

Magneto-Optic Tracking of a Flexible Laparoscopic Ultrasound Transducer for Laparoscope Augmentation

Marco Feuerstein¹, Tobias Reichl¹, Jakob Vogel¹, Armin Schneider², Hubertus Feussner², and Nassir Navab¹

¹ Computer Aided Medical Procedures (CAMP), Technische Universität München, Germany

² MITI, Department of Surgery, Klinikum rechts der Isar, Technische Universität München, Germany



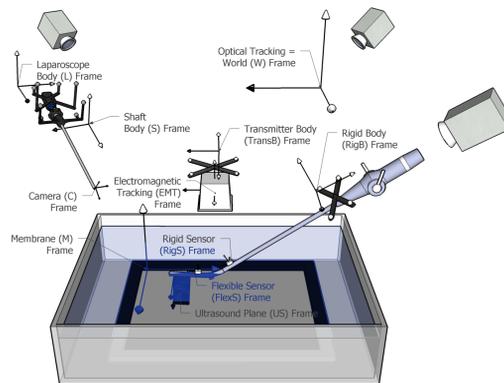
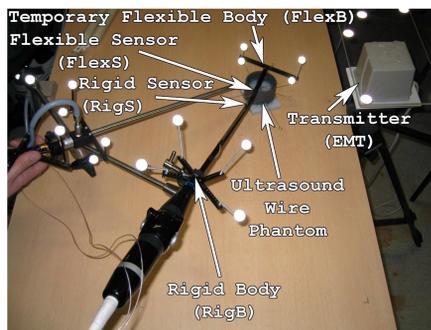
Problem Statement

- Laparoscopic ultrasound transducers are commonly localized by electromagnetic tracking systems
- Electromagnetic tracking is susceptible to ferromagnetic or electrically powered objects in its close vicinity, causing erroneous measurements due to field distortions
- Current approaches for detection or correction of field distortion are only applicable to static distortions or rigid instruments [1-5]

Conclusion

- New method for the detection and partial correction of static and dynamic magnetic field distortions online and in real time, i.e. intraoperatively, without the need for a precomputed distortion function
- Applicable to similarly constructed minimally invasive surgical instruments with bendable tips

System Setup



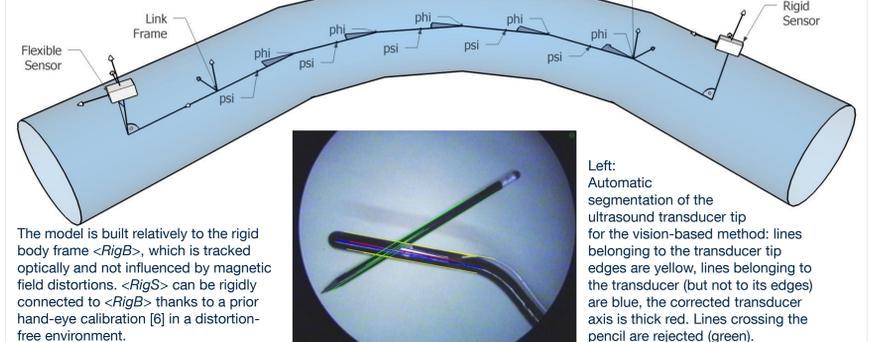
Methods

- Co-calibration of magneto-optic tracking setup by hand-eye calibration [6], followed by an optimization of the transformations $\langle EMT \text{ to } TransB \rangle$ and $\langle RigS \text{ to } RigB \rangle$ (and $\langle FlexS \text{ to } FlexB \rangle$ for error evaluation)
- Tracking redundancy-based detection and correction approach: Measurement of the deviation from the calibrated transformation $\langle RigS \text{ to } RigB \rangle$ is used as an approximation for the deviation of the flexible tip sensor

Outlook – Methods Submitted to IEEE TMI

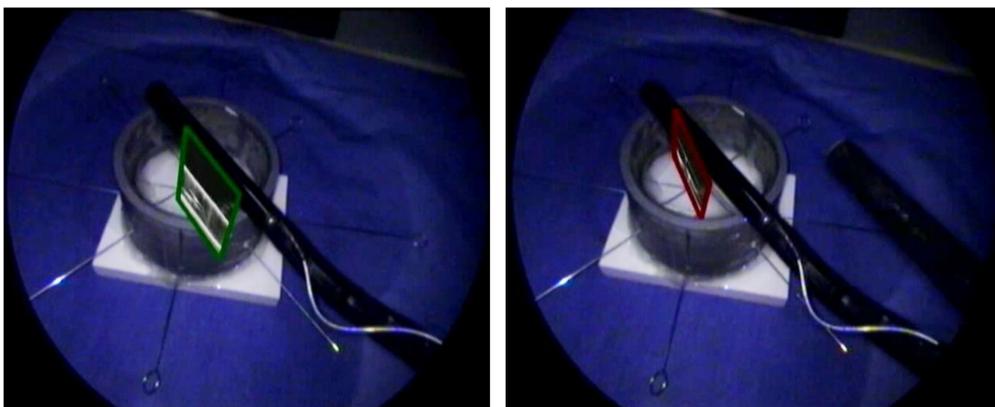
- **Model-based method:**
 - Modeling all possible transducer tip movements by reducing the 6DOF of the flexible sensor to only 2DOF for a rotation about 2 axis by ϕ and ψ
 - Optimization of these 2DOF at runtime
 - Translation and/or rotation difference between optimized and measured tip position can be used to predict field distortions online
- **Vision-based method:** Further reduction of error by combination with automatic segmentation of transducer tip in laparoscopic view and adjustment of transducer tip axis

The possible transducer tip movements can be modeled as a transformation from the flexible sensor frame $\langle FlexS \rangle$ into the rigid sensor frame $\langle RigS \rangle$, with all parameters fixed except ϕ and ψ .

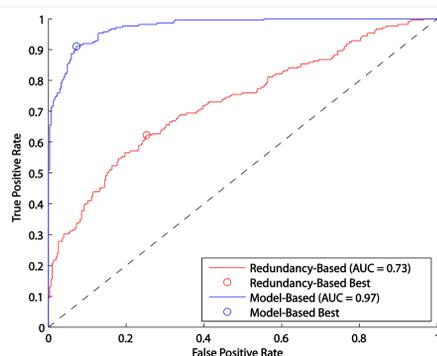


The model is built relatively to the rigid body frame $\langle RigB \rangle$, which is tracked optically and not influenced by magnetic field distortions. $\langle RigS \rangle$ can be rigidly connected to $\langle RigB \rangle$ thanks to a prior hand-eye calibration [6] in a distortion-free environment.

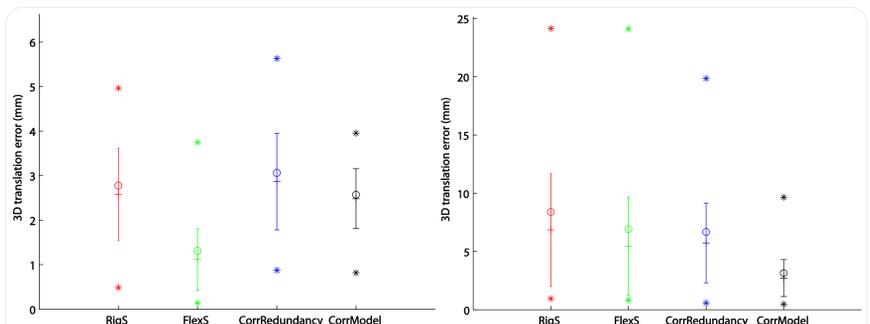
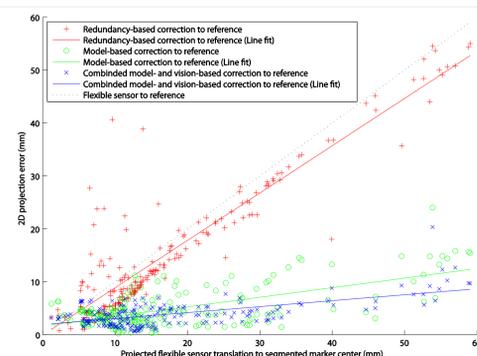
Results



Similar to [7], ultrasound B-scan images are overlaid onto the laparoscopic view (left); when distortions are detected, the frame border is colored red (right)



Error detection (left) and correction performance in terms of 2D error (right)



3D error for undistorted (left) & distorted measurements (right)

Way of Measurement	Rigid Sensor	Flexible Sensor	Redundancy-based	Model-based
Undistorted	2.91	1.28	2.92	2.27
Distorted	8.39	6.91	6.67	3.15

References

- [1] Kindratenko, A survey of electromagnetic position tracker calibration techniques, Virtual Reality: Research, Development, and Applications, 2000
- [2] Birkfellner et al., Concepts and results in the development of a hybrid tracking system for cas, MICCAI 1998
- [3] Mucha et al., Plausibility check for error compensation in electromagnetic navigation in endoscopic sinus surgery, CARS 2006
- [4] Nakamoto et al., 3d ultrasound system using a magneto-optic hybrid tracker for augmented reality visualization in laparoscopic liver surgery, MICCAI 2002
- [5] Konishi et al., A real-time navigation system for laparoscopic surgery based on three-dimensional ultrasound using magneto-optic hybrid tracking configuration, Int. Journal of CARS 2007
- [6] Daniilidis, Hand-eye calibration using dual quaternions, Int. Journal of Robotics Research 1999
- [7] Leven et al., Davinci canvas: A telerobotic surgical system with integrated, robot-assisted, laparoscopic ultrasound capability, MICCAI 2005