Registration-Free Laparoscope Augmentation for Intra-Operative Liver Resection Planning

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Problem Statement – Laparoscopic Liver Resection

- The limited endoscopic view and missing tactile feedback constrains the surgeon
- Vessels supporting the liver segment to be resected need to be divided (clipped) prior to the resection to avoid bleeding
- Only the surface of organs can be seen, but not the underlying target region (i.e. tumors and vessels)
- Surgeon does not know exactly where to cut the organ
- Vessels need to be precisely located

[www.anatomyatlases.org]
Related Work

Intraoperative image guidance by:

- Ultrasound
  - Image quality?
  - 3D data difficult to obtain
- CT/MRI
  - Bulky
  - Often only “in-plane” guidance
  - Patient motion?

[Nakada et al 2003]
[Nakamoto et al 2002, 2006]
[Leven et al 2005]
[Fichtinger et al 2005]
[Mourgues et al 2003]
[Nicolau et al 2005]
Our Approach

- Intraoperative
  - Contrast agent application
  - Cone beam CT based C-arm reconstruction
  - Augmentation of the contrasted vessel tree directly on the laparoscope video by volume rendering \textit{without} registration

- Offline prerequisites
  - Attachment of optical marker targets
  - C-arm calibration
  - Laparoscope calibration
System Components
System Calibration

- Laparoscope calibration:
  - Camera calibration
  - Hand-eye calibration
- Pointer calibration
- C-arm calibration
Accuracy Evaluation

- Navigation error:
  - Cubic evaluation phantom
  - Measured holes with tracked pointer
  - Filled bore holes with metal spheres
  - Cone beam CT reconstruction
  - Segmentation of spheres
- RMS: 1.10 mm
Accuracy Evaluation

- Augmentation error:
  - Reconstruction of plastic model with CT markers (spots and line)
  - Augmenting laparoscopic view
  - Large number of views covering the interventional working space
  - Overlay error measured in pixels and scaled to mm

- RMS: 1.58mm
  (latest results for full calibration of oblique laparoscope [Yamaguchi et al 2004] – included into submission to TMI)
Video Demonstration

- Video showing latest results incorporating port placement, liver motion analysis, and in vivo studies (under review at TMI)
Summary –
Laparoscopic Liver Resection Planning

- No need to perform an intraoperative patient registration due to **intrinsic registration** in one common tracking coordinate system
- First time usage of two independent intraoperative imaging systems, i.e. X-ray C-arm and laparoscopic camera within a registration-free navigation framework

Ex-Vivo   In-Vivo (under review at TMI)
Summary –
Laparoscopic Liver Resection Planning (cont’d)

- One of the first trials of a flatpanel based mobile C-arm on soft tissue reconstruction
- Also applicable for example to partial nephrectomy, where fluoroscopic guidance can be used (easier in terms of deformations caused by breathing)

Future work:
- Improvement of timing and protocol of contrast agent administration
- Intraoperative segmentation of liver vessels may improve the visualization quality
Thank you for your attention!