmentation of available vessel in the US images 4) Generation of 3D US vessel model 5) Implementation of an algorithm aligning the 3D vessel models of the US with that of the pre-operative MeVis-CT data. 6) Measurement of success of the alignment process.

Results:
Manual pre-alignment was achieved with a mean accuracy of 11 mm. Large vessels (e.g. cross of the portal vein) were visually identifiable on the 3D US generated model. In 8/14 (57%) datasets, alignment between the CT and US was improved according to visual inspection. Alignment did not improve in 34% of the cases, attributed to insufficient amount of vessel information in the acquired SOI (e.g. large tumours) (28%), non-convergence of alignment algorithm due to poor US image quality (7%), and an unclear technical failure of the algorithm (7%). US acquisition, vessel segmentation and automatic alignment required 49 seconds of time on average. A more quantitative assessment for alignment accuracy is currently under development.

Conclusion:
We present first results on the evaluation of an automatic US based registration approach. This will allow for precise alignment of the intraoperative situation with the pre-operative image data. First qualitative results indicate that its precision is better than those in existing (manual) alignment approaches. Involved clinicians confirmed the general usability of the presented framework in clinical routine. More data sets are currently collected to assess the precision of the approach.