Taking endoscopy to a higher dimension

Computer Aided 3-D NOTES

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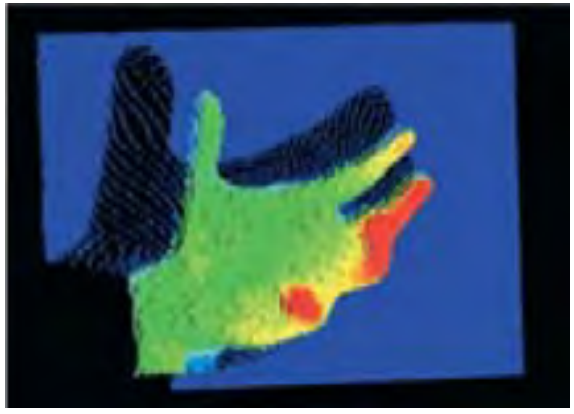
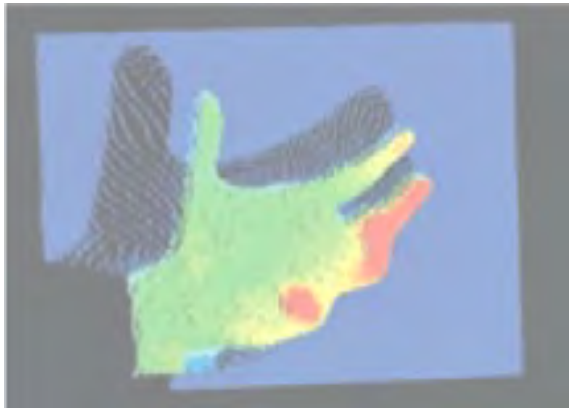
Content



Overview



Endoscopic 3-D approaches

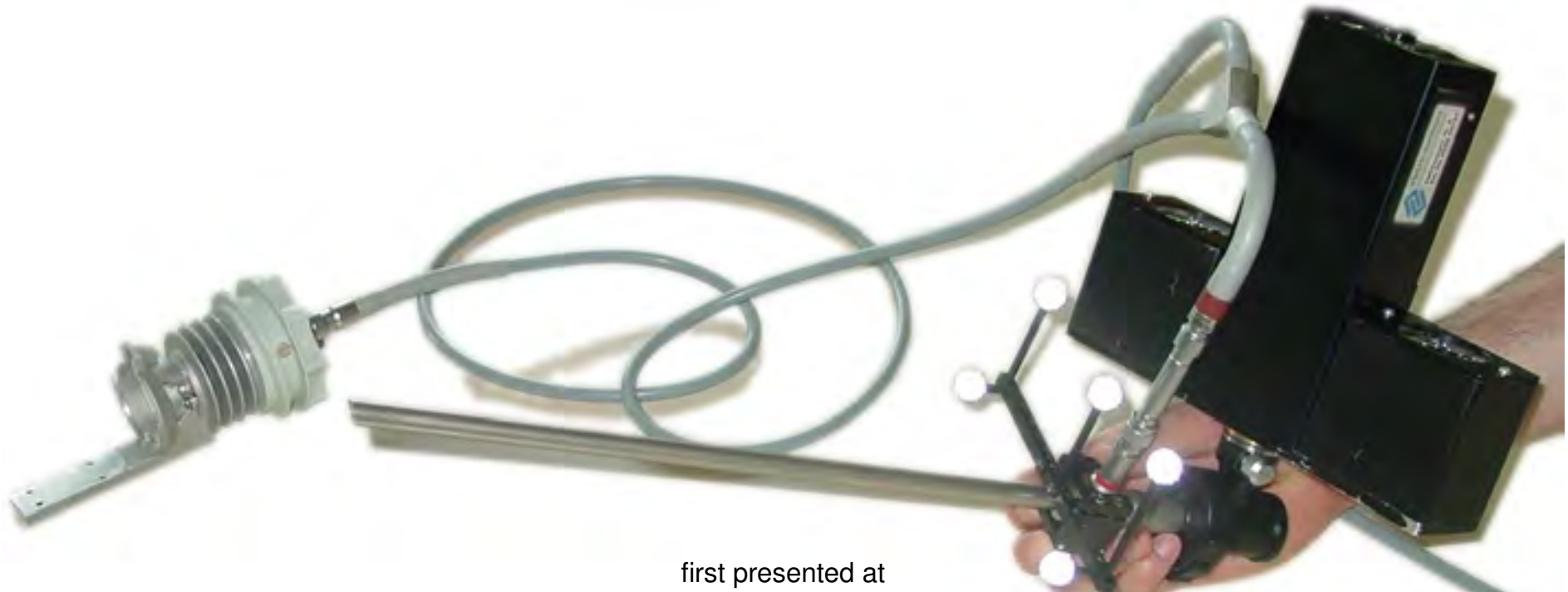
State of the Art

3-D information can be achieved with

- endoscopic ultrasound (EUS)
- magnetically anchored instruments
- passive optical approaches
  - stereo vision
  - structure from motion
  - shape from shading
- active optical approaches
  - pattern projection
  - **time-of-flight hybrid system**
- inertial sensors for gravity related orientation

First prototype of a 3-D endoscope

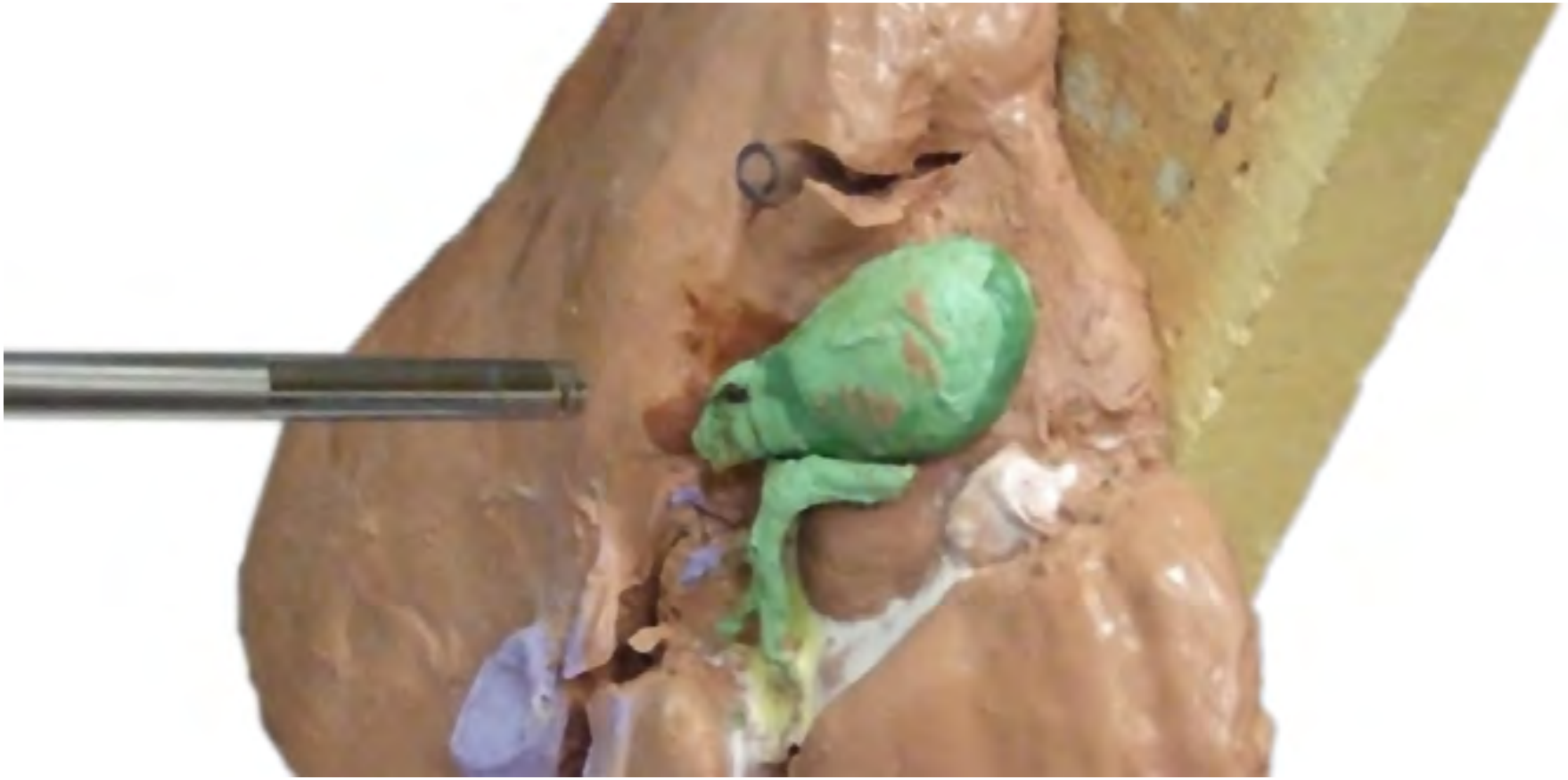
Based on time-of-flight technology



first presented at

Preliminary results

Liver phantom with gall bladder



Preliminary results

Liver phantom with gall bladder

⇒ More details in the talk of Jochen Penne et al.

'Towards NOTES^{3D}'

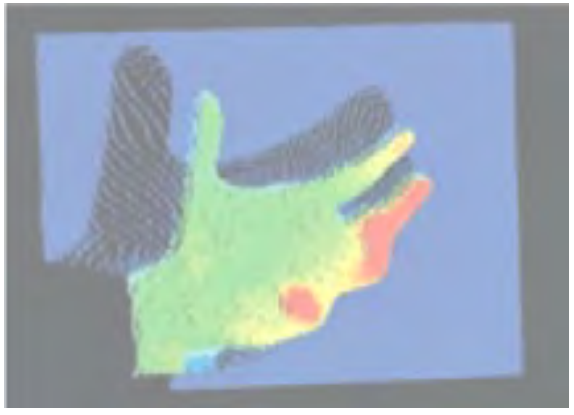
Joint funding application at Deutsche Forschungsgemeinschaft (DFG)

Participating institutes:

- LME, Erlangen (Prof. J. Hornegger)
- MITI group, Munich (Prof. H. Feussner)
- CAMP, Munich (Prof. N. Navab)
- LGDV, Erlangen (Prof. G. Greiner)
- MED1, Erlangen (Prof. E.G. Hahn)

Submitted during

Overview



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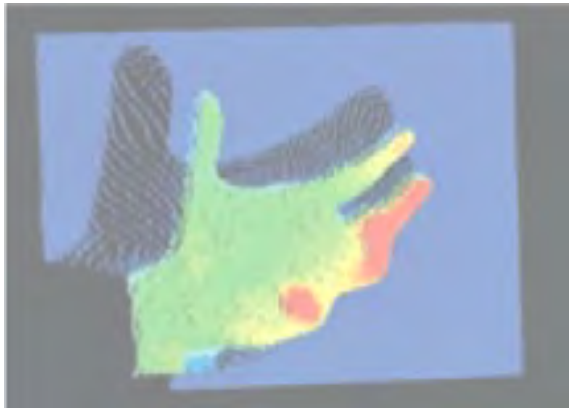


Time Line

From open surgery to NOTES

Surgery can be done as:

- open surgery
  → for hundreds of years
- minimally invasive / laparoscopic surgery
  → since the late 80s
- and through natural orifices
  → "no longer if but when" (W. O. Richards, D. W. Rattner 2005)

⇒ July 22/23, 2005 white paper and foundation of Consortium for Assessment and Research (NOSCAR) on NOTES: Natural Orifice Translumenal Endoscopic Surgery

Participating groups with NOTES

Great chance for technical innovations

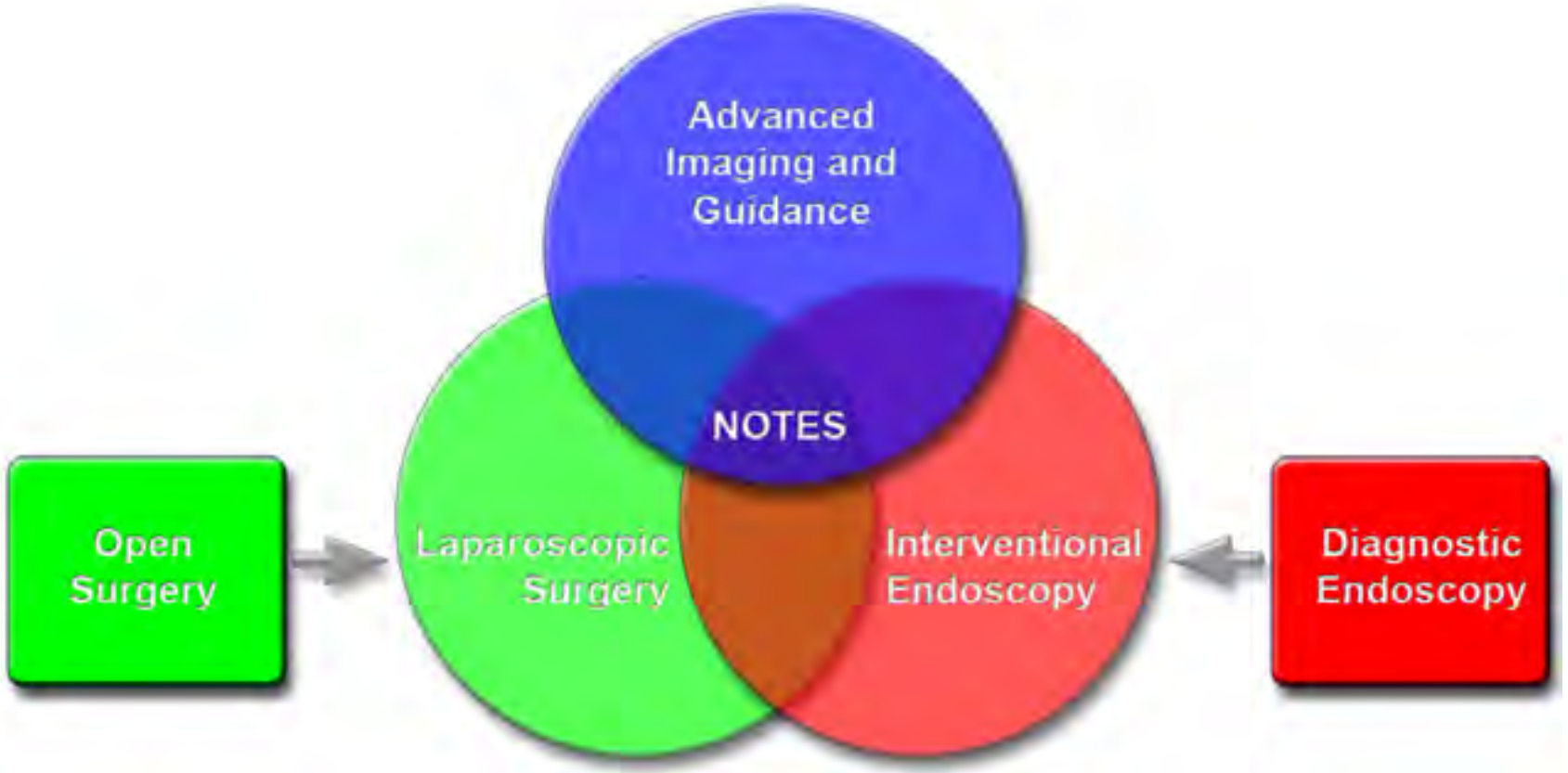
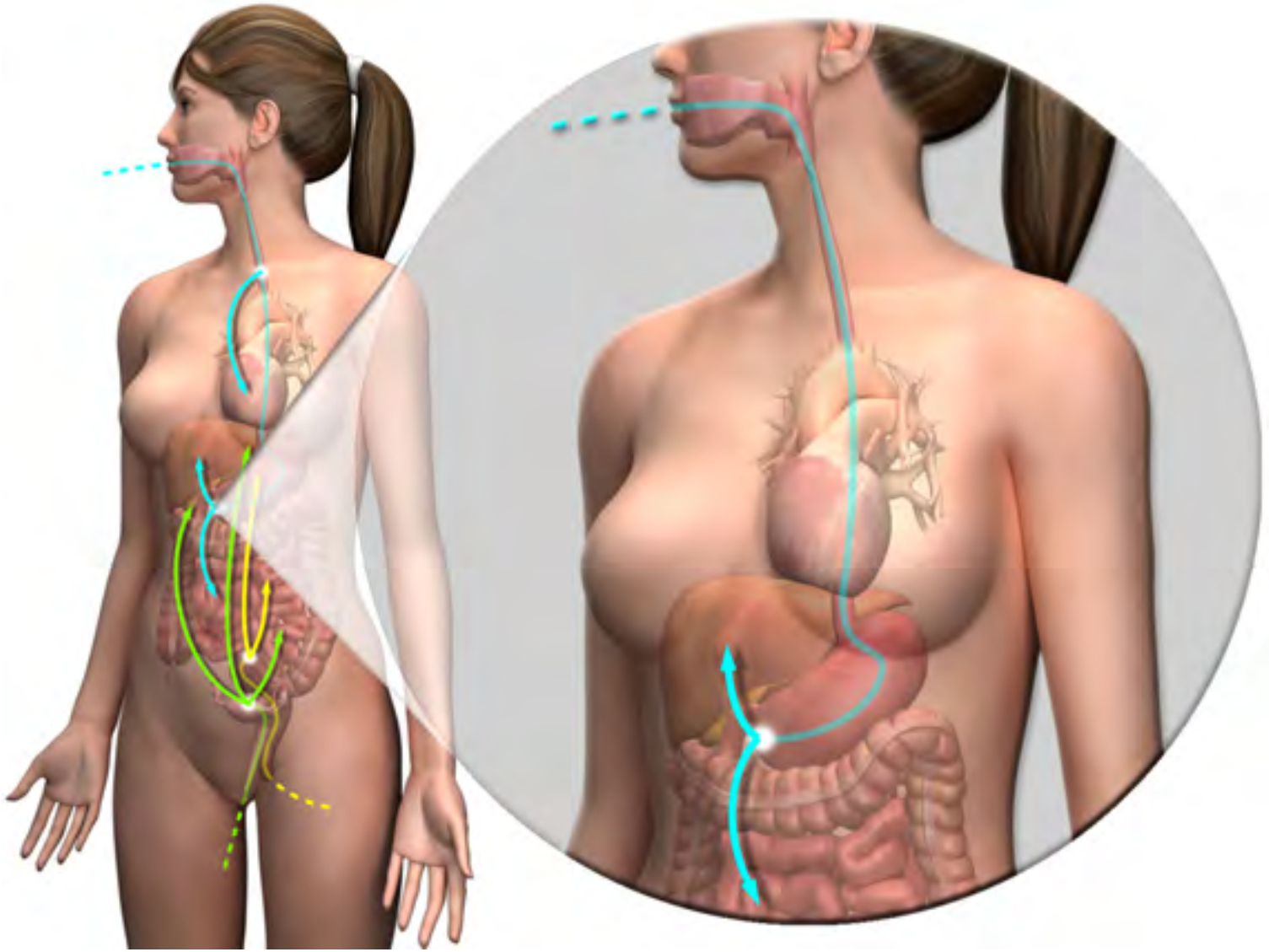


Figure: Interdisciplinarity of NOTES

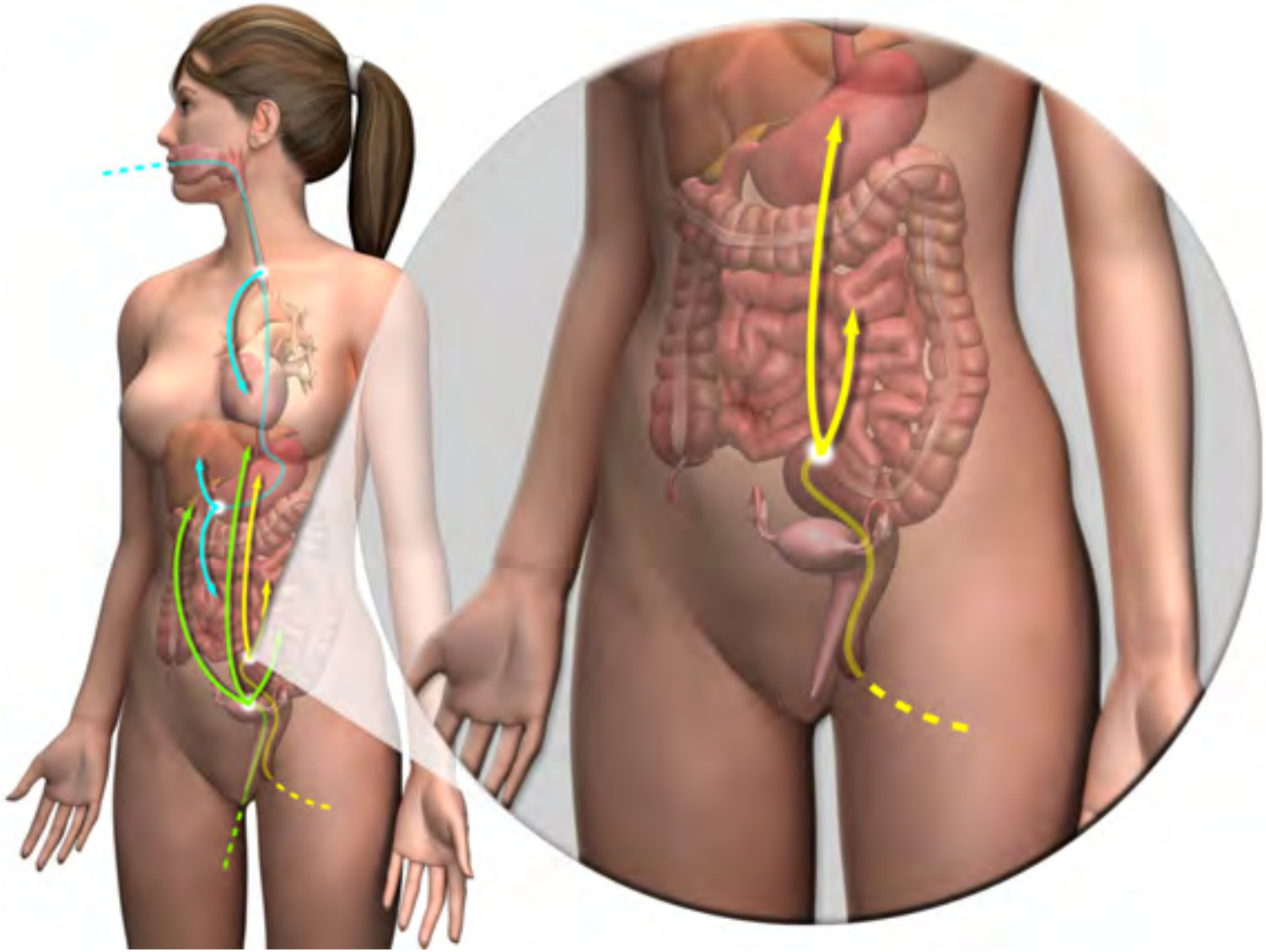
Peroral transgastric route

Natural Orifice Translumenal Endoscopic Surgery



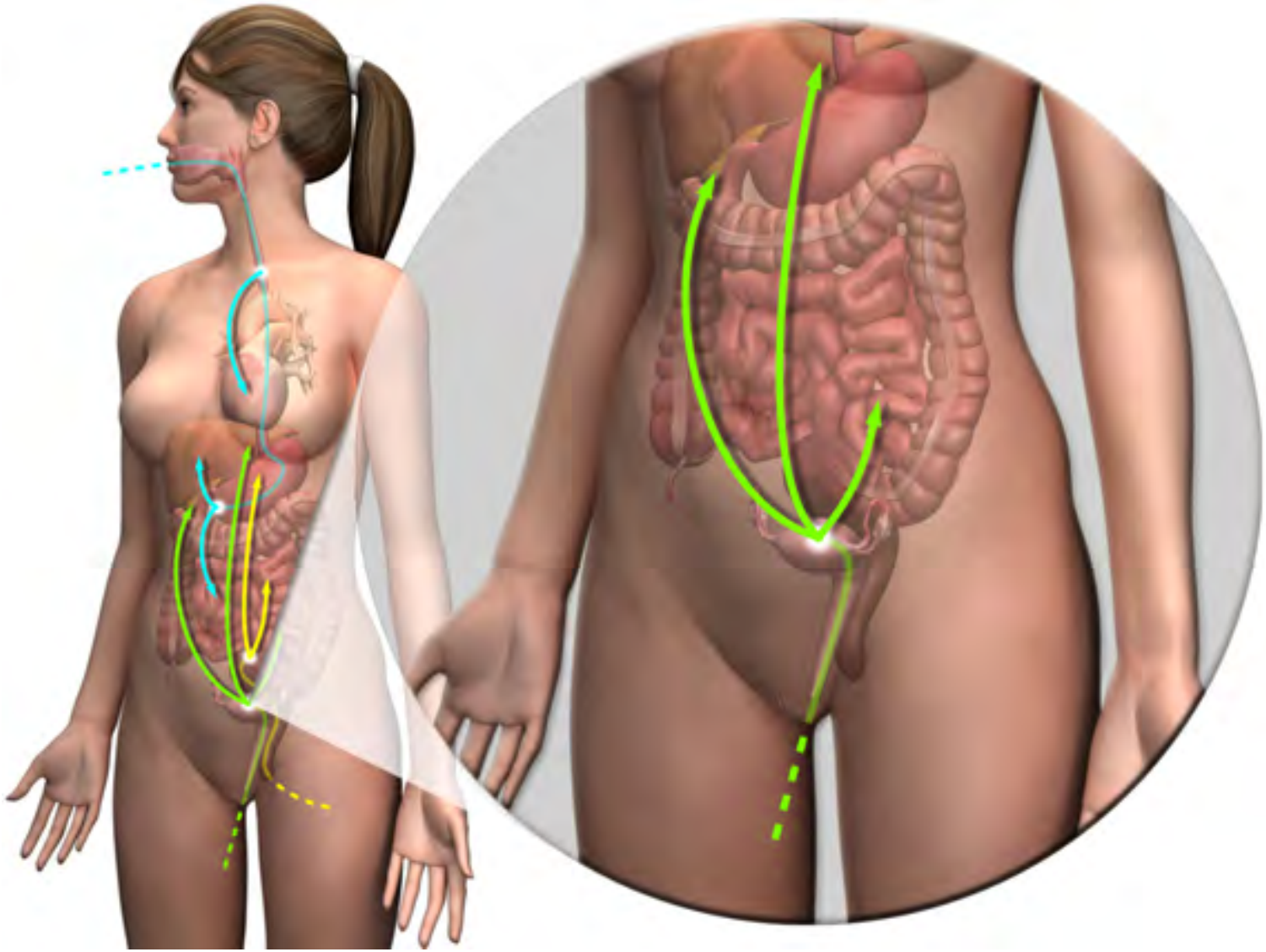
Peranal transcolonic route

Natural Orifice Translumenal Endoscopic Surgery



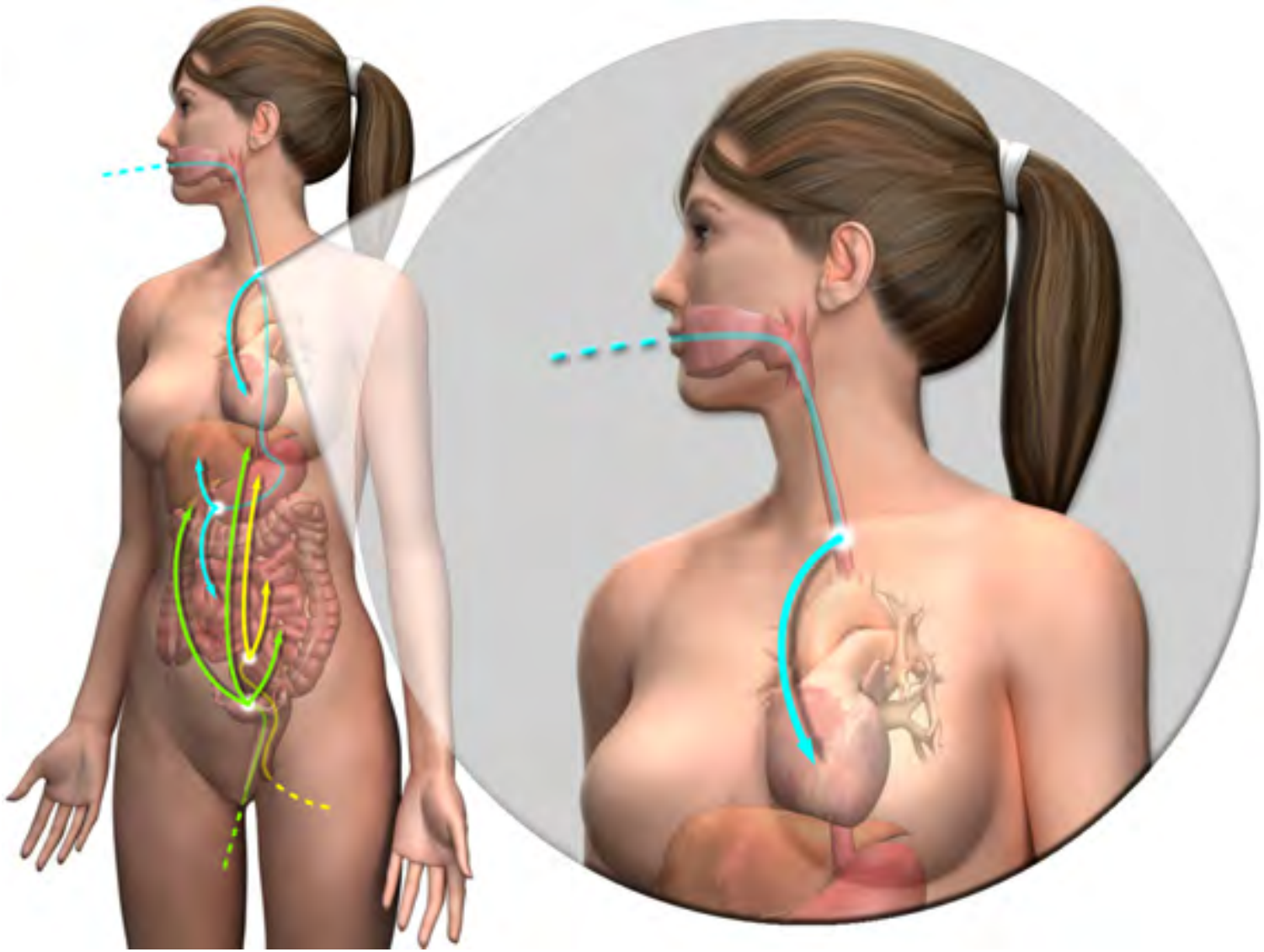
Transvaginal route

Natural Orifice Translumenal Endoscopic Surgery



Peroral transesophageal route

Natural Orifice Translumenal Endoscopic Surgery



NOTES Publications 2004-2007

Fast growing community

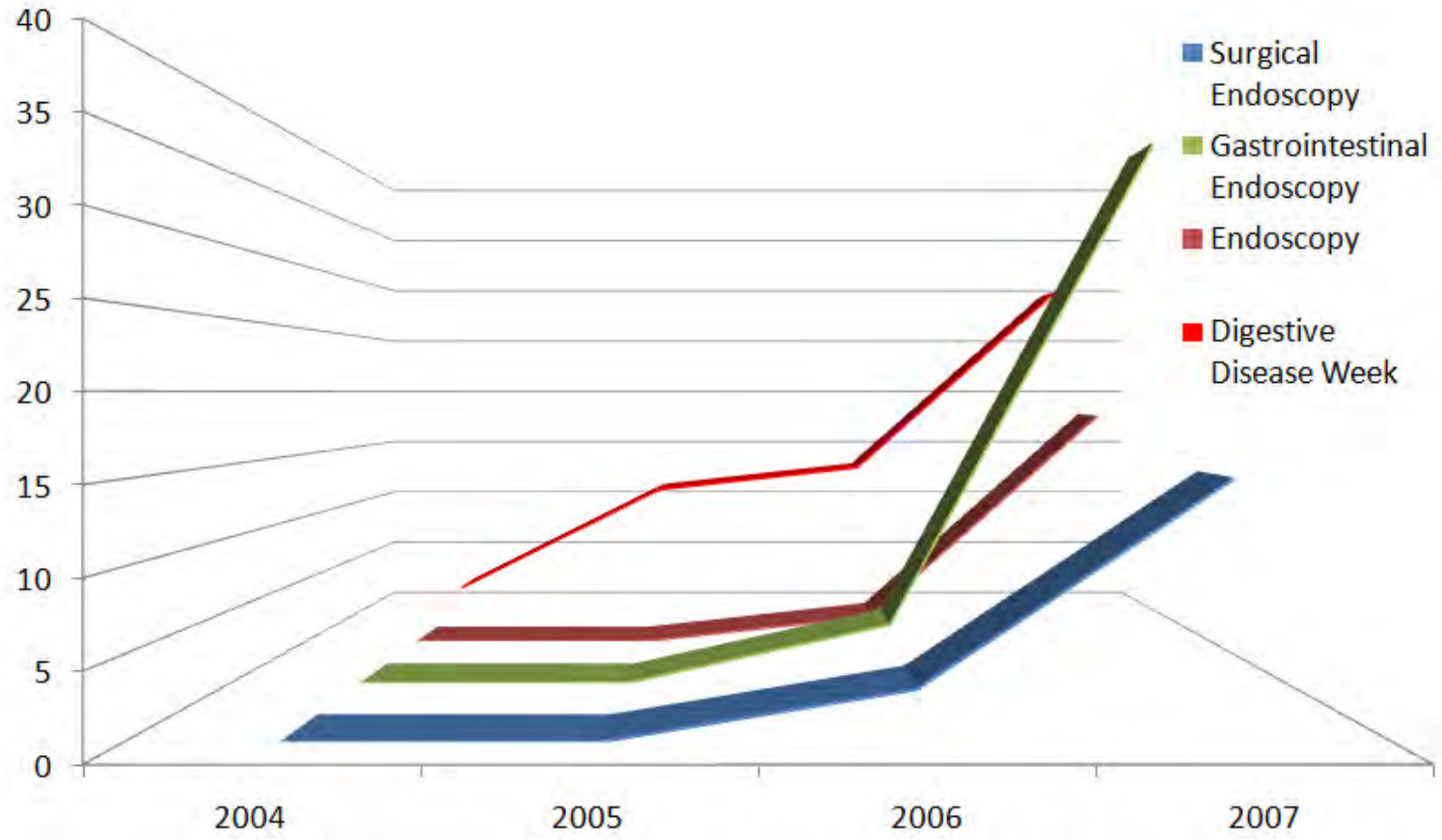
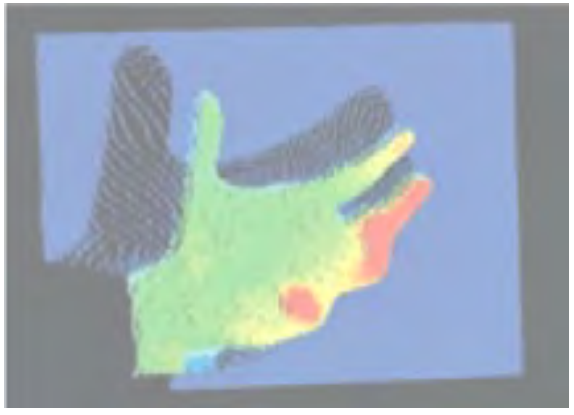


Figure: NOTES Publications in SE (SAGES), GIE (ASGE), Endoscopy (ESGE), DDW

$\Rightarrow$ In 2008 more than twice the number of publications of 2007

Overview



Potential barriers to clinical practice

According to the NOTES white paper, New York 2005

Fundamental challenges to the safe introduction of NOTES

- Access to peritoneal cavity
- Gastric or intestinal closure
- Prevention of infection
- Development of suturing and anastomotic (nonsuturing) devices
- Maintaining spatial orientation
- Development of a multitasking platform
- Management of intraperitoneal complications and hemorrhage
- Physiologic untoward events
- Training other providers

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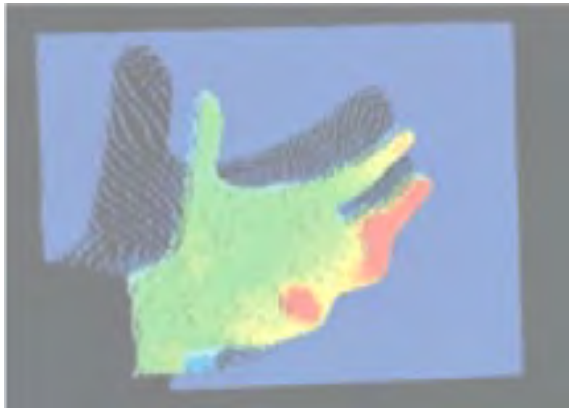

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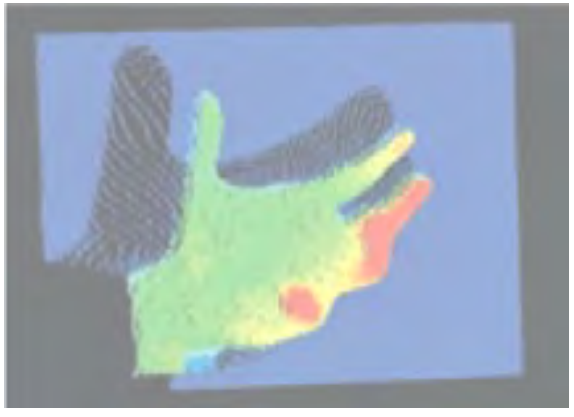


Navigation support - Orientation

Finding the entry point to the peritonial cavity

Challenge:

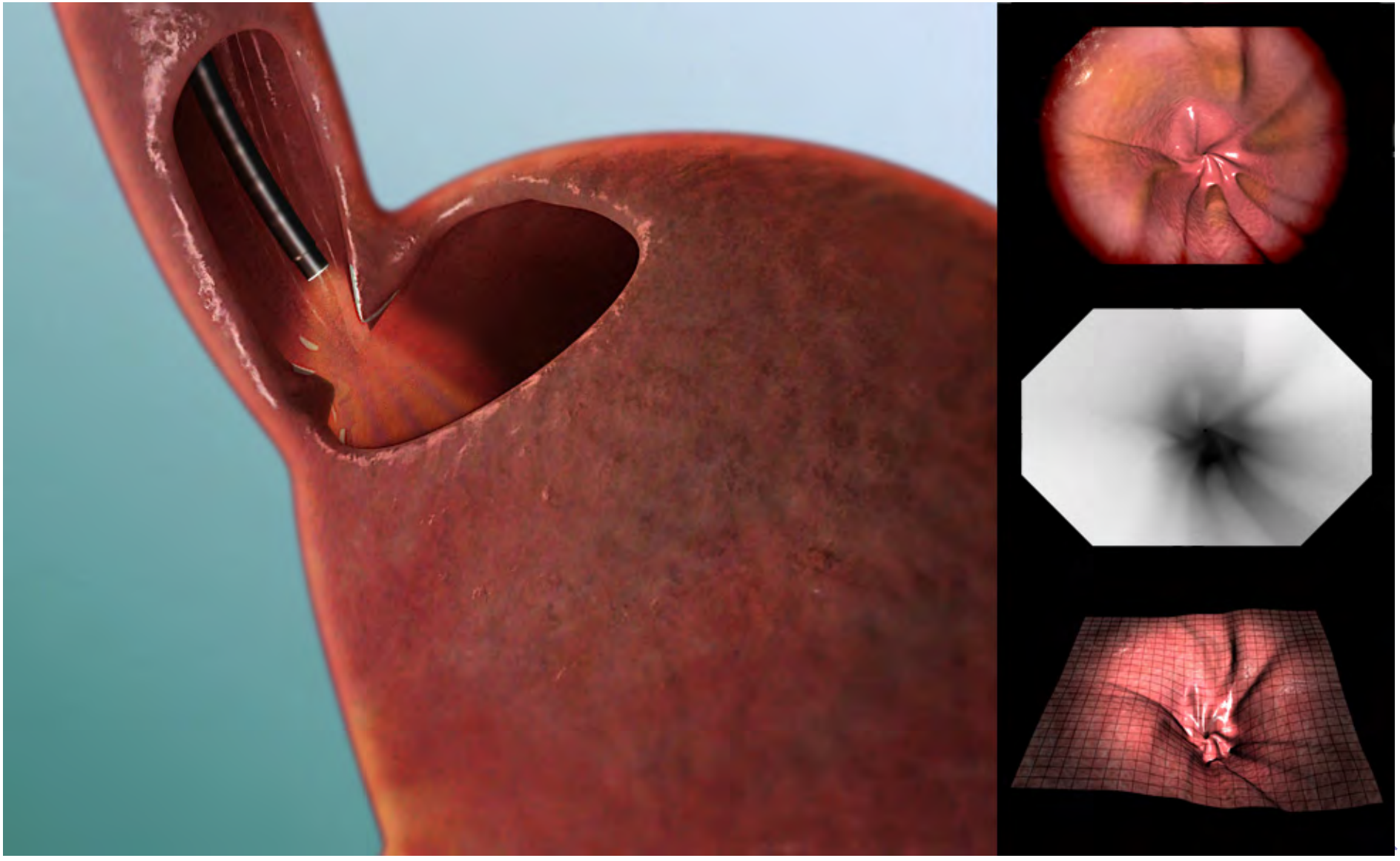
- More information on position and orientation of the robotic device or the endoscope

Solution:

- Nonrigid registration of intraoperative 3-D data with preoperative CT or MR data is possible
- Calculated transformation parameters can be used to represent, correct und visualize actual position and orientation

Navigation support - Orientation

Finding the entry point to the peritonial cavity



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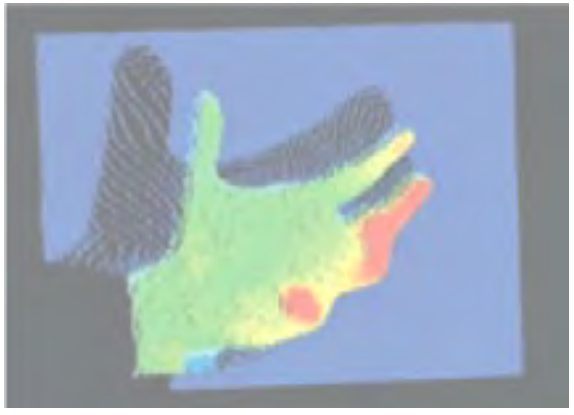


Navigation support - Augmented Reality

Finding the entry point to the peritonial cavity

Challenge:

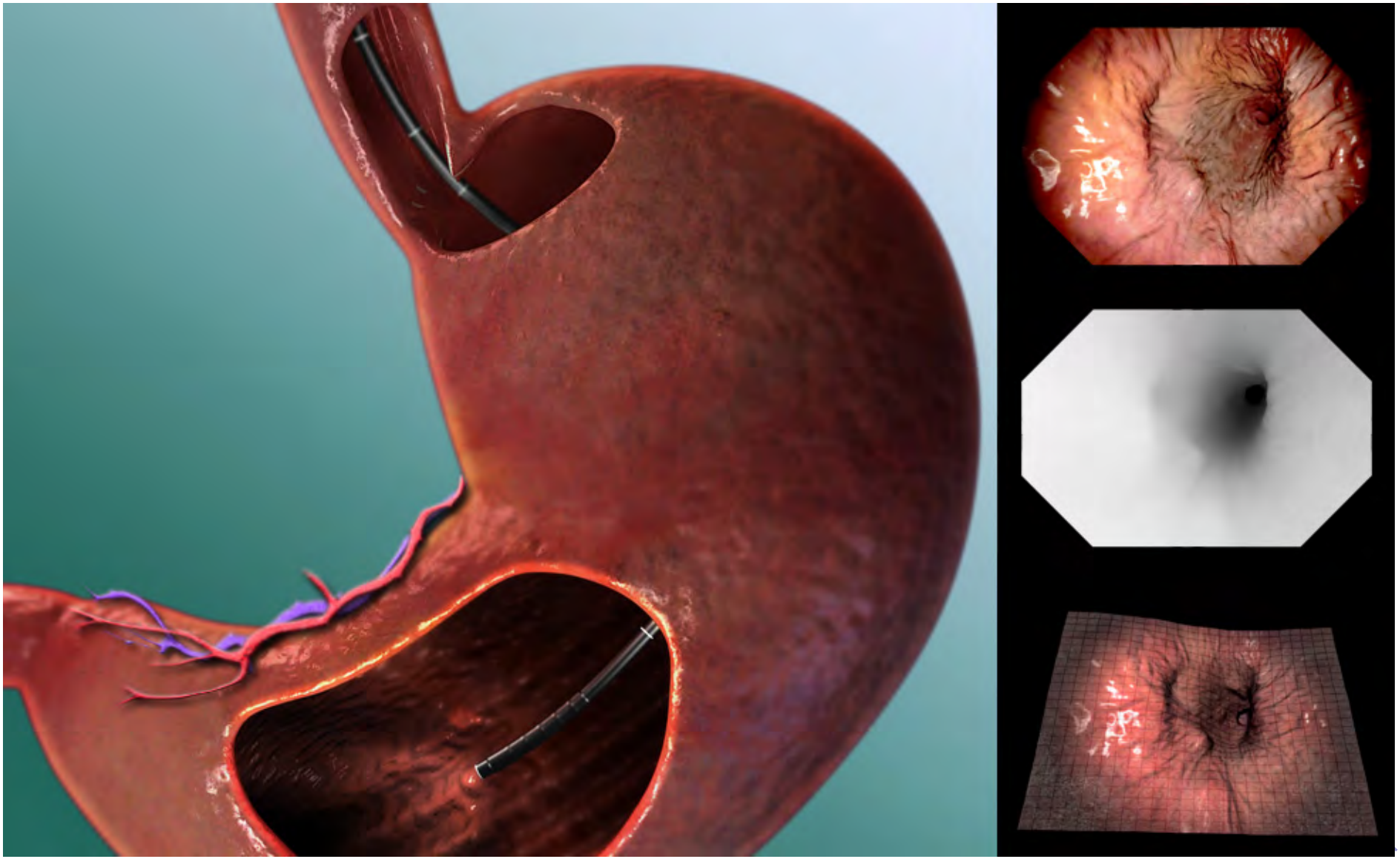
- Avoid injuries of hidden organs and vessels, e.g. while finding the entry point to the peritoneal cavity
- Knowledge of structures behind the visible wall is needed for a safe incision

Solution:

- Registration with preoperative volumes
- Segmentation of objects of interest in the preoperative volumes
- Adaption of those objects by iteratively computed transformation parameters
- Visualization of hidden organs or vessels in intraoperative endoscopic images by augmented reality

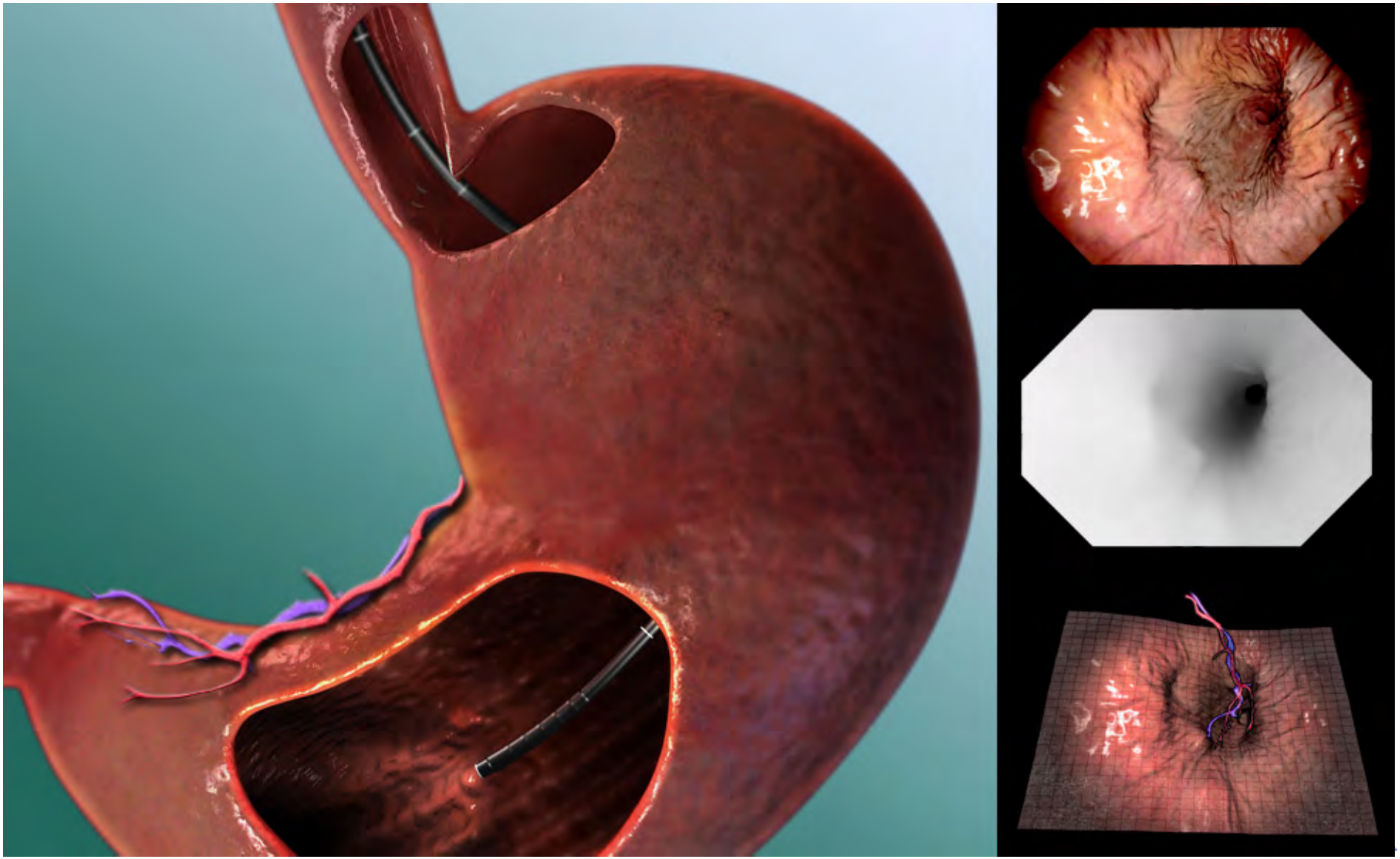
Navigation support - Augmented Reality

Finding the entry point to the peritonial cavity



Navigation support - Augmented Reality

Finding the entry point to the peritonial cavity



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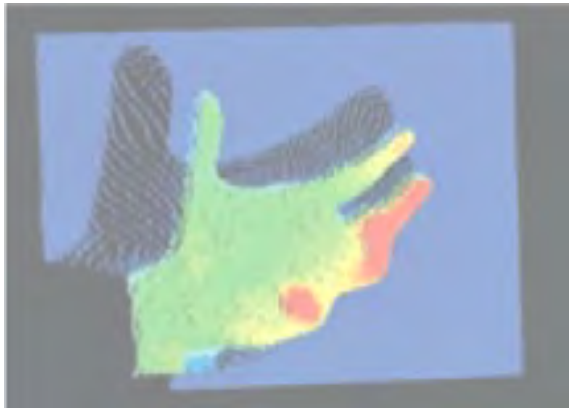


Navigation support - Off-axis view

Finding the entry point to the peritonial cavity

Challenge:

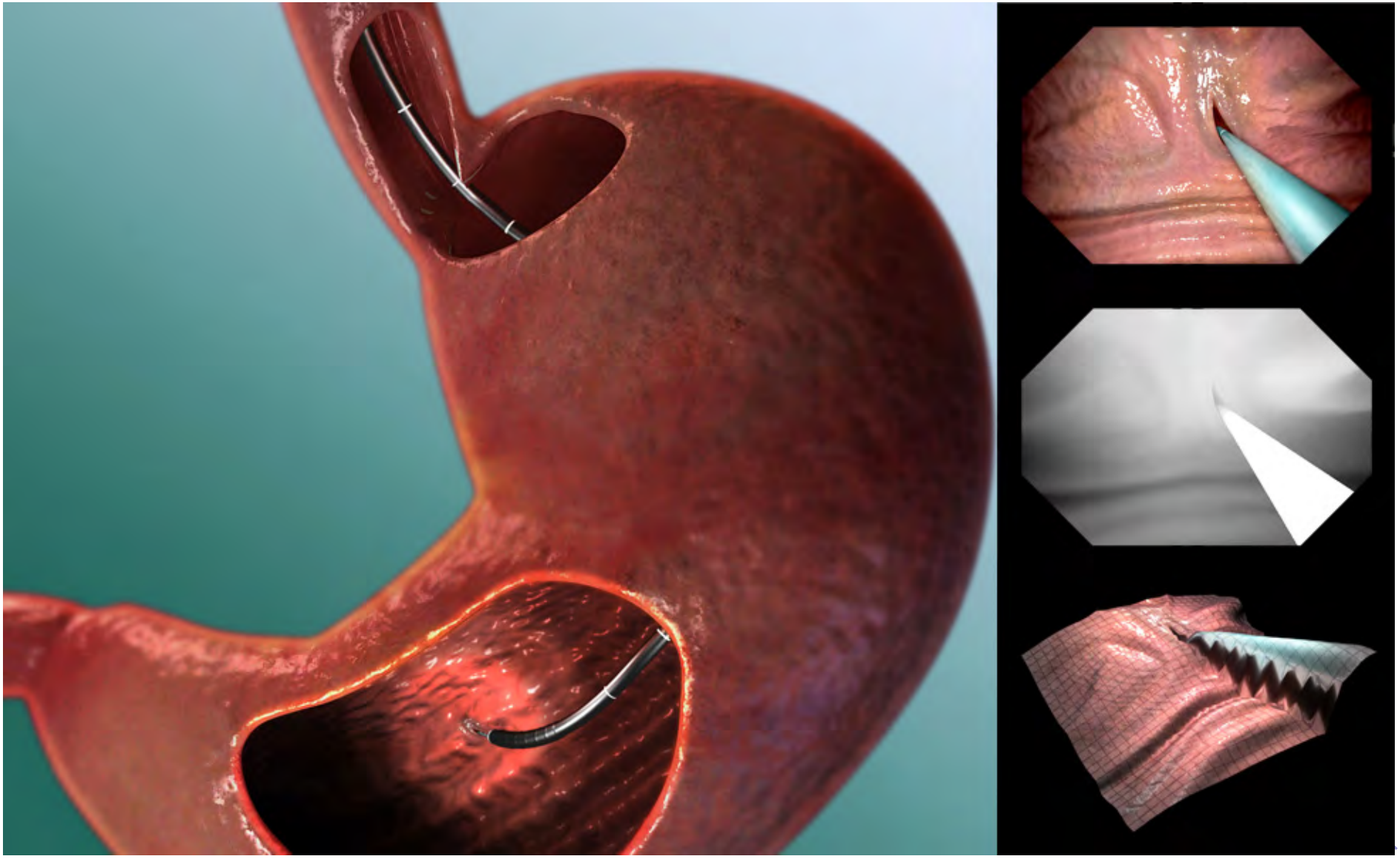
- Overcome boundaries of limited field of view like axis in-line view and loss of spatial orientation

Solution:

- 3-D surface knowledge can be used to extend and virtually rotate the field of view
- With a 3-D mosaicking technique, the field of view can be extended by reconstruction of the operation area.

Navigation support - Off-axis view

Finding the entry point to the peritonial cavity



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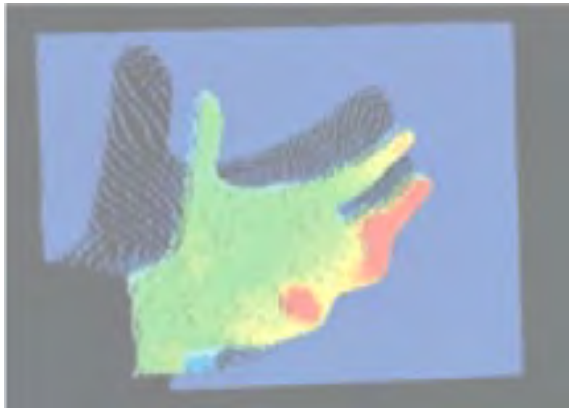


Navigation support - Collision prevention

Finding the entry point to the peritonial cavity

Challenge:

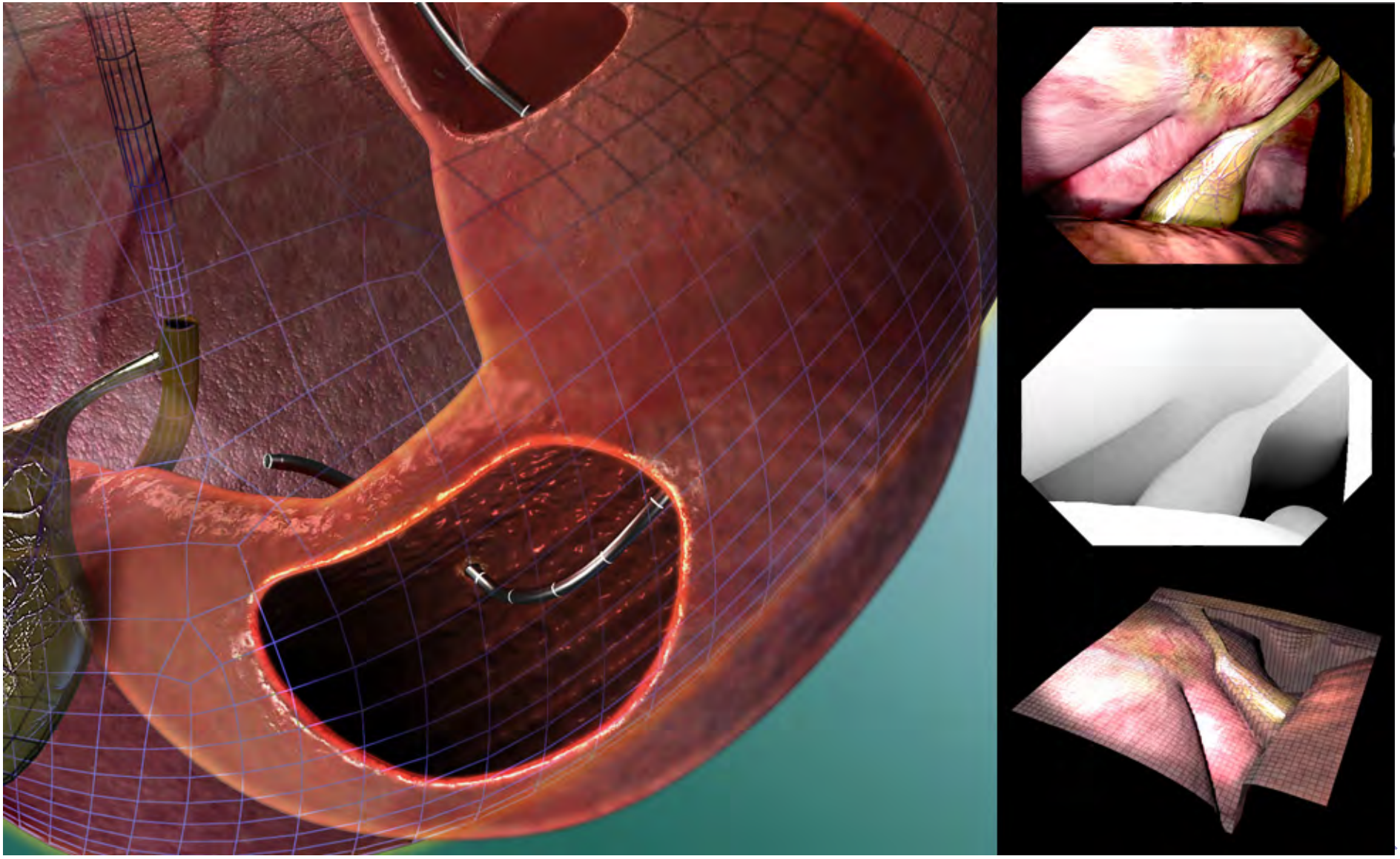
- Provide a higher grade of safety for automatic tools and robotic devices
- Especially important with multiple instruments through only one flexible endoscope

Solution:

- With real-time distance information efficient collision prevention with tissue or other instruments can be enabled
- Auto-positioning depending on respiration or other patient movements will be very helpful.

Navigation support - Collision prevention

Finding the entry point to the peritonial cavity



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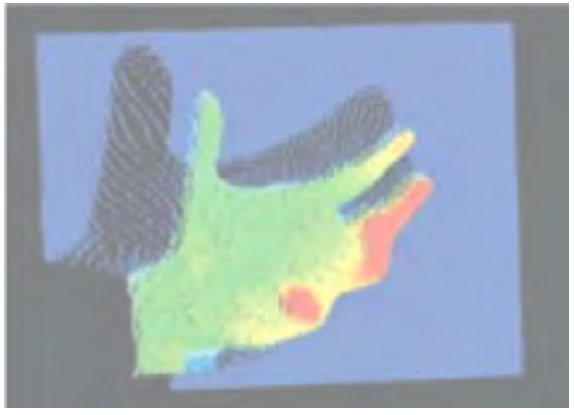
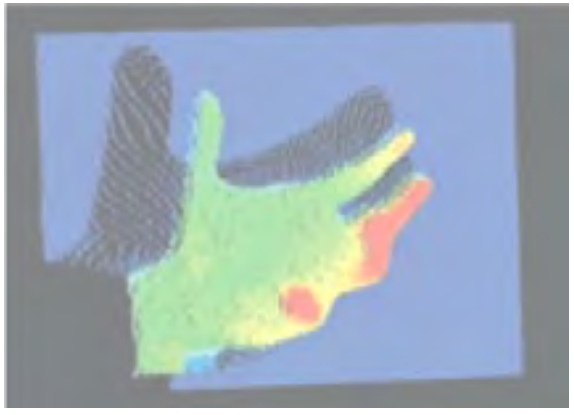


Conclusion

Endoscopic 3-D information are precondition to

- calculate intra-operative orientation
  $\longrightarrow$ registrating with pre-operative MR/CT volumes
- avoid injuries of hidden organs and vessels
  $\longrightarrow$ making them visible by augmented reality
- provide an enhanced field of view
  $\longrightarrow$ computing off-axis view or reconstructed area by stitching
- to enable collision prevention, motion compensation and automatic positioning of surgery tools
  $\longrightarrow$ using a real-time distance measurement

Overview

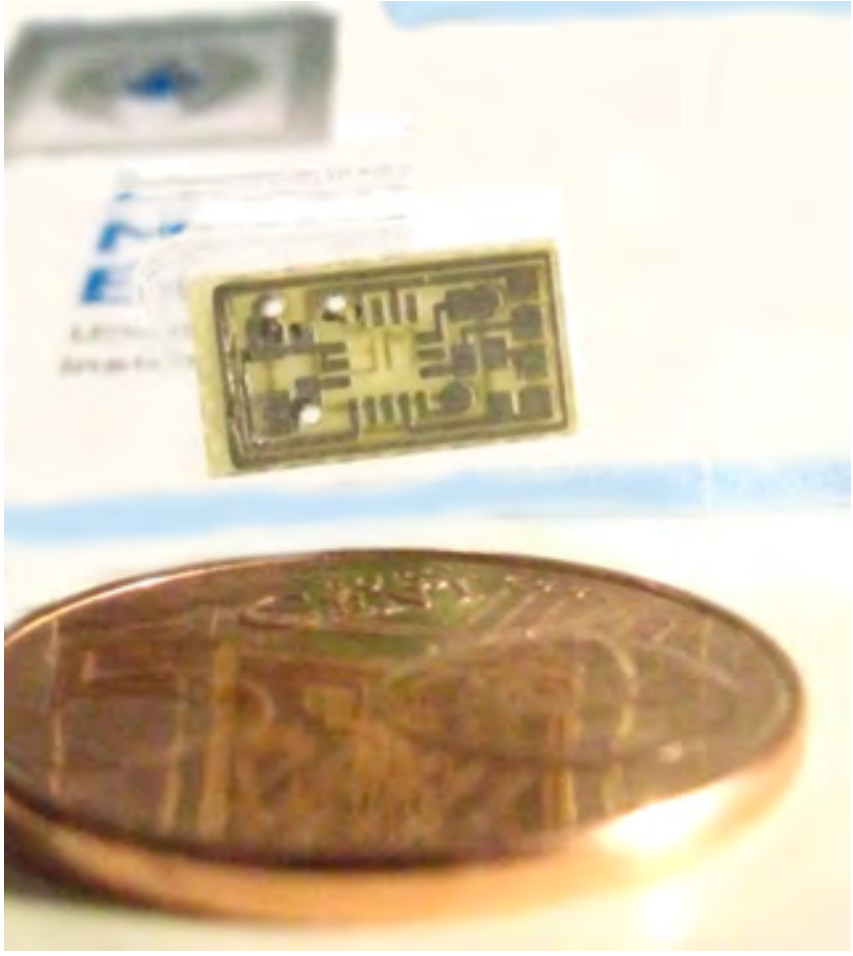


Outlook

Solution for loss of spatial orientation

real-time information of spatial orientation by measuring gravity

- using MEMS-based inertial devices:
  3-D accelerometers



The End

- Thank you for your attention!
- Any further questions?