Medical Augmented Reality
State Of the Art, Requirements and Challenges

Nassir Navab
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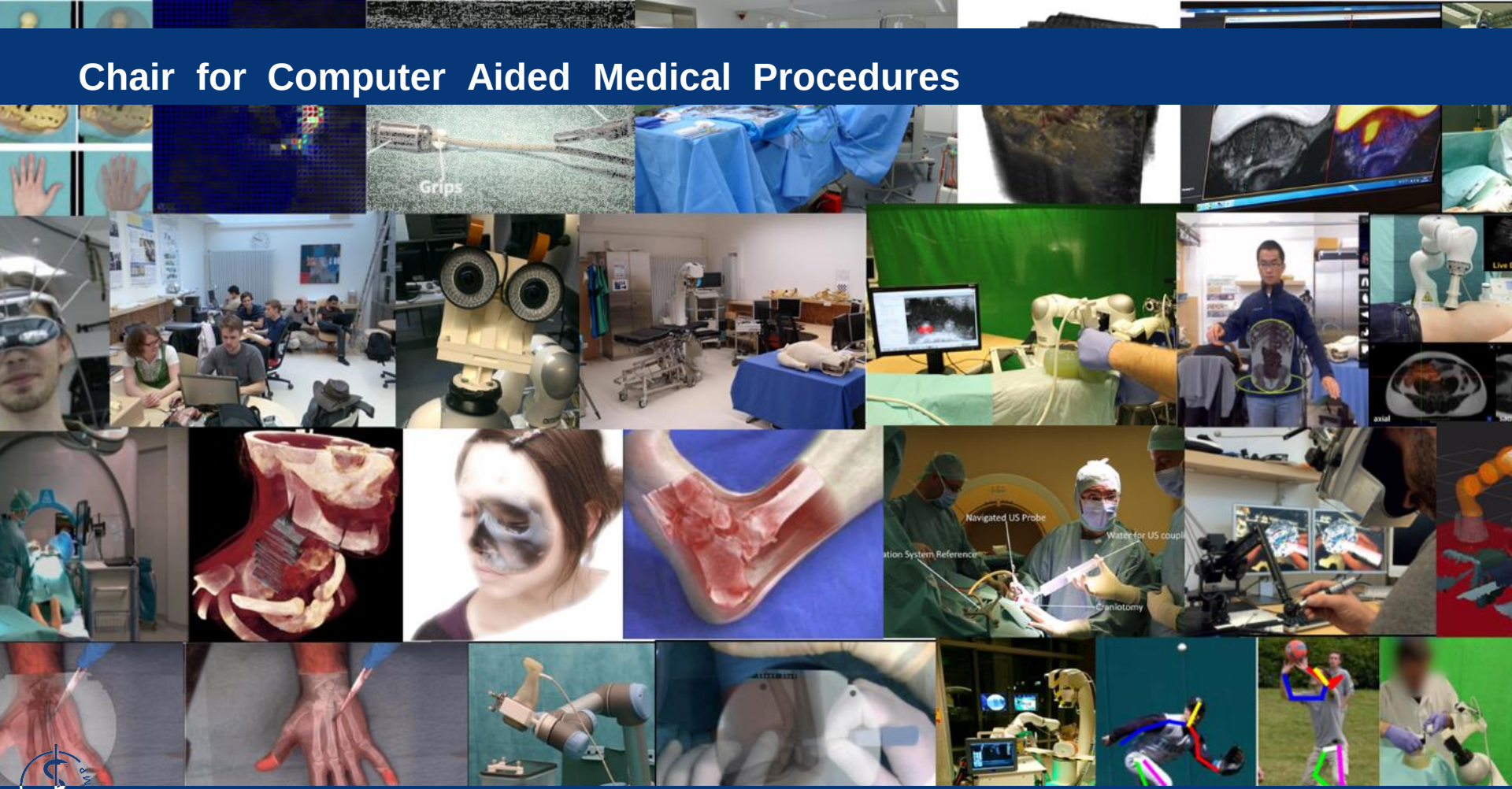
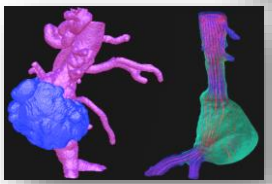
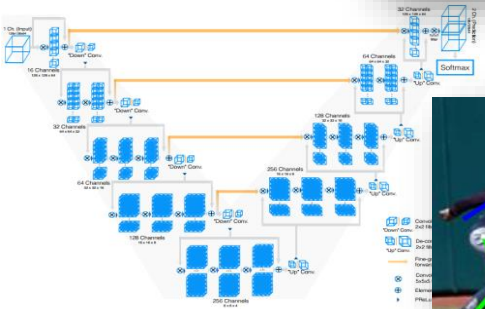
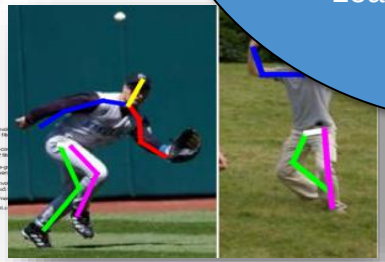
Technical University of Munich

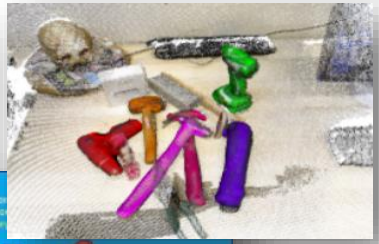
Chair for Computer Aided Medical Procedures

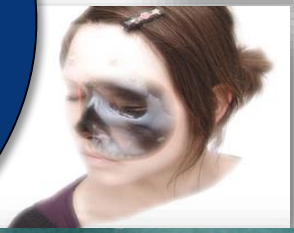












Medical Image Computing & Advance Data Visualization

Computer Vision

Machine Learning

Computer/Robot Assisted Interventions

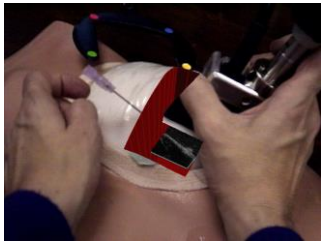
AR: Early concpets ... 1960s!

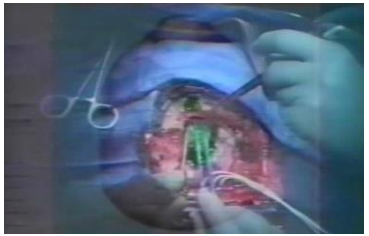
[1] Sutherland, Ivan E., “The Ultimate Display,” *Proceedings of the IFIP Congress,* pp. 506-508, 1965. [2] Video: http://www.youtube.com/watch?v=7B8aq_rsZao

Tom Furness, Unpublished
[1] Video: http://www.youtube.com/watch?v=ODa_kLVzD20

Medical AR: Challenges faced through decades

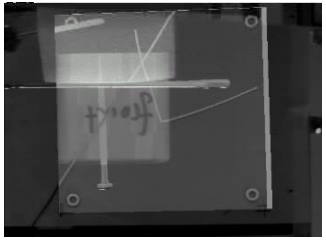
- Fuchs et al. 1993
  - » Main challenges:
    - Computational power!
    - Tracking and synchronization
- Edwards et al. 1995:
  - » Main Challenges:
    - Depth Perception
    - Workflow Integration
- Kikinis et al. 1996:
  - » Main Challenges:
    - Depth Perception
    - Workflow Integration

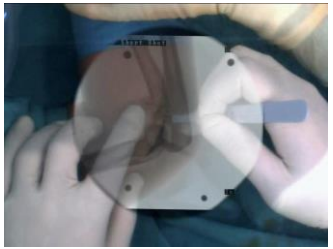




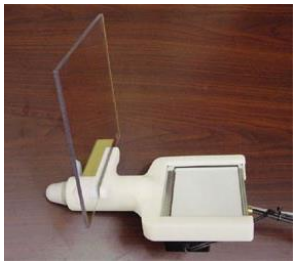
Medical AR: Challenges faced through decades

- Navab et al. 1998:
  - » Main Challenges:
    - 3D Relevance based Perception

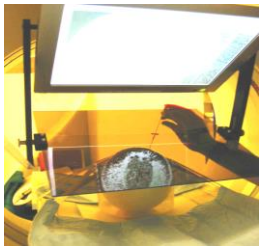


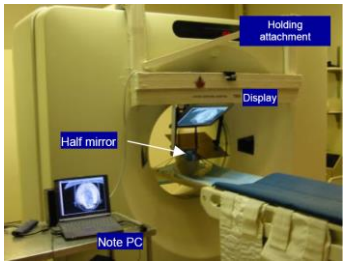


- Stetten et al. 2000:
  - » Main Challenges:
    - 3D Relevance based Perception



- Masamune et al. 2002:
  - » Main Challenges:
    - Workflow Integration

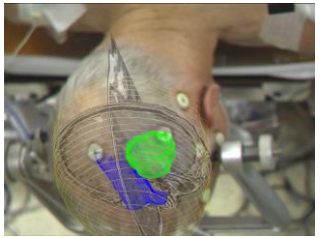




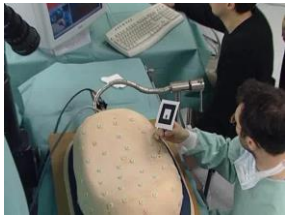
- DiGioia et al. 1998:bbb
  - » Main Challenges:
    - Tracking
    - Workflow Integration

- Birkfellner et al. 2000:
  - » Main Challenges:
    - Tracking
    - Workflow Integration

- Sauer et al. 2000
  - » Main challenges:
    - Depth Perception
    - Workflow Integration



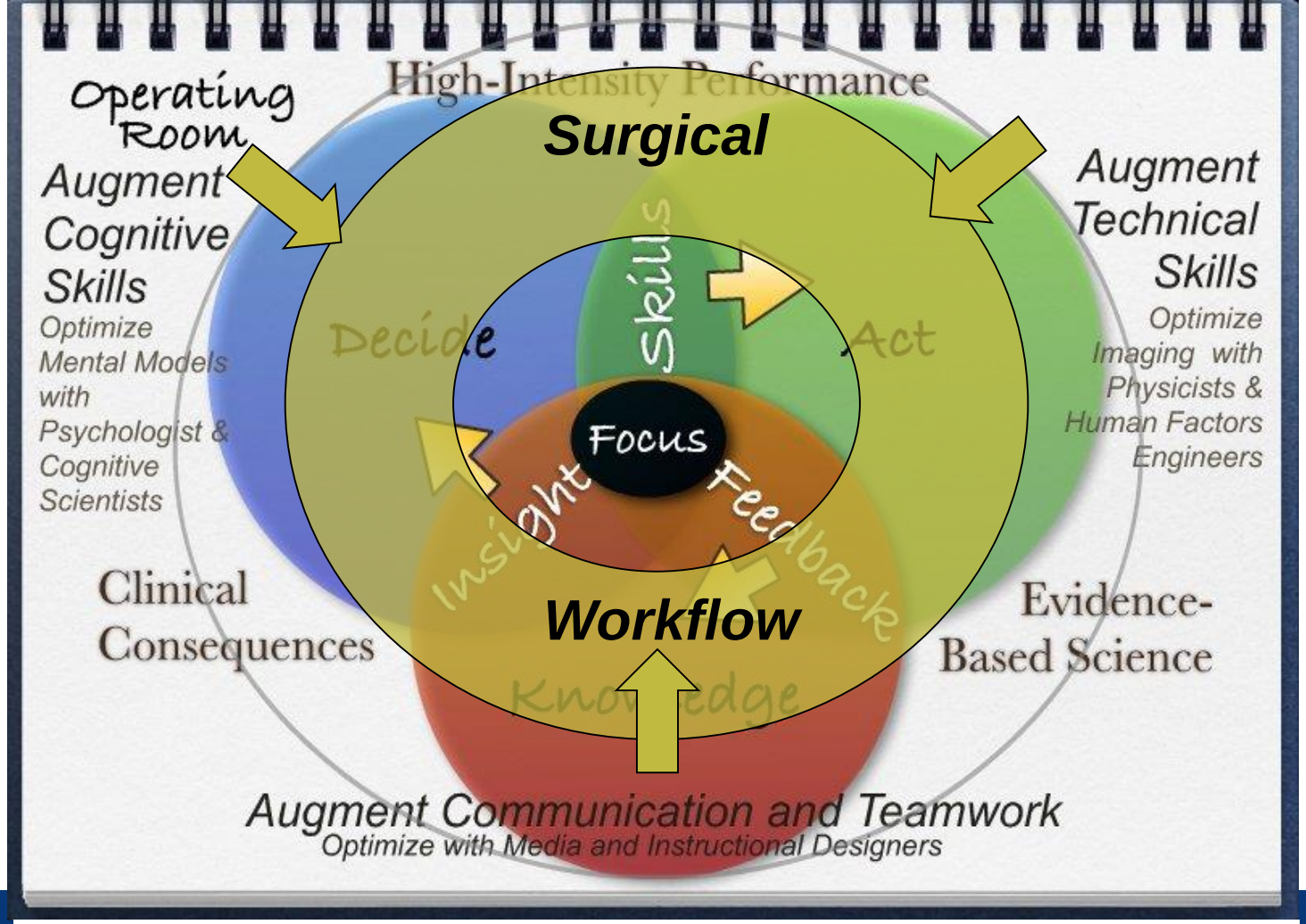
- Nicolau et al. 2004
  - » Main challenges:
    - Precision
    - Depth Perception
    - Workflow Integration



IMAGING AND VISUALIZATION IN OPERTATING ROOMS

How could we bring AR into OR?

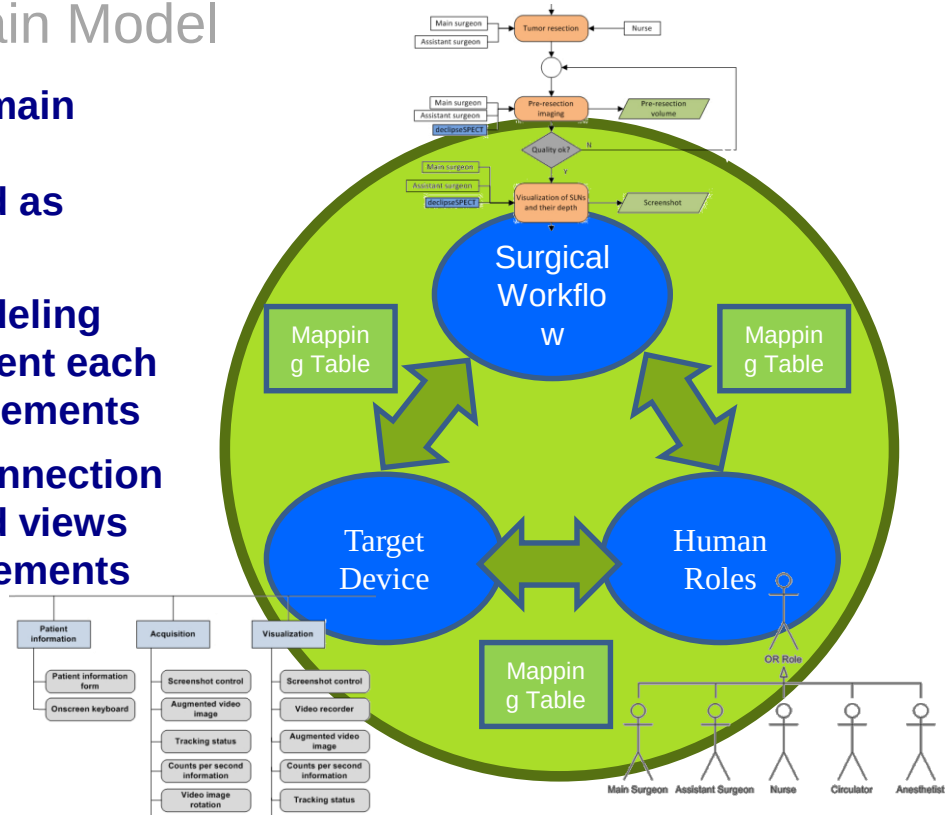
From: ‚Real World Labortories for Translational Research', Christopher Stapleton and Nassir Navab



From: ‚Real World Labortories for Translational Research', Christopher Stapleton and Nassir Navab

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**



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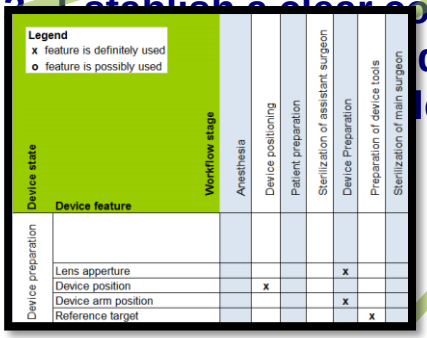
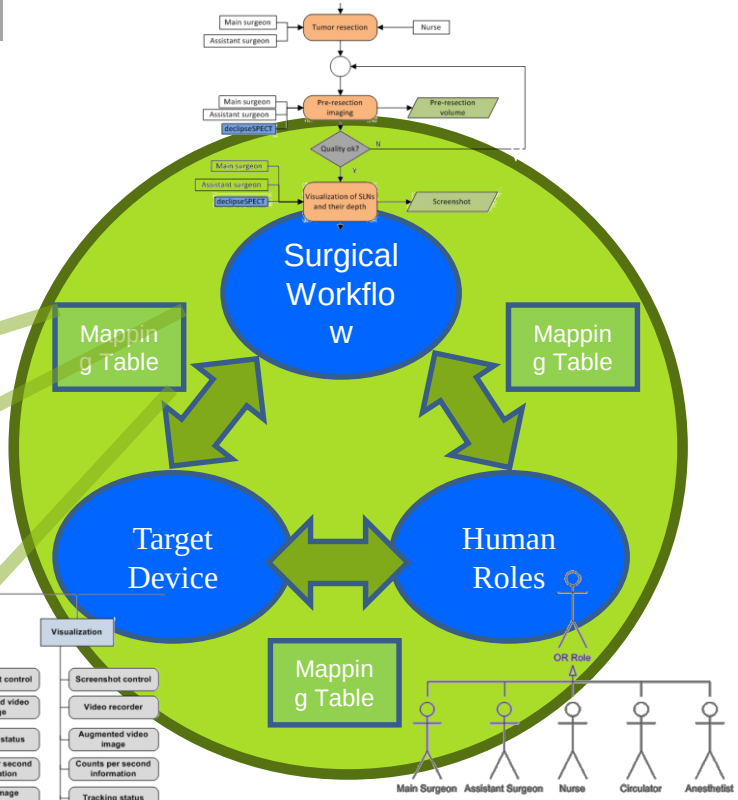
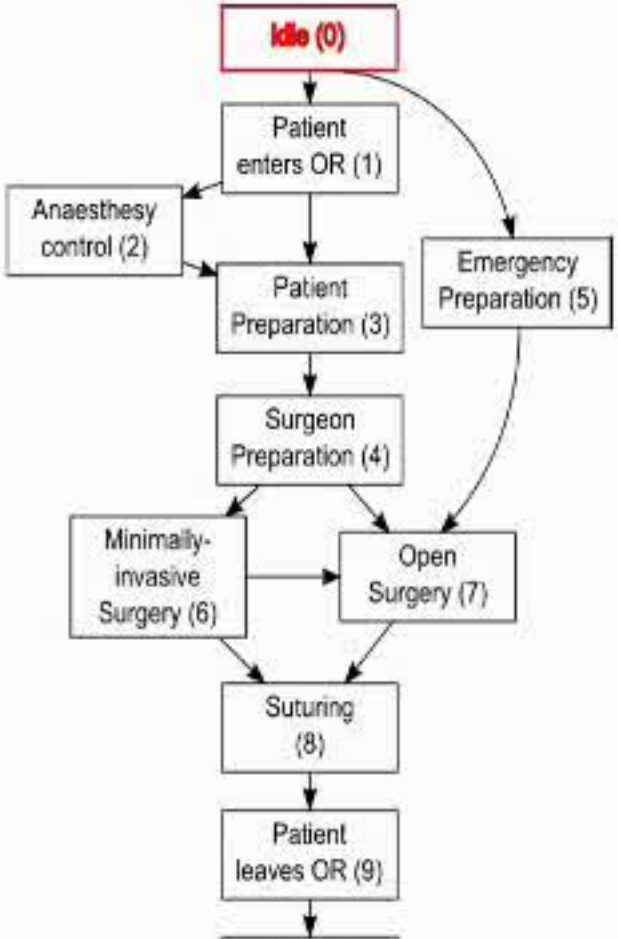




Next Generation Intraoperative Imaging

Primary Goals

- **Relevant**
- **Patient- and process- specific**

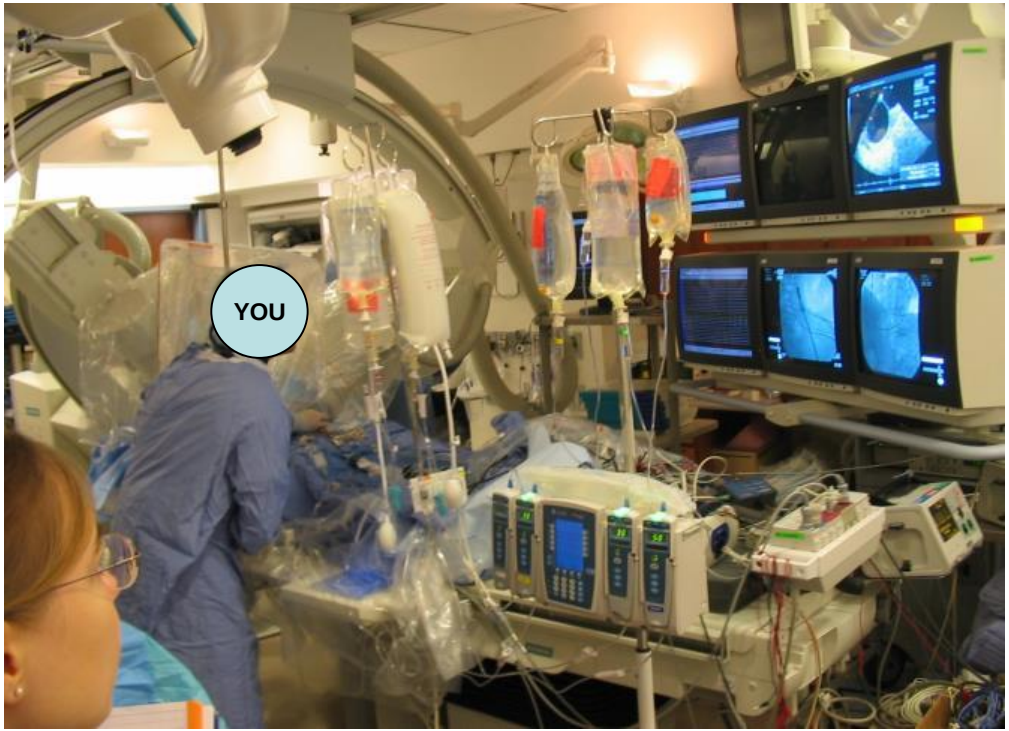

Idle (0)
Patient enters OR (1)
Anaesthesy control (2)
Patient Preparation (3)
Emergency Preparation (5)
Surgeon Preparation (4)
Minimally-invasive Surgery (6)
Open Surgery (7)
Suturing (8)
Patient leaves OR (9)

Next Generation Intraoperative Imaging

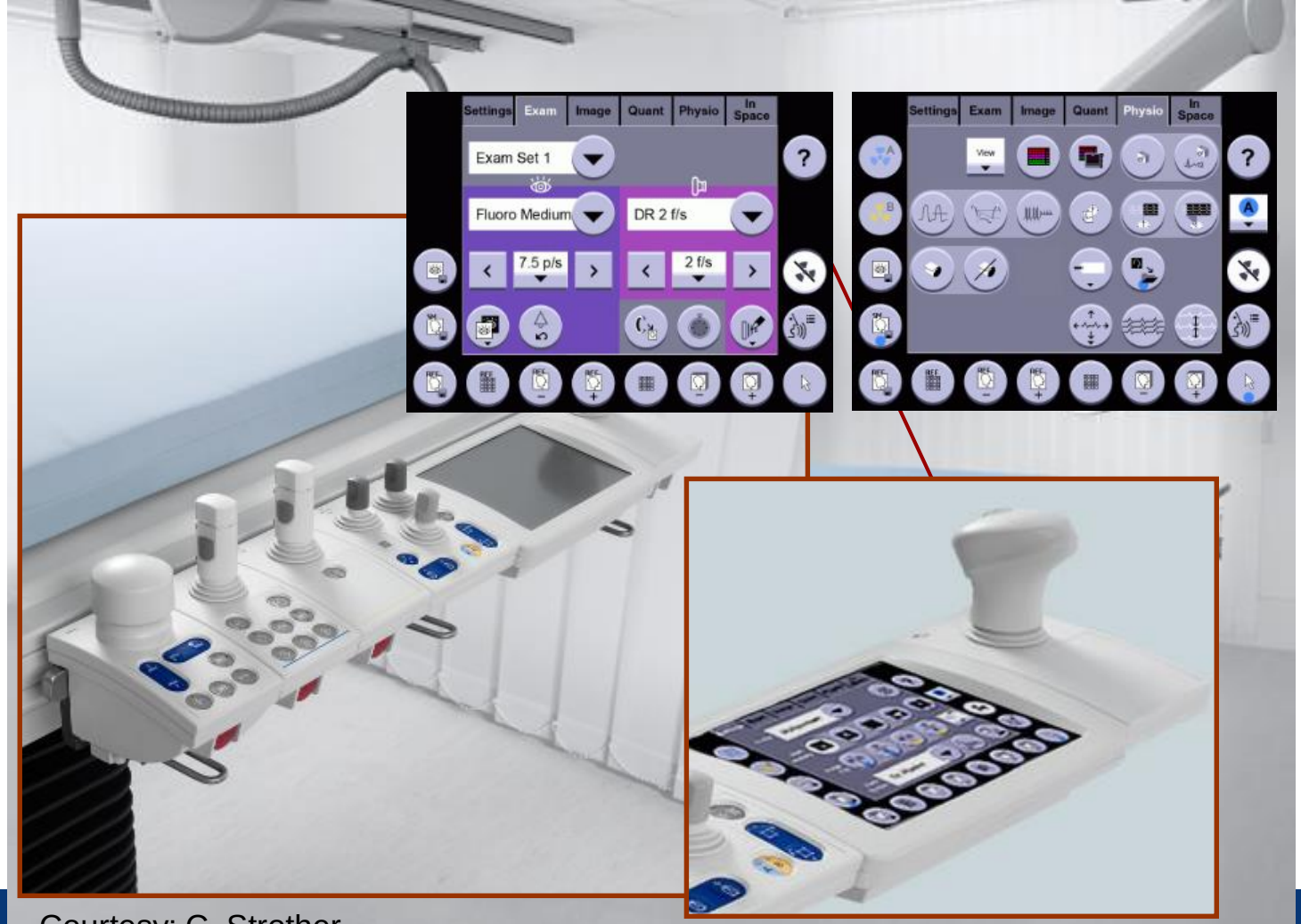
Primary Goals

- **Relevant**
- **Patient- and process- specific**
- **Fast**
- **Easy to Use**

CATH LAB AS IT APPEARS IN REALITY BROCURE



Courtesy: C. Strother



Courtesy: C. Strother

Next Generation Intraoperative Imaging

Primary Goals

- **Relevant**
- **Patient- and process- specific**
- **Fast**
- **Easy to Use**
- **Flexible**
- **Reproducible**
- **Safe**
- **Reliable**
- **Cost-effective**

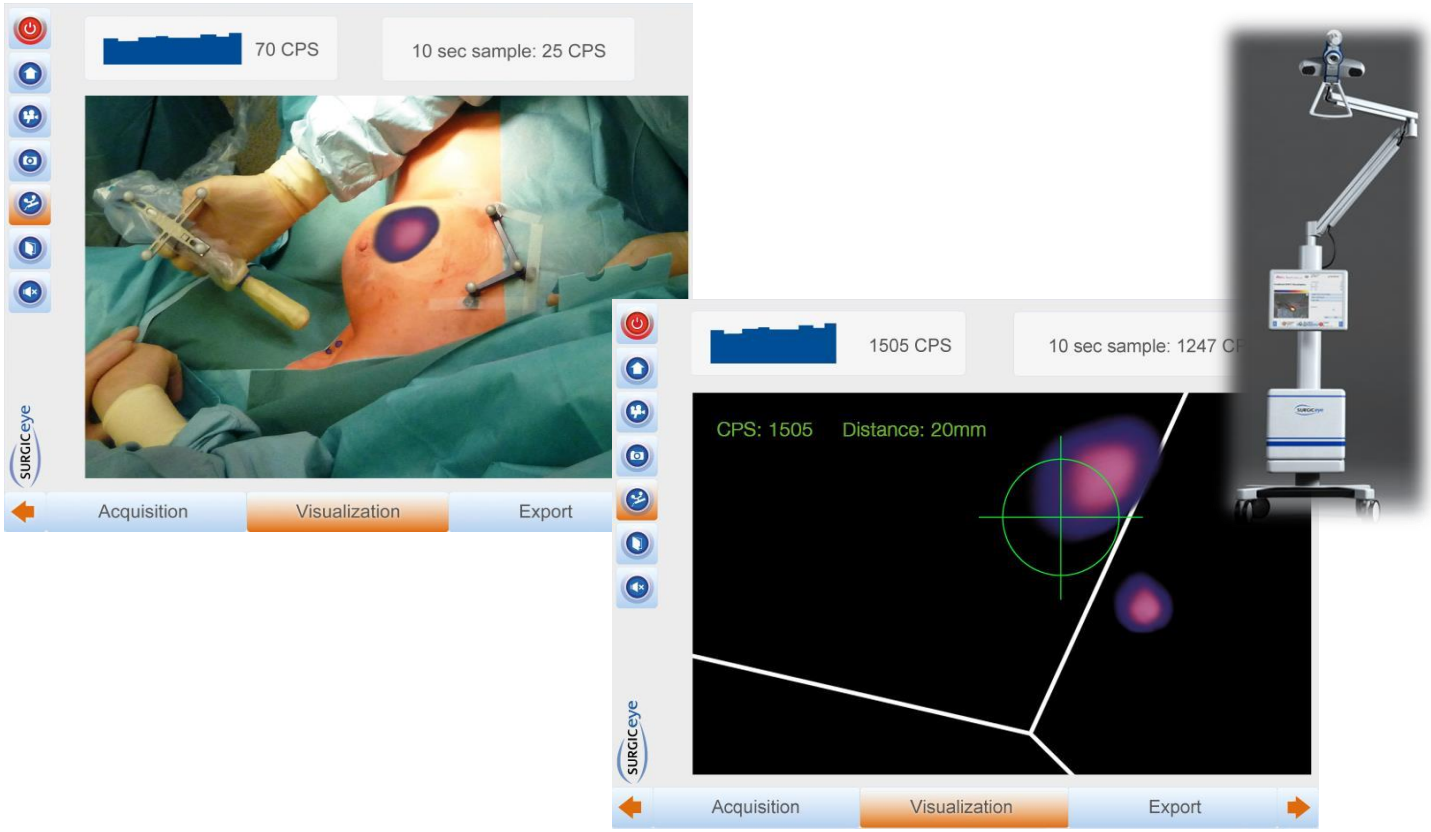
From Classic to Flexible Imaging - SPECT Imaging

Conventional diagnostic SPECT

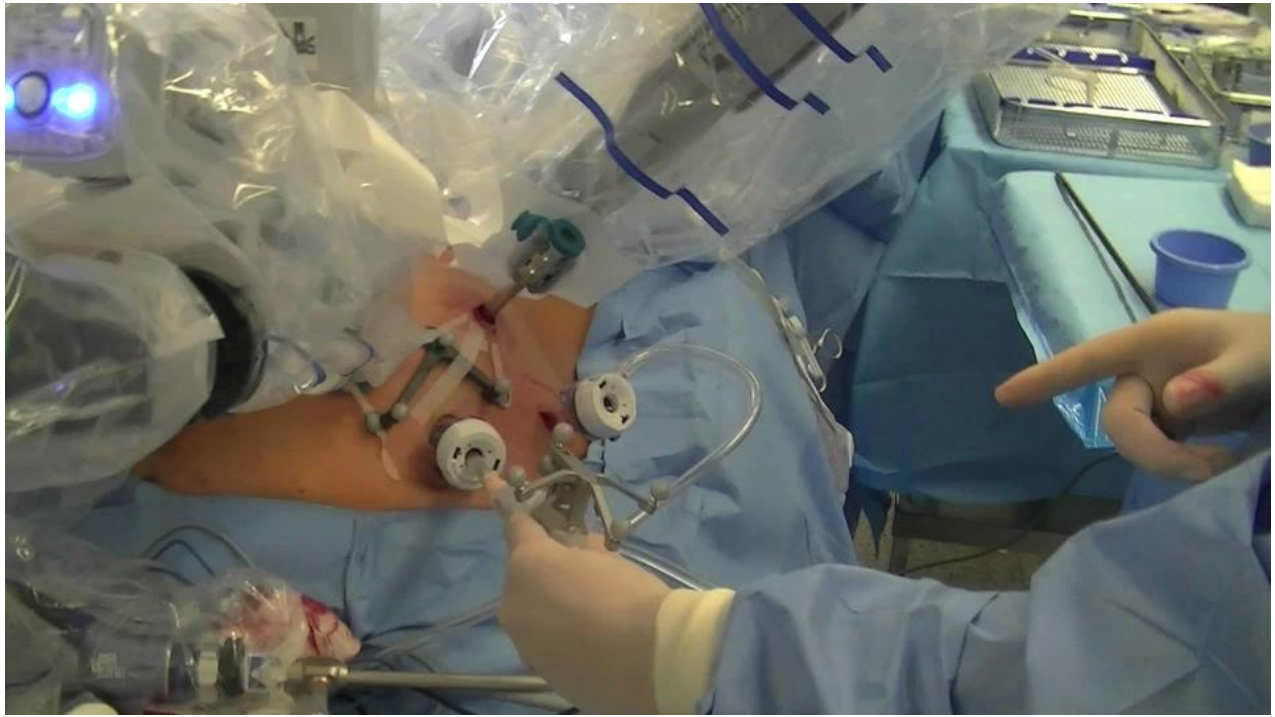
Intra-op freehand SPECT

Reproducible & reliable → **Fast & flexible**

DeclipseSPECT: Clinical Application



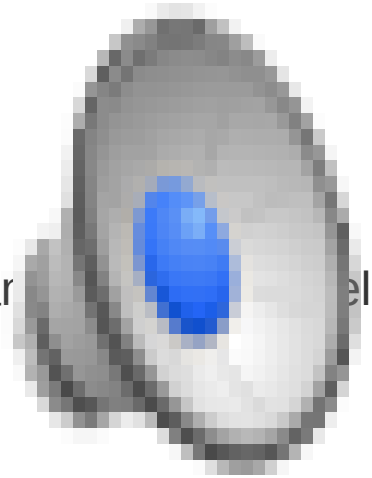
Using the laparoscopic gamma probe to generate a 3D image



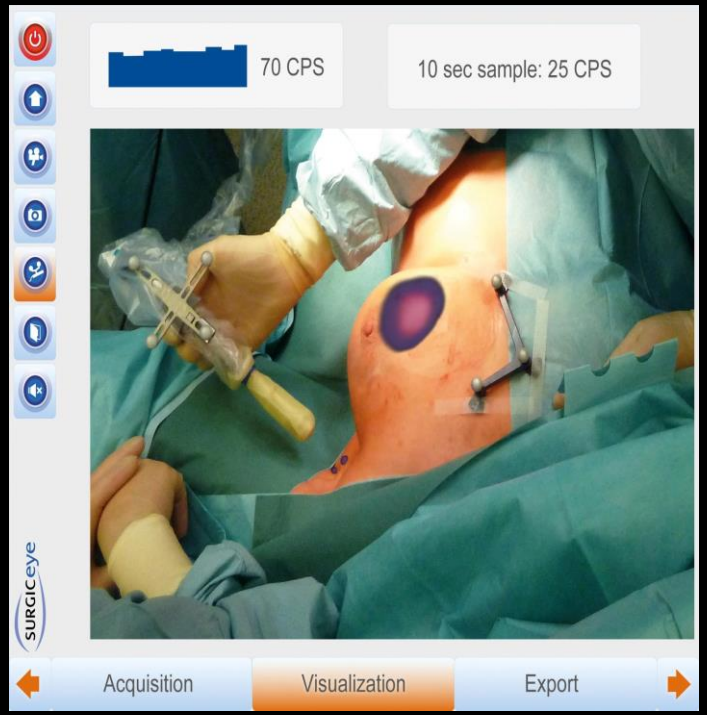
Generation of a laparoscopic freehand SPECT image

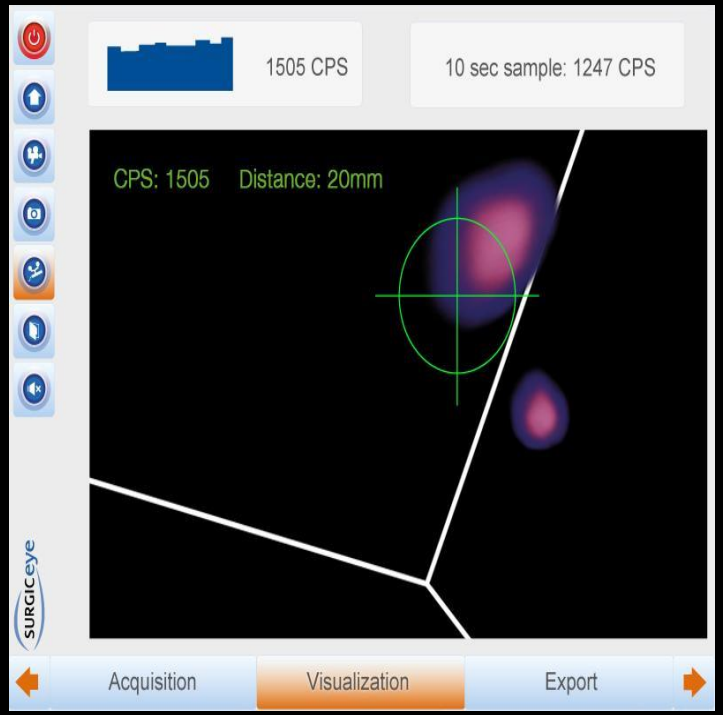
Video: Courtesy of F. W.B. van Leeuwen

- in-patient SPECT: drop-in gar eld by da Vinci

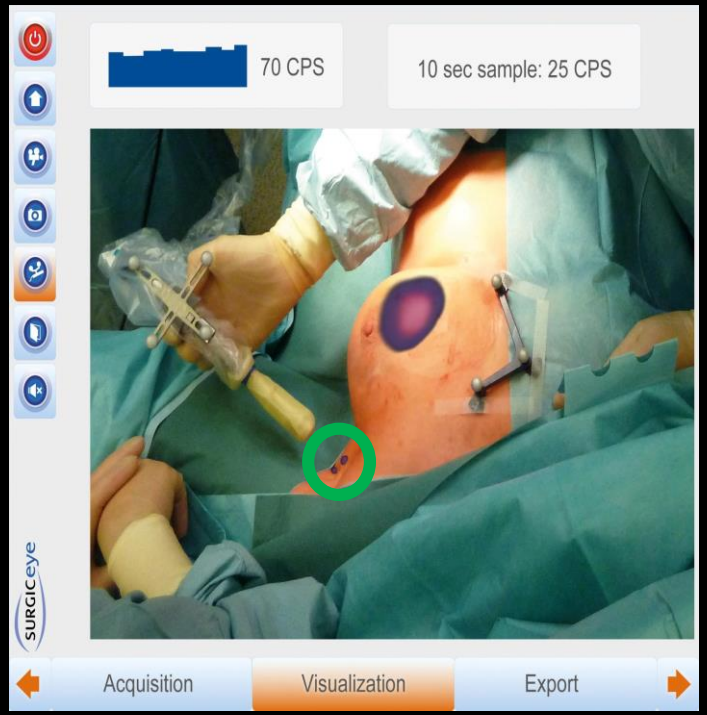


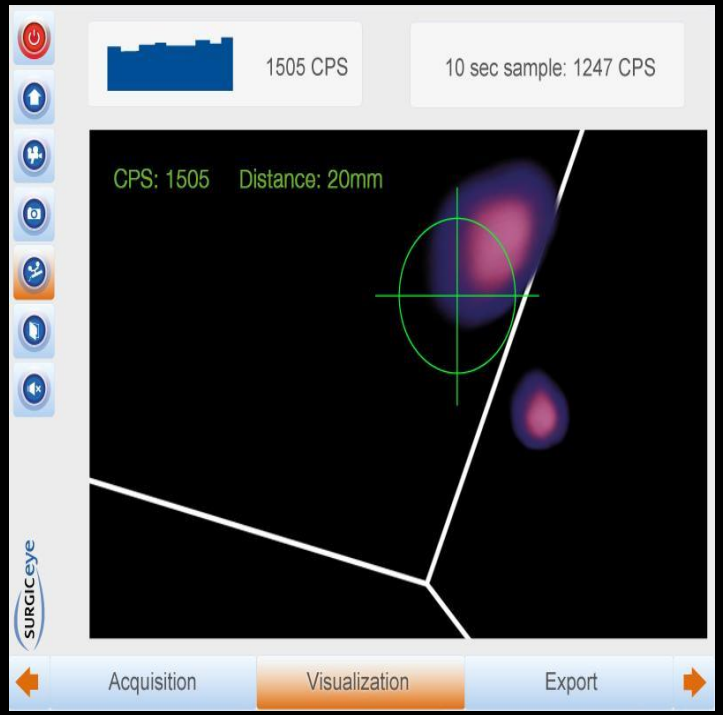
SurgicEye‘s DeclipseSPECT: First AR solutions in ORs



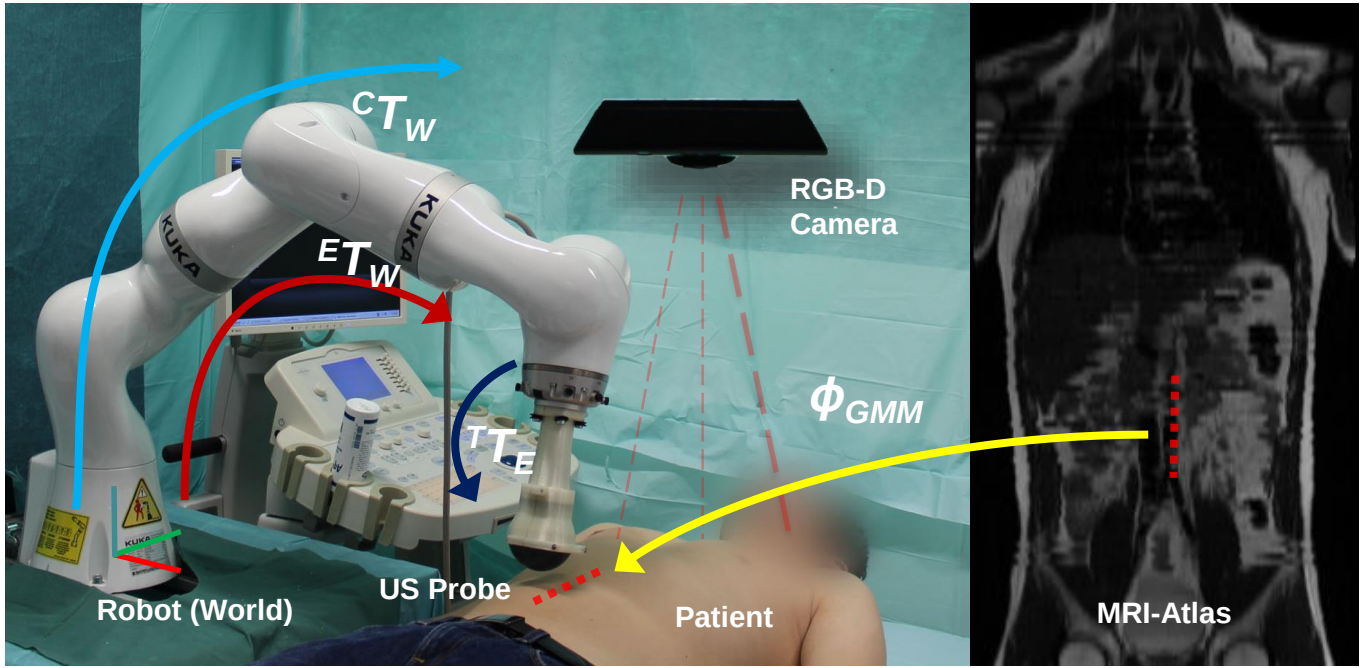


SurgicEye‘s DeclipseSPECT: First AR solutions in ORs



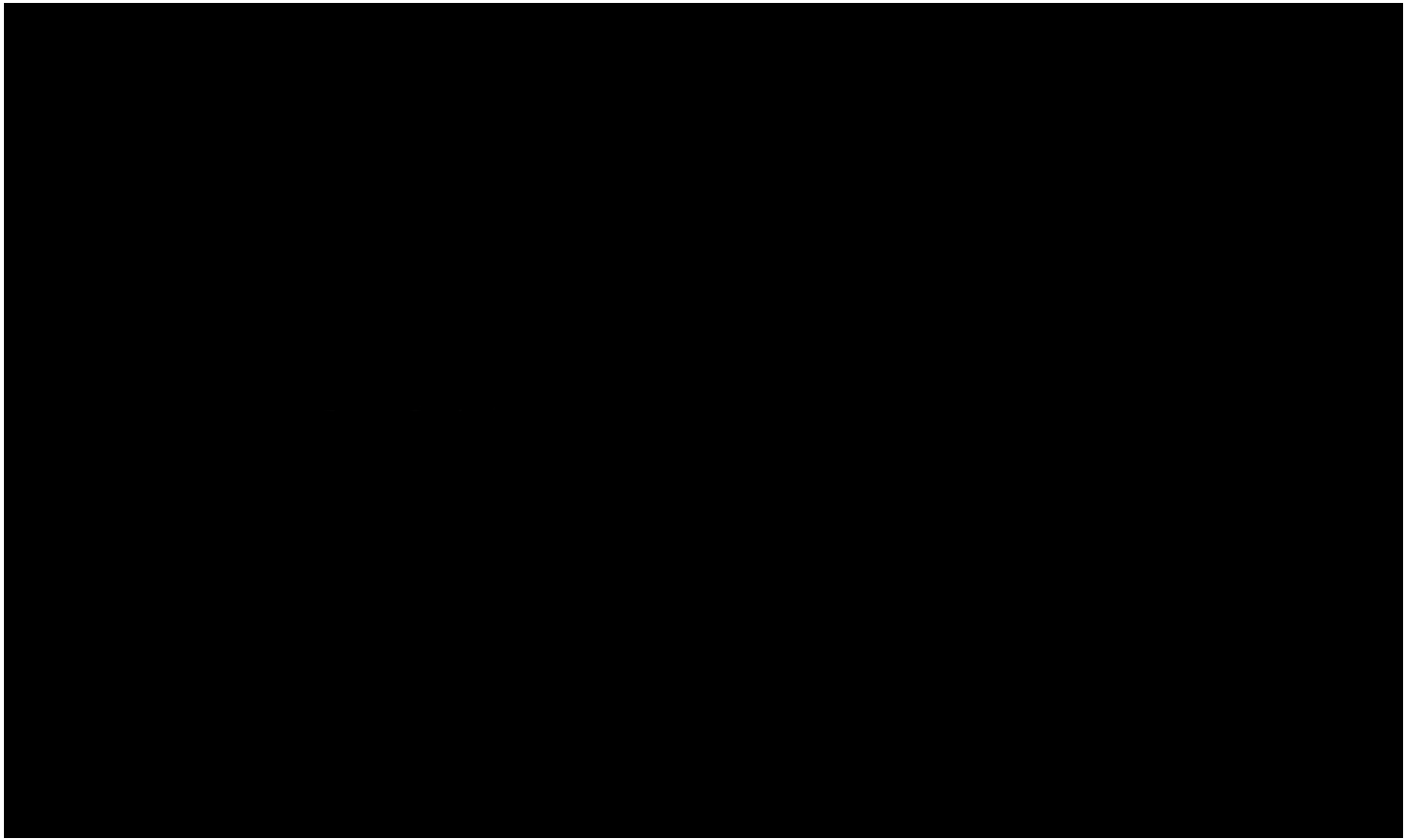


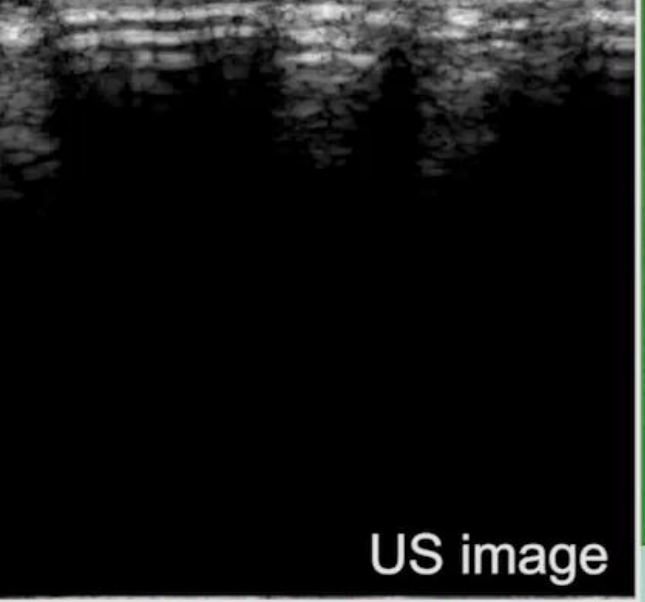
Patient Registration and Trajectory Transfer



Automatic 3D Robotic Ultrasound Acquisitions

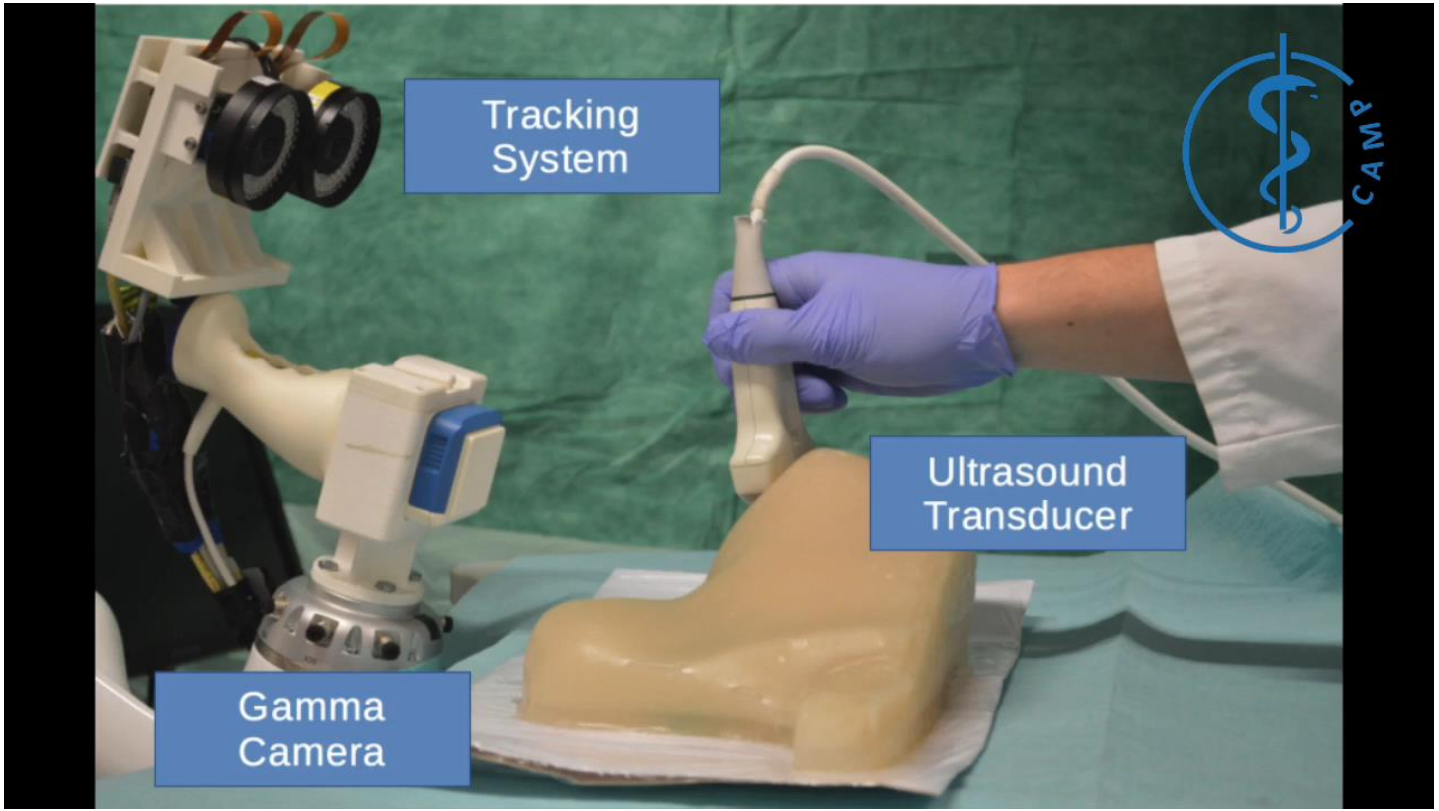
01.10.2019



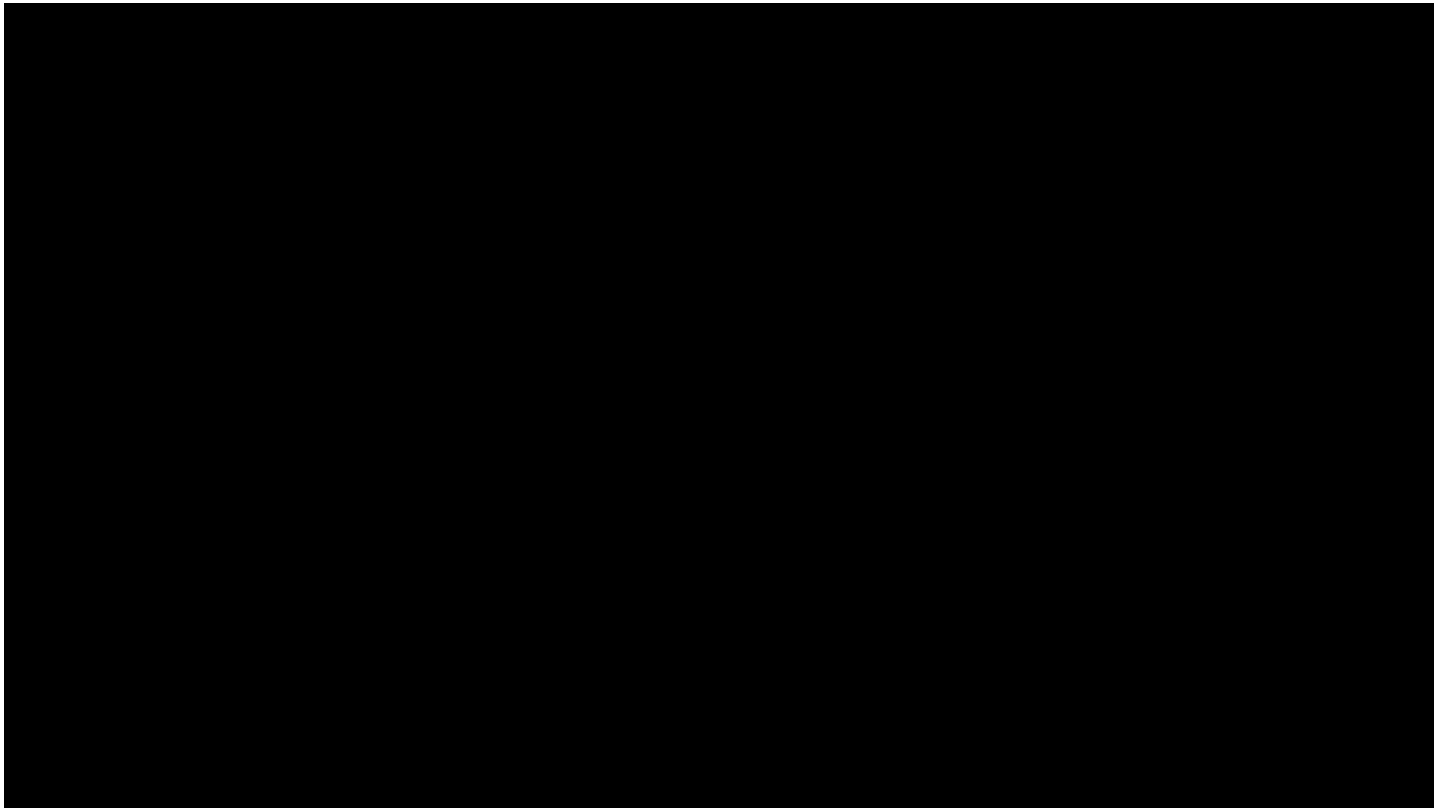

US image


Close-up view

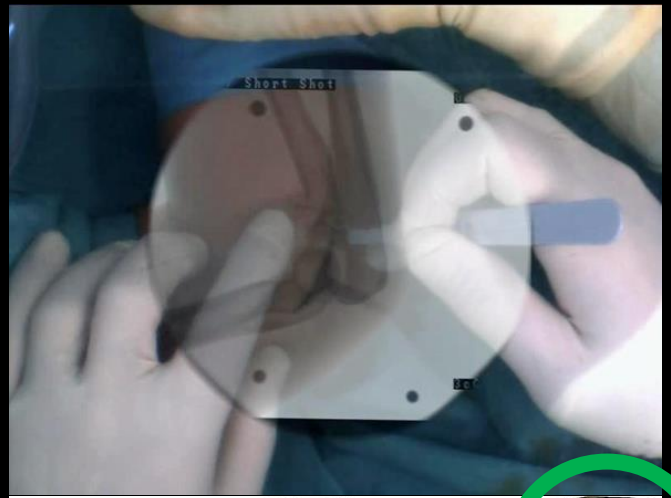
Collaborative Robotic Imaging: Freehand Punch Biopsy

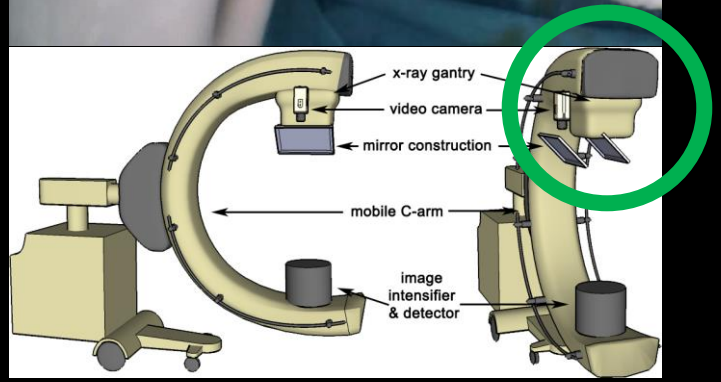


IROS 2019

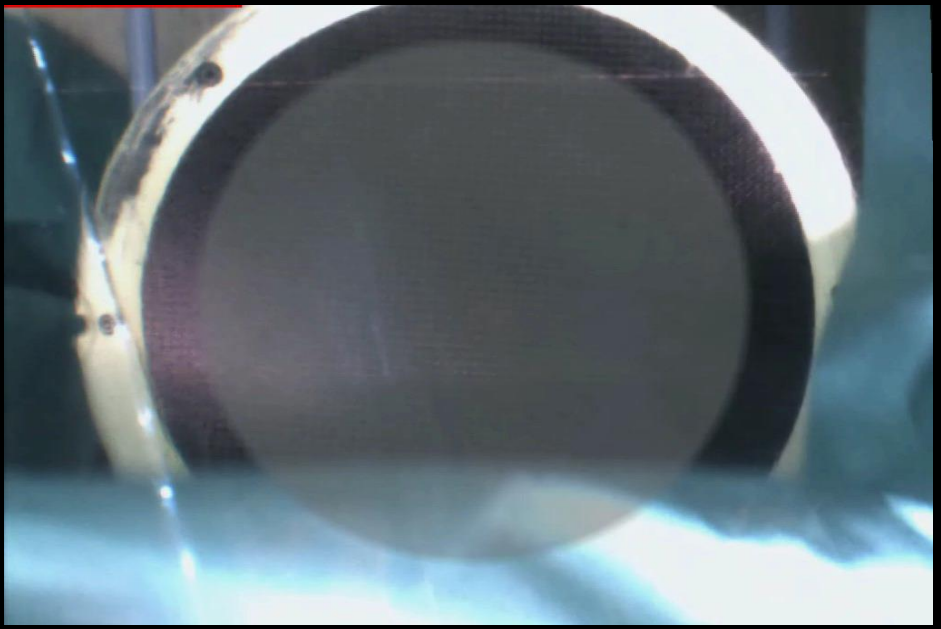


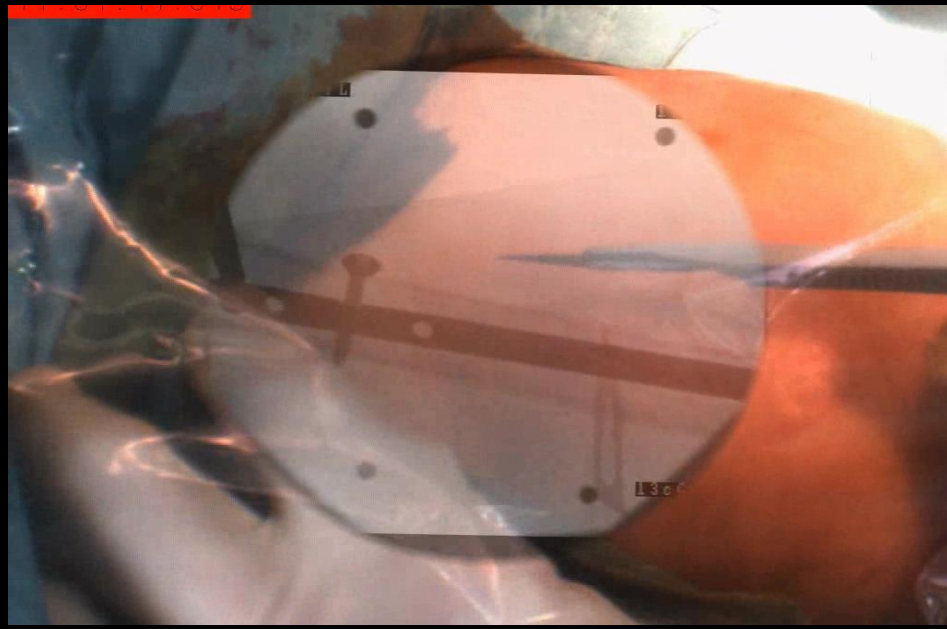
AR in OR
Relevance
&
Workflow
Integration

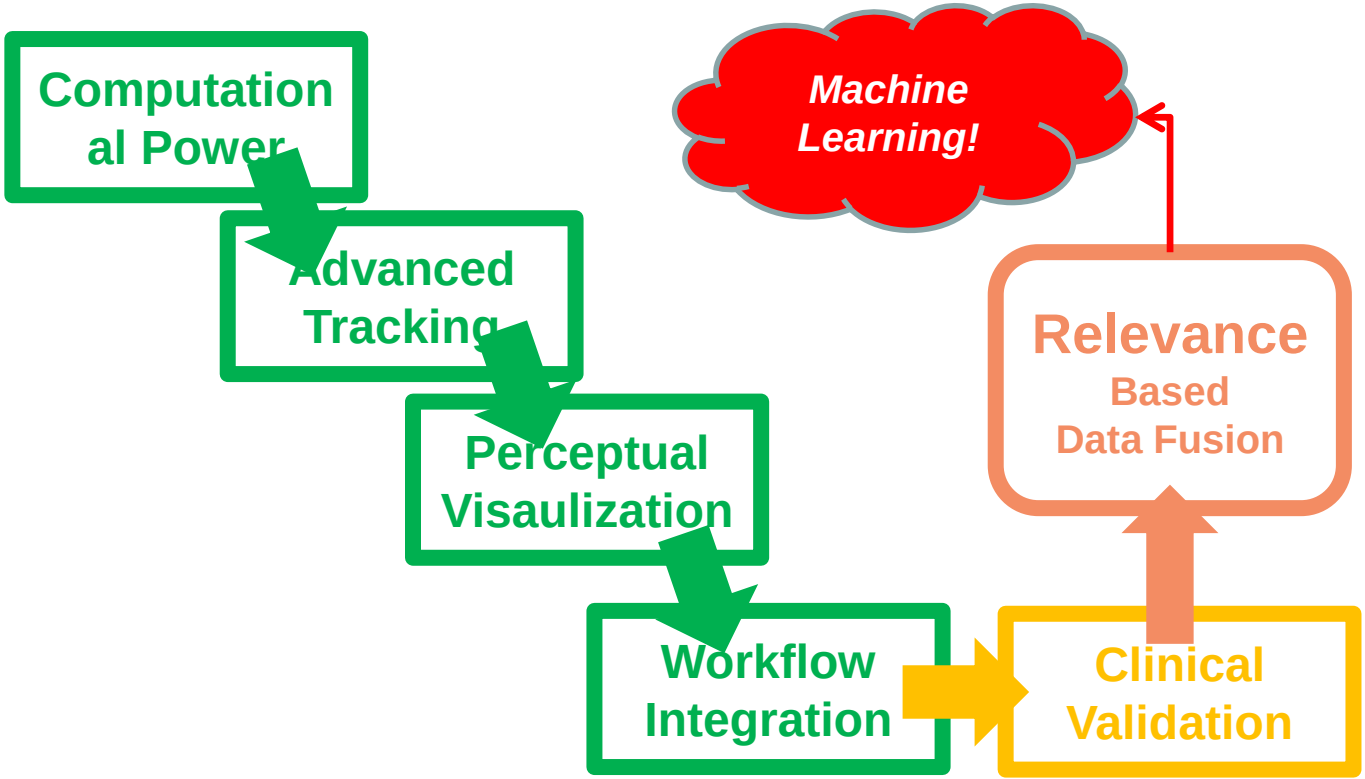




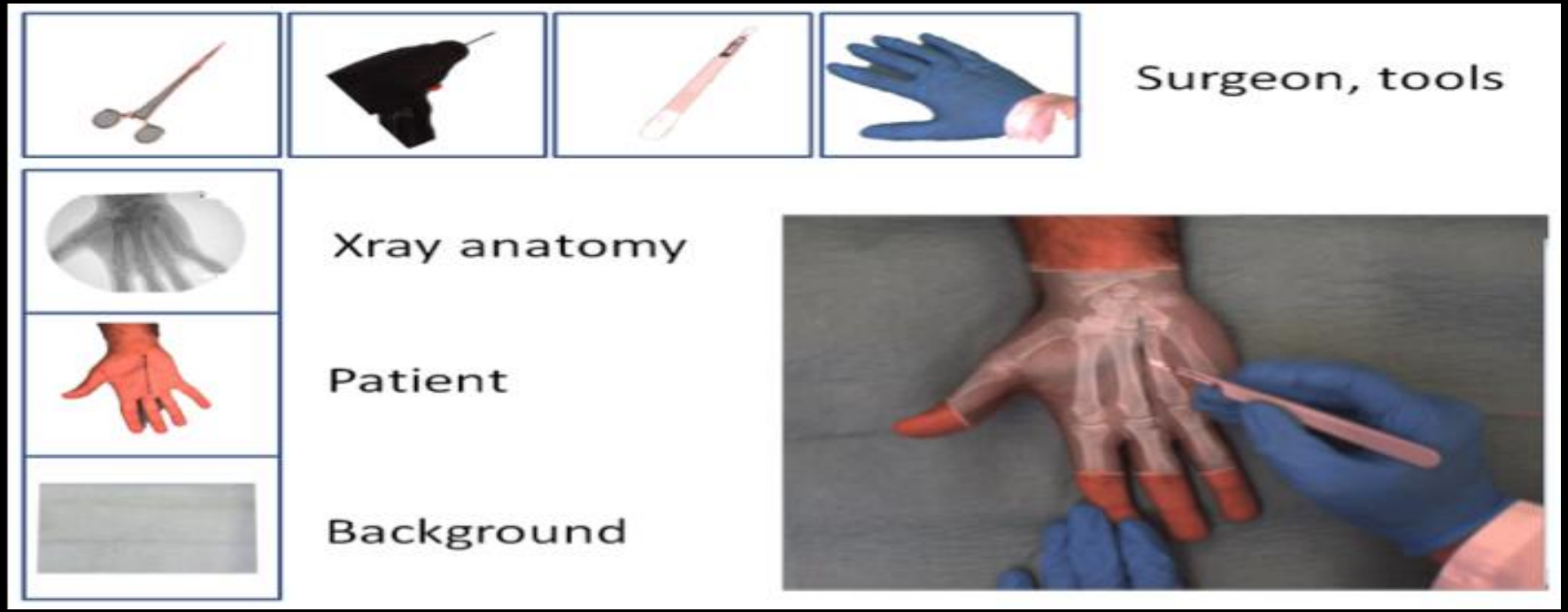
First uses of AR in Trauma Surgeries …



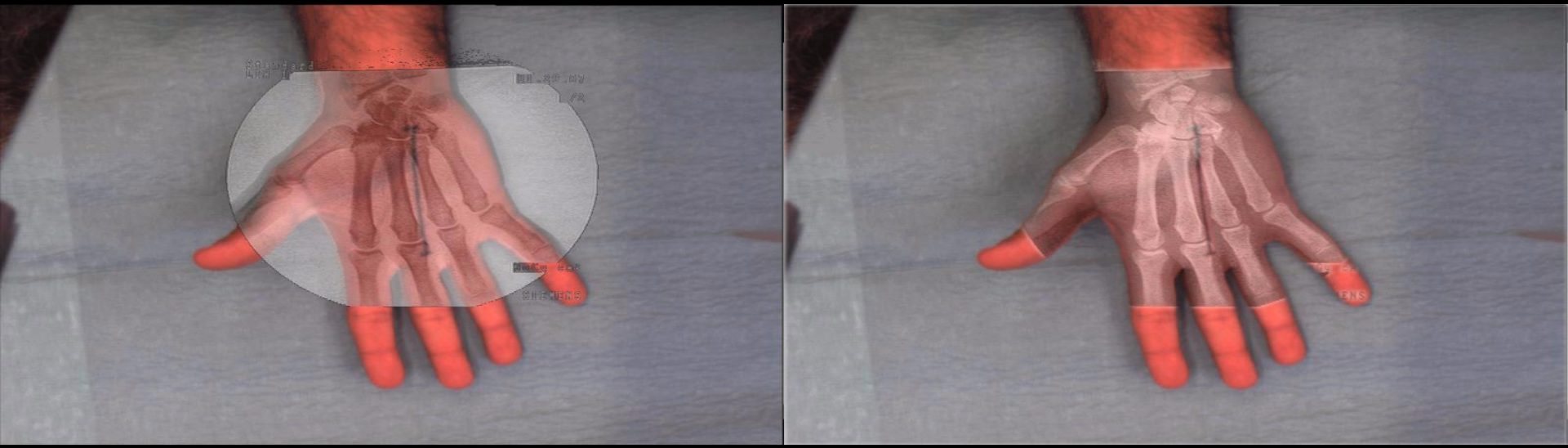



Computation
al Power
Advanced
Tracking
Perceptual
Visaulization
Workflow
Integration
Clinical
Validation
Relevance
Based
Data Fusion
Machine
Learning!

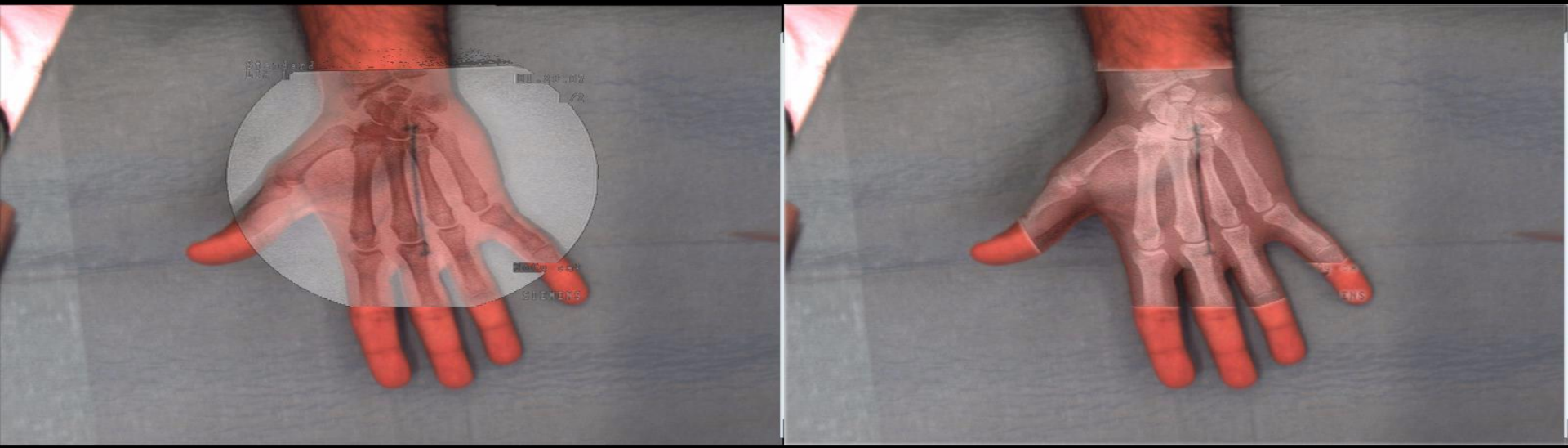
Machine Learning for Relevance based Imaging

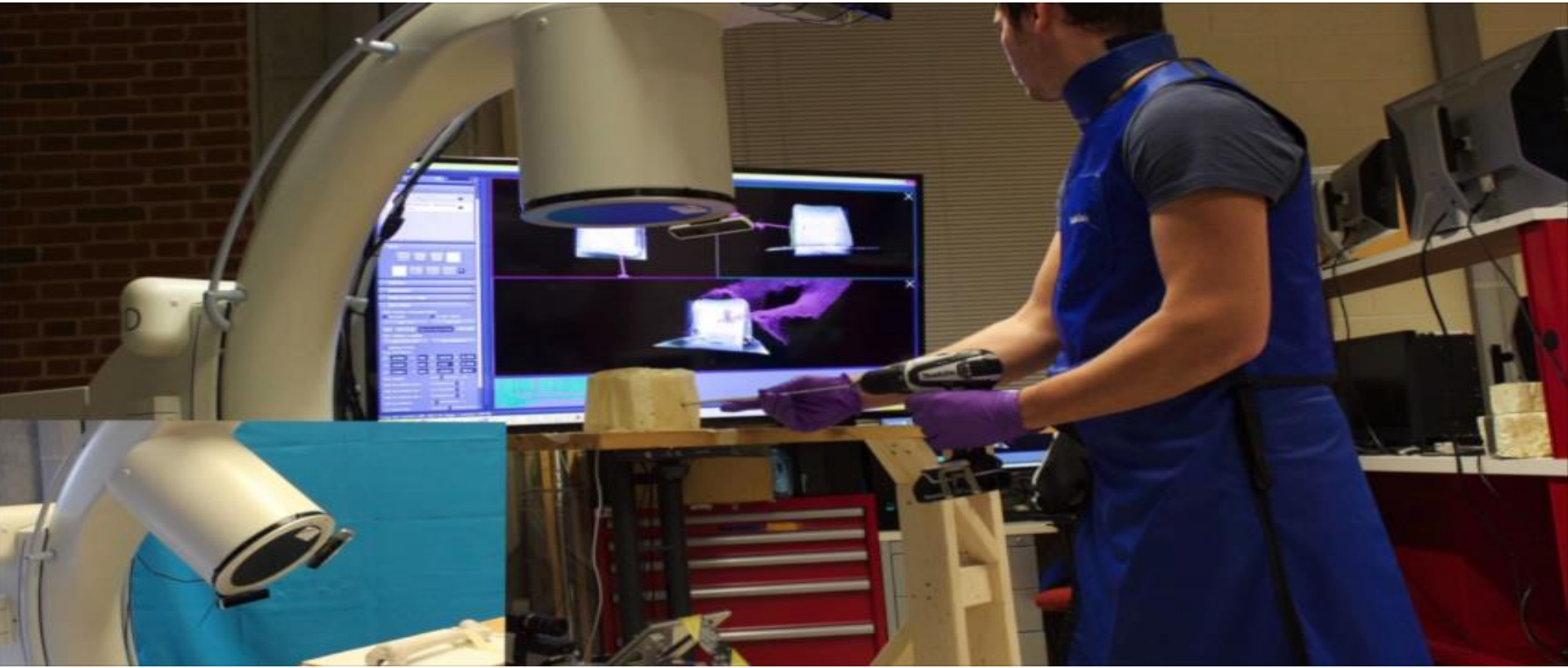


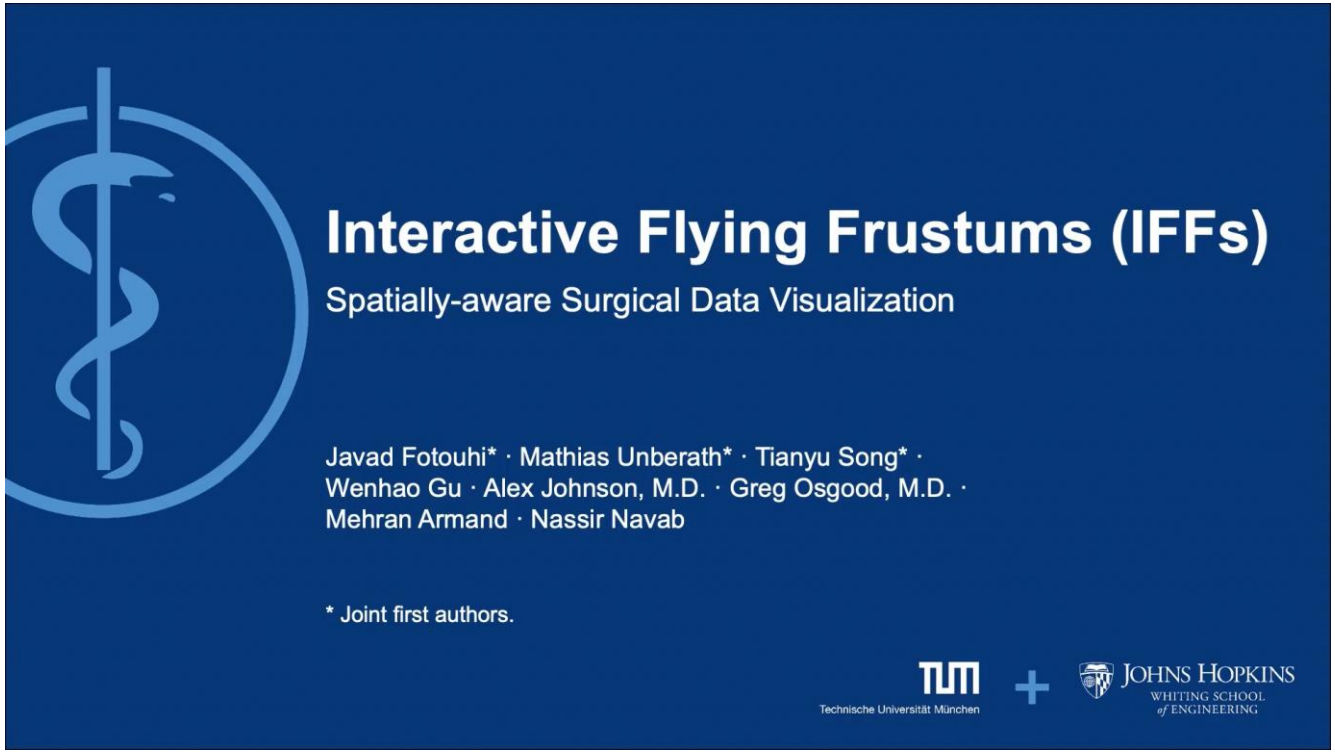
Machine Learning for Relevance based Imaging



Machine Learning for Relevance based Imaging






Interactive Flying Frustums (IFFs)
Spatially-aware Surgical Data Visualization
Javad Fotouhi* · Mathias Unberath* · Tianyu Song* ·
Wenhao Gu · Alex Johnson, M.D. · Greg Osgood, M.D. ·
Mehran Armand · Nassir Navab
* Joint first authors.
Technische Universität München
JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

The gaze is used as the mechanism to select an X-ray image.

Technische Universität München + Johns Hopkins Whiting School of Engineering

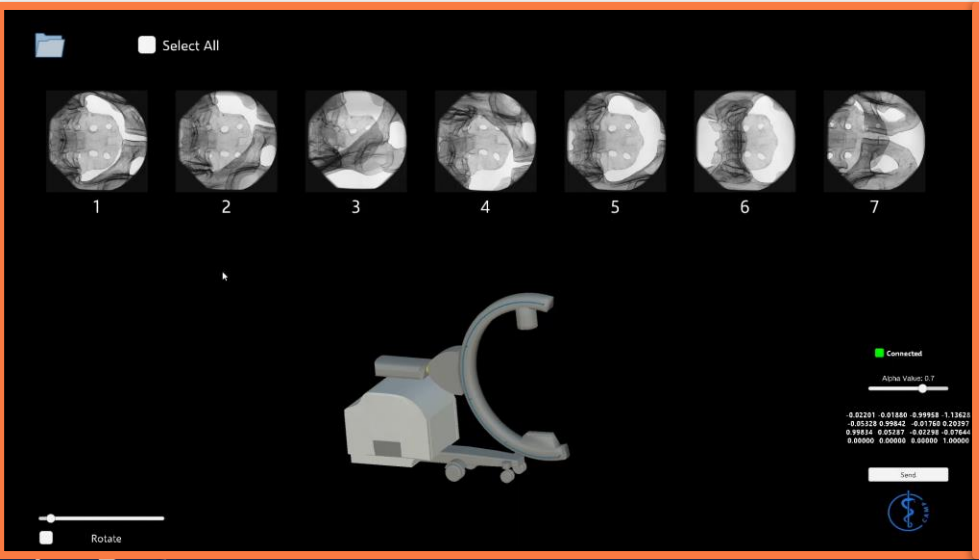
The voice command *Hide* allows the user to hide the image along with the frustum.

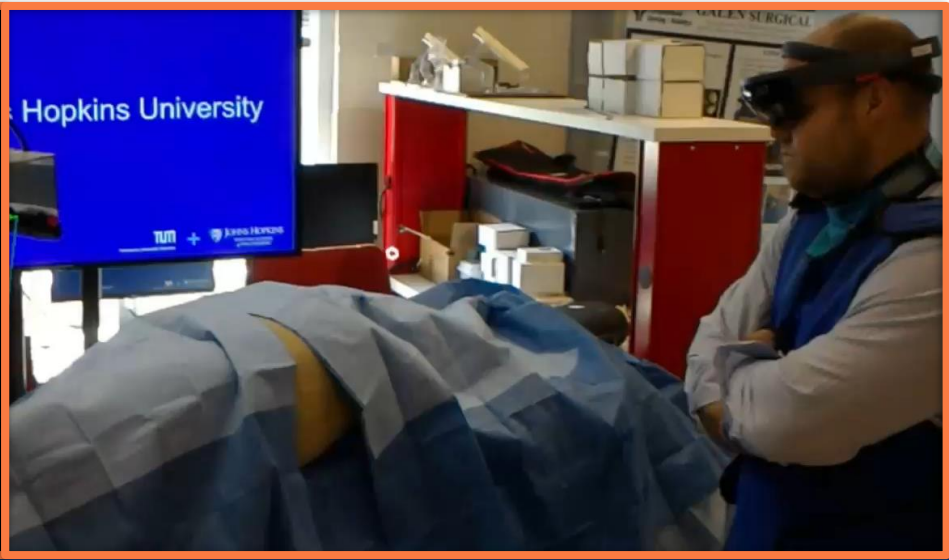
Technische Universität München + Johns Hopkins Whiting School of Engineering

Surgical replay

> Reviewing all acquisitions with their spatial and temporal information
> Surgical education

Dr. Alex Johnson, Johns Hopkins University





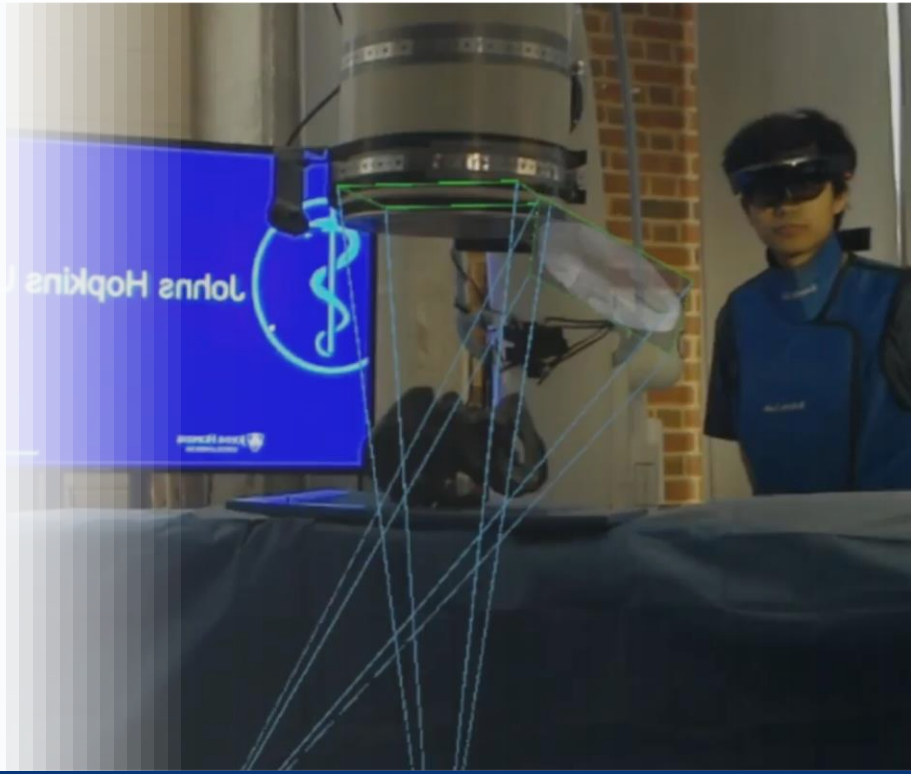
Technician-in-the-loop AR

Interventional problem

> Achieving and re-producing views
> Non-robotic scanner with redundant DoFs
> Fluoro hunting
> Trial-and-error
> Increased surgical time and radiation

Interventional solution

> AR-based assistance of X-ray technicians to reproduce desired views

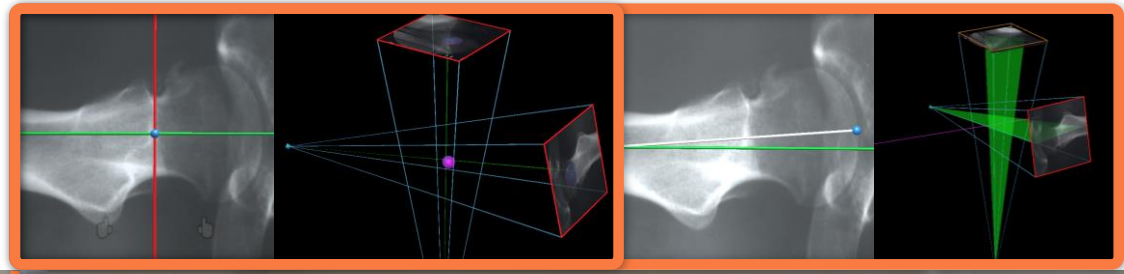


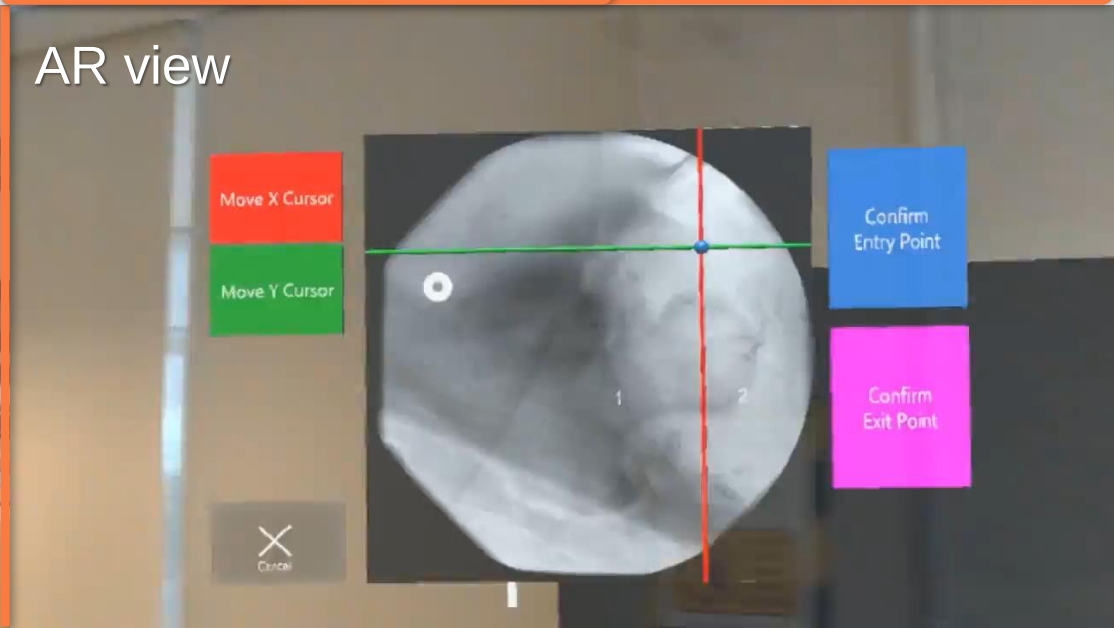
Intra-operative planning: projection onto X-ray images

> Simultaneous projection of virtual implants into multiple viewing frustums
> Projection of non-straight implants and plates

Application: Intra-operative annotation

- > 3D anatomical targets
  - Rendering corresponding rays
  - Selection on two images results in 3D targets
- > 3D trajectories through the anatomy





Interactive Flying Frustums (IFFs)

Spatially aware surgical data visualization

Observations

- Virtual-to-real alignment
- Surgeon's interaction
- Surgeon/human-centered design

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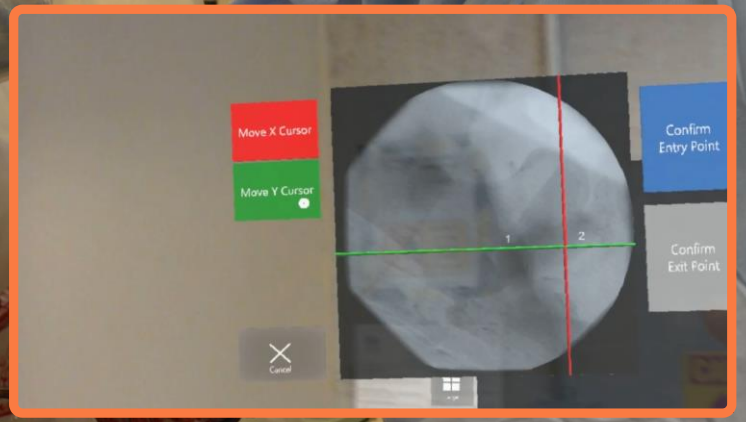
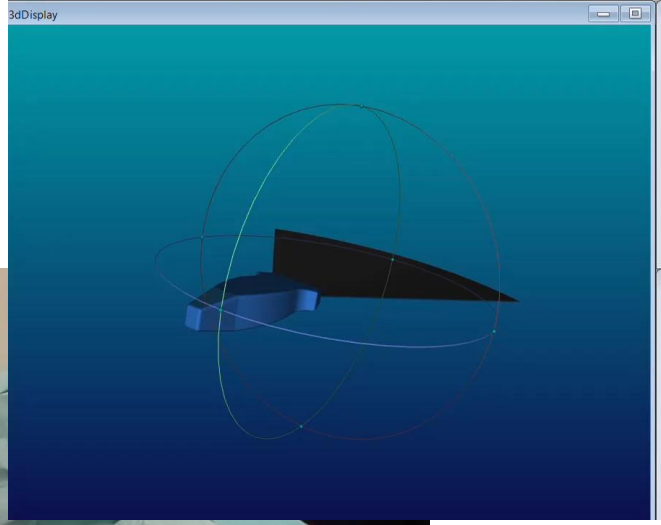
- Surgeon's interaction
- Surgeon/human-centered design

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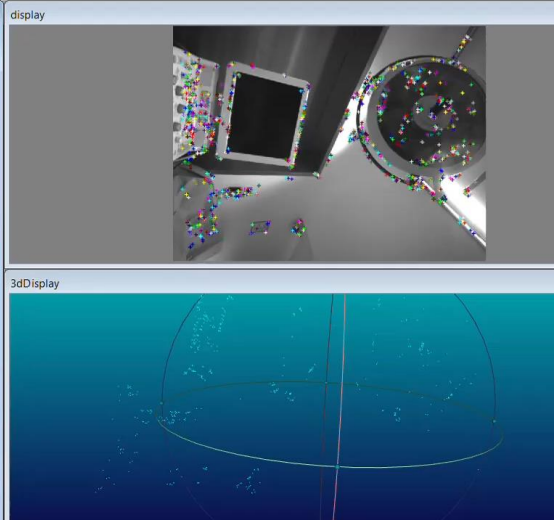
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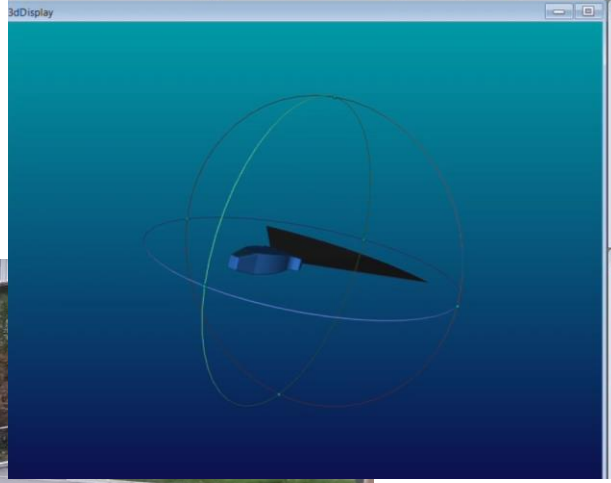
112
Notfallzentrum / Emergency
Malteser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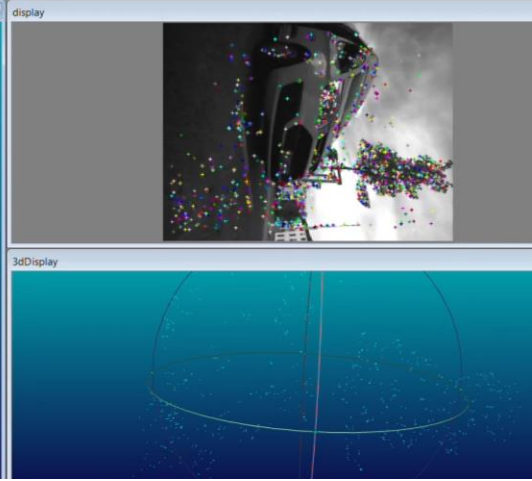
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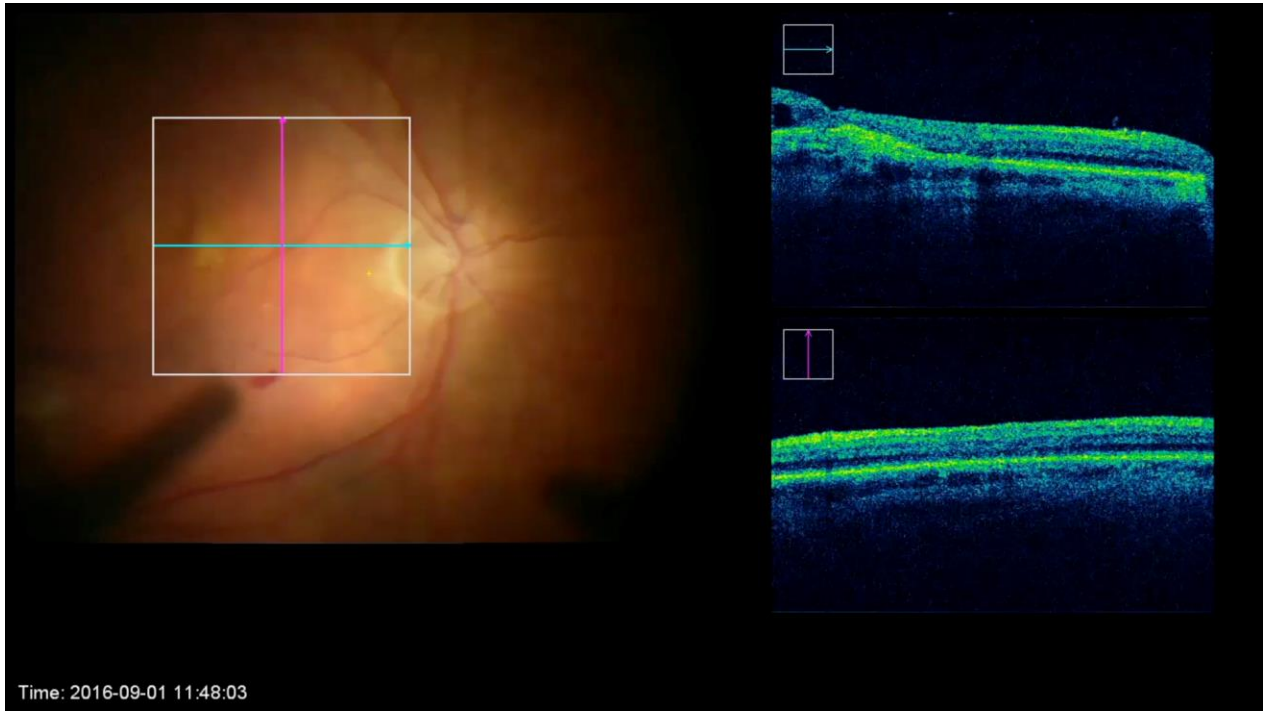
Sonified Video Sequence from a Surgery



Surgery performed by Dr. Mathias Maier at *Rechts der Isar*, Munich

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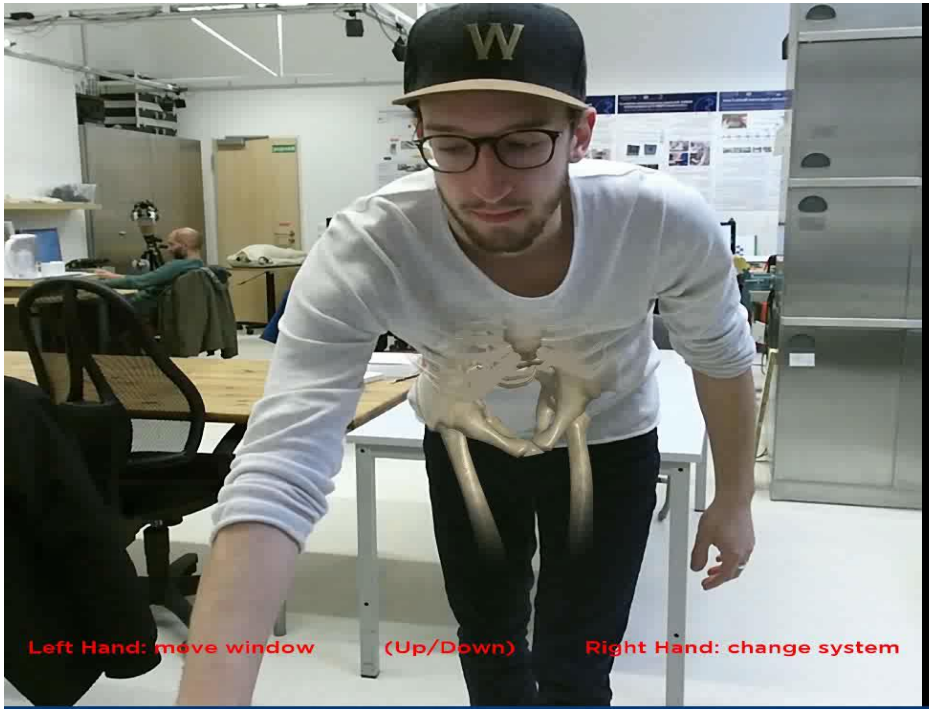
MICCAI

Thanks



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