



MEDICAL IMAGE COMPUTING & COMPUTER ASSISTED INTERVENTIONS

Nassir Navab



CAMP

A collage of three photographs showing a group of people at a camp. The top-left photo shows a group posing by a lake. The top-right photo shows a group standing on a grassy lawn in front of a building. The bottom photo is a large group of people sitting on a wooden dock over a body of water.

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

CAMP Research ...

Medical Image Computing & Advance Data Visualization
Computer Vision
Machine Learning
Computer/Robot Assisted Interventions

CAMPO & UN

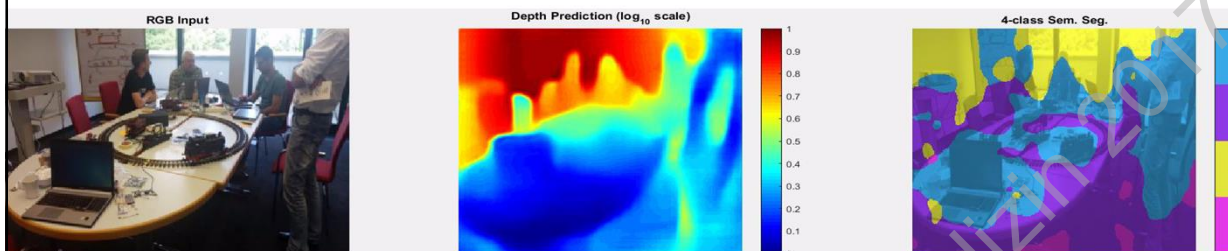
Deep Learning for Depth from one single image!

RGB Input

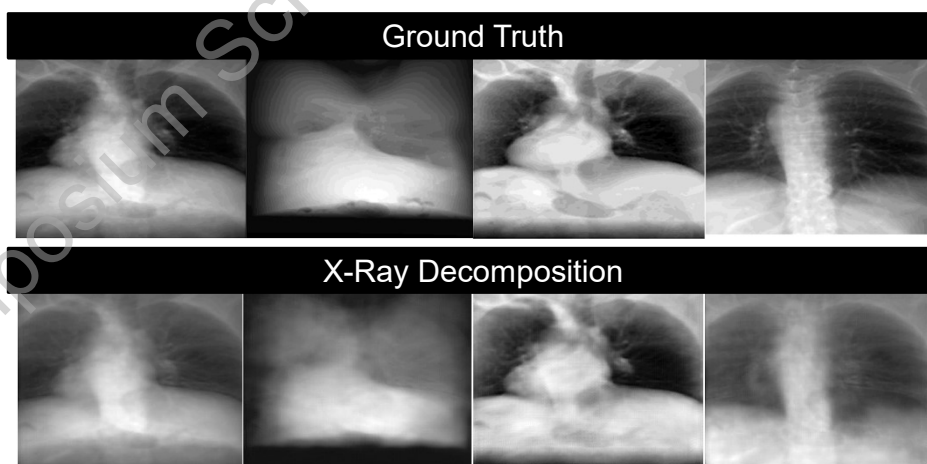
Depth Prediction (log₁₀ scale)

CAMPO & UN

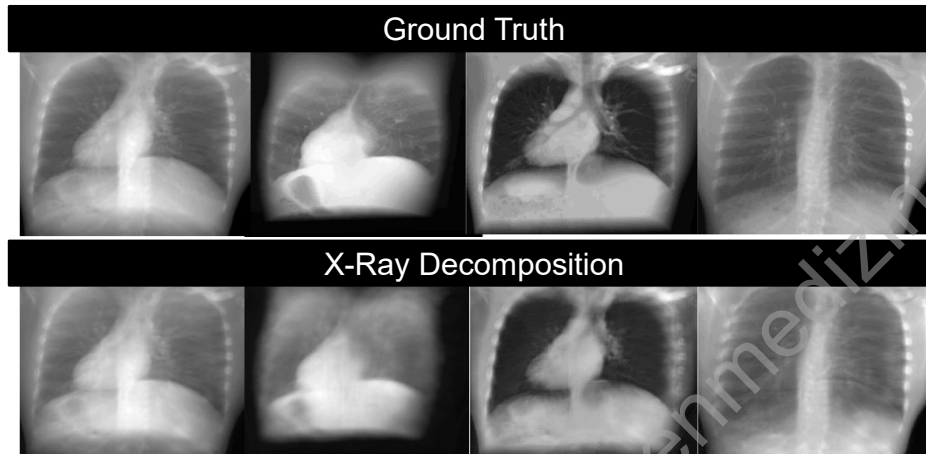
Deep Learning for Depth + Semantic segmentation from one single image!



Deep Learning for X-ray In-Depth Decomposition!



Deep Learning for X-ray In-Depth Decomposition!



Computer Aided Medical Procedures

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IMAGING & VISUALIZATION FOR COMPUTER ASSISTED INTERVENTIONS





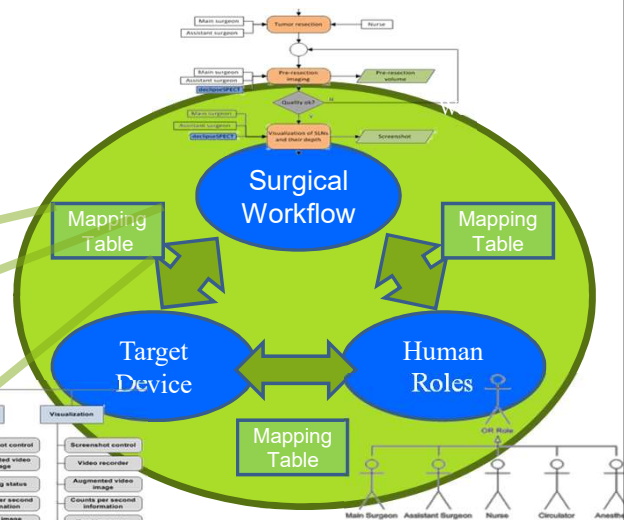
<http://www.ncigt.org/pages/AMIGO>

Surgical Data Science

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

Device feature	Workflow stage	Assess	Device positioning	Patient preparation	Stratification of assistant surgeon	Device Preparation	Preparation of device tools	Stratification of main surgeon
Device preparation								
Lens aperture			X			X		
Device position						X		
Device arm position						X		
Reference target							X	

Connection of views elements



OR Domain Model



Patient and therapy specific imaging Requirements

- Relevance
- Speed
- Flexibility
- Reproducibility
- Reliability
- Usability
- Safety



DeclipseSPECT: Clinical Application

70 CPS 10 sec sample: 25 CPS

1505 CPS 10 sec sample: 1247 CPS

CPS: 1505 Distance: 20mm

Acquisition Visualization Export

Acquisition Visualization Export



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 detector held by da Vinci



Data Analysis

Pre-incision Data

- 52 acquisitions in total
 - Average: 64.0% AR - 36.0% VR (Stdev 25.8%)
 - Average usage time: 3.15 minutes
- VR usage:
 - 41 of 52 – used (78.8%)
 - 11 of 52 – not used (21.2%)
- Threshold setting:
 - 51 of 52 – AR (98.1%)
 - 3 of 52 – VR (5.77%)
- Need for AR in VR:
 - 35 of 41 with VR (85.4%)
 - 35 of 52 total (67.3%)

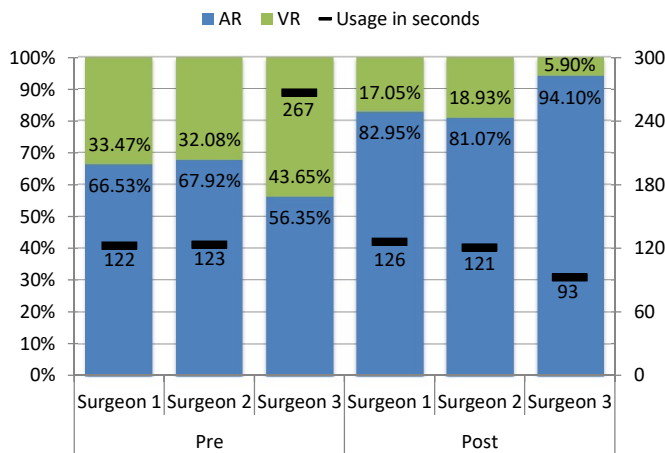
Aslı Okur et al. IEEE ISMAR 2011



Post-excision Data

- 48 acquisitions in total
 - Average: 86.4% AR - 13.6% VR (Stdev 23.0%)
 - Average usage time: 1.56 minutes
- VR usage:
 - 16 of 48 used (33.3%)
 - 32 of 48 not used (66.7%)
- Threshold setting:
 - 12 of 48 – not needed (25%)
 - 36 of 48 – needed (75%)
- Need for AR in VR:
 - 13 of 16 with VR (27.1%)
 - 13 of 48 total (81.3%)
- Comparison with pre-incision scan:
 - 29 of 48 – used (60.4%)
 - 27 in AR
 - 1 in VR
 - 1 in both

Data Analysis



14 different main surgeons were involved in total

- Different characteristics of teams led by different main surgeons
- Actual usage time and type depends on the decision maker (the main surgeon)

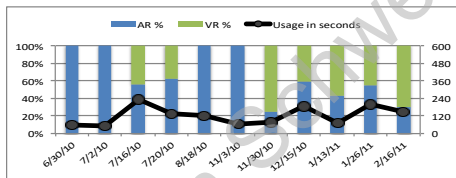
Analysis for three major users

Different usage tendencies:

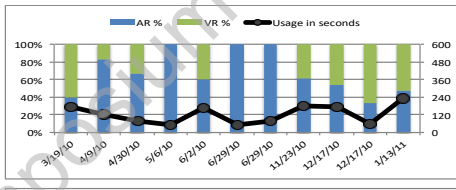
- Surgeon 1 and 2: confirmation of radioactivity before excision over the anatomy (more AR usage)
- Surgeon 3: image-guided excision (more VR usage)



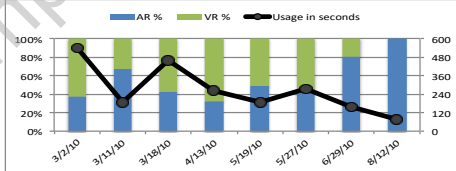
Surgeon 2



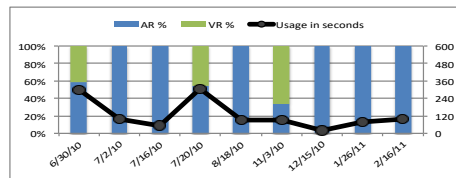
Pre-incision Surgeon 1



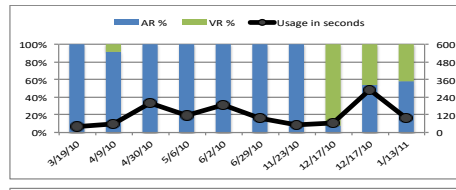
Surgeon 3



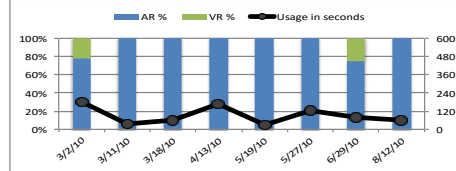
Surgeon 2



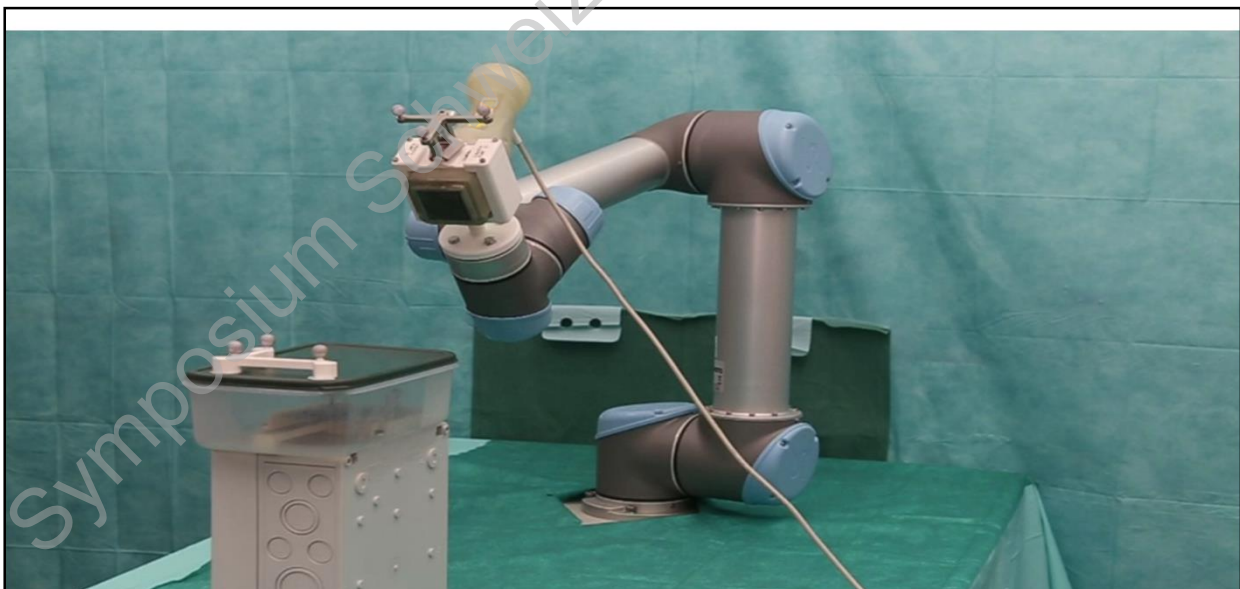
Post-excision Surgeon 1



Surgeon 3



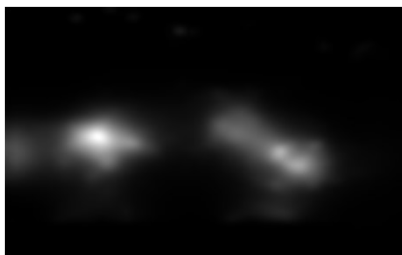
From general diagnostic imaging to flexible, reproducible and reliable patient and therapy specific imaging



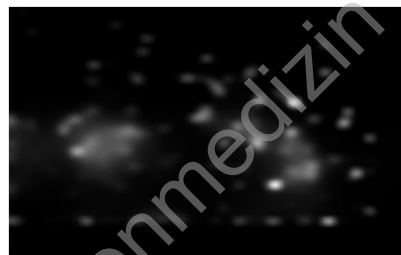
Decay compensation experiment

3 spheres loaded with $\sim 1\text{MBq}$ of $^{99\text{m}}\text{Tc}$, scanned 18 hours (3 half lives) after show the effect of the compensation in the reconstruction.

Reconstruction with compensation



Reconstruction without compensation



Gardjzabal et al. (2012), *First flexible robotic intra-operative nuclear imaging for image-guided surgery*. IPCAI

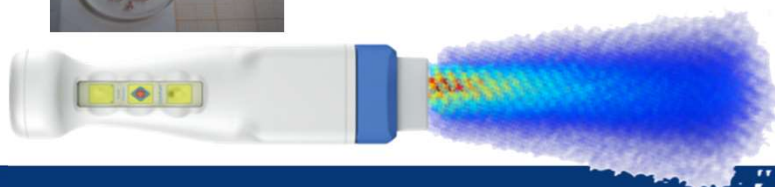
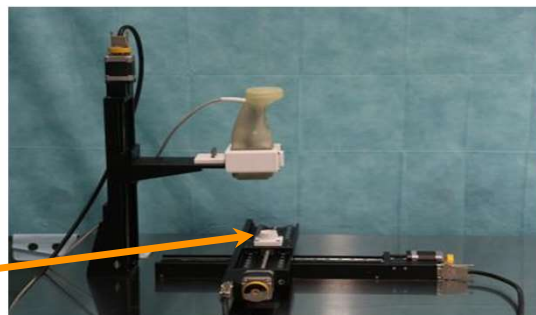


Robotic Gamma camera modeling

- $15 \times 15 \times 15\text{cm}^3$
- 1mm^3 spacing
- $41^3 = 69\text{k}$ points

Experiment

- Box-phantom with 3 radioactive spheres
- Optically tracked camera and phantom
- 6 images from 2 orthogonal directions



Towards personalized
interventional
SPECT-CT imaging

MICCAI 2014 submission #155
(supplementary material)




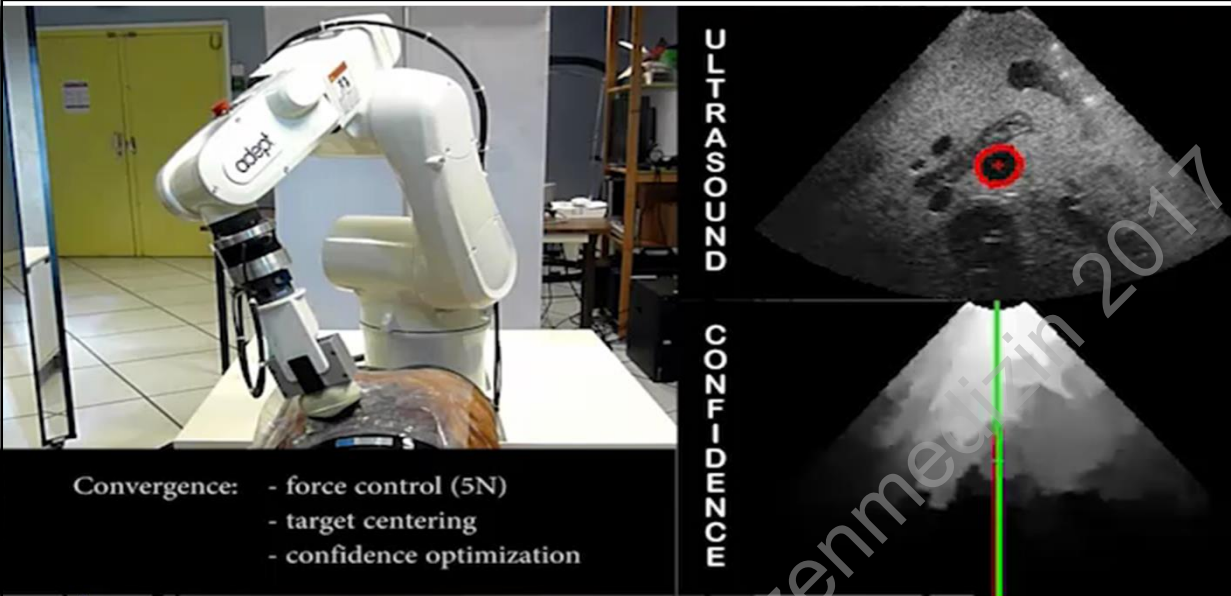
Robotic US (Optimal Acquisition), Collaboration with INRIA in Rennes

Ultrasound

Confidence

Force control
Confidence control
Teleoperation





Convergence: - force control (5N)
- target centering
- confidence optimization

ULTRASOUND
CONFIDENCE

Chatelaine, Krupa, Navab, ICRA 2015

Automatic Force-Compliant Robotic Ultrasound Screening of Abdominal Aortic Aneurysms

Salvatore Virga^{1,2}, Oliver Zetting¹, Marco Esposito¹,
Karin Pfister³, Benjamin Frisch¹, Thomas Neff¹,
Nassir Navab^{1,4}, Christoph Hennersperger¹

¹Chair for Computer Aided Medical Procedures, Technische Universität München
²KUKA Roboter GmbH, Augsburg, Germany
³Vascular and Endovascular Surgery, University Medical Center Regensburg
⁴Computer Aided Medical Procedures, Johns Hopkins University

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IEEE IROS 2016
October 9-14, Daejeon, Korea

'Desired-views' for Automatic C-arm positioning

shift the paradigm

- clinician only communicates the desired outcome of imaging.
- based on DRRs, pre-operative CTA data, and inverse kinematics

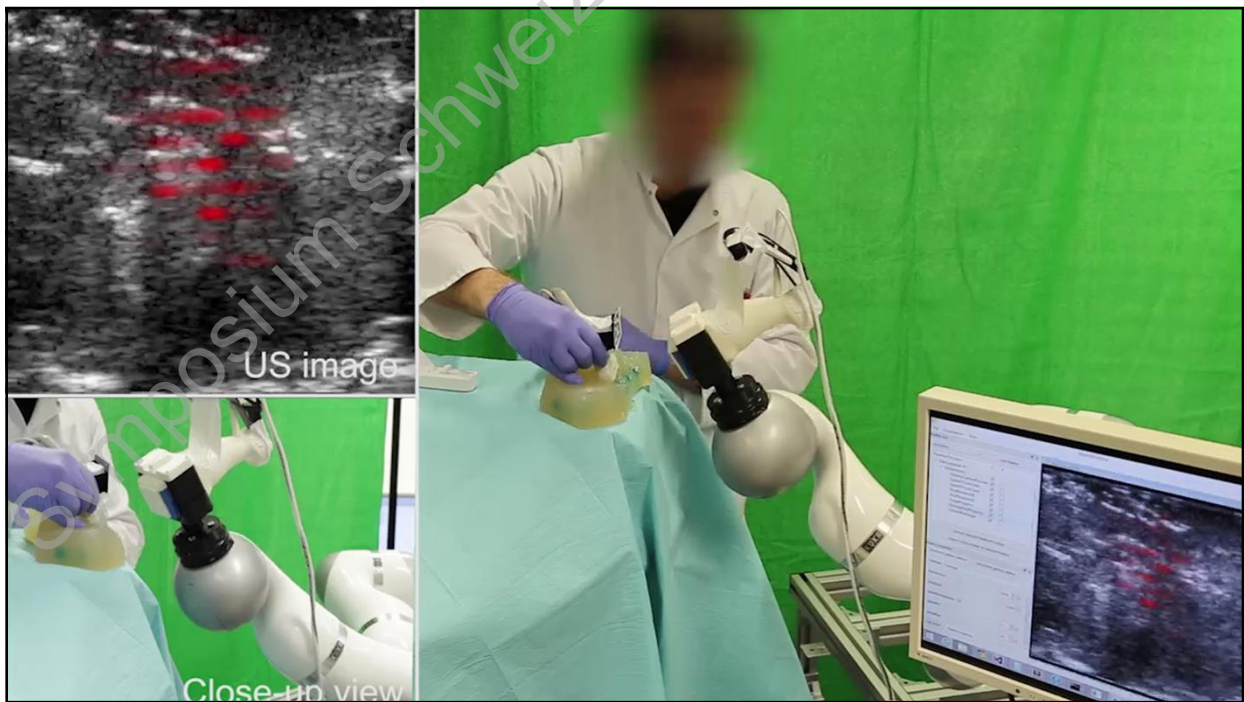
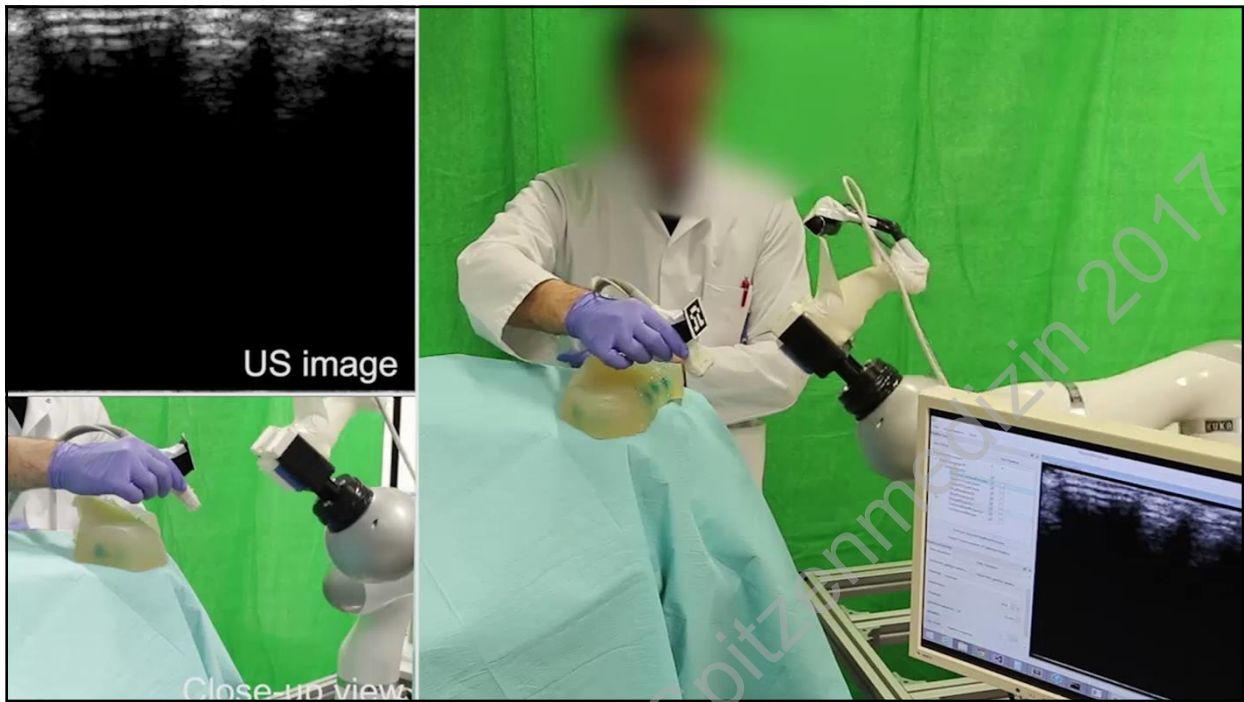
RAO 14.0
caudal 12.0

LAO 3, cranial 35 LAO 54, cranial 17 RAO 2, caudal 5 RAO 36, cranial 1 RAO 27, caudal 14 RAO 27, caudal 14 RAO 20, caudal 7 LAO 20, caudal 7

Fallavollita P, Winkler A, Habert S, Wucherer P, Stefan P, Mansour R, Ghotbi R, Navab N. *Desired-view controlled positioning of angiographic C-arms.* (MICCAI 2014)

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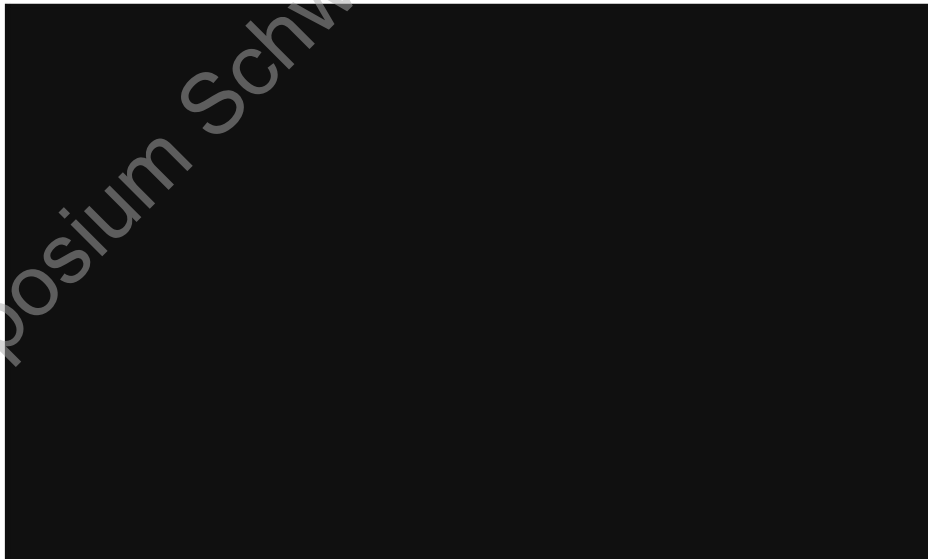
Patient fhSPECT Acquisition



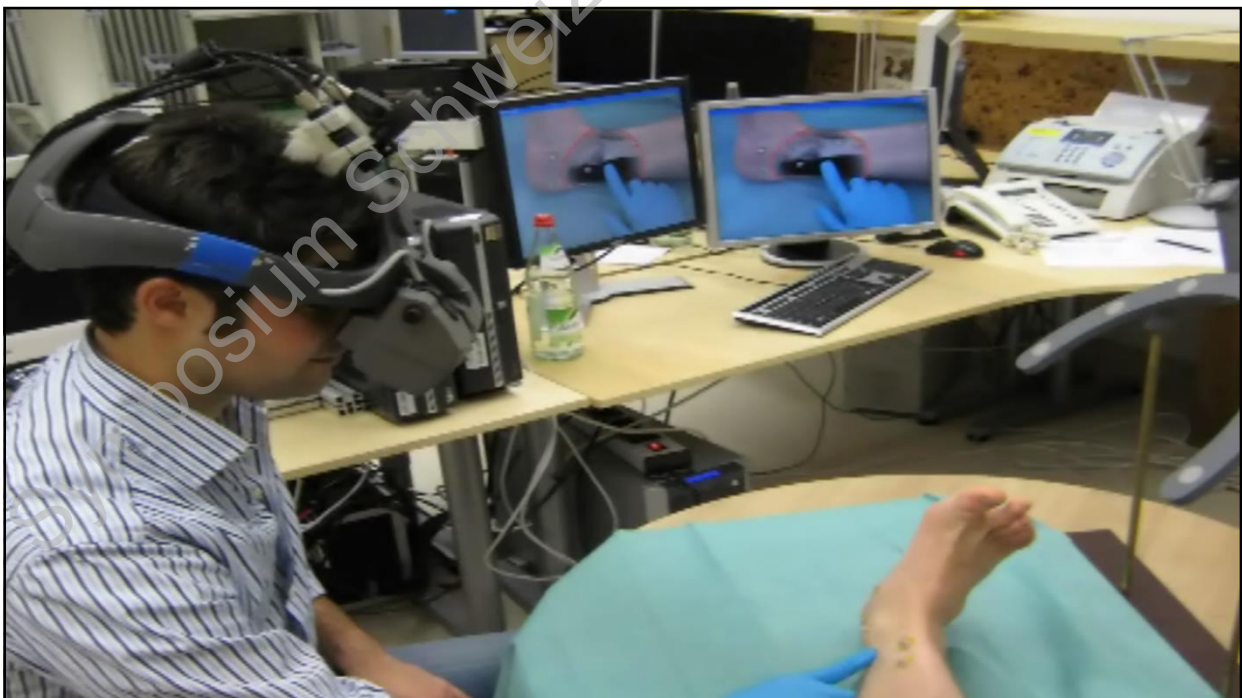
Challenges – Adoptive, intuitive and interactive visualization



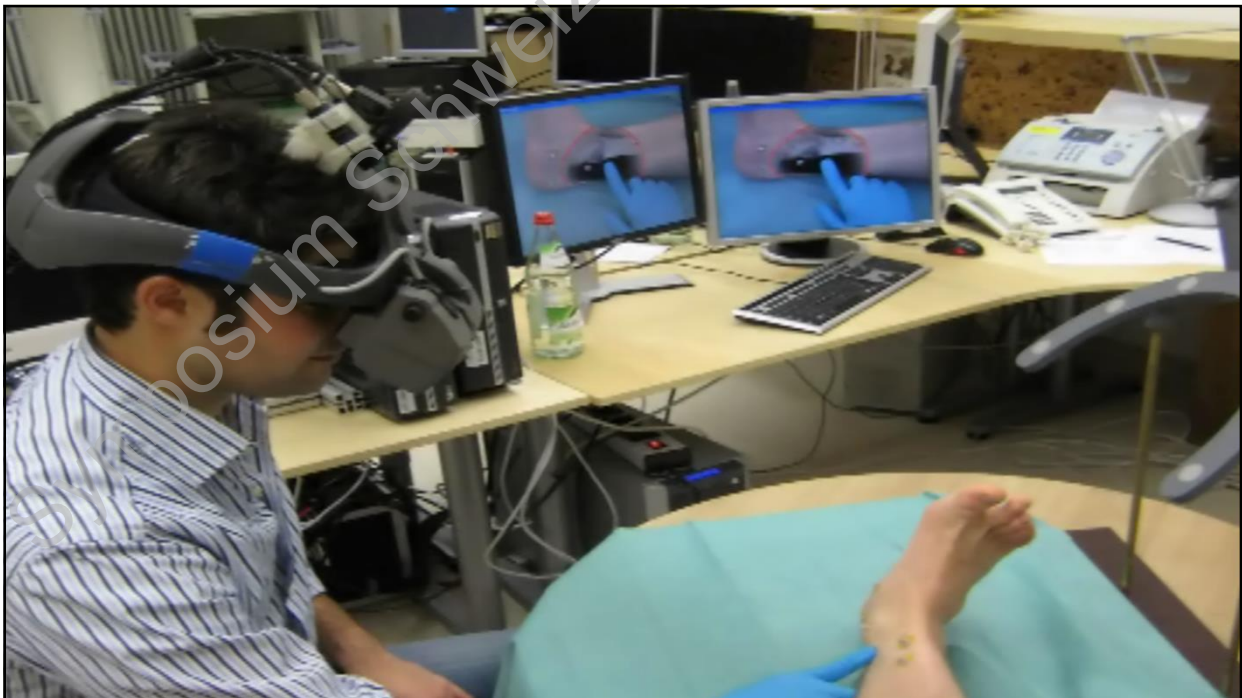
Challenges – Adoptive, intuitive and interactive visualization



Is
Augmented Reality
only about
3D image overlay?

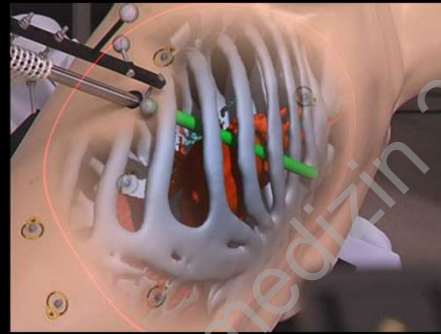


Can
we improve/fool
our
visual perception?






How to enforce
coexistence of
Real & Virtual?



Symposium Schweizer Spitzenmedizin 2017



How to explore
3D data in
Augmented
Reality?

A man in a white shirt and tie is holding a tablet. On the tablet, a 3D model of a mechanical part is displayed. He is pointing at the model with his right hand. The background is a blurred office setting.

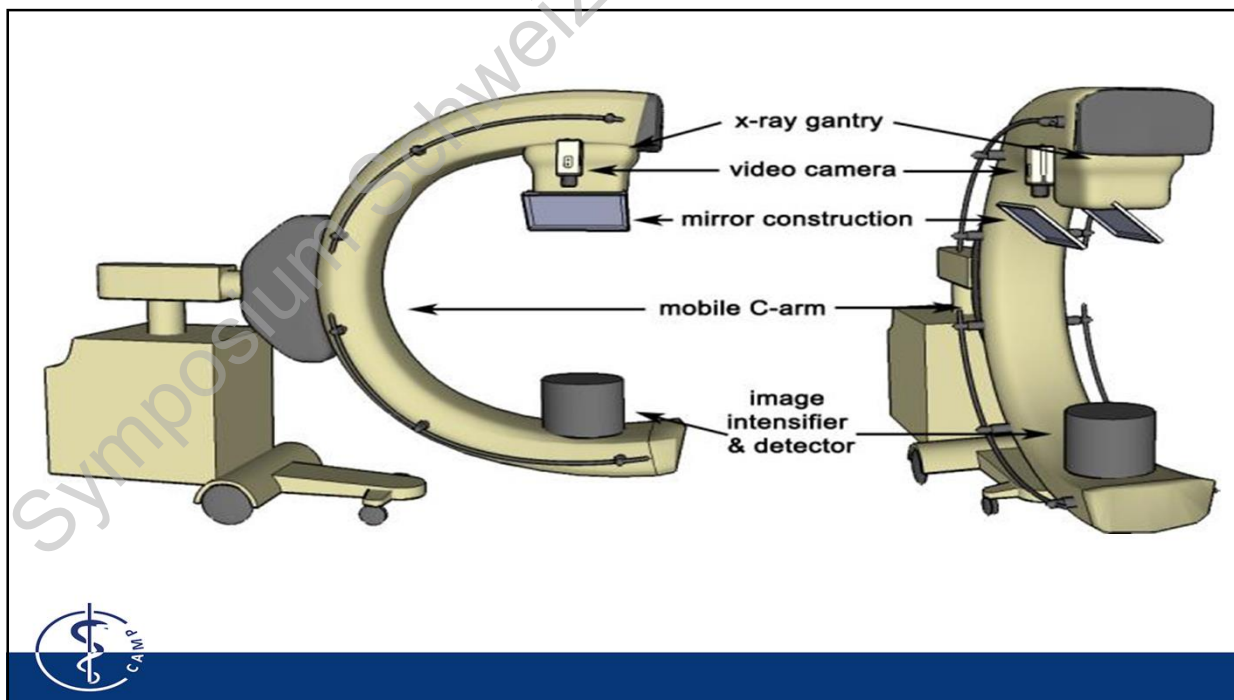
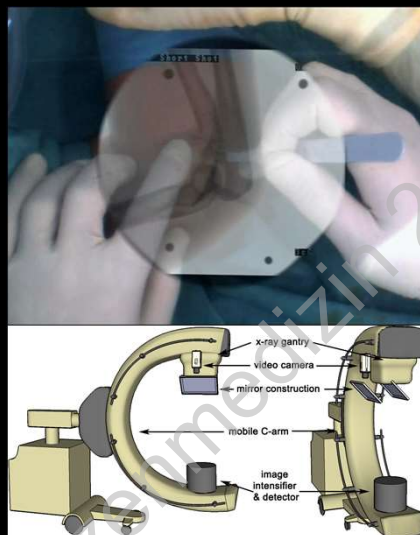
A new interaction paradigm for 3D in-situ visualization

A hand-held mirror in stereoscopic augmented reality

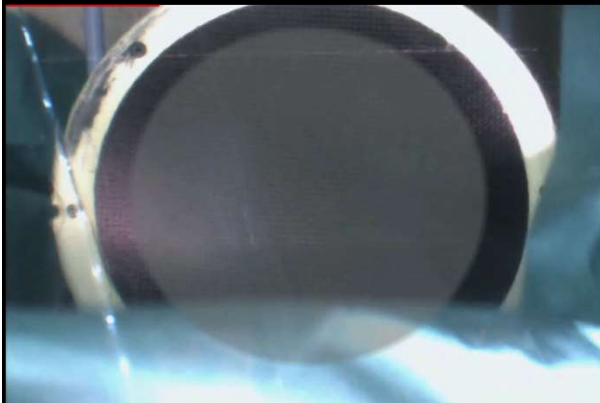
A new interaction paradigm for 3D in-situ visualization

A hand-held mirror in stereoscopic augmented reality

AR in OR Relevance & Workflow Integration



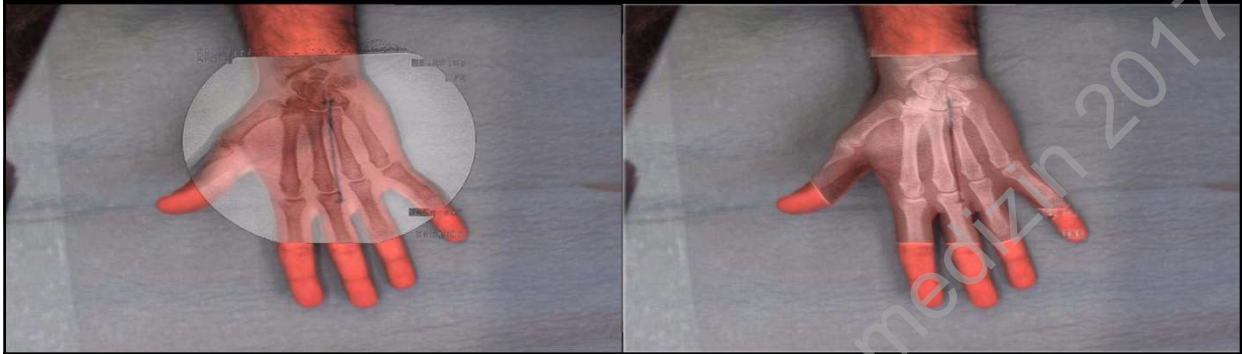
First uses of AR in Trauma Surgeries ...



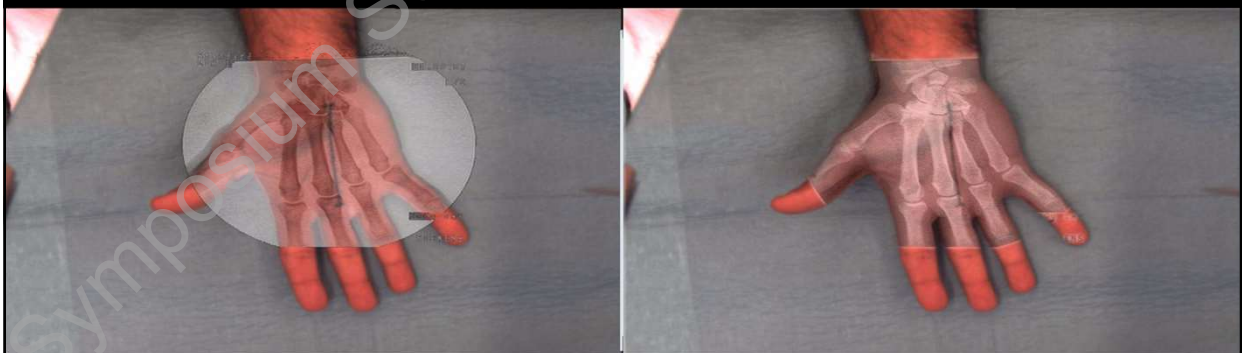
Machine Learning for Relevance based Imaging



Machine Learning for Relevance based Imaging



Machine Learning for Relevance based Imaging



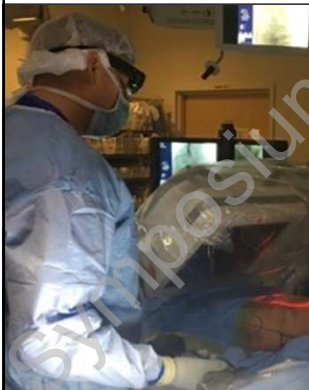


Taxonomy and Uses for 2D Medical Displays

Head Anchored

World/Body Anchored

Object Anchored



Kersten-Oertel M, Jannin P, Collins DL. DVV: a taxonomy for mixed reality visualization in image guided surgery. IEEE Trans Vis Comput Graph. 2012 Feb;18(2):332-52. doi: 10.1109/TVCG.2011.50. PubMed PMID: 21383411.





Computer Aided Medical Procedures

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Computer Aided Medical Procedures

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Left Hand: move window (Up/Down) Right Hand: change system

Prof. Nassir Navab camp@jhu.edu TUM Technische Universität München JOHNS HOPKINS WHITING SCHOOL OF BIOMEDICAL ENGINEERING Prof. Nassir Navab camp@jhu.edu

Skeleton

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Technical components of simulation environment with CT imagina

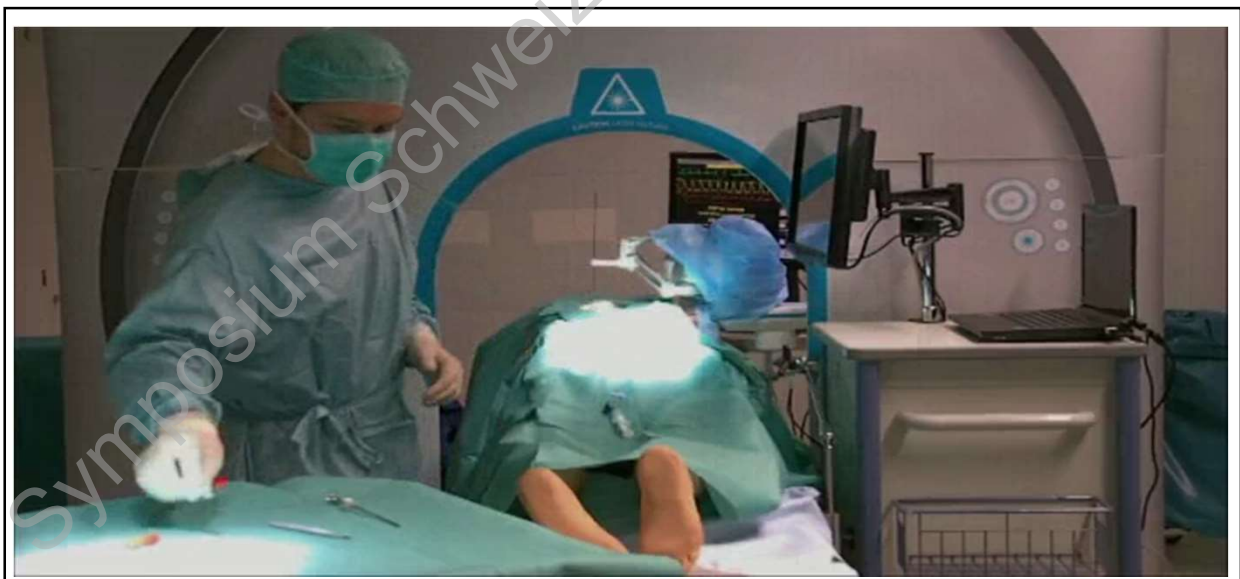
1 2 3 4 5 6 7 8

Computer Aided Medical Procedures Slide 30




A photograph of a surgical team in an operating room. A surgeon in blue scrubs and a surgical cap is standing on the left, looking towards a patient lying on a table. The patient is covered with a blue drape, and a bright surgical light is focused on the patient's body. In the background, there is a large blue archway structure, likely part of a C-arm or similar imaging equipment. To the right, there is a desk with a computer monitor and other medical equipment. A large, semi-transparent watermark "Symposium Schweizer Spitzenmedizin 2017" is overlaid diagonally across the image.

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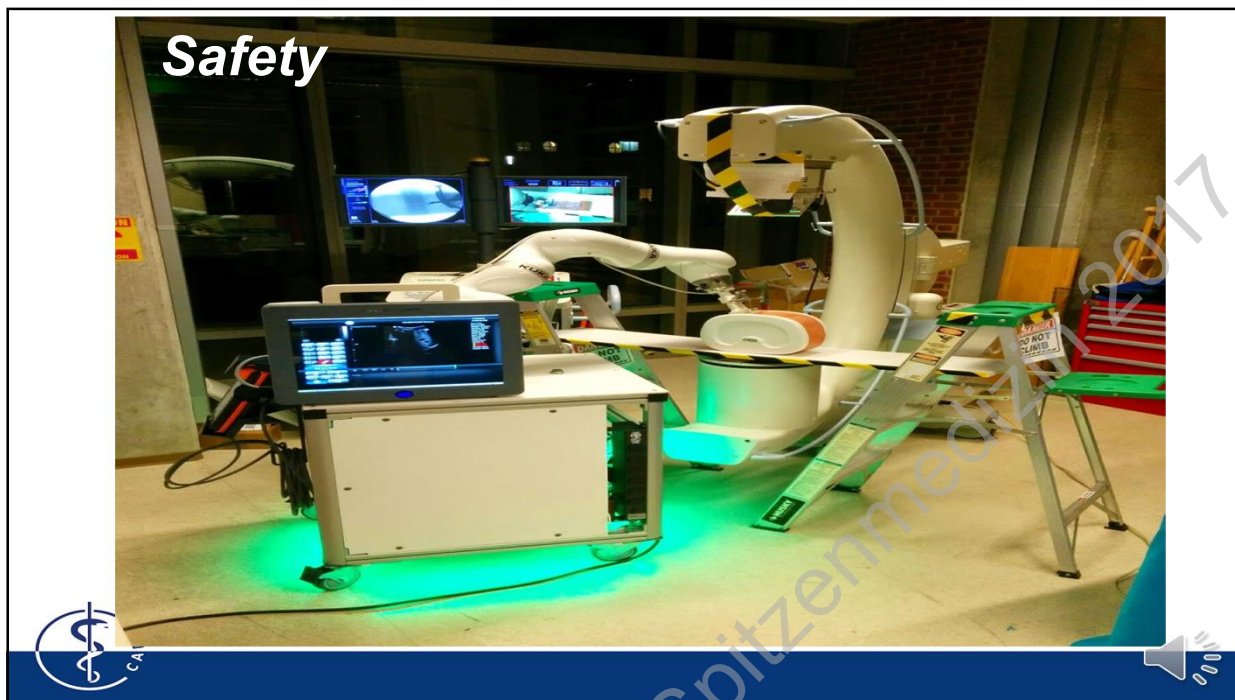


A photograph of a surgical team in an operating room, identical to the one above. A surgeon in blue scrubs and a surgical cap is standing on the left, looking towards a patient lying on a table. The patient is covered with a blue drape, and a bright surgical light is focused on the patient's body. In the background, there is a large blue archway structure, likely part of a C-arm or similar imaging equipment. To the right, there is a desk with a computer monitor and other medical equipment. A large, semi-transparent watermark "Symposium Schweizer Spitzenmedizin 2017" is overlaid diagonally across the image.

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We propose a realistic, radiation-free mixed-reality simulation system to address this problem for C-arm based surgery





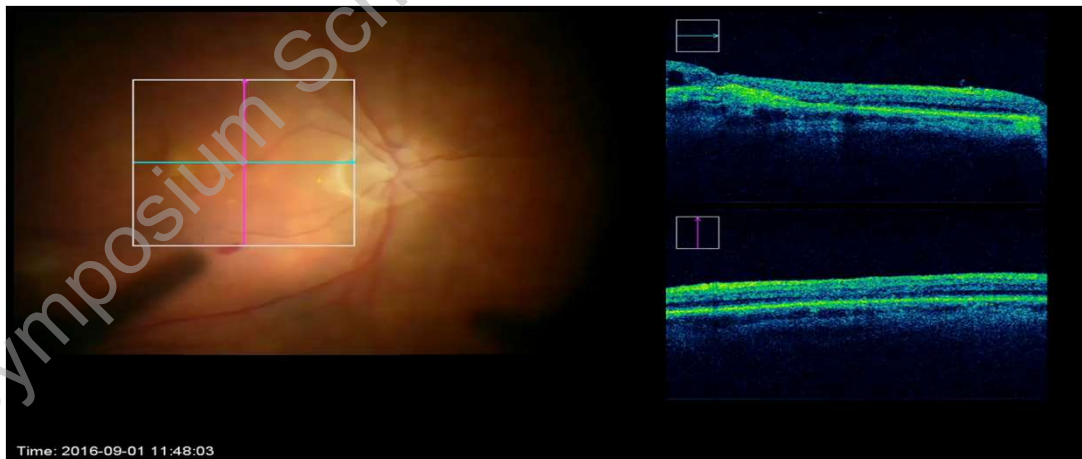
Safety

Symposium Schweizer Spitzenmedizin 2017

 Habert ISMAR 2015, Padoy MICCAI 2015, Ladikos MICCAI 20110



Sonified Video Sequence from a Surgery



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



Sasan Matinfar, Surgical Soundtracks

September 11, 2017

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4