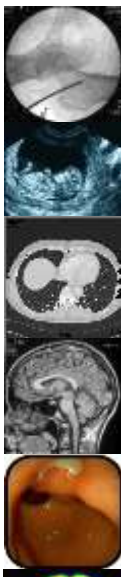
AR *in* OR

Augmented Reality in the Operating Rooms

Nassir Navab

Problem statement



- Short history of medical imaging
  - Medical X-Rays 1896
  - Ultrasonography 1953
  - Computed Tomography (CT) 1972
  - Magnetic Resonance Imaging (MRI) 1973
  - Camera endoscopy 1987
  - PET, fMRI, 3D Ultrasonography, Optical Imaging, …
  - OCT, PET/CT, PET/MR. Photo-acoustic, …
- → Doctors are confronted with more and more imaging data
- → Increase of imaging data makes its intelligent visualization and its proper integration into medical procedures necessary

* Terry M. Peters, Image-guided surgery: From X-rays to Virtual Reality, Comput Methods Biomech Biomed Engi 2000;4(1):27-57

Center for Computational Science in Medicine
Technische Universität München + JOHNS HOPKINS UNIVERSITY

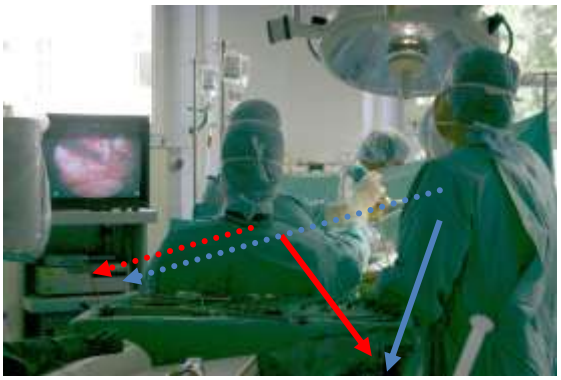
Problem statement

- In most ORs 3D imaging data is currently displayed inappropriately:
  - on 2D screens

Slide 3

Problem statement

- In most ORs 3D imaging data is currently displayed inappropriately:
  - on 2D screens



Slide 4

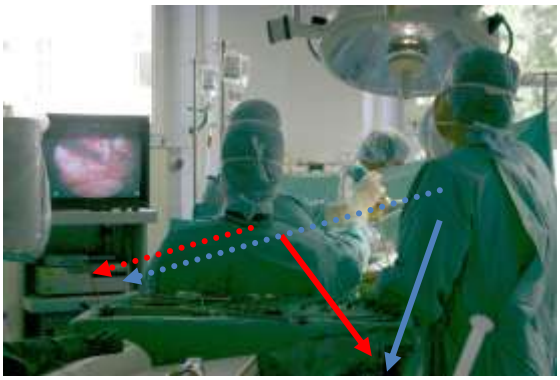
Problem statement

- In most ORs 3D imaging data is currently displayed inappropriately:
  - on 2D screens
  - at least one Screen for each Imaging device

Slide 5

Problem statement

- In most ORs 3D imaging data is currently displayed inappropriately:
  - on 2D screens
  - at least one screen for each imaging device
  - far away from operation situ



Slide 6

Medical AR in 1990s

For more details see:

T. Sielhorst, M. Feuerstein, N. Navab
'Advanced Medical Displays: A Literature Review of Augmented Reality '

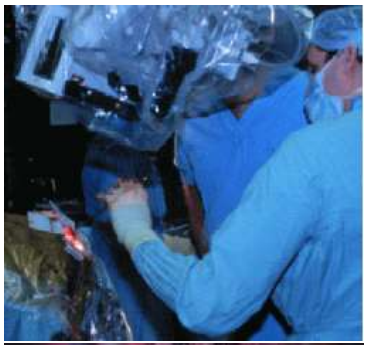
Special Issue of the IEEE/OSA Journal of Display Technology on Medical Displays

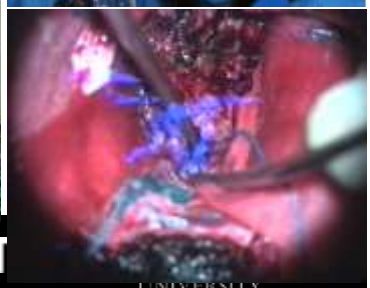
Slide 7

Operating microscope

- First attempt by Edwards et al. 1995 at Guy's Hospital, London
- External mount, stereo view

P. J. Edwards, D. L. G. Hill, D. J. Hawkes, R. Spink. "Stereo Overlays in the Operating Microscope for Image Guided Surgery",
Proc. Computer Assisted Radiology 1995





Center for Computational Science in Medicine
Technische Universität München

Operating binocular

- Birkfellner, Figl et al. 2000: Varioscpe AR at Vienna General Hospital
- Head mounted, stereo view

W. Birkfellner, M. Figl, K. Huber, F. Watzinger, F. Wanschitz, R. Hanel, A. Wagner, D. Rafolt, R. Ewers, H. Bergmann:
„The Varioscope AR - A Head-Mounted Operating Microscope for Augmented Reality", MICCAI 2000

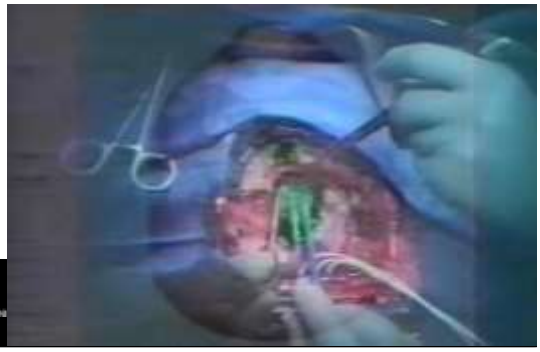
Center for Computational Science in Medicine

Technische Universi

AR on External Monitor

- Kikinis, Jolesz, Grimson, et al 1996 at Brigham and Women's Hospital
- Mono, external mount

W.E.L. Grimson, G.J. Ettinger, T. Kapur, M.E. Leventon, W.M. Wells, R. Kikinis, Utilizing Segmented MRI Data in ImageGuided Surgery, International Journal of Pattern Recognition and Artificial Intelligence 1996



Center for Computational Science in Medicine

Technische

AR on External Monitor

- Mono, external mount
- Video, but not see through

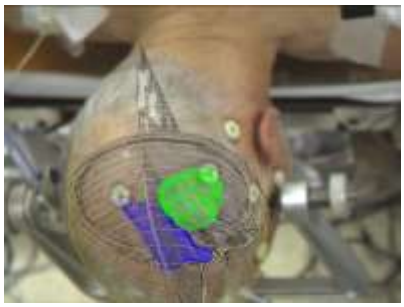
S. Nicolau et al., 2004, IRCAD & INRIA

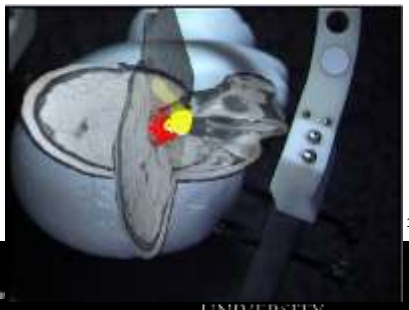
Head mounted display

- Fuchs, State et al.: 1992 at UNC
- Stereo, video see through

Head mounted display

- Sauer et al. 2000 at Siemens Corporate Research, NJ
- Stereo video see through
- Synchronized real and virtual images





13

Center for Computational Science in Medicine

Technische Universität München

UNIVERSITY

Challenges – Adoptive, intuitive and interactive visualization

Slide 14

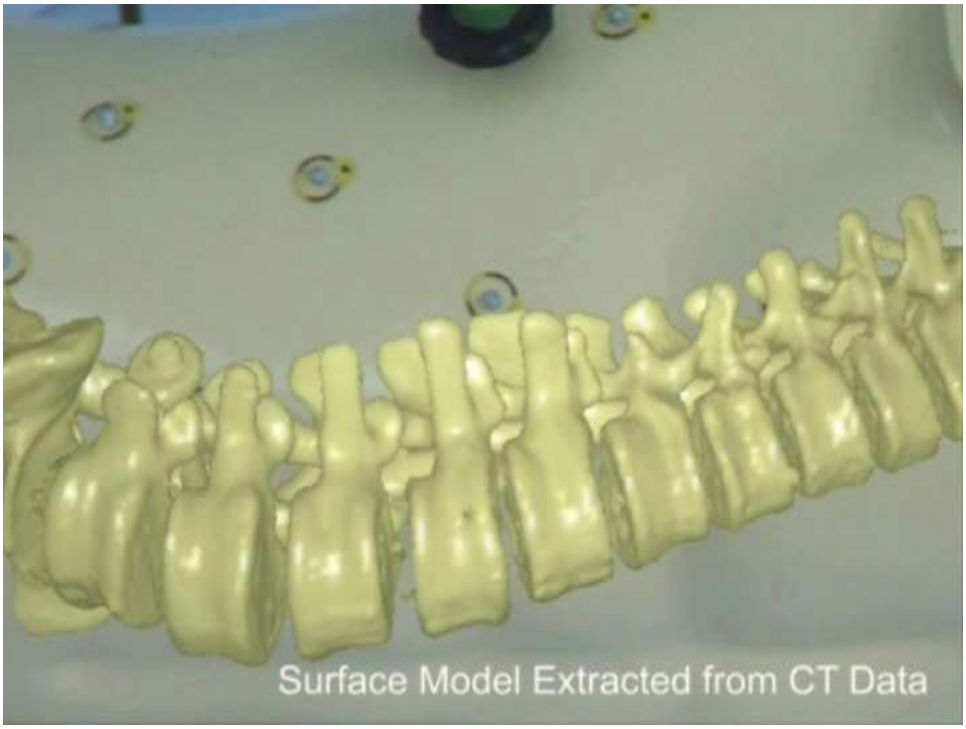
Center for Computational Science in Medicine

Technische Universität München + JOHNS HOPKINS UNIVERSITY

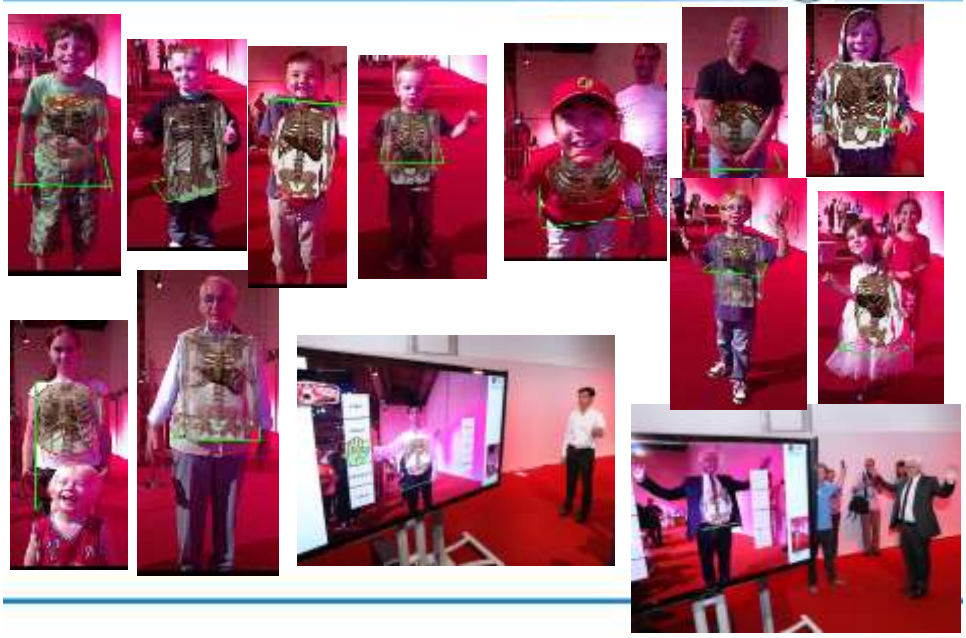
Challenges – Adoptive, intuitive and interactive visualization

Slide 15

Center for Computational Science in Medicine — Technische Universität München + JOHNS HOPKINS UNIVERSITY


Surface Model Extracted from CT Data

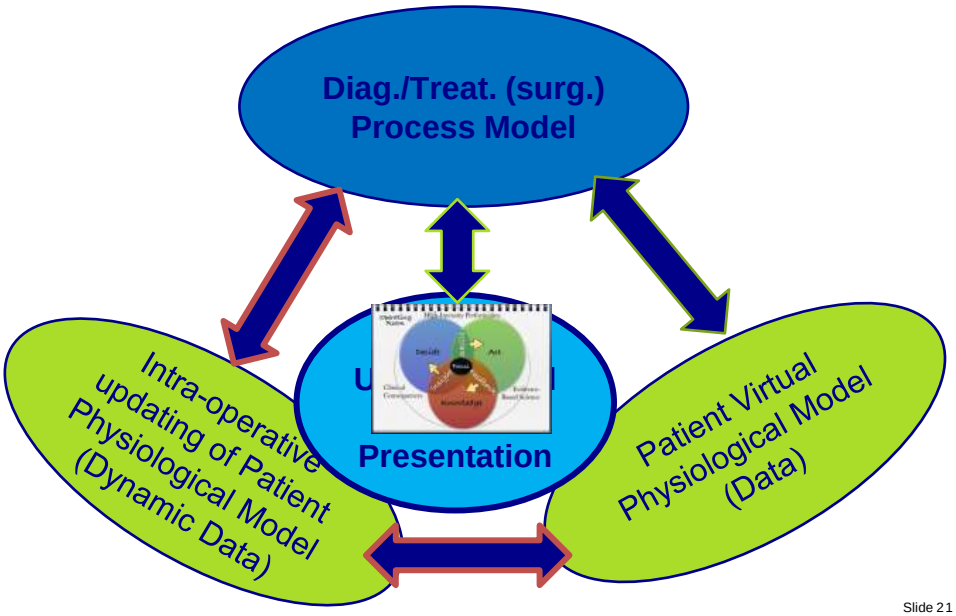

MAGIC MIRROR
The effect of the "Magic Mirror" is similar to X-ray vision, creating the illusion that you can see into your own body. The technology behind this process is called Augmented Reality, combining real and virtual images of the body. It could, in the future, make it possible for surgeons to look inside patients' bodies during an operation.
Please stand on the marked spot on the floor. Please select your body size from the terminal.



Computer Aided Medical Procedures | Technische Universität München

IMAGING AND VISUALIZATION IN OPERTATING ROOMS

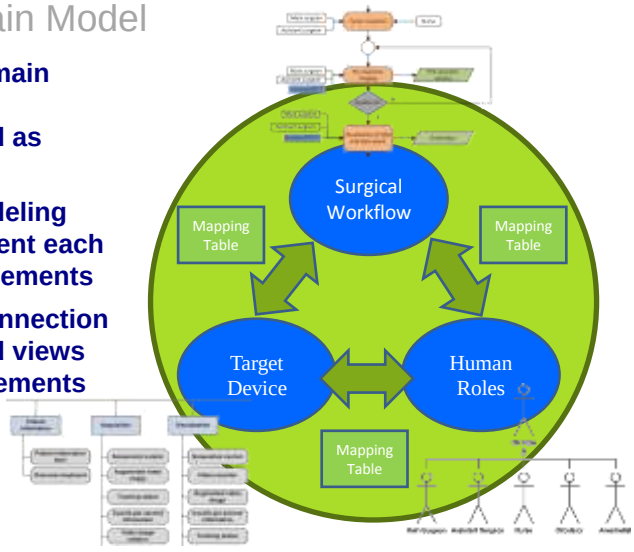
How do we bring AR into OR?



Slide 21

OR Specific Domain Model

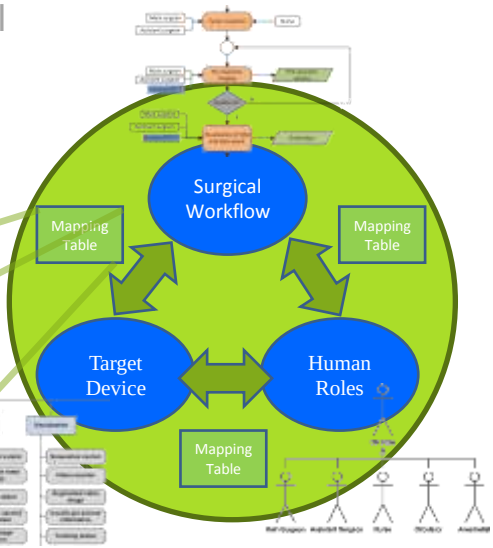
1. **Decompose the domain into its sources of complexity modeled as distinct views**
2. **Select a proper modeling technique to represent each view and drive its elements**
3. **Establish a clear connection between the defined views by mapping their elements**



Slide 22

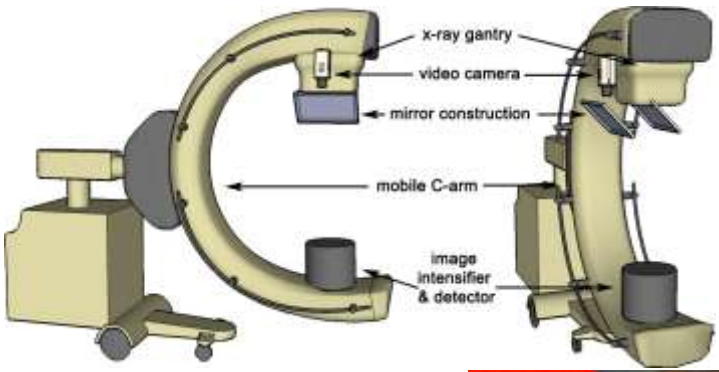
OR Specific Domain Model

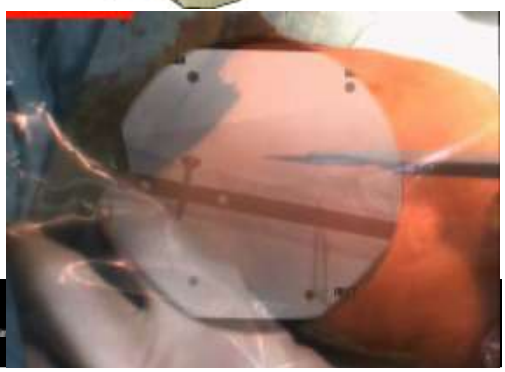
1. **Decompose the domain into its sources of complexity modeled as distinct views**
2. **Select a proper modeling technique to represent each view and driving its elements**
3. **Establish a clear connection [illegible] views [illegible] elements**



Slide 23

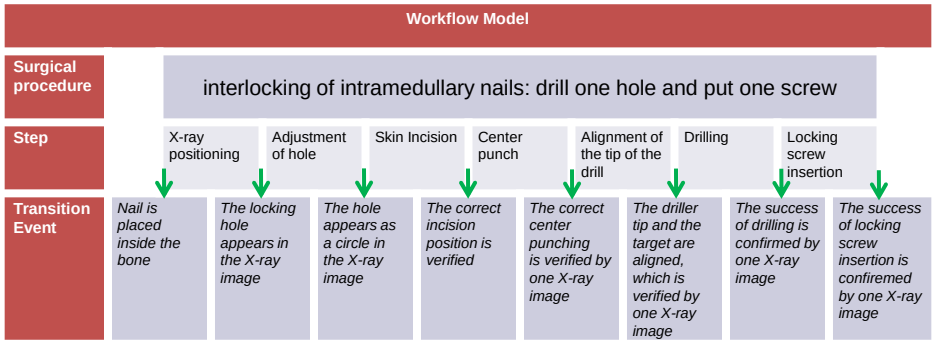
Center for Computational Science in Medicine — Technische Universität München + JOHNS HOPKINS UNIVERSITY



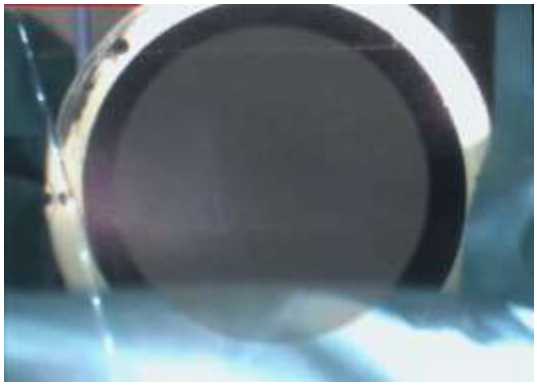


Center for Computational Science in Medicine — Technische Univ

Workflow Model of Interlocking



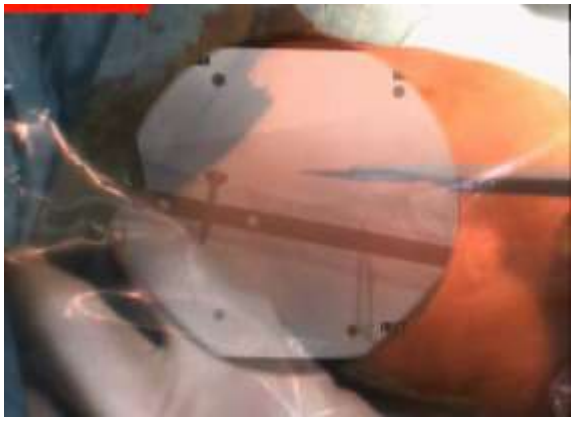
Interlocking: X-ray Positioning



- For X-ray positioning, the live video with an overlaid X-ray image circle (like an aiming circle) provides an intuitive video-based guidance for moving C-arm to the desired position.

Center for Computational Science in Medicine
Technische Universität München + JOHNS HOPKINS UNIVERSITY

Interlocking: Target Locatisation



- Surgeons can quickly find the locking hole and make a skin cutting using the guidance of a live video with an aligned X-ray image.

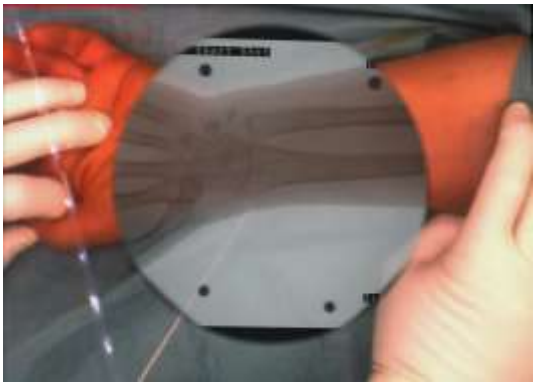
Slide 27

Interlocking: Drilling Axis Control

- An X-ray augmented by a live video supports surgeons to orient and place the tool for drilling through the bone and locking hole.

Slide 28

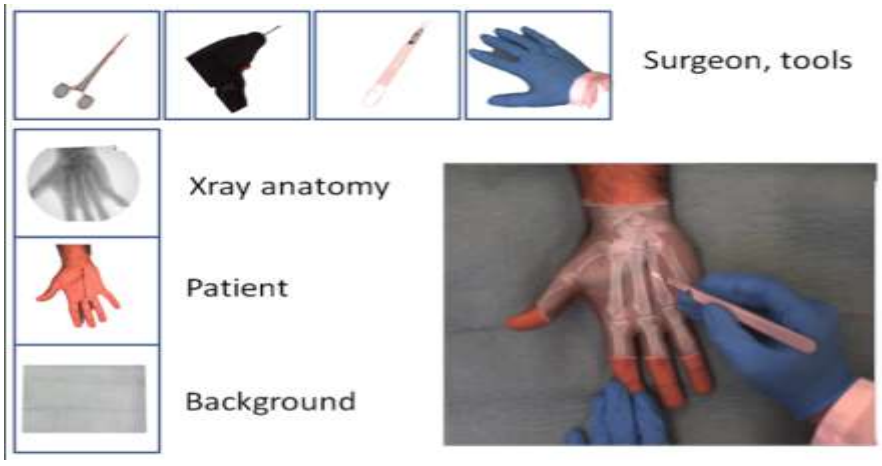
Further Clinical Applications: Incision Placement



- The X-ray and video image overlay can be used to plan the correct incision, placing it exactly above the fracture with what the surgeon considers as the optimal length, minimizing the wound.

Slide 29

Machine Learning for Relevance based Imaging

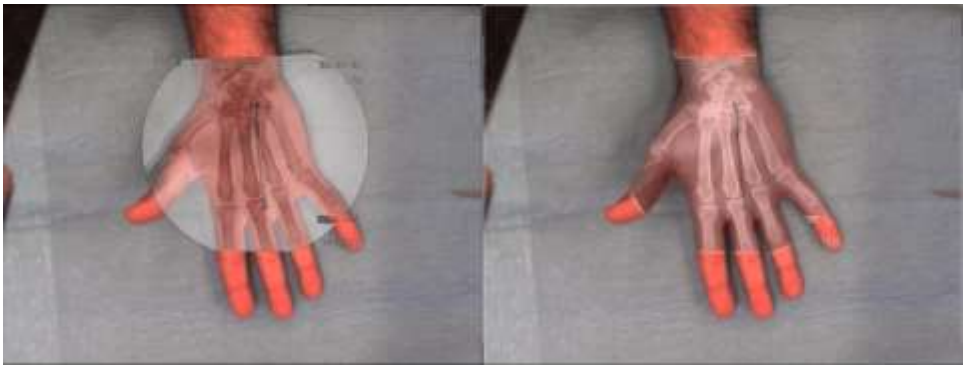


IPCAI 2014, Japan

Slide 30

Machine Learning for Relevance based Imaging

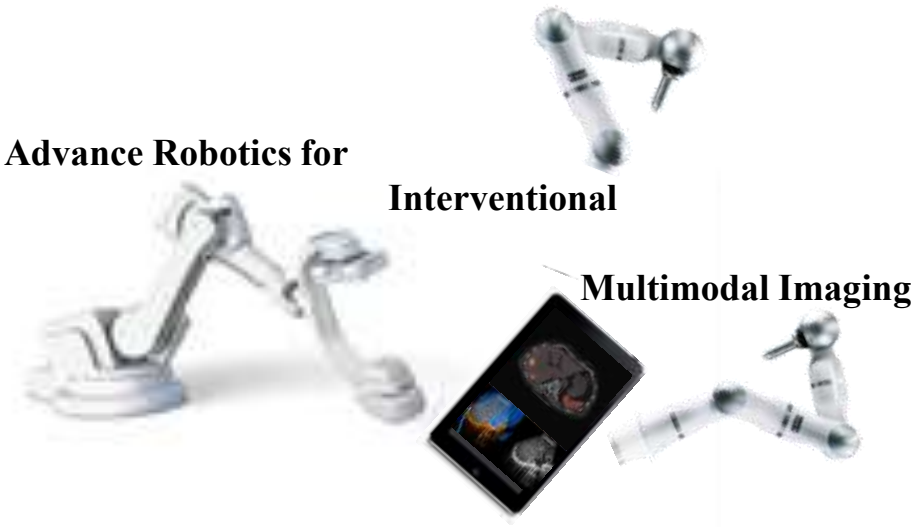
Machine Learning for Relevance based Imaging



Machine Learning for Relevance based Imaging

Patient and therapy specific imaging

- Advances in therapeutic imaging have not been comparable to the ones in diagnostic imaging
- One needs to develop novel intra-operative anatomical/functional/nuclear/molecular imaging to monitor therapy at the point where the care is given
- The imaging needs to be patient and process specific resulting in high impact on the outcome of the therapy
- Requirements:
  - Speed
  - Flexibility
  - Reproducibility
  - Reliability
  - Relevance

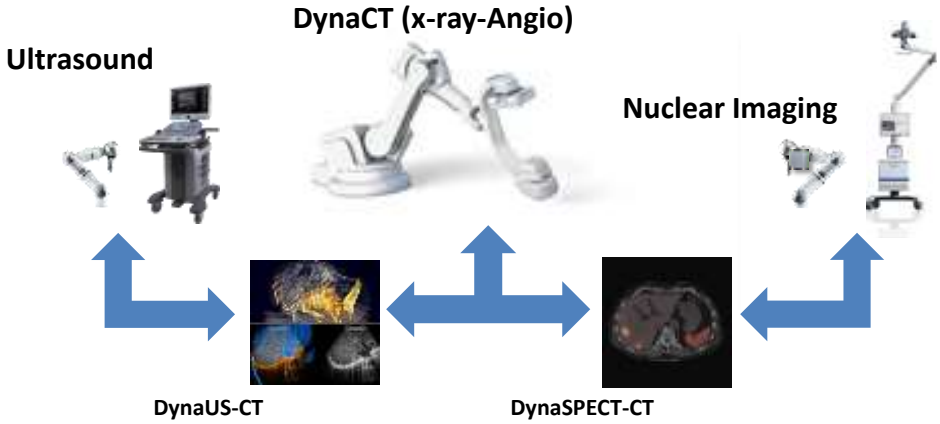


Shaping the Future of interventional imaging

Slide 35

Center for Computational Science in Medicine — Technische Universität München + JOHNS HOPKINS UNIVERSITY

Objectives: Novel Interventional Multimodal Imaging



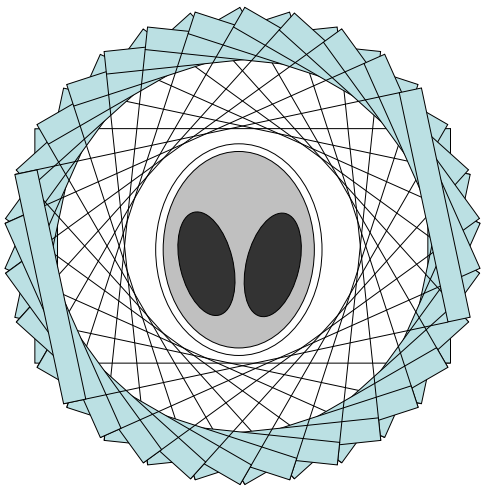
Shaping the Future of interventional imaging

Slide 36

Center for Computational Science in Medicine — Technische Universität München + JOHNS HOPKINS UNIVERSITY

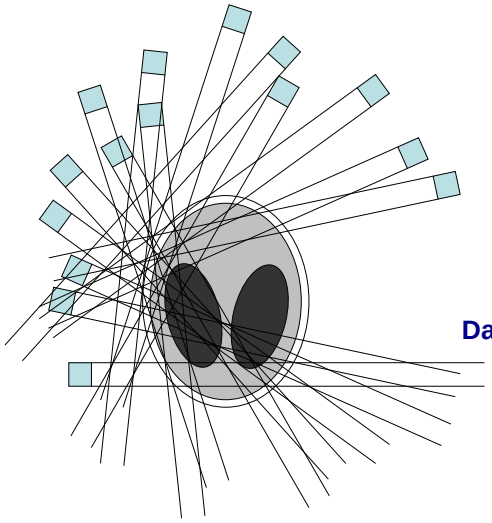
Diagnostic SPECT

Conventional SPECT imaging



Complete tomographic data
Almost symmetric set
>180° covered
Center in center of ROI
> 8 billion events

Freehand SPECT imaging

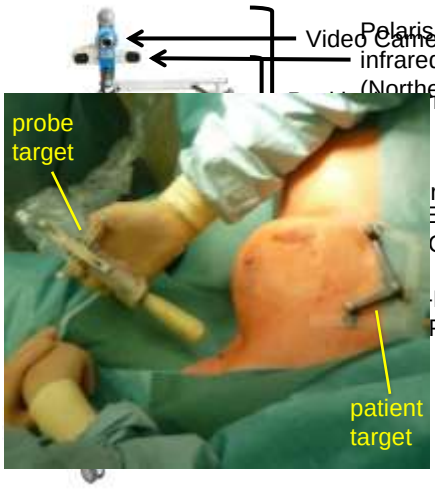


Data with tracked non-imaging probe

Non-uniform / non-symmetric set
<180° covered
Center depends on scan
< 40 thousand events

Slide 39

System Description



Video Camera

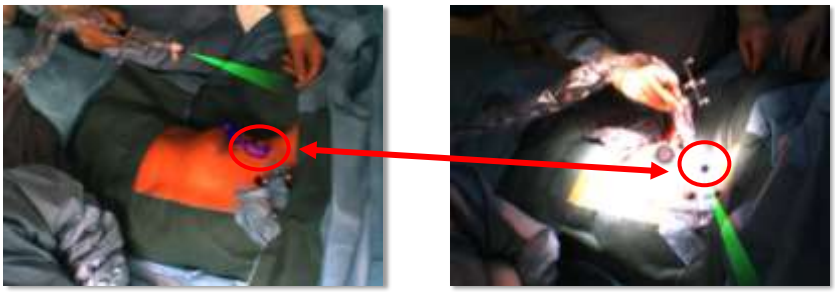
Polaris Vicra
infrared optical tracking system
(Northern Digital, Canada)

reen
ECT car system
GmbH)

Probe System gamma detector
Photonics, Germany)

Slide 40

Towards individualized cancer therapy



Pre-incision image

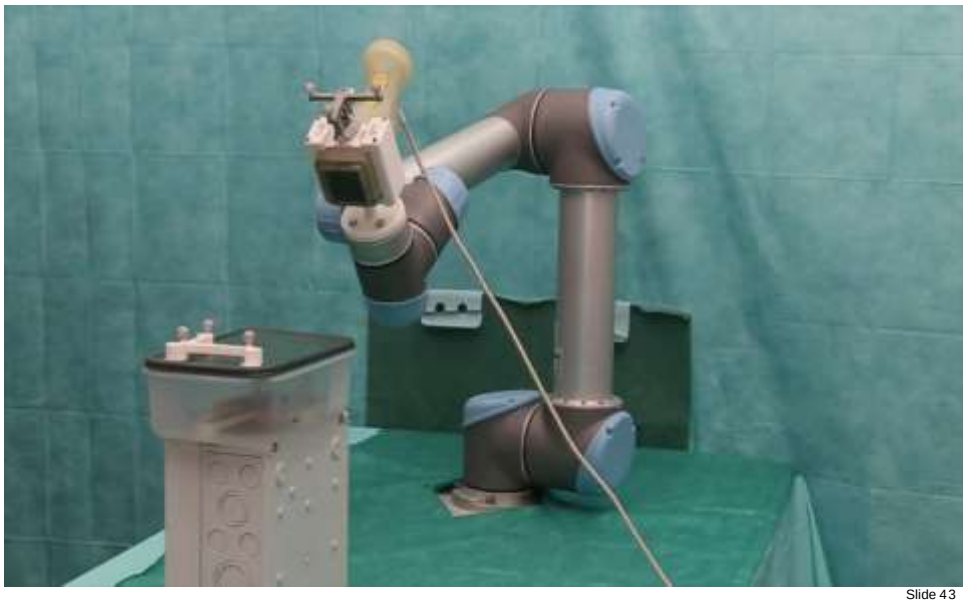
Post-excision image

- The missed SLN was found in control scan (post-excision image)
- To date therapy has been monitored for hundreds of patients using this intra-operative nuclear imaging modality

Slide 41

From general diagnostic imaging to flexible, reproducible and reliable patient and therapy specific imaging

Slide 42



Slide 43

Center for Computational Science in Medicine — Technische Universität München + JOHNS HOPKINS UNIVERSITY

Objectives: Novel Interventional Multimodal Imaging

KUKA Lightweight Robot

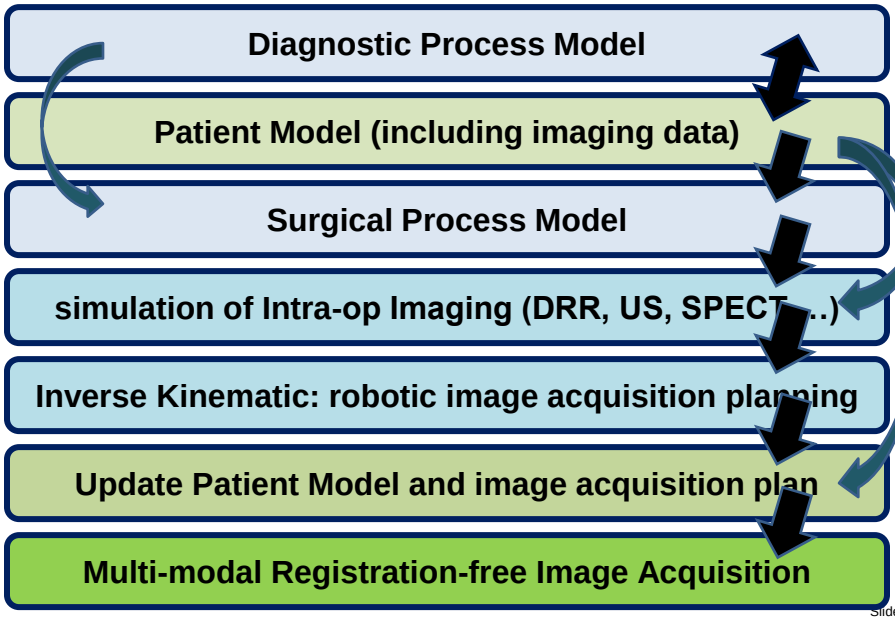
ultrasound point to point experiment

Berhnhard Fürst — Christoph Hennersperger

Nassir Navab

Computer Aided Medical Procedures (CAMP)

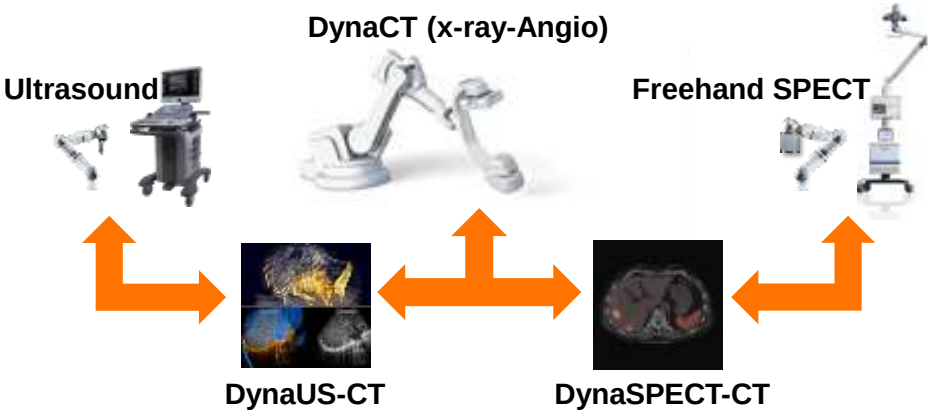
SURGICeye — ImFusion — KUKA — SIEMENS



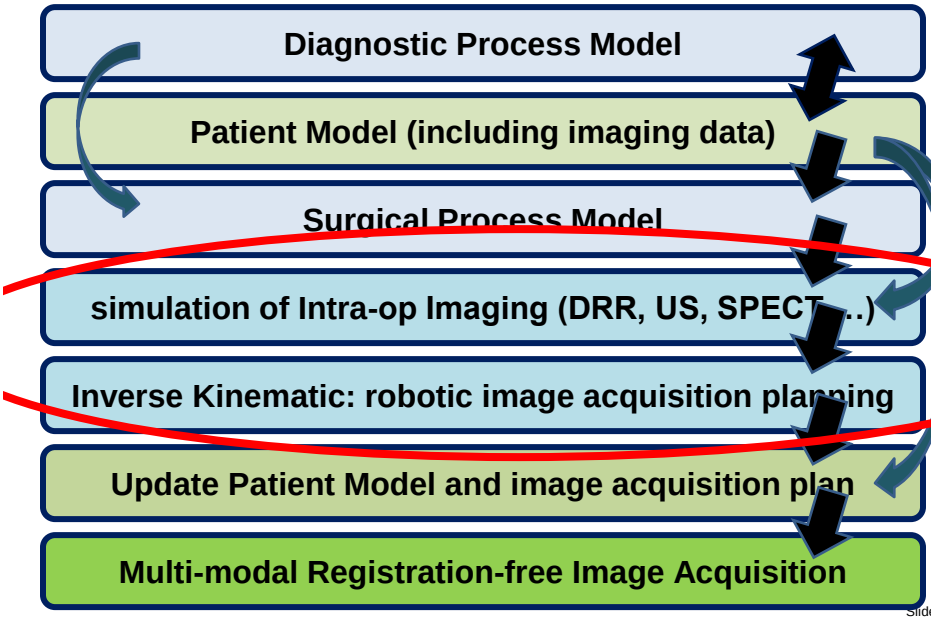
Slide 45

Center for Computational Science in Medicine — Technische Universität München + JOHNS HOPKINS UNIVERSITY

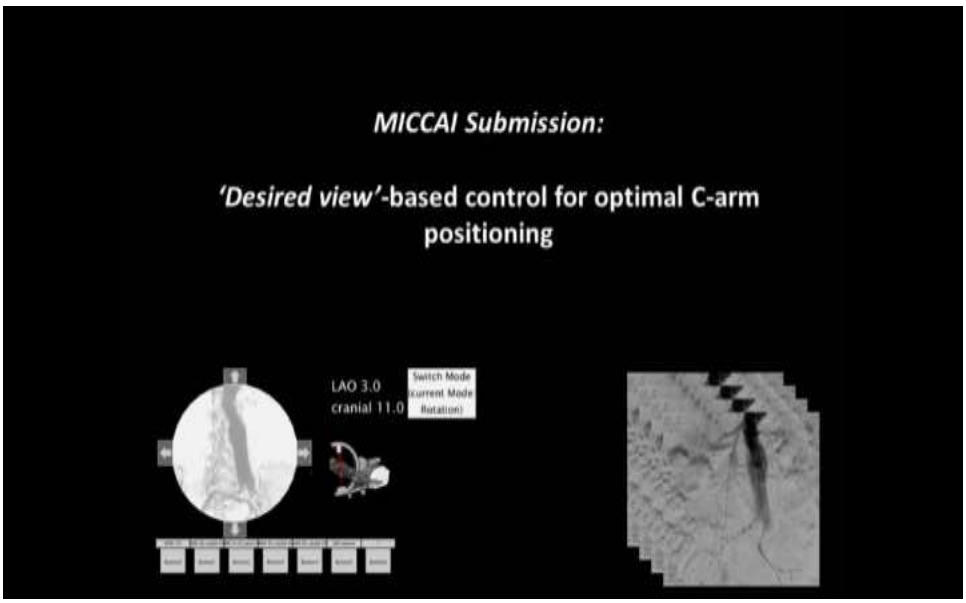
Objectives: Novel Interventional Multimodal Imaging



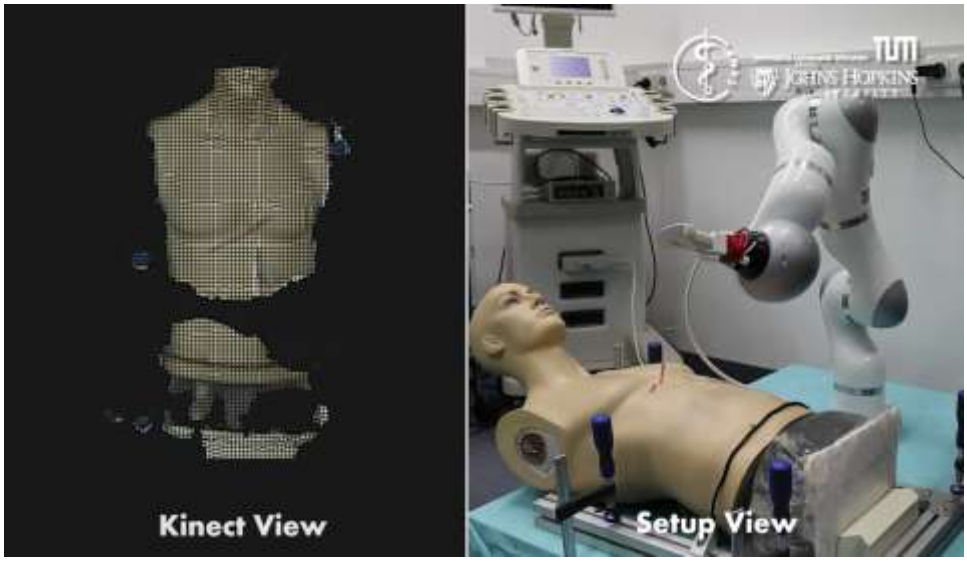
SURGICeye · ImFusion · KUKA · SIEMENS · MRI



Slide 47

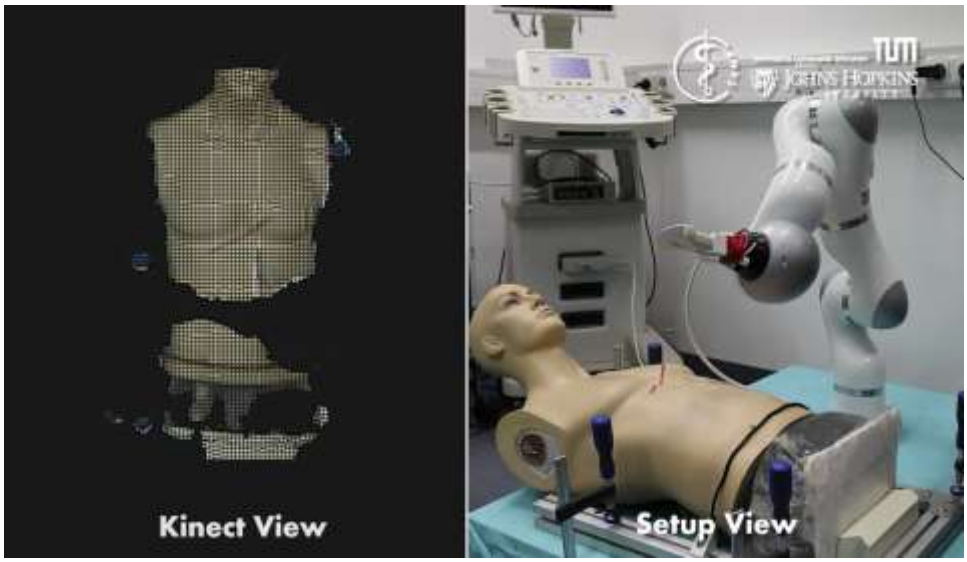


Slide 48



Slide 49

Center for Computational Science in Medicine
Technische Universität München + JOHNS HOPKINS UNIVERSITY



Slide 50

Center for Computational Science in Medicine
Technische Universität München + JOHNS HOPKINS UNIVERSITY

Slide 51

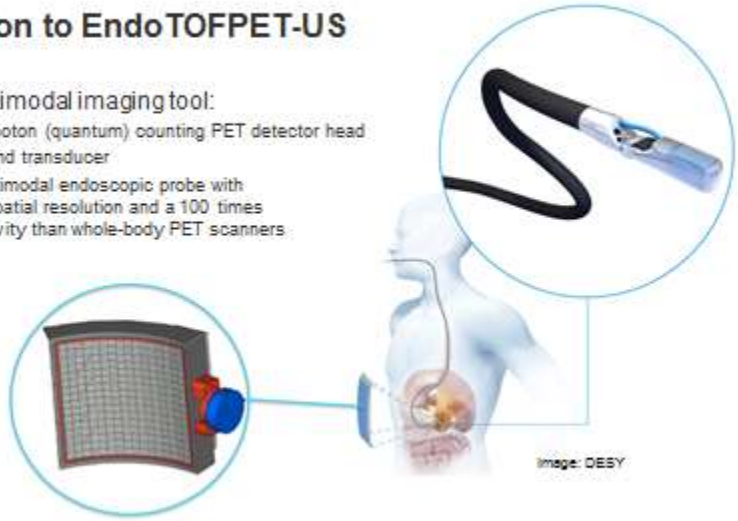
Center for Computational Science in Medicine
Technische Universität München + JOHNS HOPKINS UNIVERSITY

Slide 52

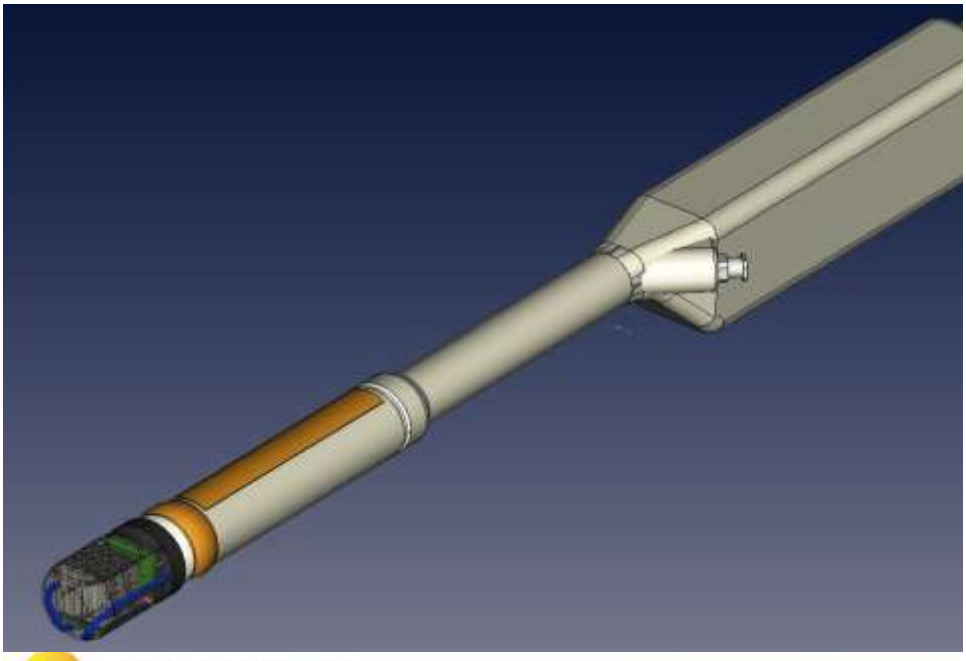
Center for Computational Science in Medicine
Technische Universität München + JOHNS HOPKINS UNIVERSITY

Introduction to EndoTOFPET-US

- Novel multimodal imaging tool:
  - Single-photon (quantum) counting PET detector head
  - Ultrasound transducer
- Miniaturized bimodal endoscopic probe with a millimeter spatial resolution and a 100 times higher sensitivity than whole-body PET scanners

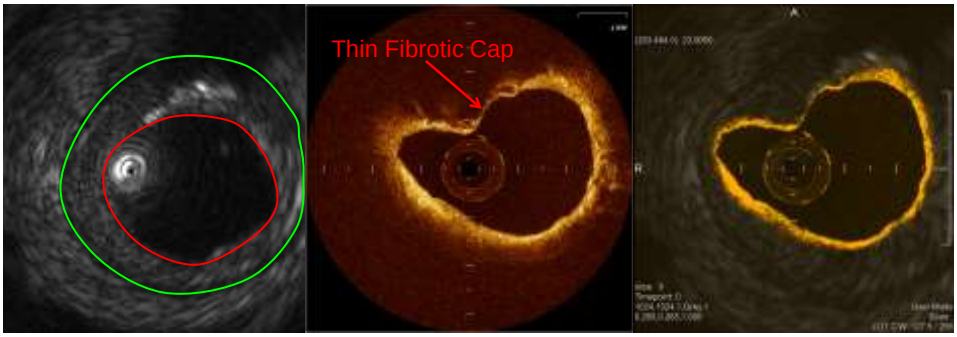


ENDO TOFPET US
Endoscopic TOFPET & Ultrasound



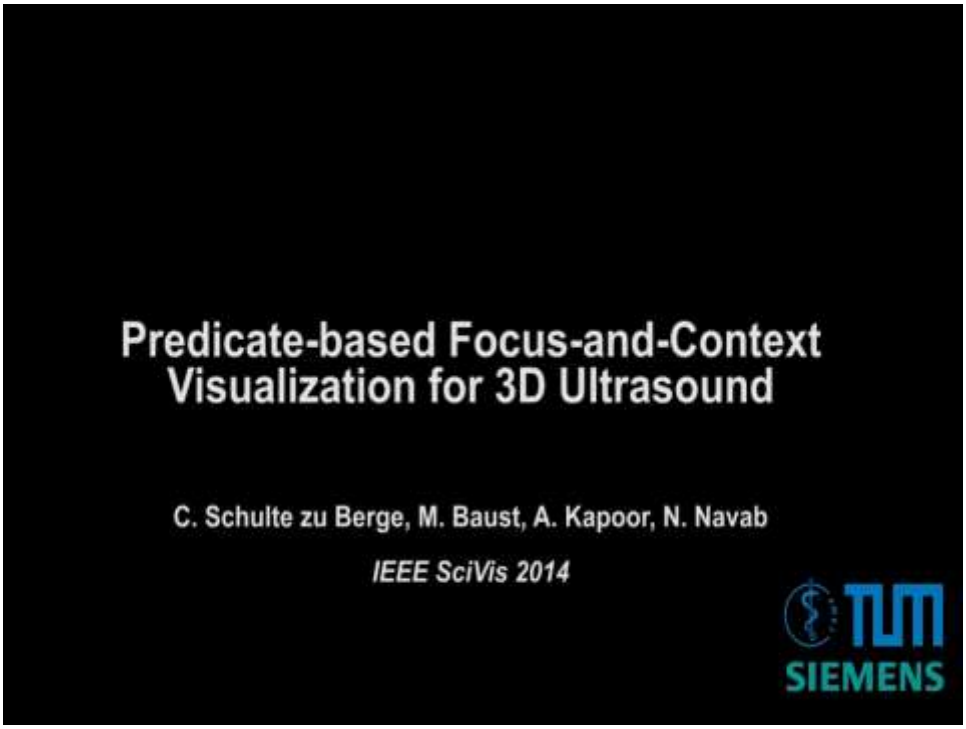
ENDO TOFPET US
Endoscopic TOFPET & Ultrasound

Relevance-Based Data Fusion and Visualization



IVUS OCT Fused IVUS-OCT

The visualization is more informative in contrast to classical alpha-blending technique, *Eslami. Katouzian, Navab*, *CAMP, 2012*




Dr. S. Demirci


Dr. S. Ilic


Dr. A. Katouzian


Dr. P. Fallavollita


Dr. M. Baust


Dr. B. Frisch


Dr. T. Peng


Dr. D. Mateus


Dr. T. Lasser

CAMP@TUM

10 YEARS ANNIVERSARY!

Funding & Publications

- 7 EU FP7
- DFG SFB 824
- BFS, SFB, BMBF
- 6 DFG & 2 BFS Individual
- Excellence cluster MAP
- TUM Grants
- Industrial Partners

Publications :

- > 100 MICCAI papers
- > 80 TMI/MedIA/IJCV/PAMI papers
- > 60 CVPR/ECCV/ICCV papers
- > 200 others (JNM, ISMAR, IPMI, SPIE, WBIR, SNM, …)

chair for computer aided medical procedures | wwwnavab.cs.tum.edu

Thank You

More information: http://campar.in.tum.de