

Medical Augmented Reality

State Of the Art, Requirements and Challenges

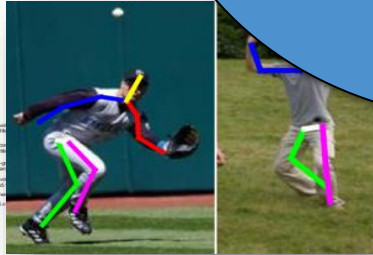
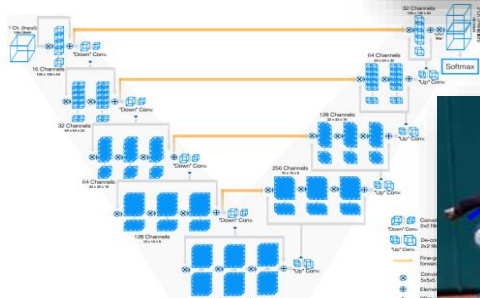
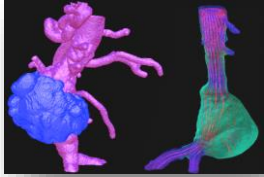
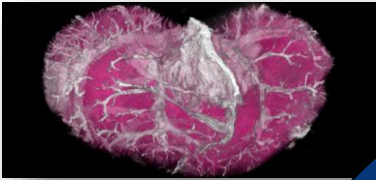


Nassir Navab

Chair for Computer Aided Medical Procedures
Technical University Munich (TUM), Germany

Chair for Computer Aided Medical Procedures



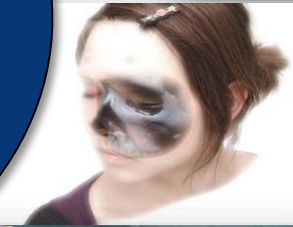
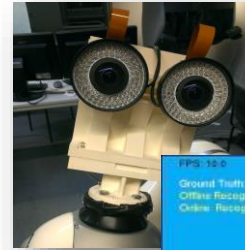


Medical Image
Computing &
Advance Data
Visualization

Machine
Learning

Computer Vision

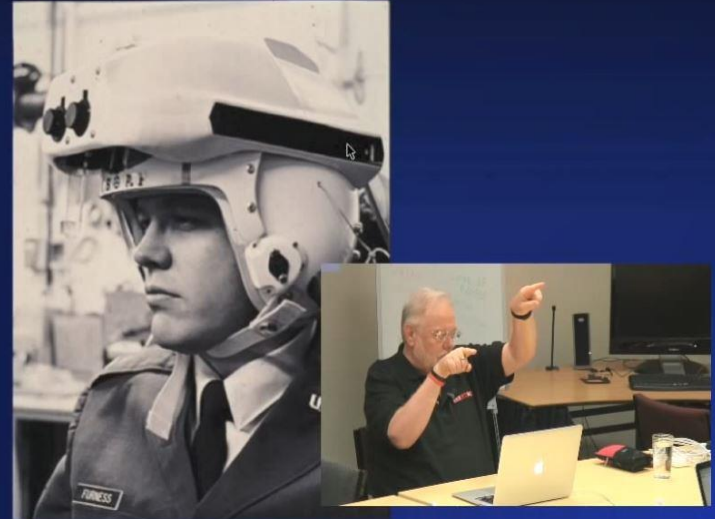
Computer/Robot
Assisted
Interventions



AR: Early concpets ... 1960s!



early helmet sight (1968)



[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Tom Furness, Unpublished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

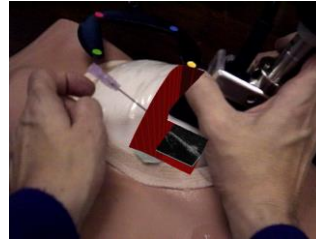


Medical AR: Challenges faced through decades

■ Fuchs et al. 1993

» Main challenges:

- Computational power!
- Tracking and synchronization



■ Edwards et al. 1995:

» Main Challenges:

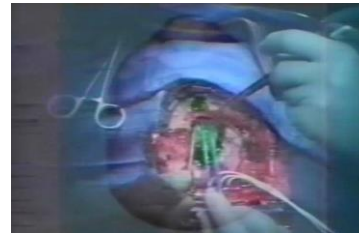
- Depth Perception
- Workflow Integration



■ Kikinis et al. 1996:

» Main Challenges:

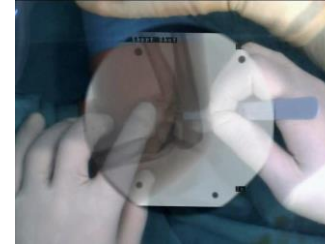
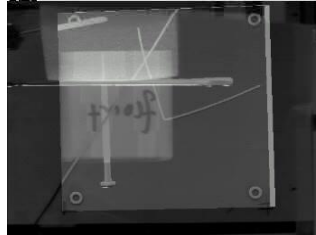
- Depth Perception
- Workflow Integration



Medical AR: Challenges faced through decades

- Navab et al. 1998:

- » Main Challenges:
 - 3D Relevance based Perception



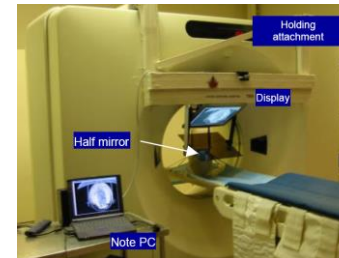
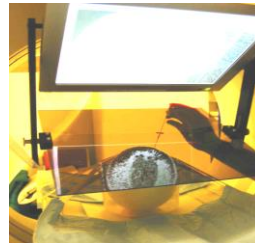
- Stetten et al. 2000:

- » Main Challenges:
 - 3D Relevance based Perception



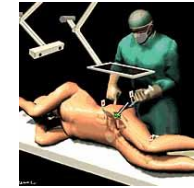
- Masamune et al. 2002:

- » Main Challenges:
 - Workflow Integration



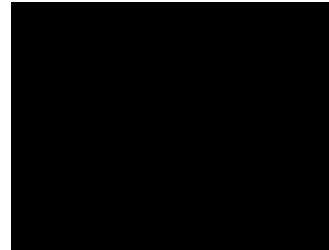
■ DiGioia et al. 1998:bbb

- » Main Challenges:
 - Tracking
 - Workflow Integration



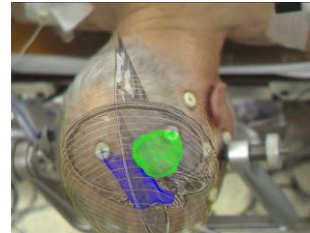
■ Birkfellner et al. 2000:

- » Main Challenges:
 - Tracking
 - Workflow Integration



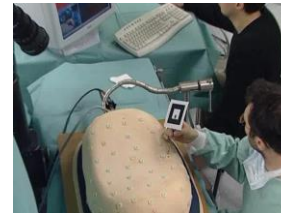
■ Sauer et al. 2000

- » Main challenges:
 - Depth Perception
 - Workflow Integration



■ Nicolau et al. 2004

- » Main challenges:
 - Precision
 - Depth Perception
 - Workflow Integration









IMAGING AND VISUALIZATION IN OPERATING ROOMS

How could we bring AR into OR?



Operating Room

High-Intensity Performance

Surgical

Decide

Skills

Act

Focus

Insight

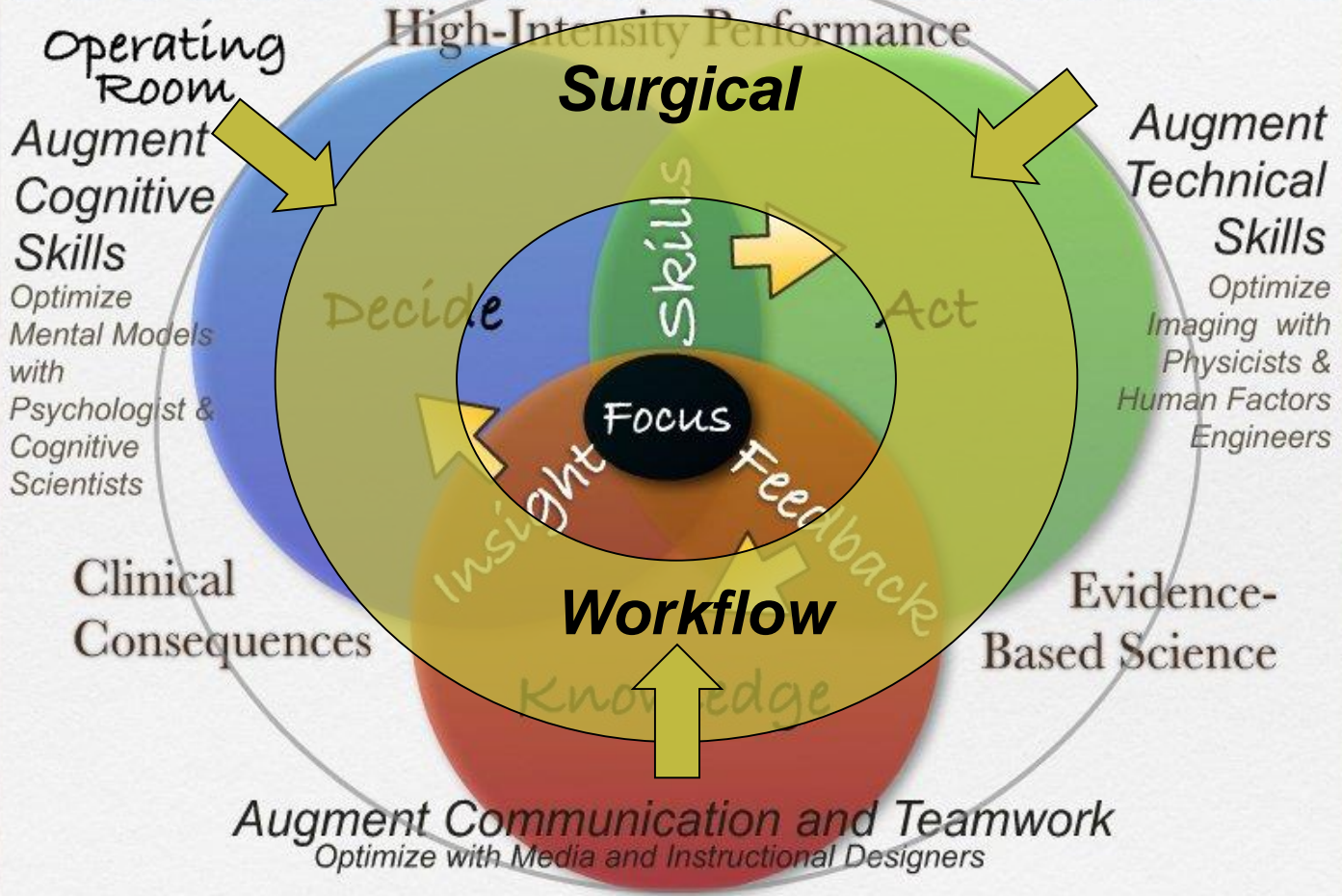
Feedback

Clinical Consequences

Evidence-Based Science

Workflow



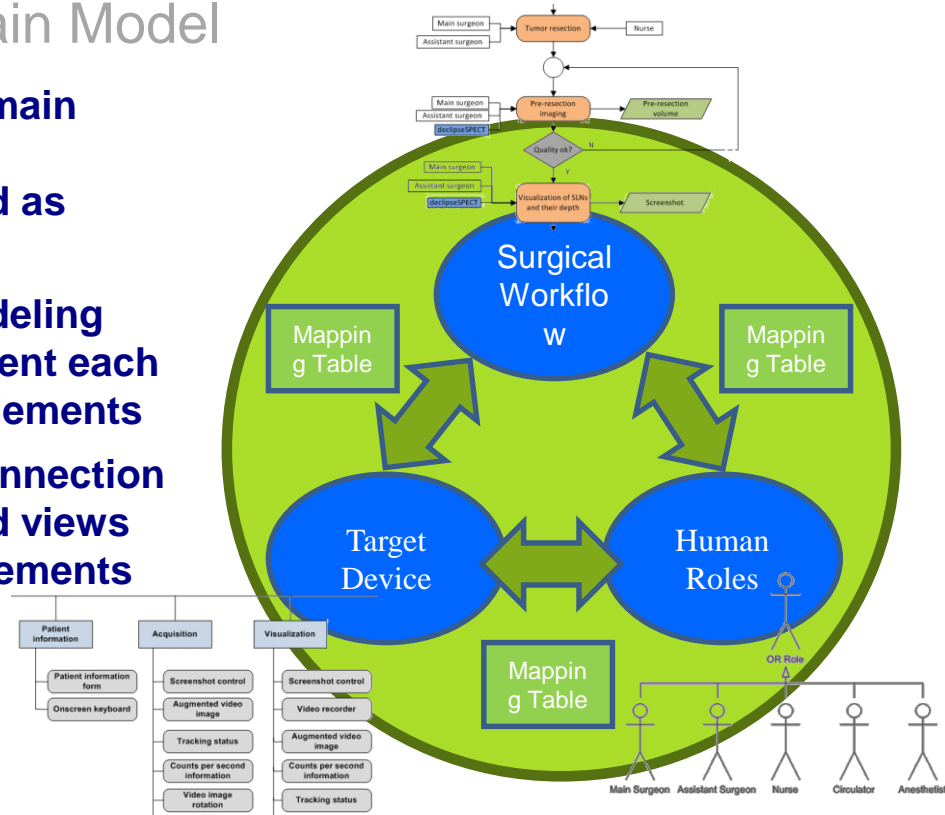


From: „Real World Laboratories for Translational Research“, Christopher Stapleton and Nassir Navab



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

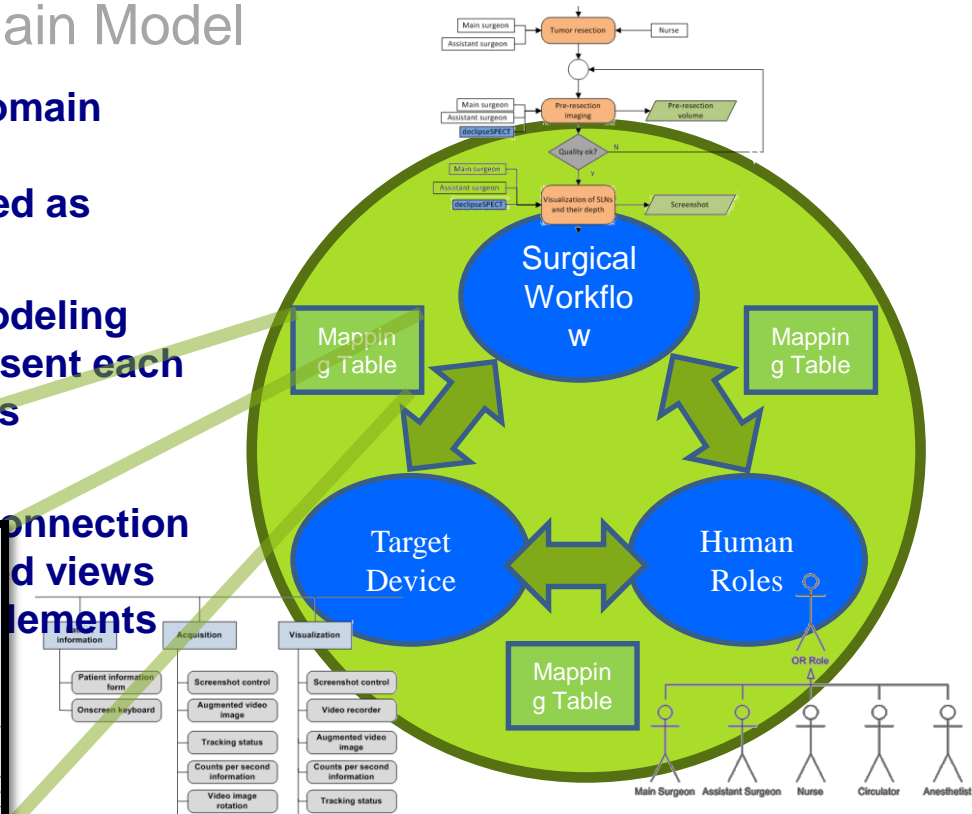


OR Specific Domain Model

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 between views and elements

Legend		Workflow stages					
x feature is definitely used		Anesthesia	Device positioning	Patient preparation	Sterilization of assistant surgeon	Device Preparation	Preparation of device tools
o feature is possibly used							
Device state	Device feature						
Device preparation	Lens aperture					x	
	Device position		x				
	Device arm position					x	
	Reference target						x



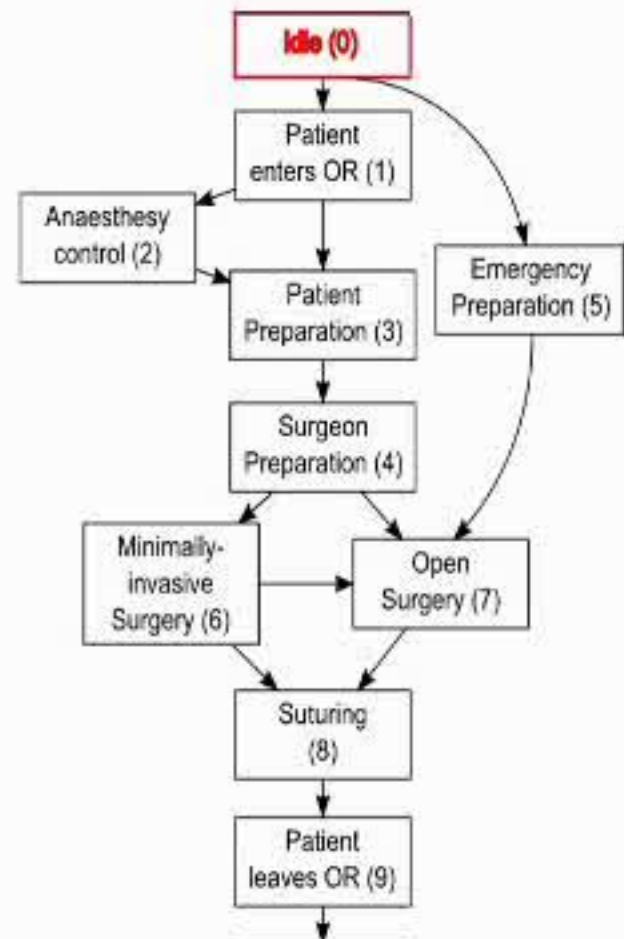
Next Generation Intraoperative Imaging

Primary Goals

- Relevant
- Patient- and process- specific



Images courtesy of KUKA GmbH; by Neoflash, Kalumet, Bme591wikiproject – Wikimedia Foundation, under CC BY-SA 3.0 license



Next Generation Intraoperative Imaging

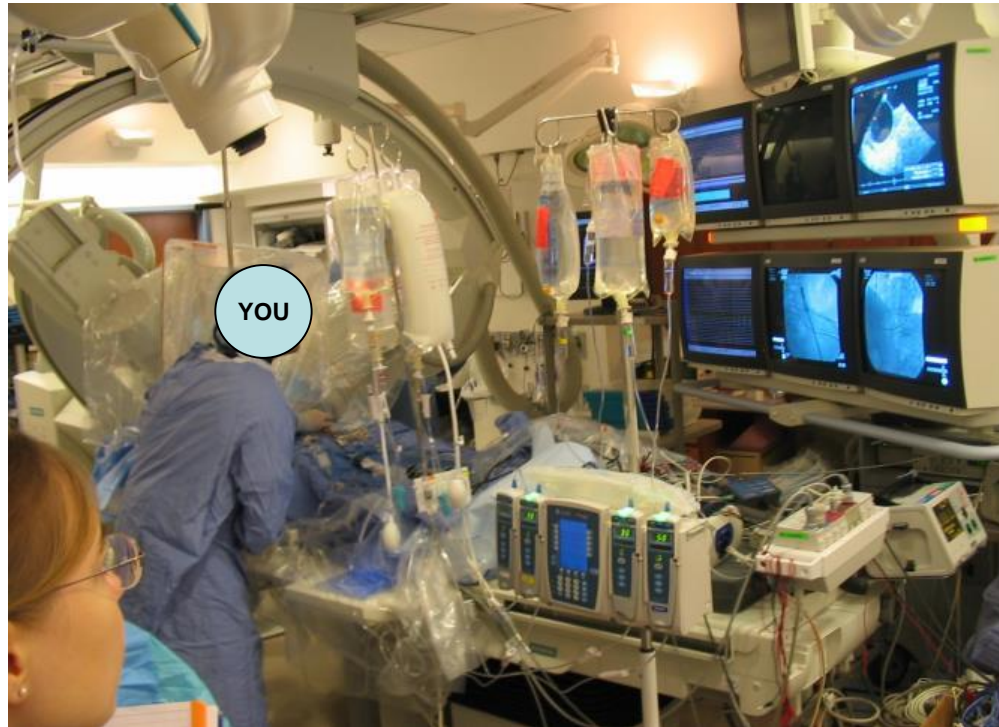
Primary Goals

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

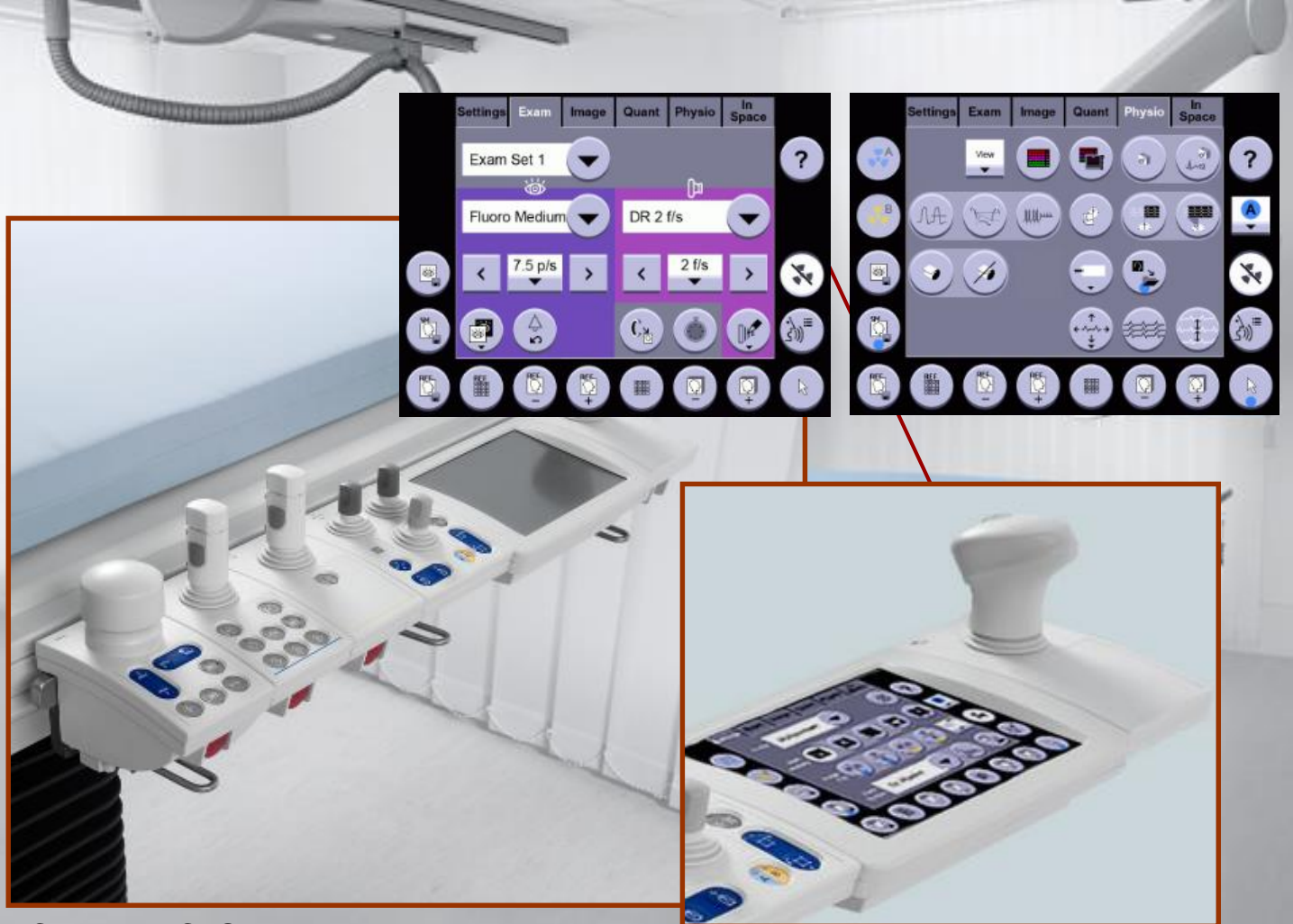


Images courtesy of KUKA GmbH; by Neoflash, Kalumet, Bme591wikiproject – Wikimedia Foundation, under CC BY-SA 3.0 license

CATH LAB AS IT APPEARS IN REALITY BY PROCURE



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



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From Classic to Flexible Imaging - SPECT Imaging

Conventional diagnostic SPECT

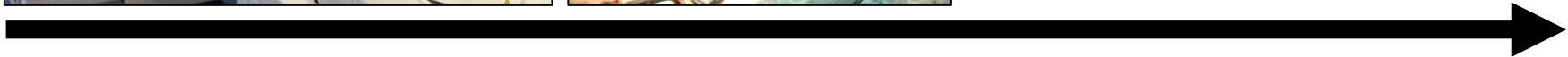


Intra-op freehand SPECT



Reproducible & reliable

Fast & flexible



DeclipseSPECT: Clinical Application

This screenshot shows the software interface during the acquisition phase. At the top left, there is a power button and a home button. A blue bar graph displays a count rate of 70 CPS. To its right, a box indicates a 10-second sample with 25 CPS. The central video feed shows a surgical procedure on a patient's abdomen, with a purple circular overlay indicating the SPECT camera's field of view. A vertical toolbar on the left contains icons for home, zoom, pan, and other navigation functions. The 'surciceye' logo is visible on the left side. At the bottom, three buttons labeled 'Acquisition', 'Visualization', and 'Export' are present, with 'Acquisition' being the active mode.

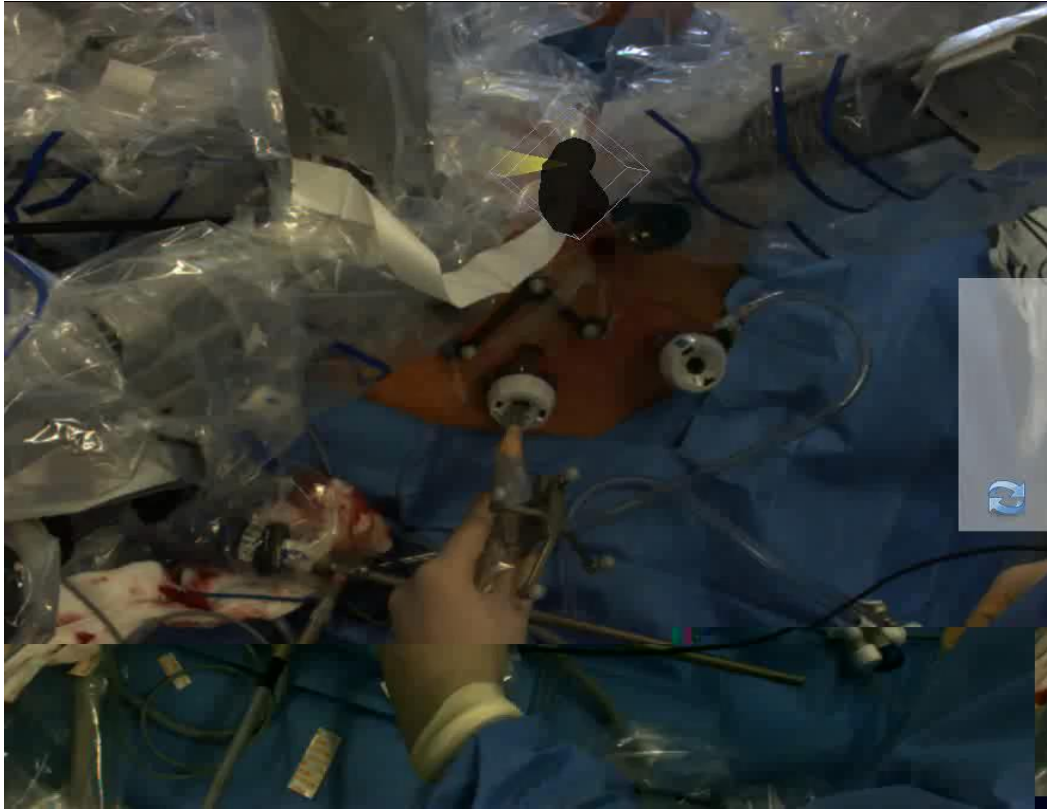
This screenshot shows the software interface during the visualization phase. At the top left, there is a power button and a home button. A blue bar graph displays a count rate of 1505 CPS. To its right, a box indicates a 10-second sample with 1247 CPS. The central video feed shows a dark background with a green crosshair and a purple circular overlay, indicating the SPECT camera's field of view. Text on the screen reads 'CPS: 1505 Distance: 20mm'. A vertical toolbar on the left contains icons for home, zoom, pan, and other navigation functions. The 'surciceye' logo is visible on the left side. At the bottom, three buttons labeled 'Acquisition', 'Visualization', and 'Export' are present, with 'Visualization' being the active mode.



Using the laparoscopic gamma probe to generate a 3D image

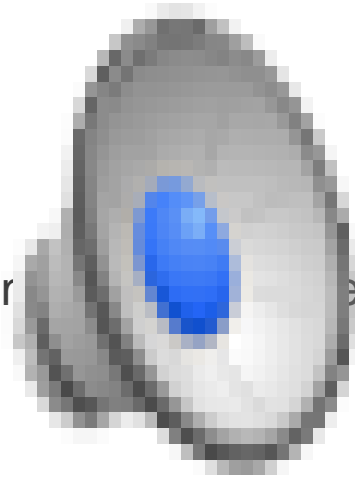


Generation of a laparoscopic freehand SPECT image



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

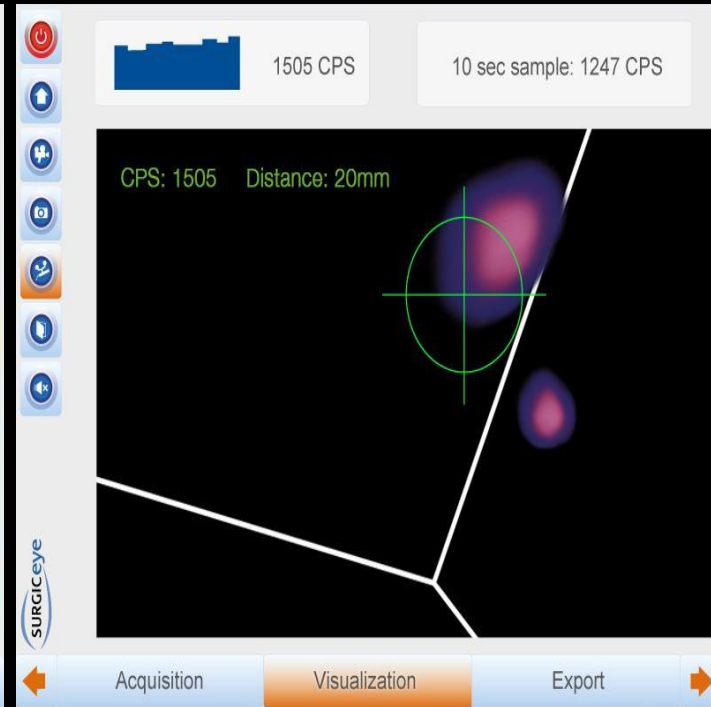
- in-patient SPECT: drop-in gamma camera held by da Vinci



SurgicEye's DeclipseSPECT: First AR solutions in ORs



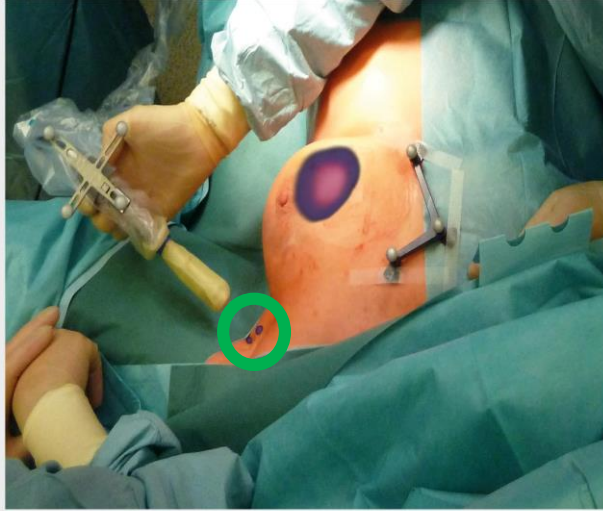
The interface shows a live surgical video feed with a purple and blue heat map overlaid on the patient's chest. A hand in a yellow glove is holding a surgical instrument. The top left features a red power button and a home button. A blue bar graph shows a reading of 70 CPS, with a box indicating a 10 sec sample of 25 CPS. The SURGICEYE logo is on the left. At the bottom, the 'Acquisition' tab is selected, with 'Visualization' and 'Export' tabs also visible.



The interface displays a zoomed-in view of the heat map from the previous screen. A green crosshair is centered on the largest heat spot. Text in the top left corner reads 'CPS: 1505' and 'Distance: 20mm'. The top right shows a blue bar graph with a reading of 1505 CPS and a box for a 10 sec sample of 1247 CPS. The SURGICEYE logo is on the left. At the bottom, the 'Visualization' tab is selected, with 'Acquisition' and 'Export' tabs also visible.



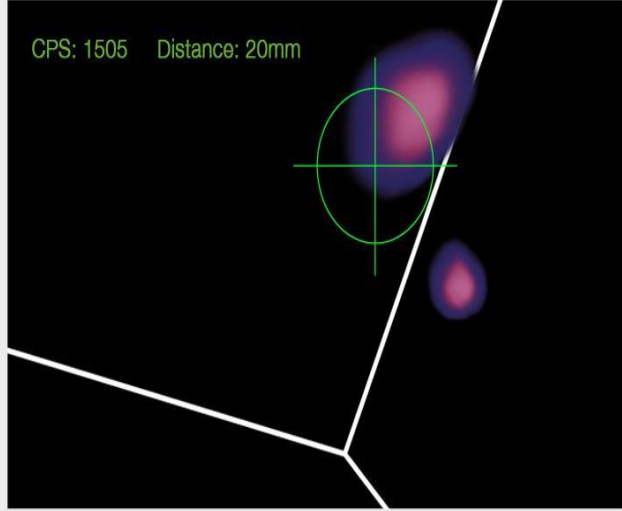
SurgicEye's DeclipseSPECT: First AR solutions in ORs



70 CPS 10 sec sample: 25 CPS

Acquisition Visualization Export

The interface shows a real-time surgical video feed. A heatmap overlay is visible on the patient's abdomen, with a green circle highlighting a specific area of interest. The top of the interface features a power button, a home button, and a vertical toolbar with various icons. A status bar at the bottom contains three buttons: 'Acquisition', 'Visualization' (which is highlighted in orange), and 'Export'.



1505 CPS 10 sec sample: 1247 CPS

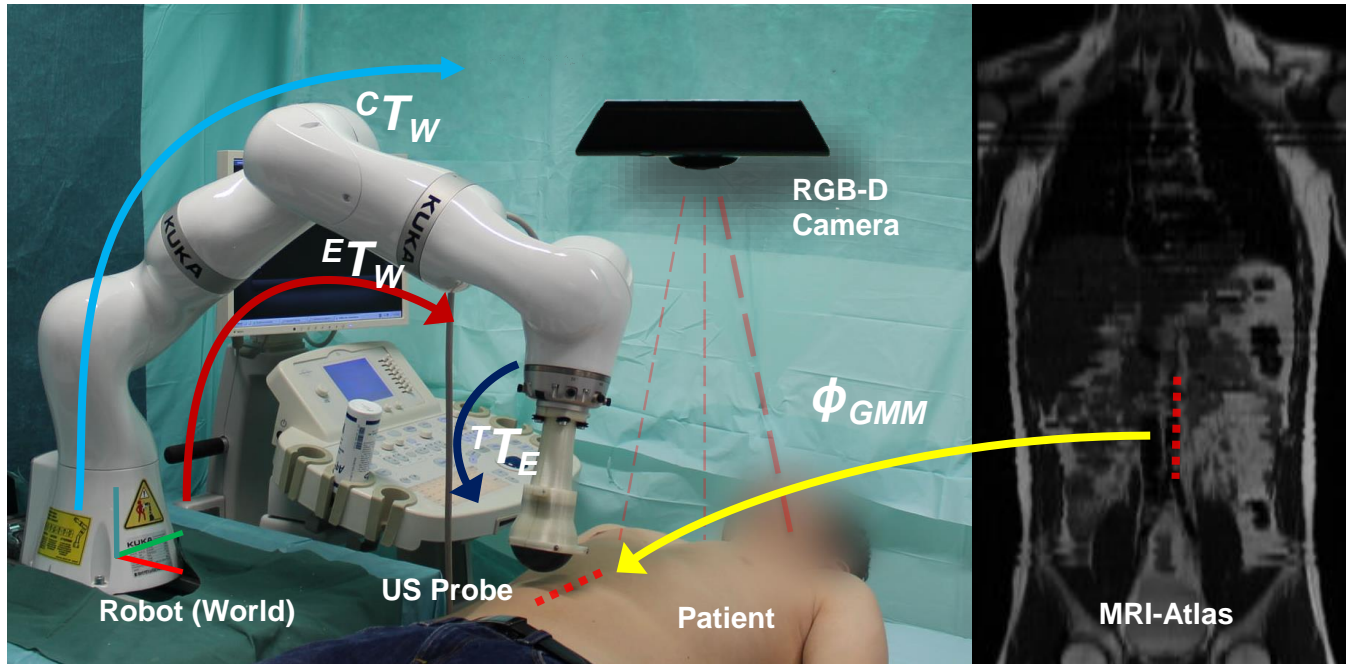
CPS: 1505 Distance: 20mm

Acquisition Visualization Export

This interface shows a zoomed-in view of the heatmap from the previous screen. A green crosshair is centered on a bright purple spot. The text 'CPS: 1505' and 'Distance: 20mm' is displayed in green. The top status bar shows '1505 CPS' and '10 sec sample: 1247 CPS'. The bottom navigation bar is identical to the first screen, with 'Visualization' highlighted.



Patient Registration and Trajectory Transfer

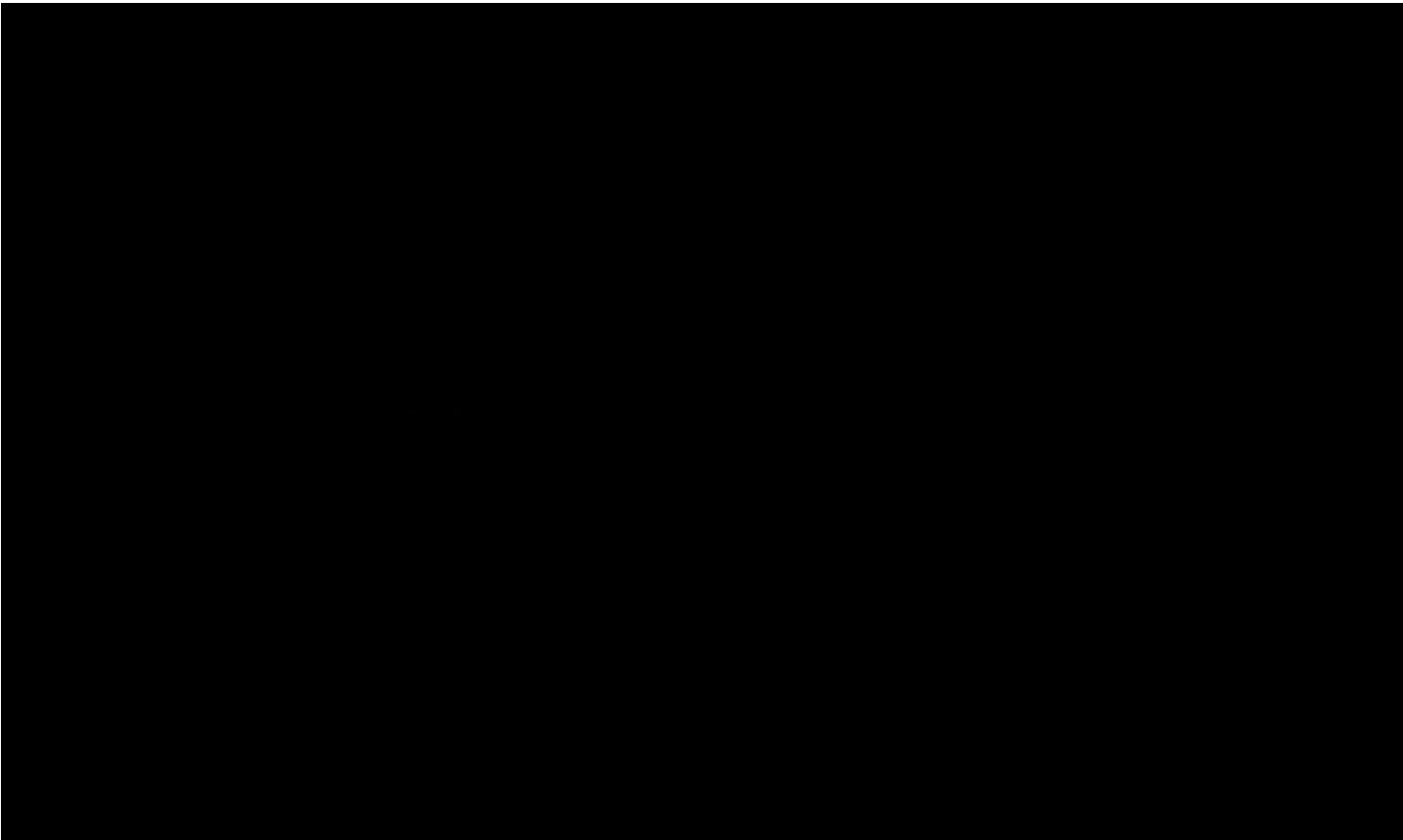


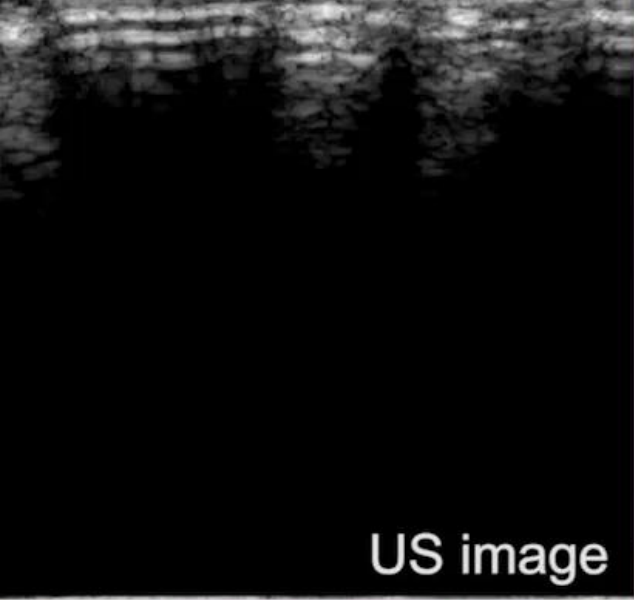
Automatic 3D Robotic Ultrasound Acquisitions



Robotic Acquisition







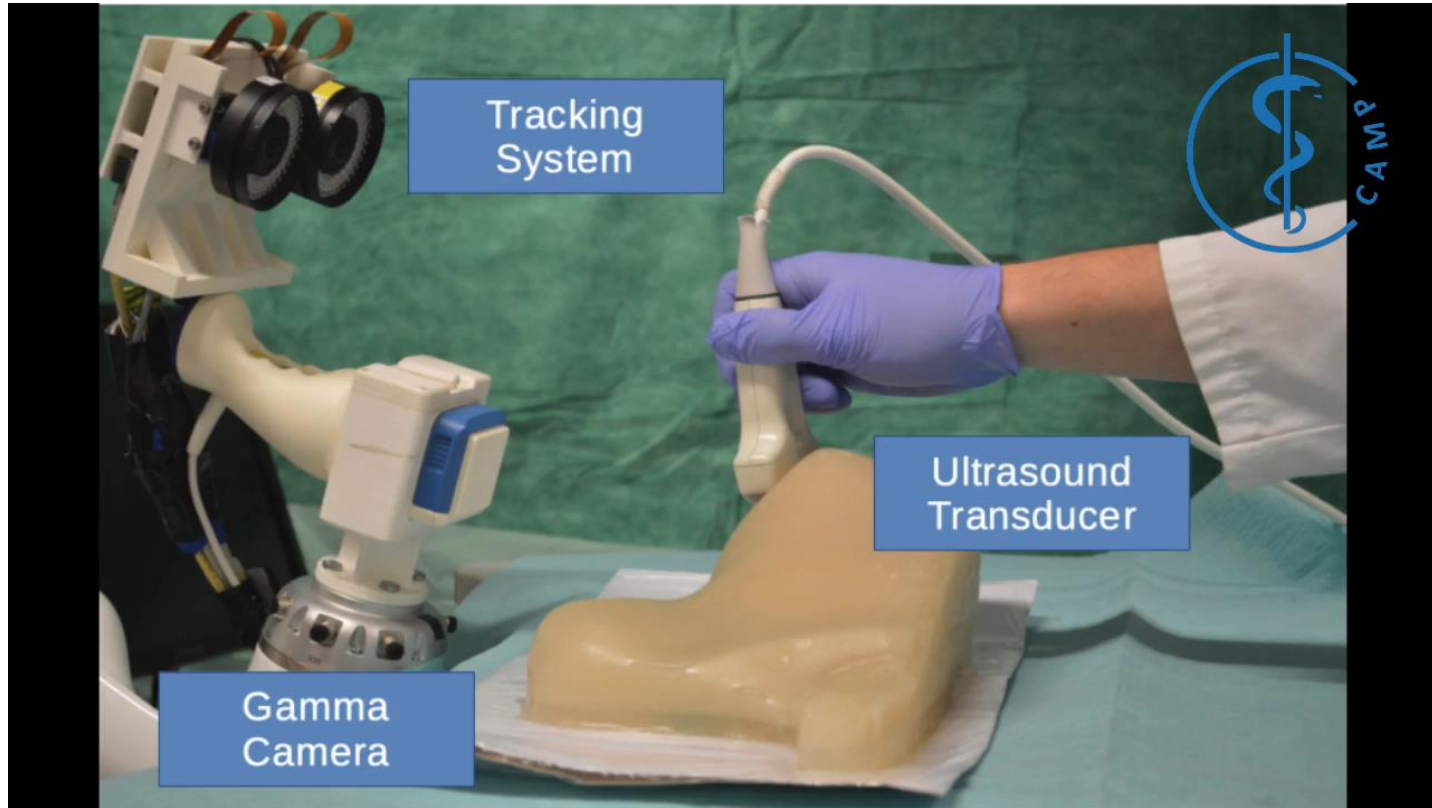
US image

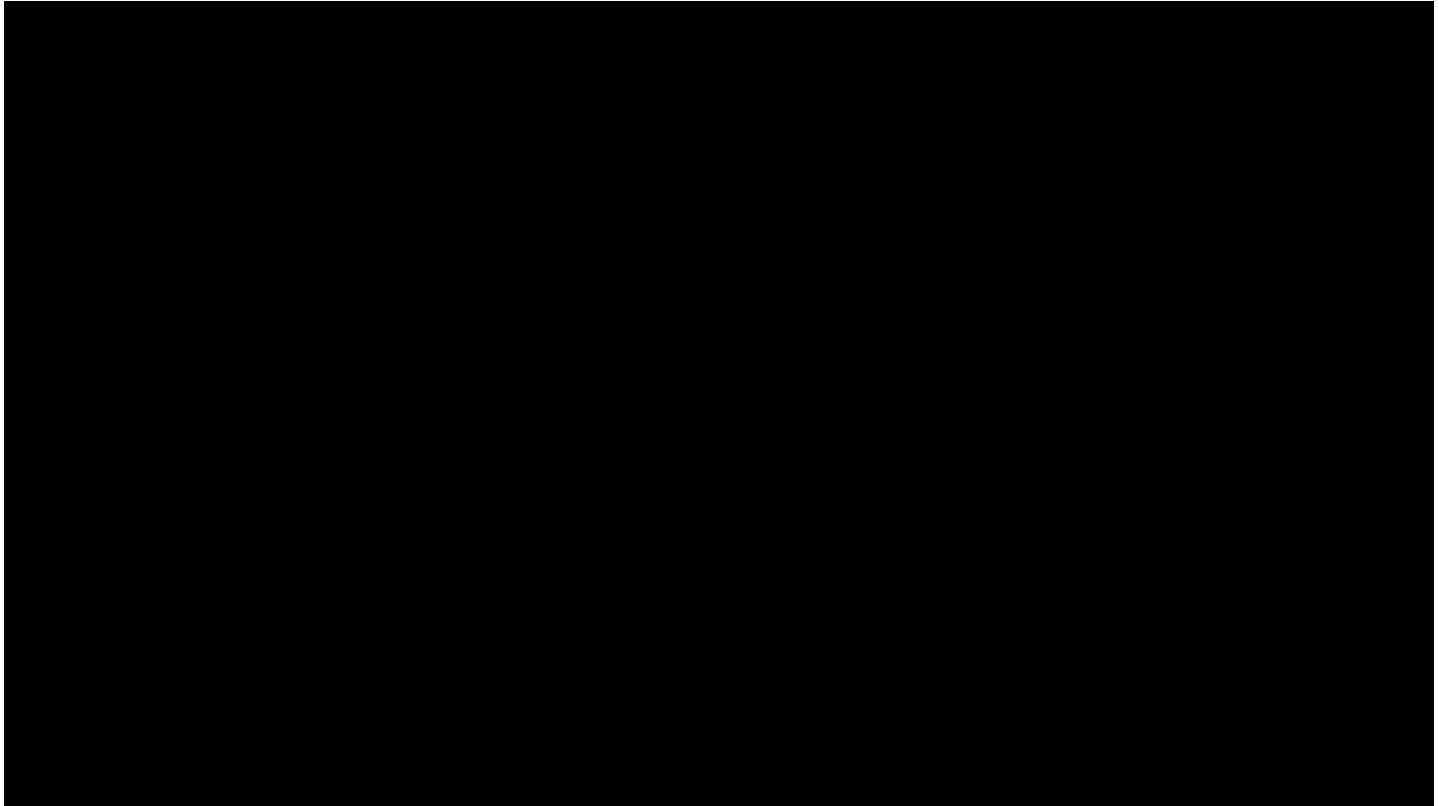


Close-up view

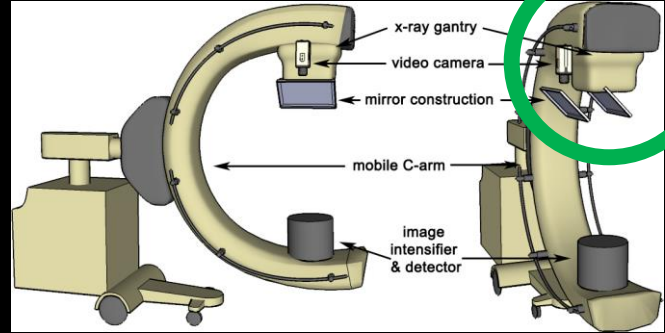
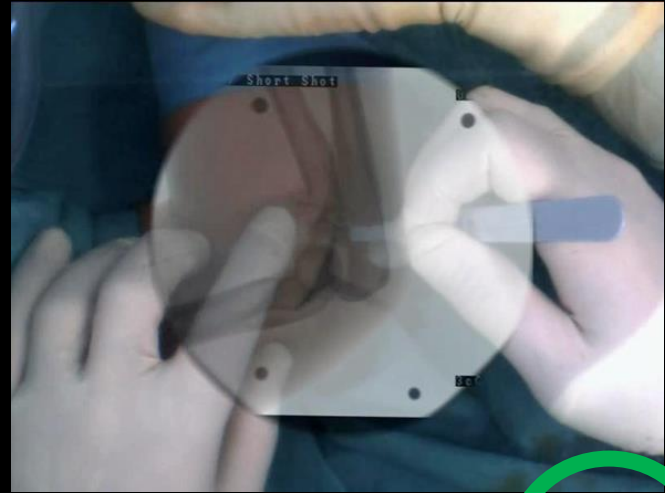


Collaborative Robotic Imaging: Freehand Punch Biopsy

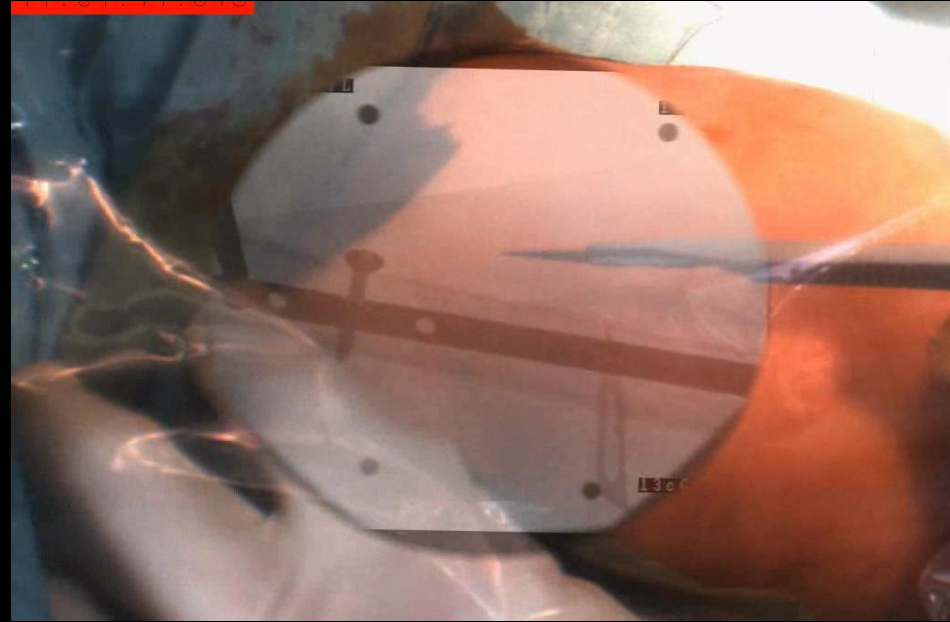
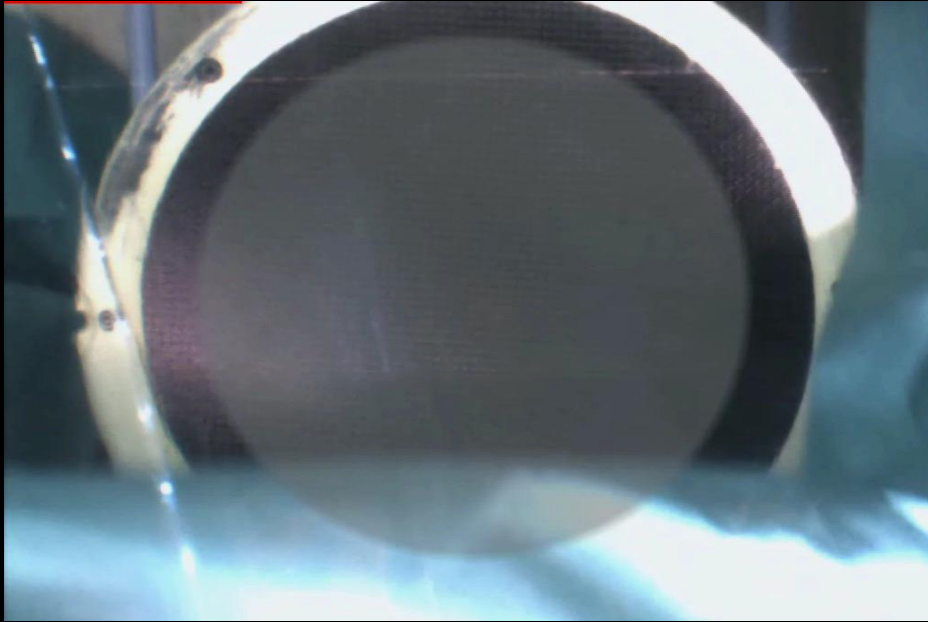


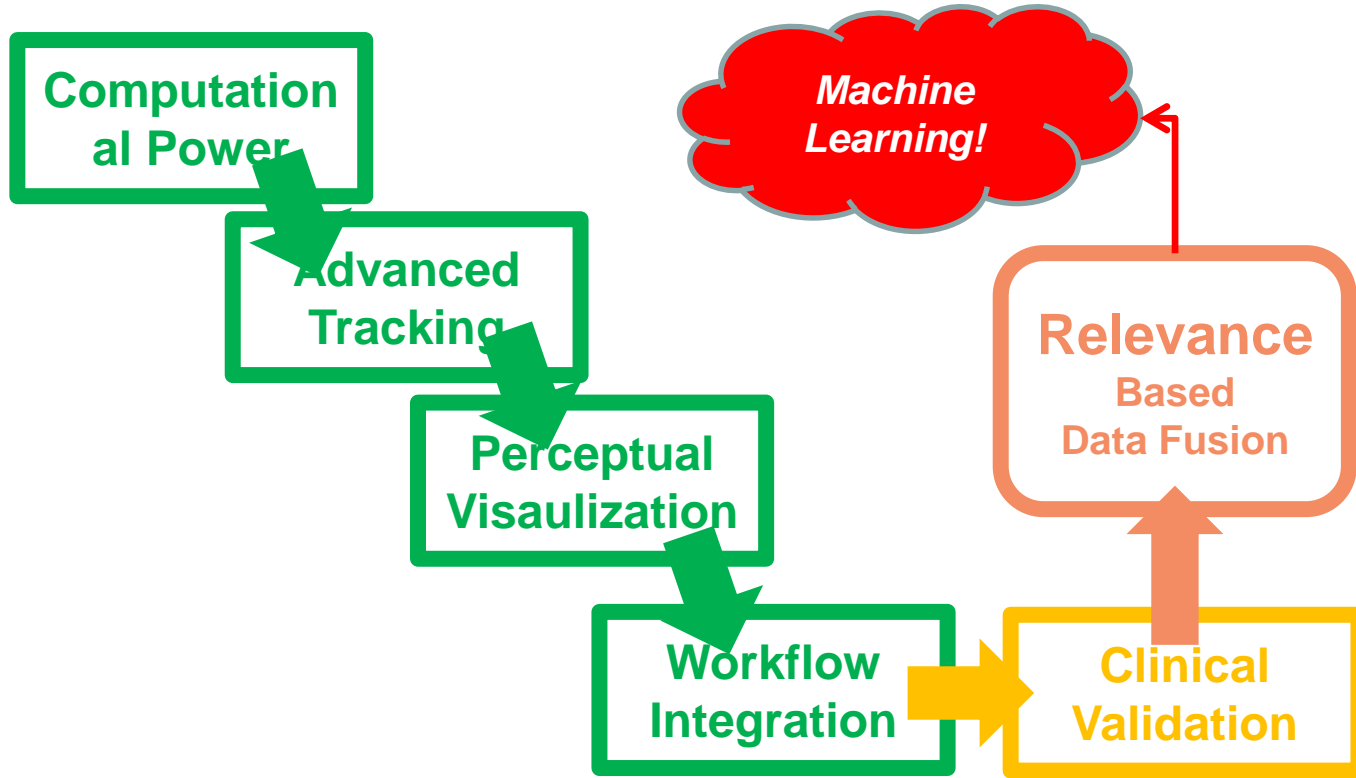


AR in OR Relevance & Workflow Integration



First uses of AR in Trauma Surgeries ...

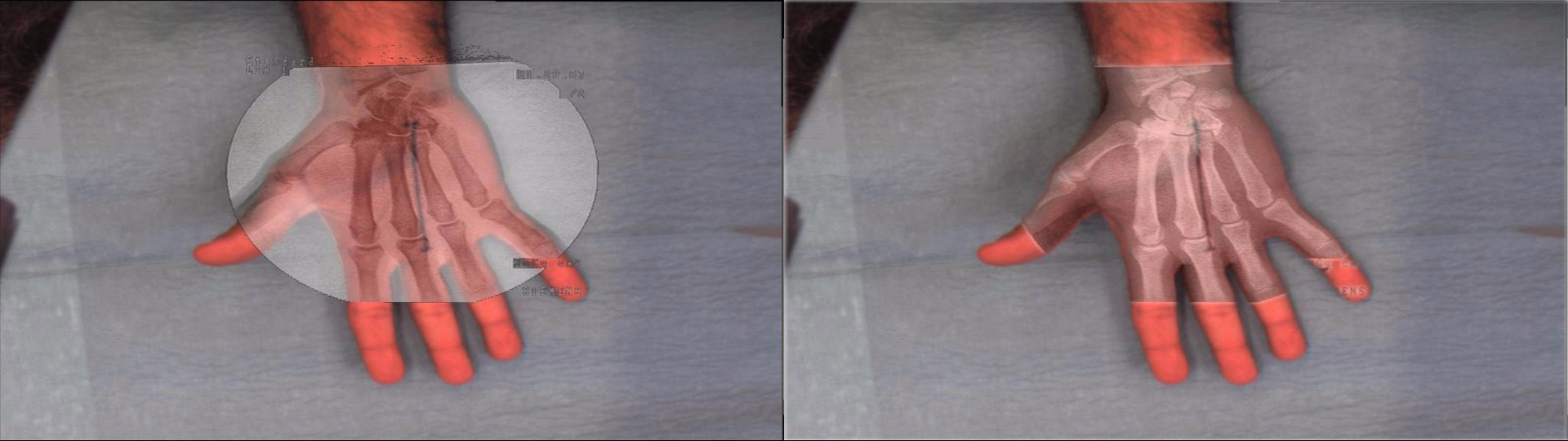




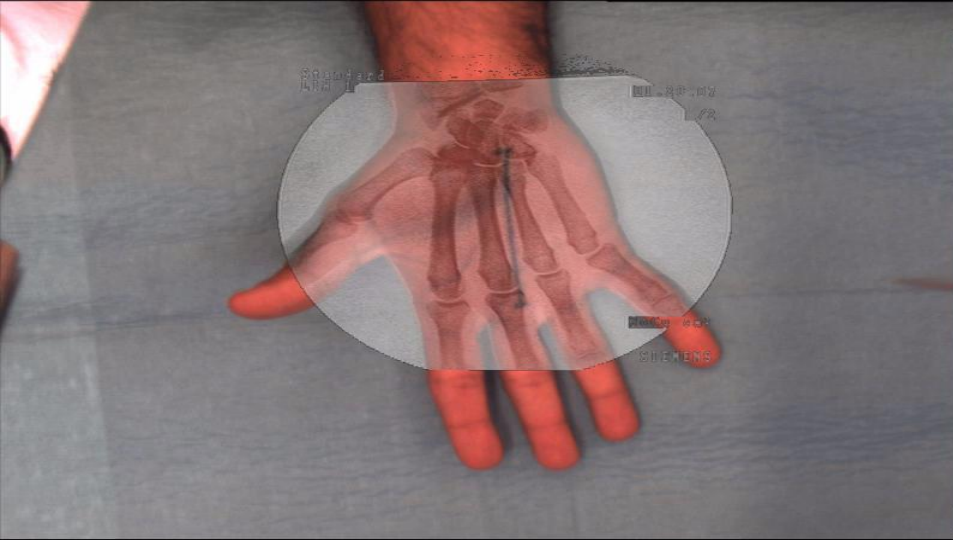
Machine Learning for Relevance based Imaging

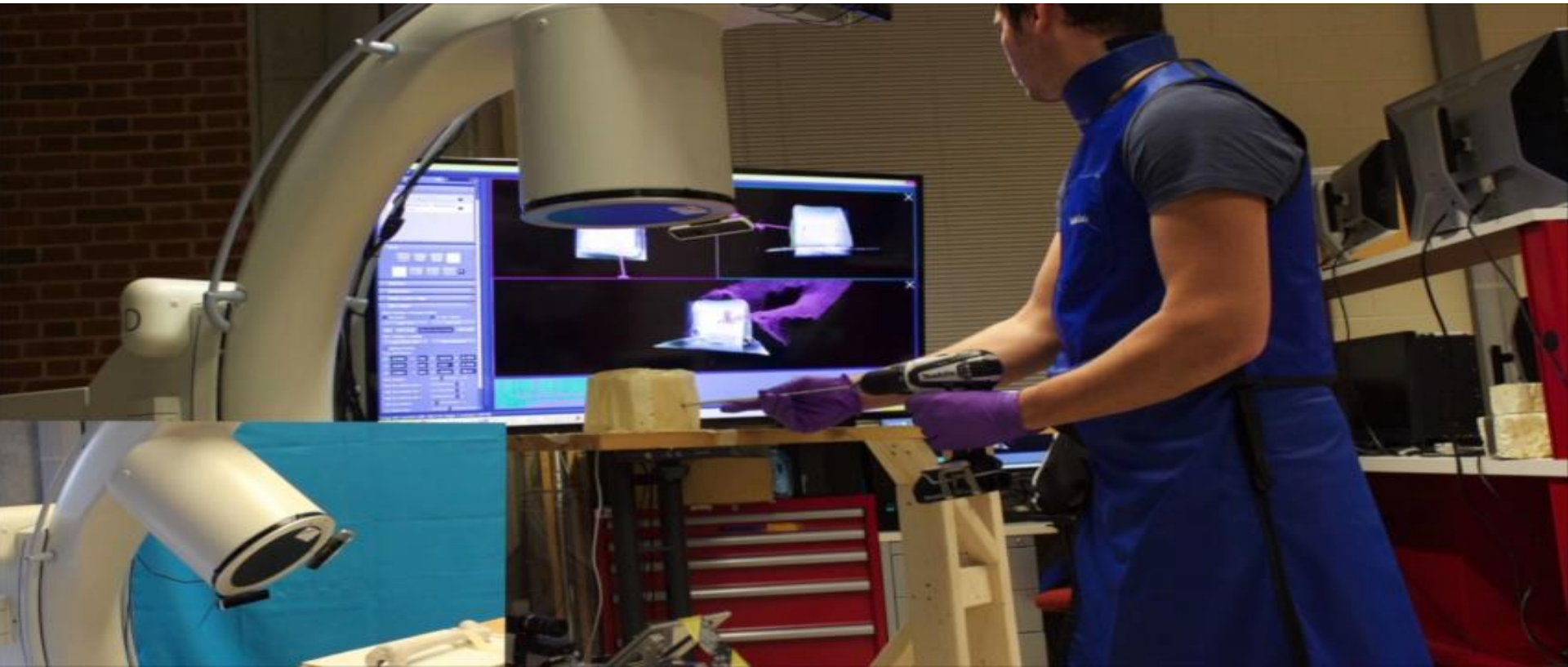


Machine Learning for Relevance based Imaging



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.



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



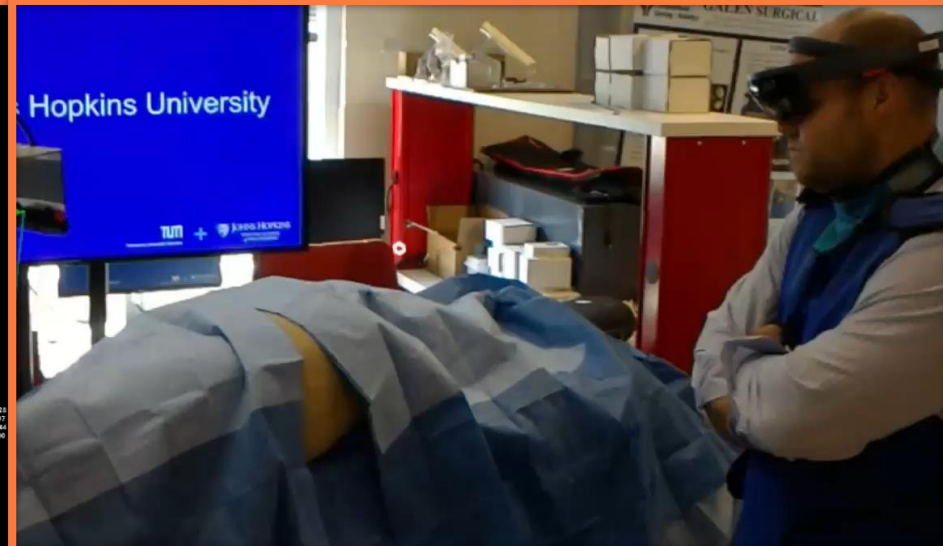
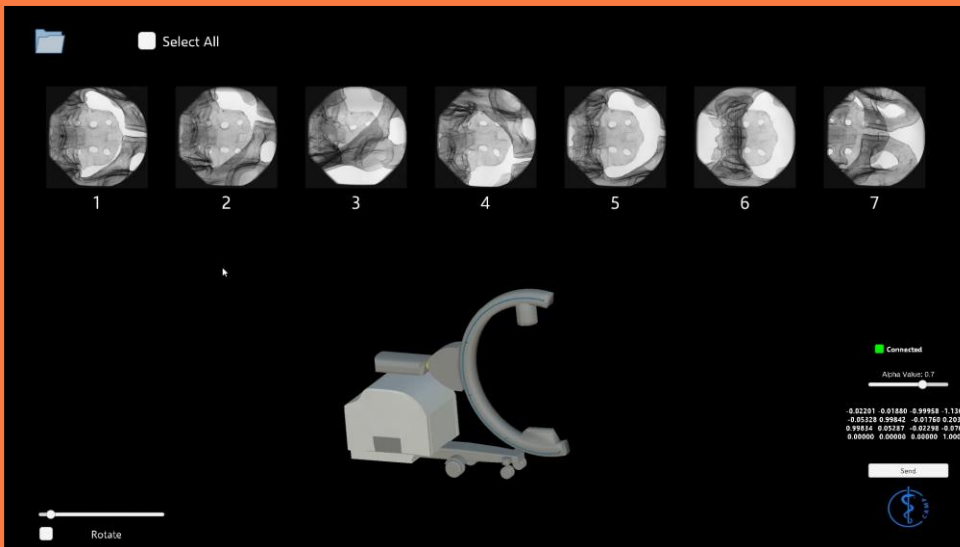
The voice command *Hide* allows the user to hide the image along with the frustum.



Surgical replay

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

Dr. Alex Johnson, Johns Hopkins University



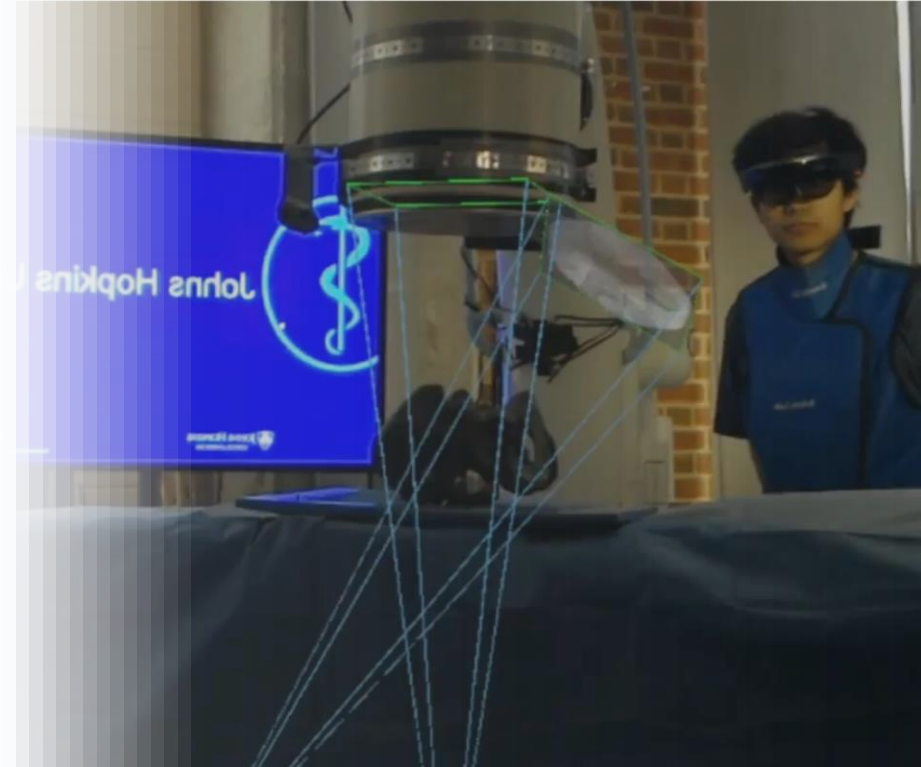
Technician-in-the-loop AR

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



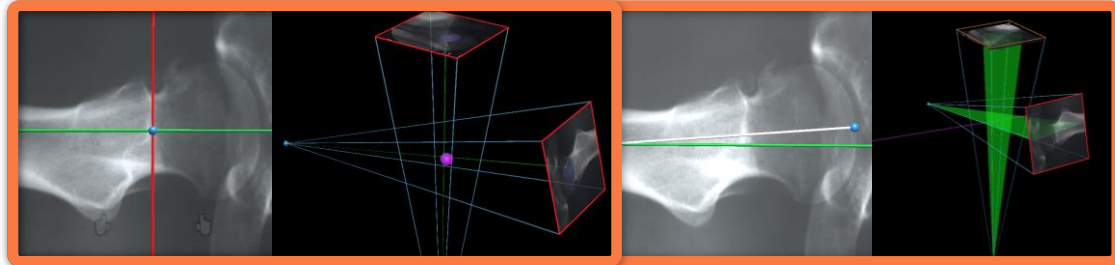
Intra-operative planning: projection onto X-ray images

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

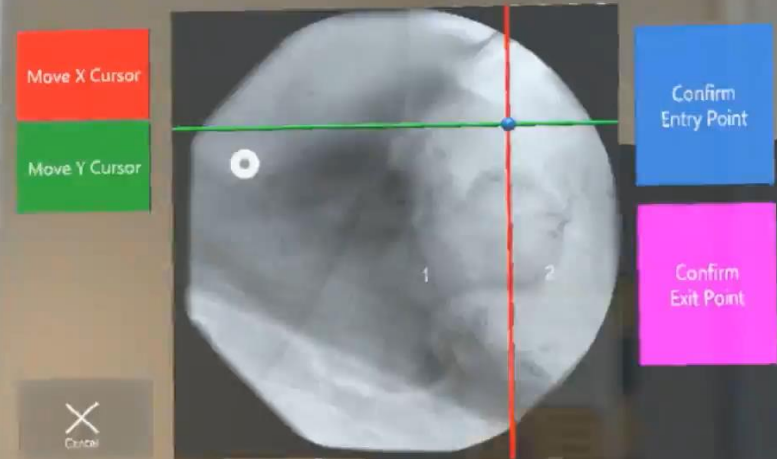


Application: Intra-operative annotation

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



AR view



Dr. Greg Osgood
Chief of orthopedics trauma, Johns Hopkins Hospital

Interactive Flying Frustums (IFFs)

Spatially aware surgical data visualization

Observations

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

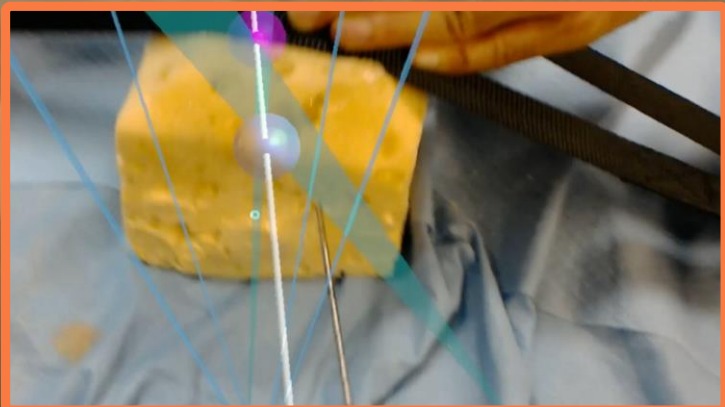


Interactive Flying Frustums (IFFs)

Spatially aware surgical data visualization

Observations

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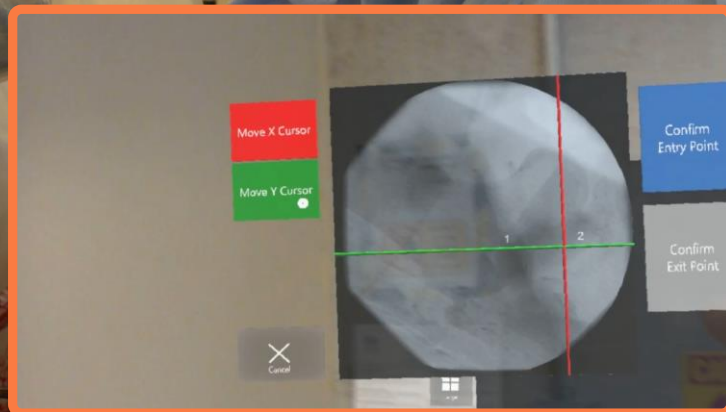
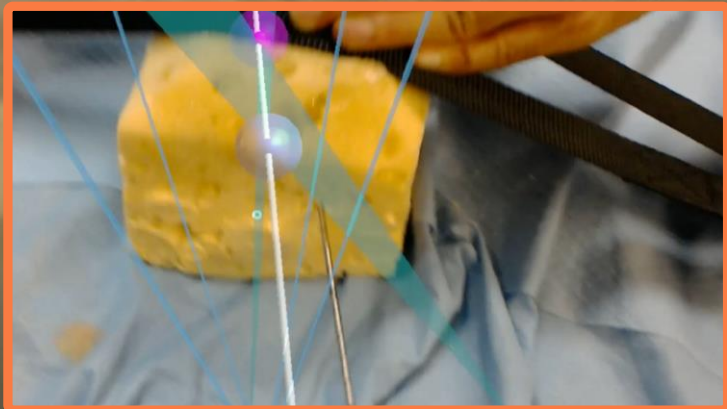


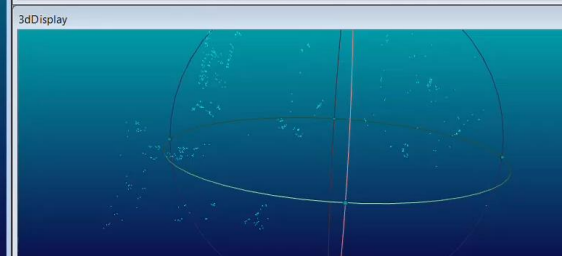
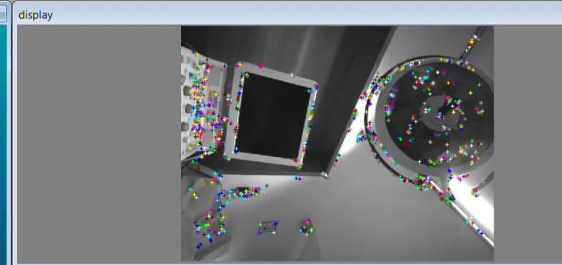
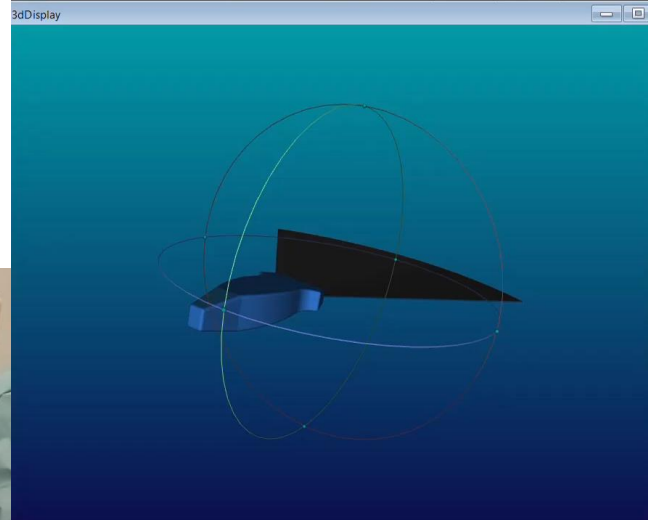
Interactive Flying Frustums (IFFs)

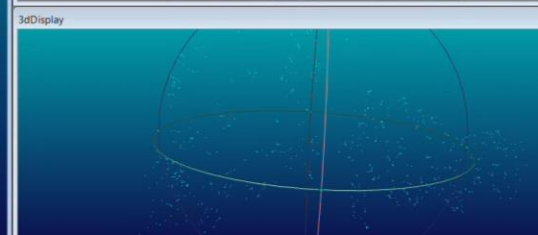
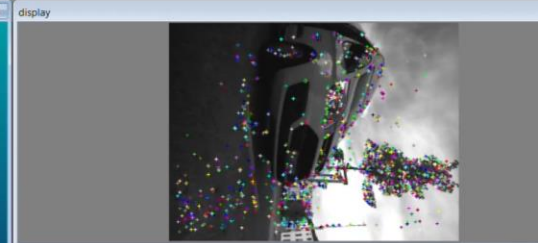
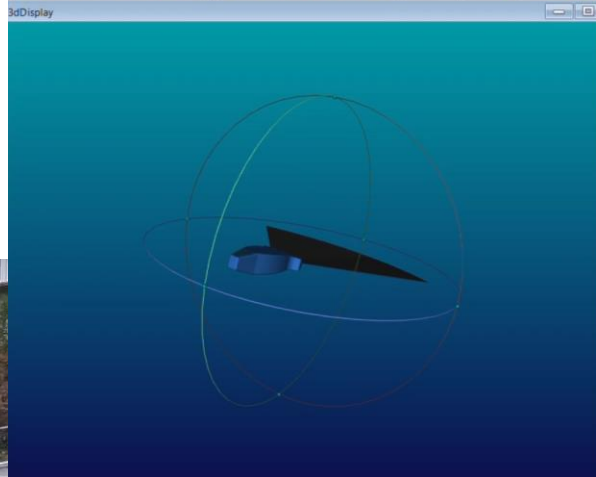
Spatially aware surgical data visualization

Observations

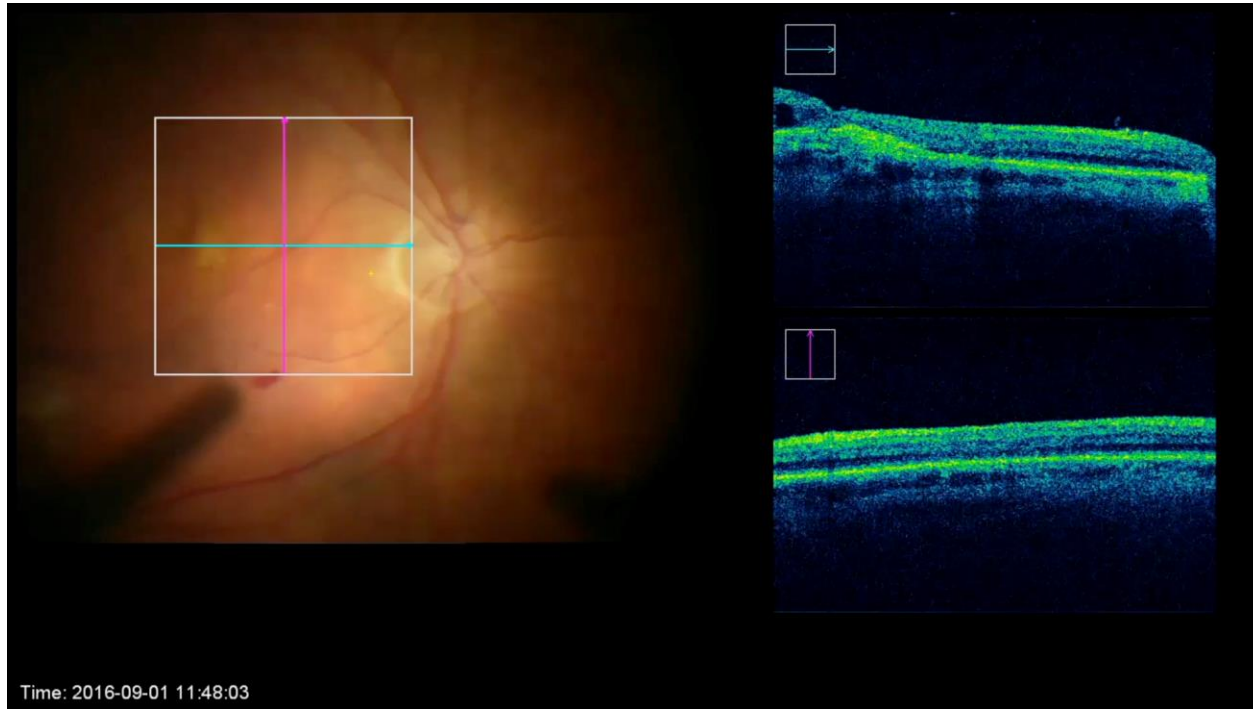
- > Virtual-to-real alignment
- > Surgeon's interaction
- > Surgeon/human-centered design







Sonified Video Sequence from a Surgery



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



Der Balgrist
Universitätsklinik
Balgrist

Technische
Universität
München

TUM

LMU

KLINIKUM
der Universität München

JOHNS HOPKINS
UNIVERSITY

HMZ

M
MICCAI

magic
leap

Microsoft

Microsoft

comerge

stryker

ImFusion



MEDICAL AUGMENTED REALITY

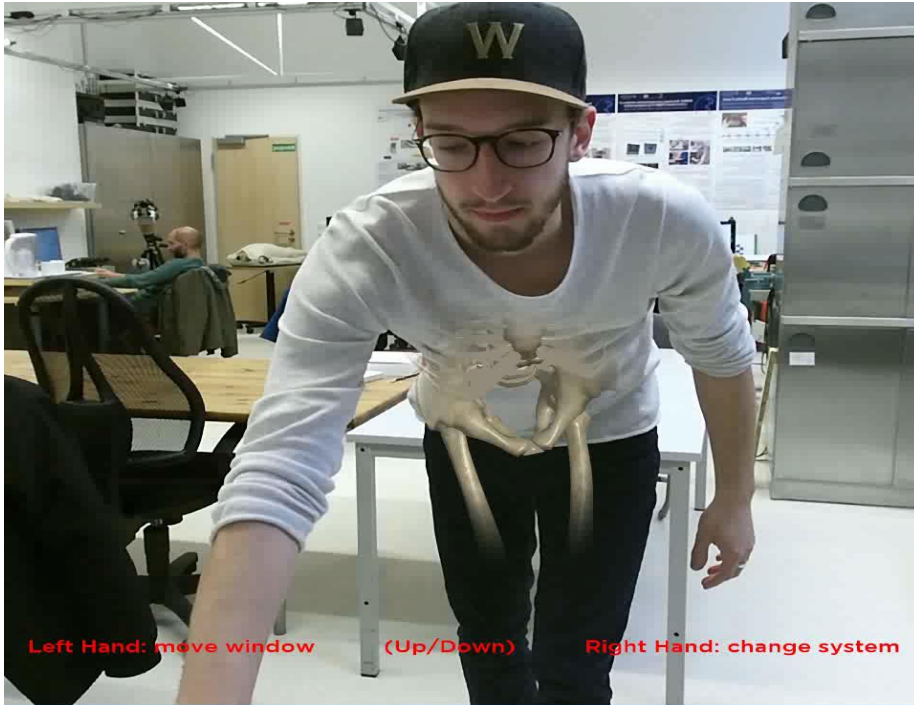
SUMMER SCHOOL

5-16

AUG 19

BALGRIST HOSPITAL ZURICH

Thanks



Left Hand: move window

(Up/Down)

Right Hand: change system



Skeleton

Prof. Nassir Navab
camp@jhu.edu



Prof. Nassir Navab
camp@jhu.edu



More information: <http://medicalaugmentedreality.org>