

# Respiratory Motion Analysis: Towards Gated Augmentation of the Liver

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# Outline

- Liver Motion Analysis
- Augmentation of the Laparoscope
- Towards Gated Augmented Reality System
- Related Medical Augmented Reality Activities @ CAMP

# Aim for Motion Analysis

Analysis of the correlation between the respirator and the actual liver motion

1mm repositioning error after one respiratory cycle expected

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[Zhang05] Zhang, H., Banovac, K., Cleary, K., Increasing registration precision for liver movement with respiration using electromagnetic tracking, CARS 05

[Nicolau04] S. Nicolau, A. Garcia, X. Pennec, L. Soler, and N. Ayache, Augmented reality guided radio-frequency tumor ablation, in Computer Animation and Virtual World, 2004,

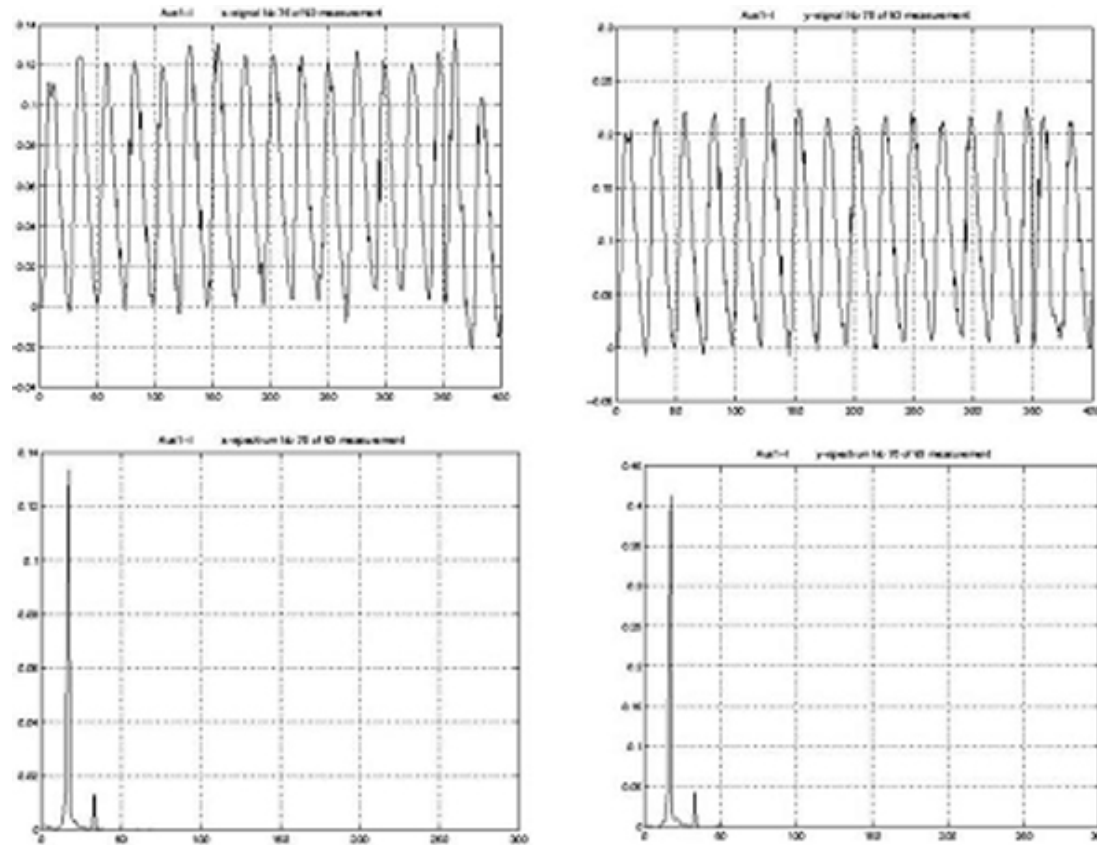
[Wong00] Wong, J. W., Sharpe, M. B., Jaffray, D. A., Kini, V. R., Robertson, J. M., Stromberg, J. S., Martinez, A. A., The Use Of Active Breathing Control (ABC) To Reduce Margin For Breathing Motion, Int.J.Radiation Oncology Biol.Phys., 44 1999, pp. 911 - 919

# Experiment for the Motion Analysis

- motion tracker MiniBIRD (Ascension)
  - three sensors attached to specific points on the liver (extended with a specific frame and sutured onto the liver)
  - transmitter well placed to cover the entire working volume
- 
- 15 pigs were used
  - 9 different arrangement of the three sensors on each pig
  - 5 measurements for each arrangement

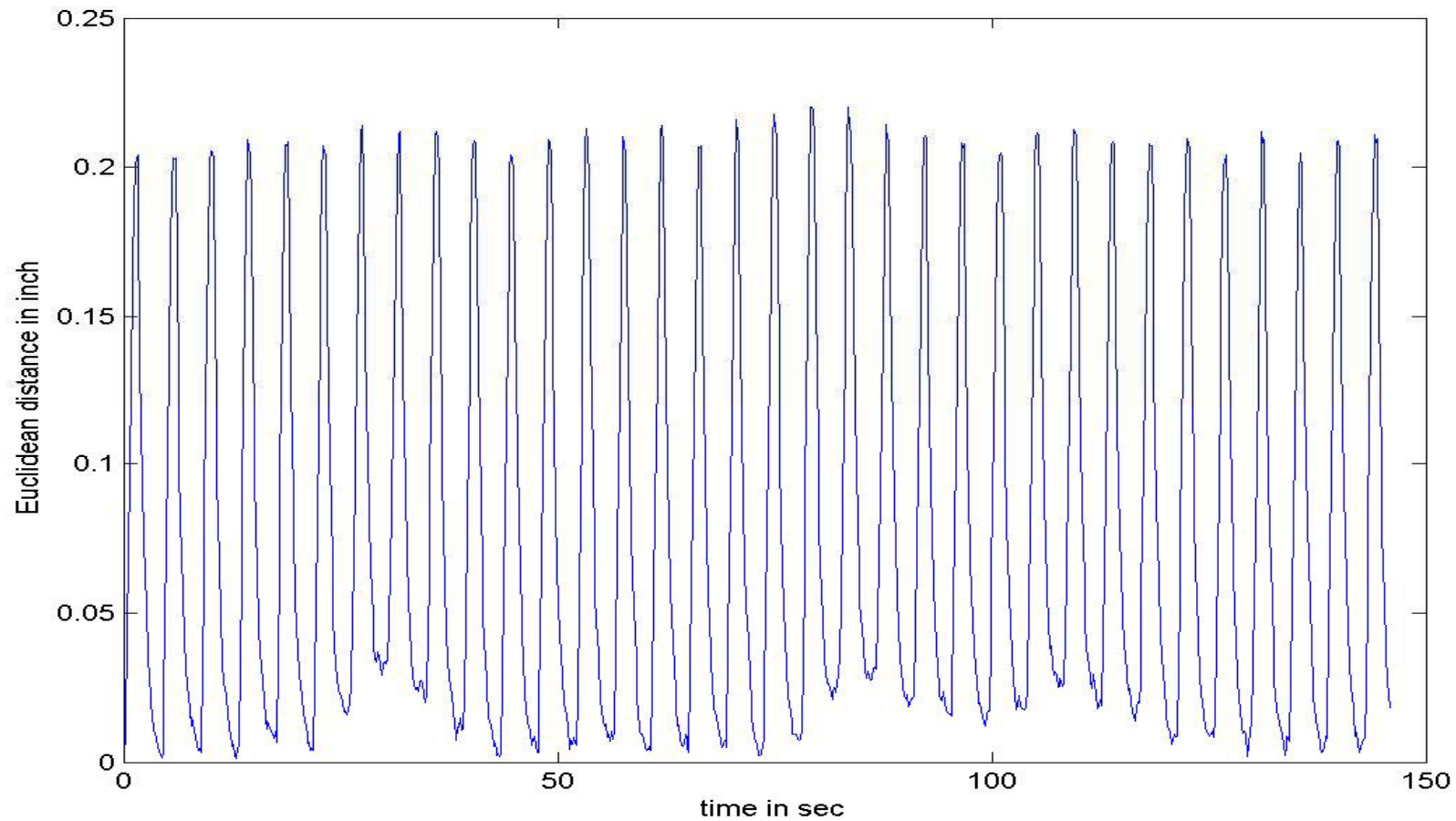


# Motion of a sensor



The Motion of one Sensor in X and Y direction and its Fourier space

# Repositioning in the Central Axis



Repositioning Error after one respiratory cycle  
at the plateau is less than 1mm (0.04 inch)

# Augmentation of Laparoscopic View

- Benefit
  - Advantage to see insight the liver with the laparoscope
  - Detection of nodules and vessels
  
- Challenges
  - Precise real-time tracking
  - Calibration of the laparoscope
  - Registration of the imaging data (e.g. CT)
  - Compensation for organ motion

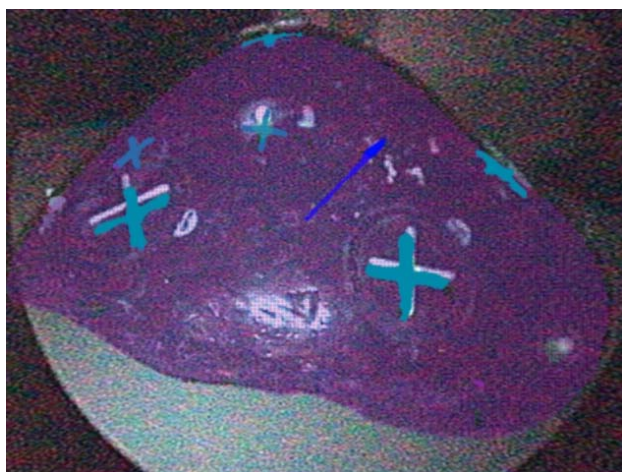
[Fuchs98] H. Fuchs et al., *“Augmented Reality Visualization for Laparoscopic Surgery”*, MICCAI 1998

[Nakamoto2002] M. Nakamoto et al., *“3D Ultrasound System Using a magneto-optic hybrid tracker for augmented reality visualization in laparoscopic liver surgery”*, MICCAI 2002

[Shahidi ] R. Shahidi et al., *“Implementation, Calibration and Accuracy Testing of an Image-Enhanced Endoscopy System”*, IEEE Transactions on Medical Imaging, 21(12), Dec. 2002



# The Augmentation Setup



Augmented View

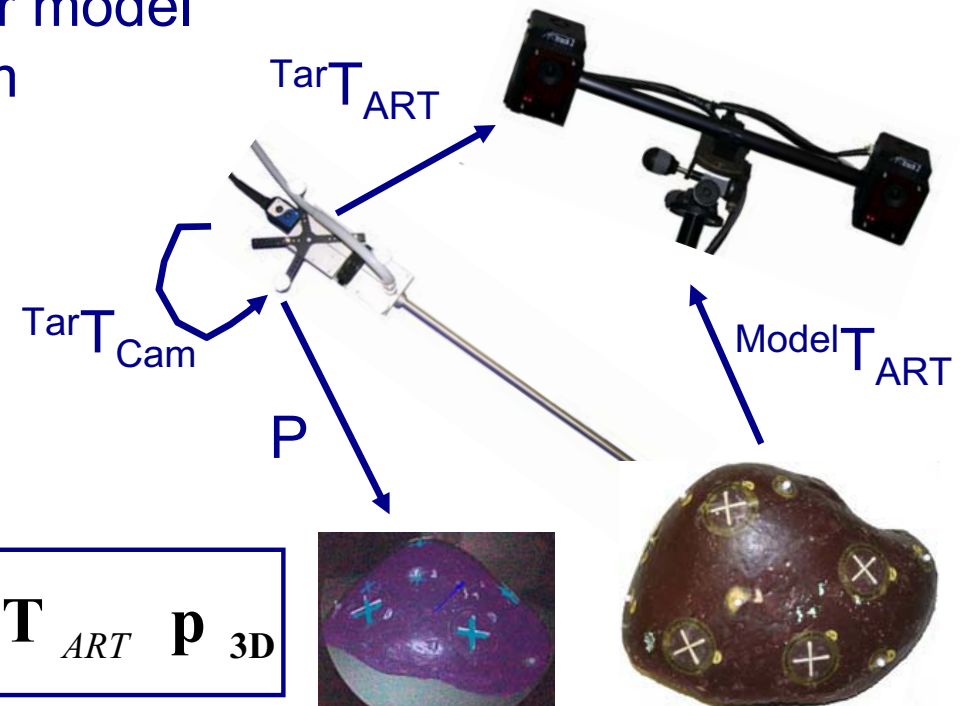


Liver Dummy with Fiducials



# Calibration and Registration

- Calibrate the Laparoscope (distortion and intrinsic parameters)
- Estimation of the rigid transformation of the camera center and the target attached to the laparoscope
- Point based registration of the liver model into the tracking coordinate system
- Tracking of the laparoscope and update the projection of the virtual model



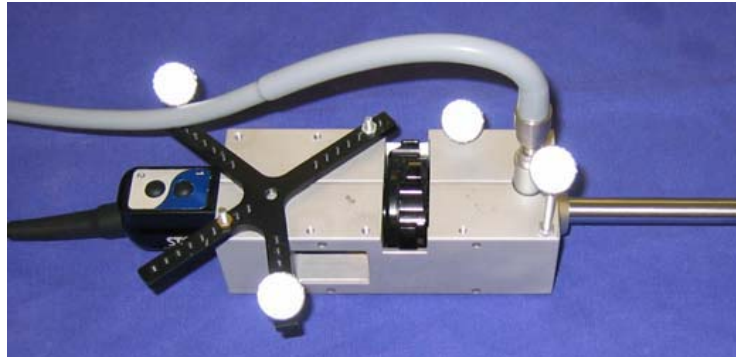
$$\mathbf{p}_{2D} = \mathbf{P}^{Tar} \mathbf{T}_{Cam} \left( \begin{matrix} Tar & \mathbf{T}_{ART} \end{matrix} \right)^{-1} Model \mathbf{T}_{ART} \mathbf{p}_{3D}$$

# Laparoscope Augmentation



# Tracking and Calibration

- Tracking Target



- Number of Cameras

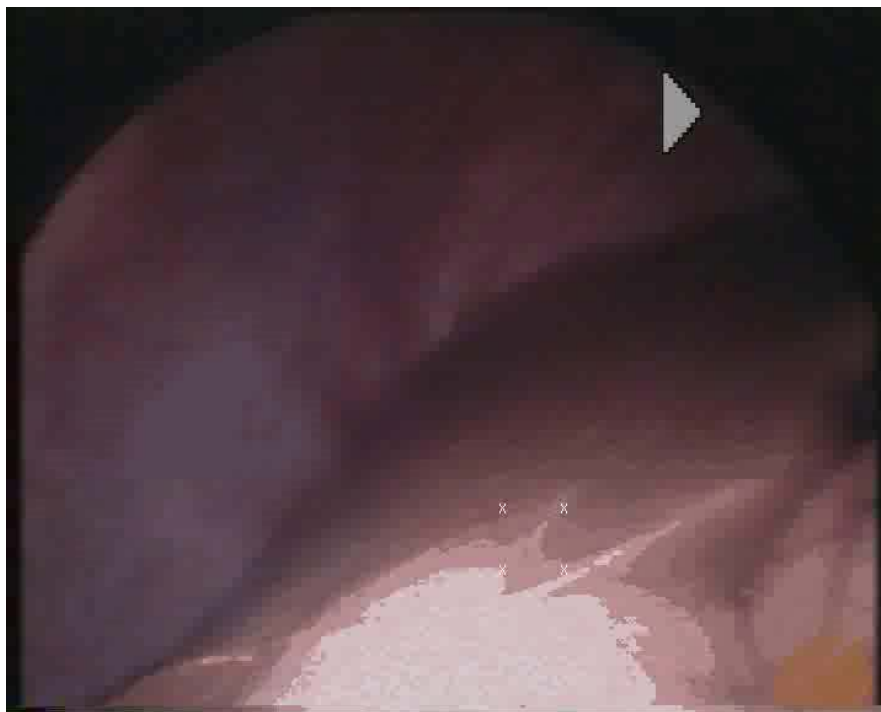
- One stereo-rig not sufficient
- Four or better six tracking cameras required

- Laparoscope Calibration Methods

- Direct Linear Transformation
- Iterative Pose Estimation
- Hand Eye-Calibration

# Gated Liver Augmentation

- Exhalation plateau adjusted to about 3sec
- Register Model to the liver at exhalation
- Augment only during the exhalation plateau



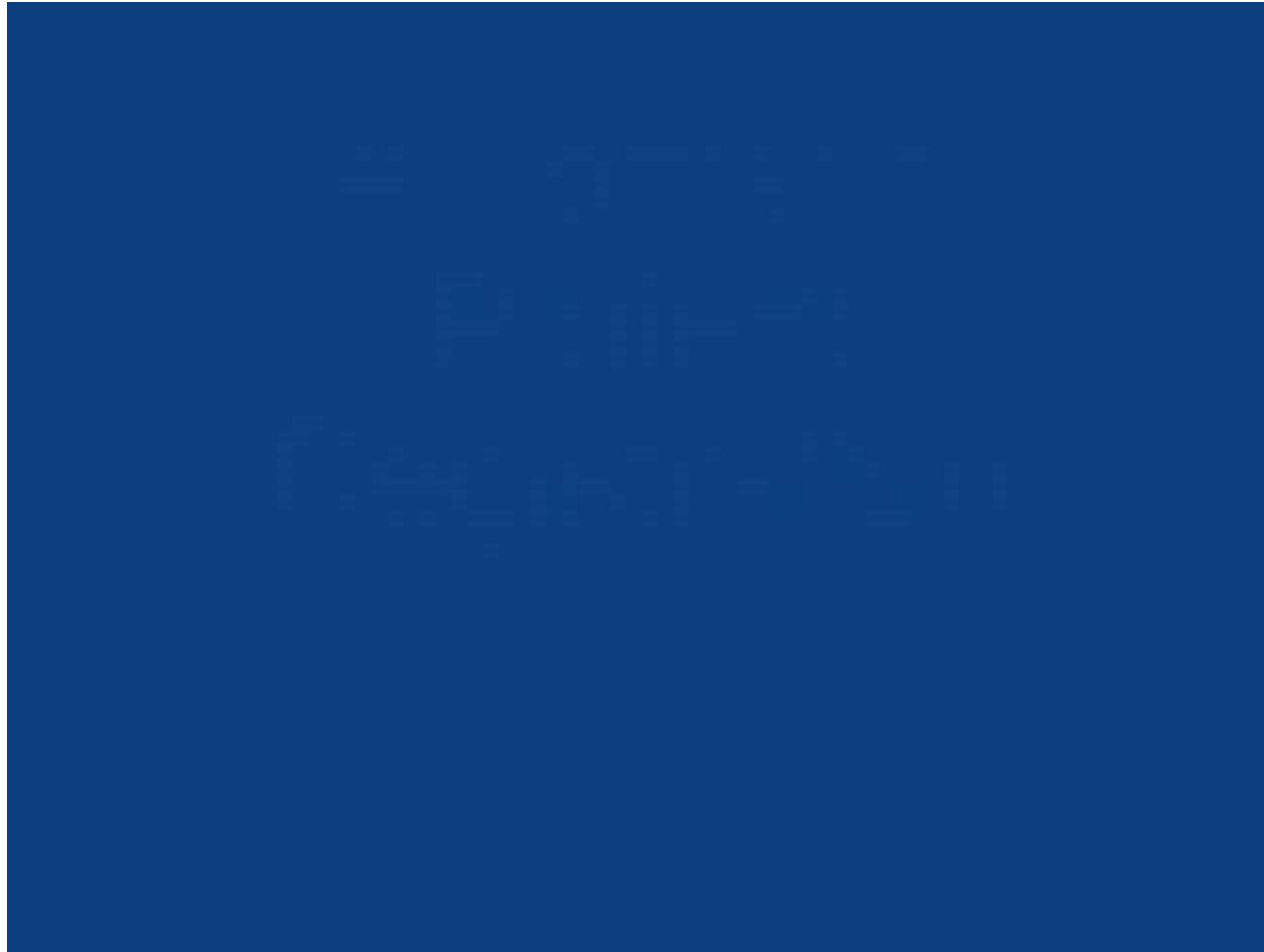
Simple Augmentation



Gated Augmentation

# Augmented Reality Activities @ CAMP

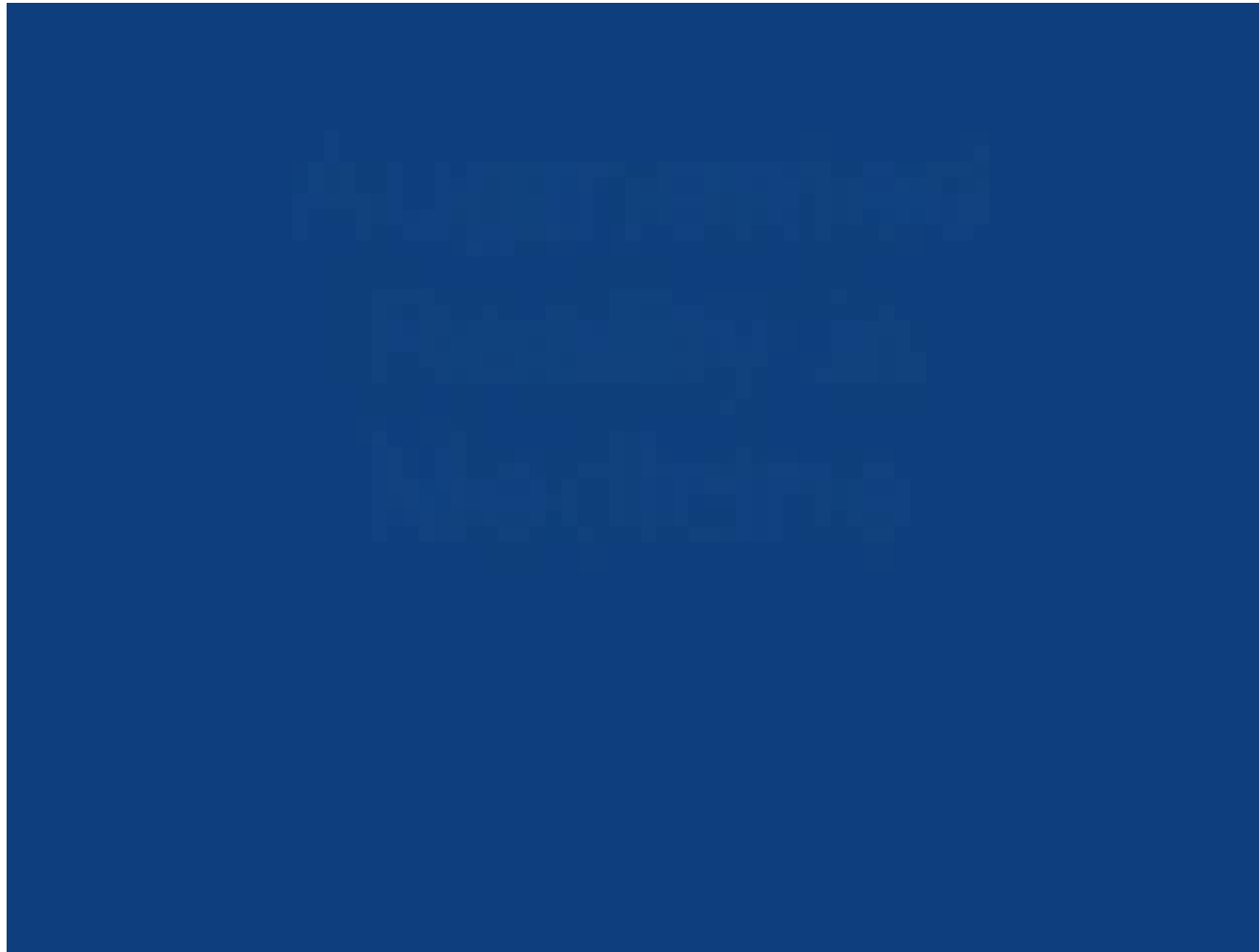
Automatic Patient Registration for Port Placement in Minimally Invasive Endoscopic Surgery



M. Feuerstein et al. In collaboration with Deutsches Herzzentrum München – accepted for MICCAI'05

# Augmented Reality Activities @ CAMP

Navigation and AR visualization for minimally invasive spine surgery (NARVIS – BFS)



In collaboration with Klinikum Innenstadt (München) / ART (Weilheim) / Siemens Corporate Research (Princeton, USA)

# Conclusion – Impact of Augmented Reality

- Benefit (“GPS” for Minimally Invasive Procedure)
  - Non-invasive Target Localization
  - Visualize Internal Anatomy (e.g. hepatic vein / bile duct)
  - 3D Navigation (including tool tracking)
  
- Challenges
  - Visualization and Information Representation
  - Precision, Accuracy, and Reliability in Tracking, Registration, and Calibration
  - Deformable Objects / Intraoperative Imaging





# ISMAR 05

[www.ismar05.org](http://www.ismar05.org)

Fourth IEEE and  
ACM International  
Symposium on Mixed  
and Augmented Reality

October 5-8, 2005, Vienna, Austria

# Submission Deadlines

**April 08, 2005 Short/Long Papers**

**April 08, 2005 Poster**

**June 30, 2005 Demo**

## **General Chair**

Nassir Navab, TU München, Germany

Wolfgang Birkfellner, Medical University Vienna, Austria

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Ron Azuma, HRL Laboratories, USA

Oliver Bimber, Bauhaus Universität Weimar, Germany

Kosuke Sato, Osaka University, Japan

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Emanuel Wenger, Academy of Sciences, Vienna, Austria

Leonid Dimitrov, Academy of Sciences, Vienna, Austria

## **Demo/Exhibition Chair**

Anton Fuhrmann, VRVIS Vienna, Austria

## **Workshops Chair**

Gudrun Klinker, TU München, Germany

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