source: https://doi.org/10.48350/91457 | downloaded: 26.3.2025

Conclusion

The spatial orientation in NOTES is necessary for the development of new surgical devices. By estimating the orientation of the endoscopic cameras, we can reorient or combine multiple images. Although some different views about horizon stabilization still exist [4], most of the studies have acknowledged the necessity of the combination with the secondary image in the advanced procedures.

The use of only accelerometer for tilt angle estimation is difficult. In a study, a method of reducing the shock based error has been presented. However, the reduction method based on the comparison of the accelerometer reading and the constant magnitude of g could not very effective.

We have introduced a new method for tilt angle estimation with accelerometer and gyroscope. The complexity and size of the required hardware are similar to the other methods. The notable advantages of the proposed method are small error, very small time delay, and smooth angle change even under the strong motion. The performance of our method has been simulated at some data rates. The result should be confirmed by more experiments in the further research.

References

[1] Rattner D, Kalloo A (2006) Asge/sages working group on natural orifice translumenal endoscopic surgery. Surg Endosc 20: 329–333

[2] Höller K, Penne J, Schneider A, Jahn J et al. (2009) Endoscopic orientation correction. In: Medical image computing and computer-assisted intervention. Springer, Berlin, pp 459–466

[3] Luinge H, Veltink P (2004) Inclination measurement of human movement using a 3-D accelerometer with autocalibration. Neural Systems and Rehabilitation Engineering 12(1): 112–121

[4] Sodergren M, Warren A, Nehme J, Clark J et al. (2013) Endoscopic horizon stabilization in natural orifice translumenal endoscopic surgery: A randomized controlled trial. Surg Innov 21(1): 74–9

US-CT registration for open liver surgery navigation: workflow and retrospective analysis under clinical condition

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Keywords Image-guided system · Open liver surgery · Ultrasound vessel segmentation · Registration

Purpose

Although image-guided navigation systems have been introduced to improve the outcomes of liver surgery since many years, the technology is still not applied routinely in the clinics in a large scale. One main reason is that a fast and robust fusion between the preoperative scans, such as computer tomography (CT) or magnetic resonance image (MRI), and intraoperative ultrasound (US) scans is not available on a robust level and outside of academic environments. Specifically, intraoperative sonography suffers from different drawbacks such as small FOV, noise and various artifacts during image acquisition, making it difficult to register to the high quality CT/MR scan. Moreover, a clinically applicable registration workflow needs to be simple and efficient so that the surgery is not disrupted by the operation of the system. While landmark-based approaches [1], surface scanning [2] as well as 3D US/CT registration approaches [3] have been presented in the literature, to date no clinical experience with a real-time 2D ultrasound approach have been described.

To address the aforementioned challenges, we present a novel US-to-CT registration approach based on real-time vessel segmentation and 3D compounding of a user-defined US recording. We integrated the proposed method into a commercially available navigation system (CAScination AG, Switzerland) and subsequently performed extensive accuracy and efficacy investigation in clinical trials.

Methods

Seven patients with diagnosed liver cancer underwent open liver surgery supported by image-guidance. To this end, preoperative multi-phase CT images were scanned and processed (MeVis Distant Services). During surgery, 2D US images were acquired by either an integrated linear transducer (7 MHz) or a stand-alone US system (Flex Focus 800, BK Medical, USA) with an 8816 transducer (10 MHz). For the purpose of co-registration of the available 3D data with the patient, US sweeps were recorded where vessel structures were identified in real-time and compounded in 3D [4]. The co-registration algorithm uses a generalized binary space partitioning tree [5], which provides a global optimization of the transformation space.

The proposed registration method consists of the following steps:

1. Initialization: User identifies and marks a region of interest (ROI) in the virtual model where a precise registration is to be performed on the real liver. We hypothesize that a local rigid registration of only a certain volume of the organ shall be sufficiently accurate.
2. 2D US sweep: User performs a 2D US sweep within the ROI. During the sweep, a real-time vessel segmentation [1] implemented in GPU is performed. After completion, a 3D volume of the segmented vascular structure within the ROI is compounded.
3. US/CT registration: A US/CT registration is subsequently performed to align the compounded vessels from US to the 3D vascular model from CT.
4. Accuracy verification: User exams the registration accuracy by verifying if the CT model is well overlaid on the US image (Fig 1).

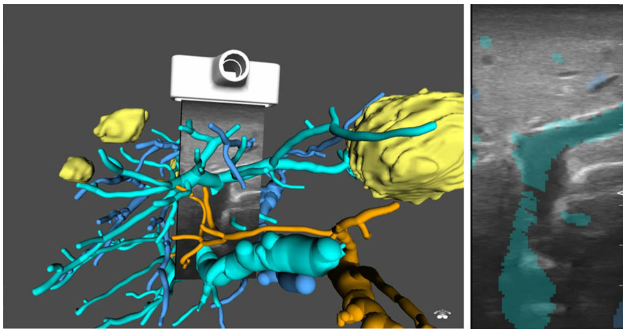


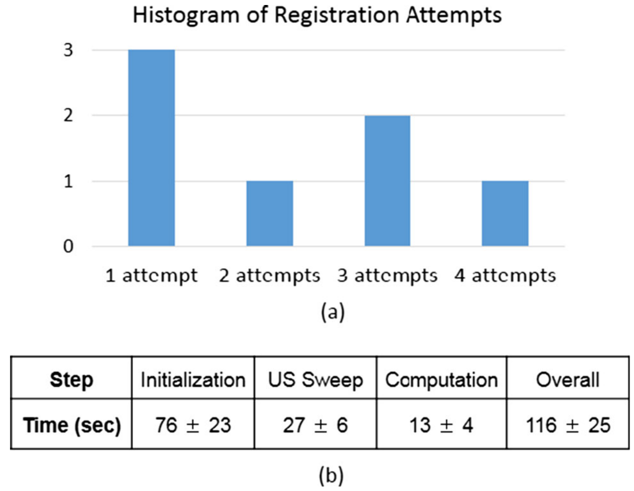
Fig. 1 Visual accuracy assessment of the registration result of one case

Results

To validate the proposed registration workflow, we conducted a retrospective analysis of the recorded image and registration data in terms of the co-registration accuracy within the ROI, the time needed for registration and the success rates.

A ground truth was generated by an image analyst and a surgeon by manually aligning a US sweep with a given CT data set. Then, the intraoperatively achieved registration was compared to the ground truth by measuring the surface distance error of the corresponding points between the 3D CT models transformed by the two transformations within the ROI.

A mean accuracy of 6 ± 2 mm was achieved (n = 7). In addition, after each registration was performed, surgeon was asked to qualitatively rate the registration accuracy with (sufficiently accurate, less accurate, inaccurate) from which we could count the number of registration attempts to reach “accurate” results. As shown in Fig. 2a, the first registration attempt yielded accurate results in three cases, while in other four cases it took no more than four attempts to reach sufficient accuracy.



Step	Initialization	US Sweep	Computation	Overall
Time (sec)	76 ± 23	27 ± 6	13 ± 4	116 ± 25

Fig. 2 a Histogram of the registration attempts in seven cases. **b** Table of the times needed for the various steps of the registration

Conclusions

To the best of our knowledge, this is the first report on real-time intraoperative US-to-CT registration using a navigated 2D ultrasound under clinical conditions. In addition, surgeons can use this approach on their own without further need for technical assistance. To this end, the proposed method requires only one landmark selection by the surgeon to initialize the registration process. This ensures registration accuracy in the region of interest and accelerates the numerical computation. We integrated the proposed method into a commercially available navigation system and validated extensively in real open liver surgeries. The obtained accuracy is 6 ± 2 mm, which is smaller than the 10 mm safety margin suggested by the R0 resection and radio-frequency/microwave ablation guideline. This indicates that the proposed registration method could potentially provide sufficient accuracy during surgical navigation in open liver surgery. Despite the variations in US imaging properties due to varying tissue properties and as a result of the present pathologies, no more than four individual registration attempts were needed to achieve sufficient registration accuracy. Moreover, efficacy measurements show that the overall operation time of the registration module is within 2 min, which is not disruptive to the existing surgical workflow.

Future work will focus on exploring the sensitivity of the registration algorithm to the input conditions such as different ROI selection and US vessel segmentation. Moreover, we will investigate a more anatomically meaningful user interaction to shorten the initialization process even more.

References

[1] M. Peterhans, A. vom Berg, B. Dagon, D. Inderbitzin, C. Baur, D. Candinas S. Weber. A navigation system for open liver surgery: design, workflow and first clinical applications. International Journal of Medical Robotics and Computer Assisted Surgery, vol 7(1), p 7–16, 2011

[2] S. Beller, M. Hunerbein, S. Eulenstein, T. Lange, P. Schlag, Feasibility of Navigated Resection of Liver Tumors Using Multiplanar Visualization of Intraoperative 3-dimensional Ultrasound Data, Annals of Surgery, vol 246(2), p 288–294, 2007

[3] Cao, R. Thompson, P. Dumpuri, B.M. Dawant, R.L. Galloway, S. Ding, M.I. Miga. Laser range scanning for image-guided neurosurgery: Investigation of image-to-physical space registrations. Medical physics, vol 35(4), p 1593–1605, 2008

[4] Dagon, C. Baur, V. Bettschart, Real-time Update of 3D Deformable Models for Computer Aided Liver Surgery. In Proceedings of IAPR, 2008

[5] Papazov, D. Burschka. Stochastic Global Optimization for Robust Point Set Registration. Computer Vision and Image Understanding, vol. 115(12), p 1589–1609, 2011

Feasibility evaluation of an image-guidance system for laparoscopic liver ablation procedures

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Keywords Image-guided surgery · Laparoscopy · Liver ablation · Multi-center evaluation

Purpose

During laparoscopy, a two-dimensional (2D) video camera is introduced into the patient’s abdomen, providing visual information regarding the operative field. Despite its evident benefits, a laparoscopic approach suffers from several drawbacks, such as reduced haptic and visual feedback. These aspects weaken the spatial understanding and perception, thus resulting in a need of extensive training for the surgeon. These drawbacks become even more relevant during tumor ablation when tumors might not be visible with common imaging modalities, due to chemotherapy shrinkage and lack of haptic feedback.

To address the aforementioned limitations, one direction is to use the image-guided system (IGS). Common IGS systems map the tracked surgical instruments as well as the patient model into a common coordinate system in a virtual scene. This virtual scene allows the surgeon to anticipate the position of underlying anatomical structures (e.g. tumors, vessel) when approaching with a surgical instrument, thus offering both haptic and visual feedback.

Despite the potential benefits of IGS for laparoscopic liver procedures, its use in a clinical environment is still limited, with few examples of its clinical use in the operating room. This scarcity relegates the benefits of IGS on a theoretical level and an evaluation of the feasibility for laparoscopic guided liver procedures is, to date, missing. In addition, the efficacy of IGS for laparoscopic liver procedures is unclear because there is no focus its specific use for particular laparoscopic surgical procedures (e.g. resection, ablation).

Within this work we present a multi-center study of an IGS for laparoscopic procedures aimed at defining a setup and workflow in a clinical context. The feasibility of the IGS was evaluated in 23 laparoscopic liver ablation procedures with a retrospective analysis performed to measure the accuracy, efficacy and clinical outcome.