Real-time 3D reconstruction: applications to collision detection and surgical workflow monitoring

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Presented by Nicolas Padoy
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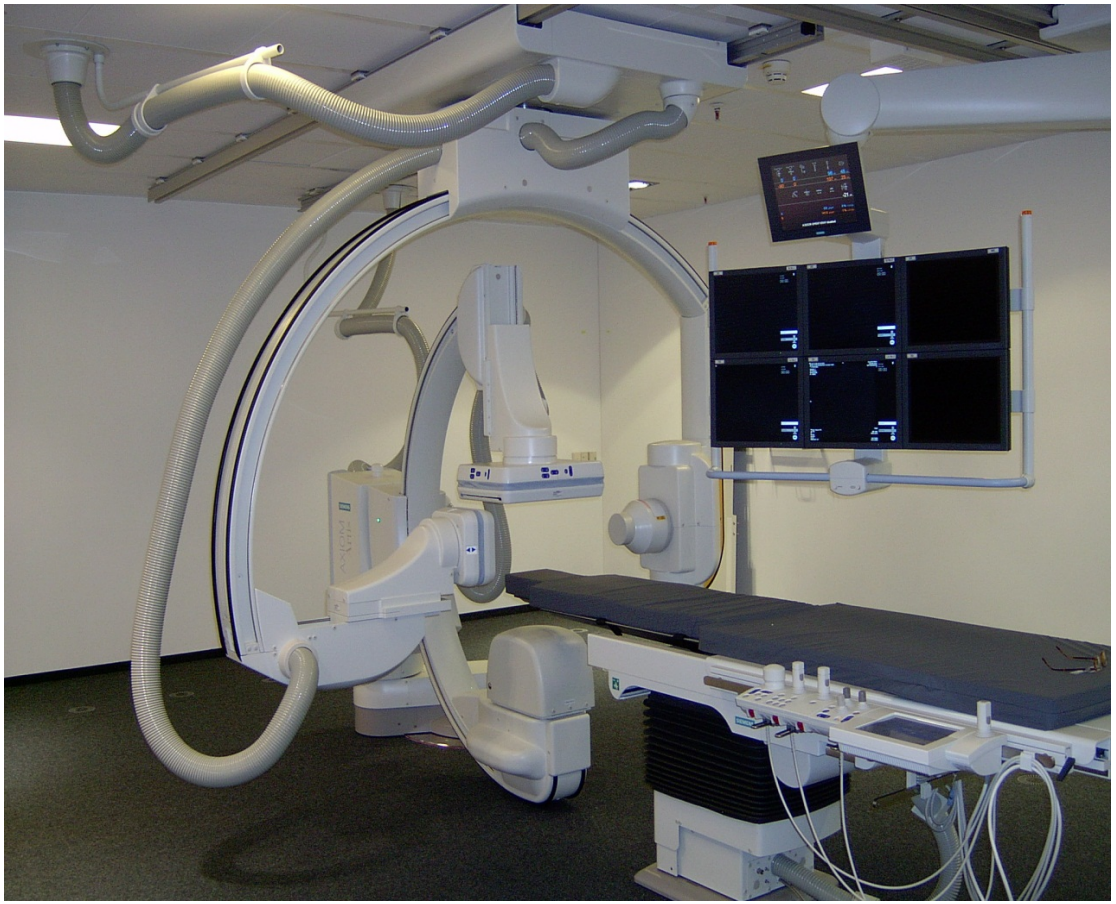
Motivation

Due to safety concerns:

Medical Robots are not used at their full speed & functionality:

- Need to predict and avoid collisions



Siemens/Kuka Angiographic robot (Zeego)

Motivation

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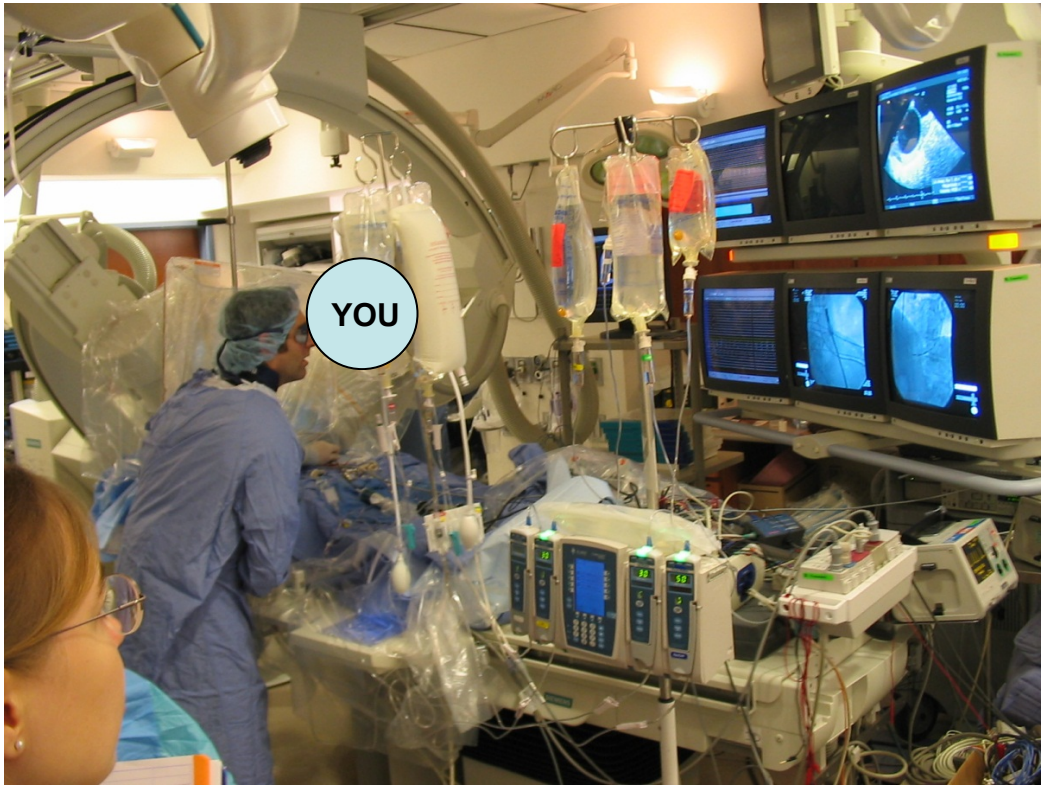


- Need to predict and avoid collisions
- Need to reconstruct & recognize objects in dynamic, complex environment
- Need to recover and monitor surgical workflow

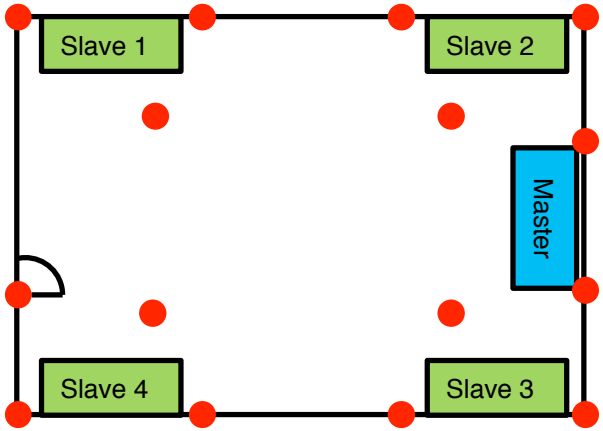
Multi-view Real-time Reconstruction

Shape-from-Silhouette: Real-time 3D reconstruction Systems

- There are many real-time systems today
- It is comparatively easy to build such a system due to increase in computational power and its availability at reasonable price
- Most systems use the volumetric approach due to its simplicity
- One notable exception is the GrImage platform at INRIA Rhône-Alpes

Shape-from-Silhouette: CAMP system

- 16 synchronized cameras mounted on the ceiling
- Working volume 3.5m x 3.5m x 2.5m
- Runs at 30 Hz

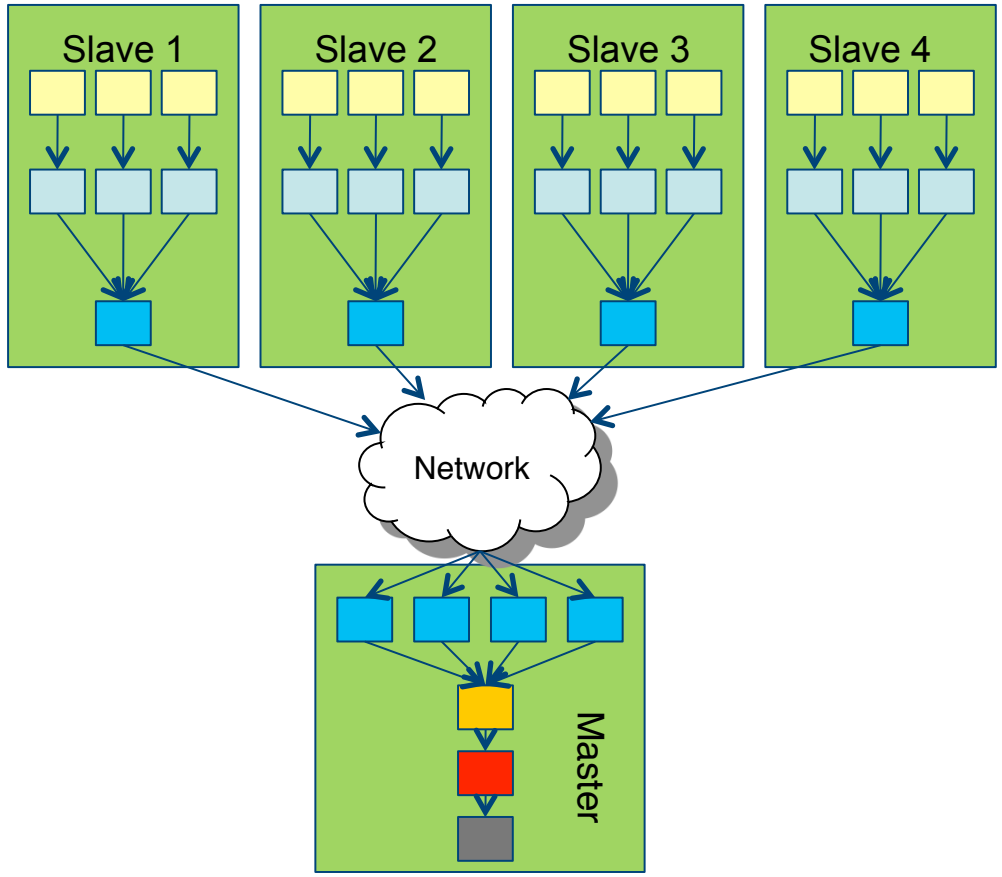


Shape-from-Silhouette: CAMP system

Camera images

Silhouette images

Local Reconstruction



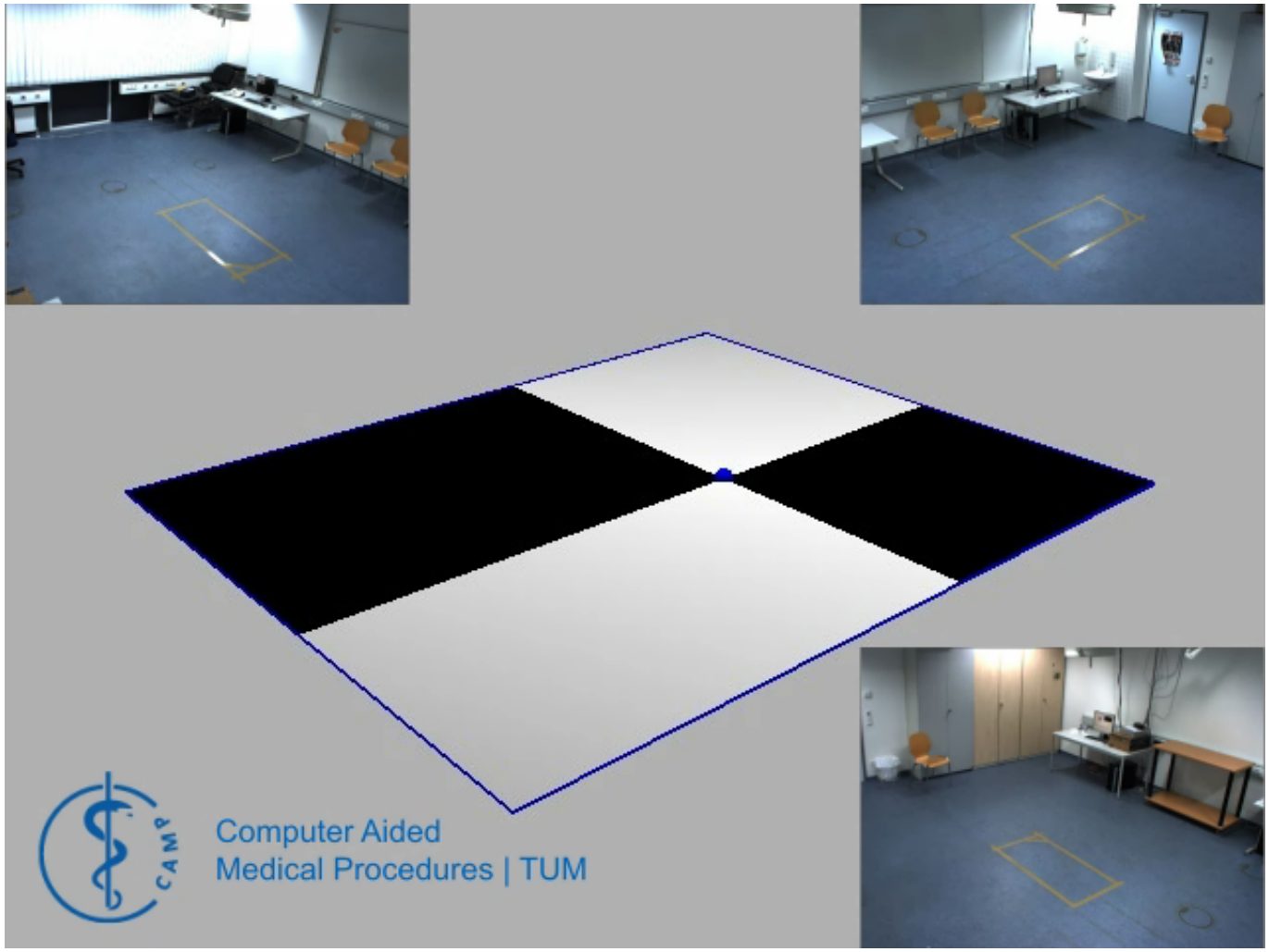
Local Reconstructions

Global Reconstruction

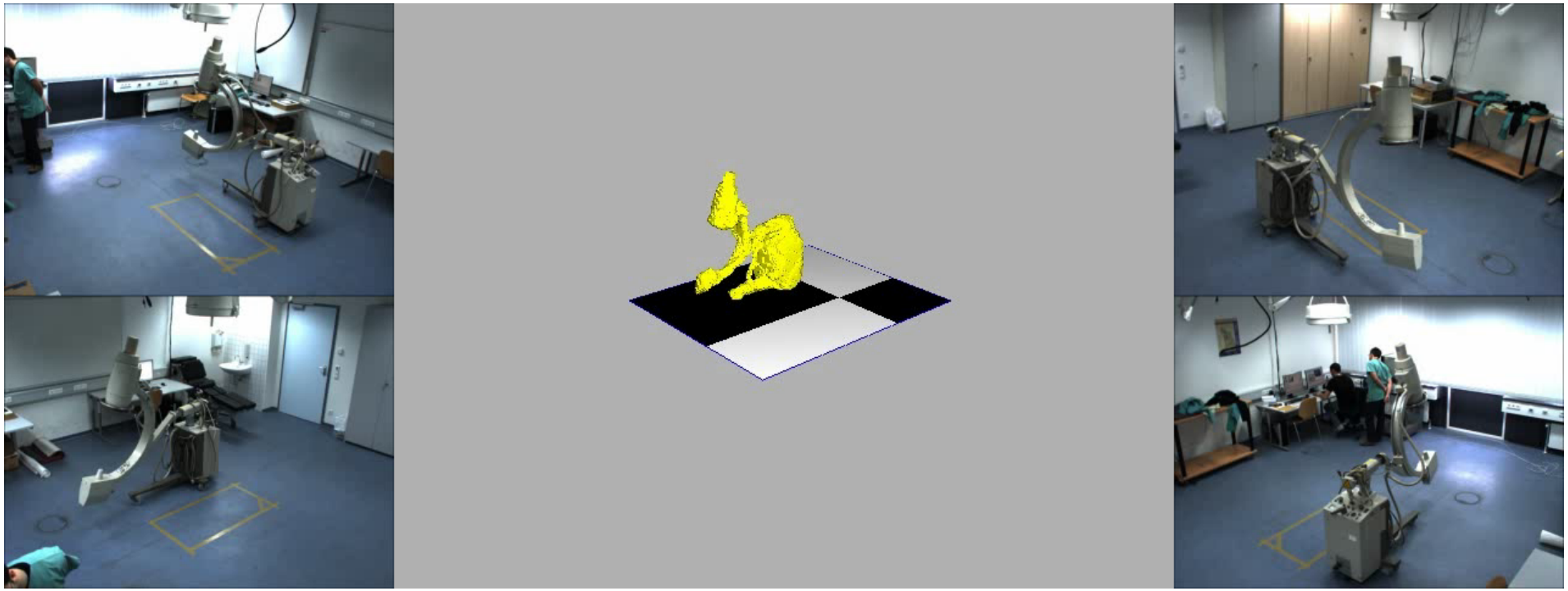
Secure Hulls

Visualization

Shape-from-Silhouette: CAMP system



Collision Avoidance System: CAMP system



Shape-from-Silhouette: Summary

- Advantages
  - Only silhouette images are required
  - No need for correspondences or texture
  - Robust
  - Efficient and easy to implement
- Disadvantages
  - Cannot recover concavities not seen in the silhouette images
  - Artifacts for complex scenes and low number of cameras
  - Needs calibrated input images
  - Silhouettes need to be recovered

Additional applications of real-time 3D reconstruction:

Increasing the safety for interventional radiology crew:

Real-time 3D reconstruction

+

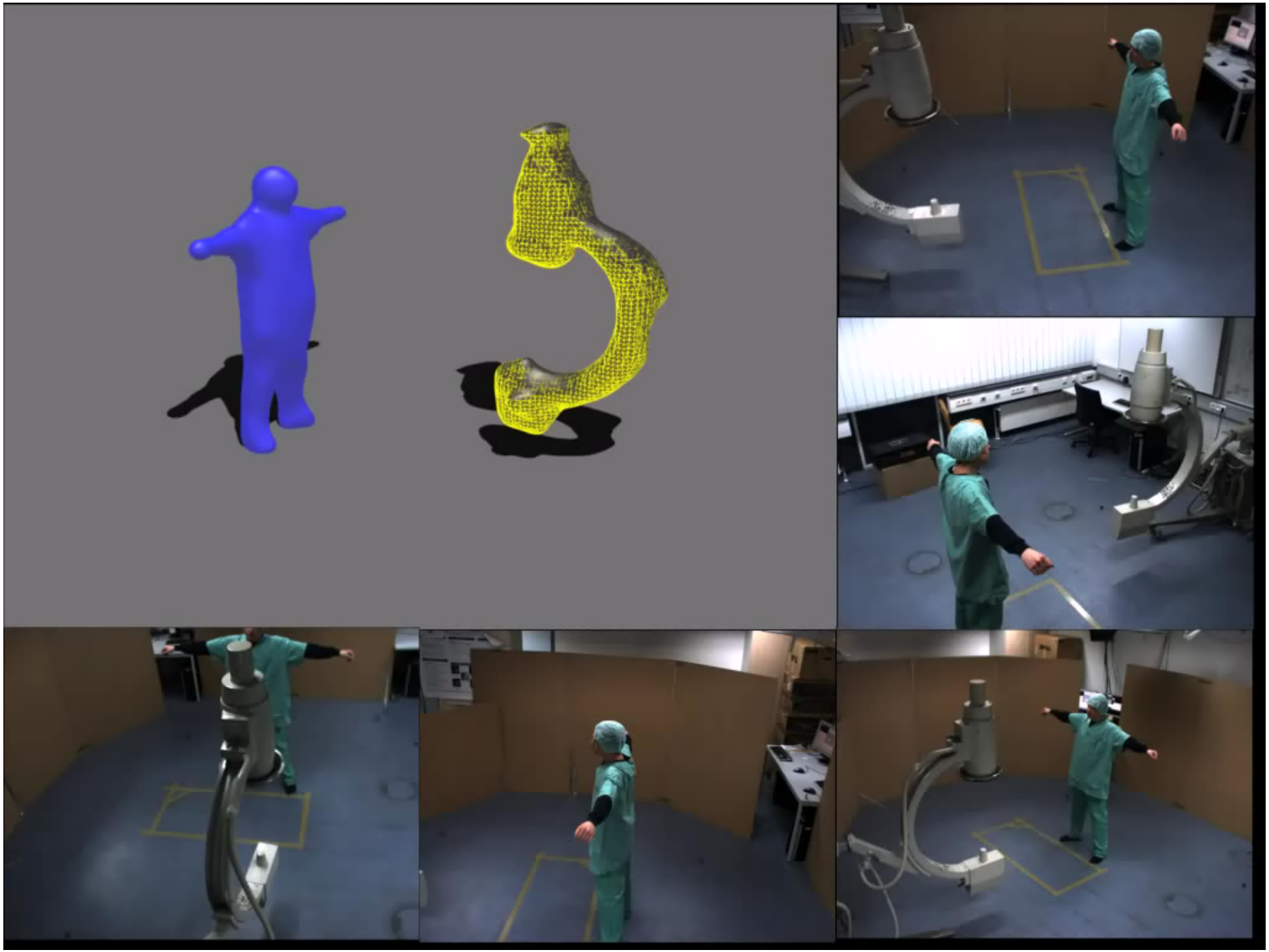
Recognition and 3D surface path tracking

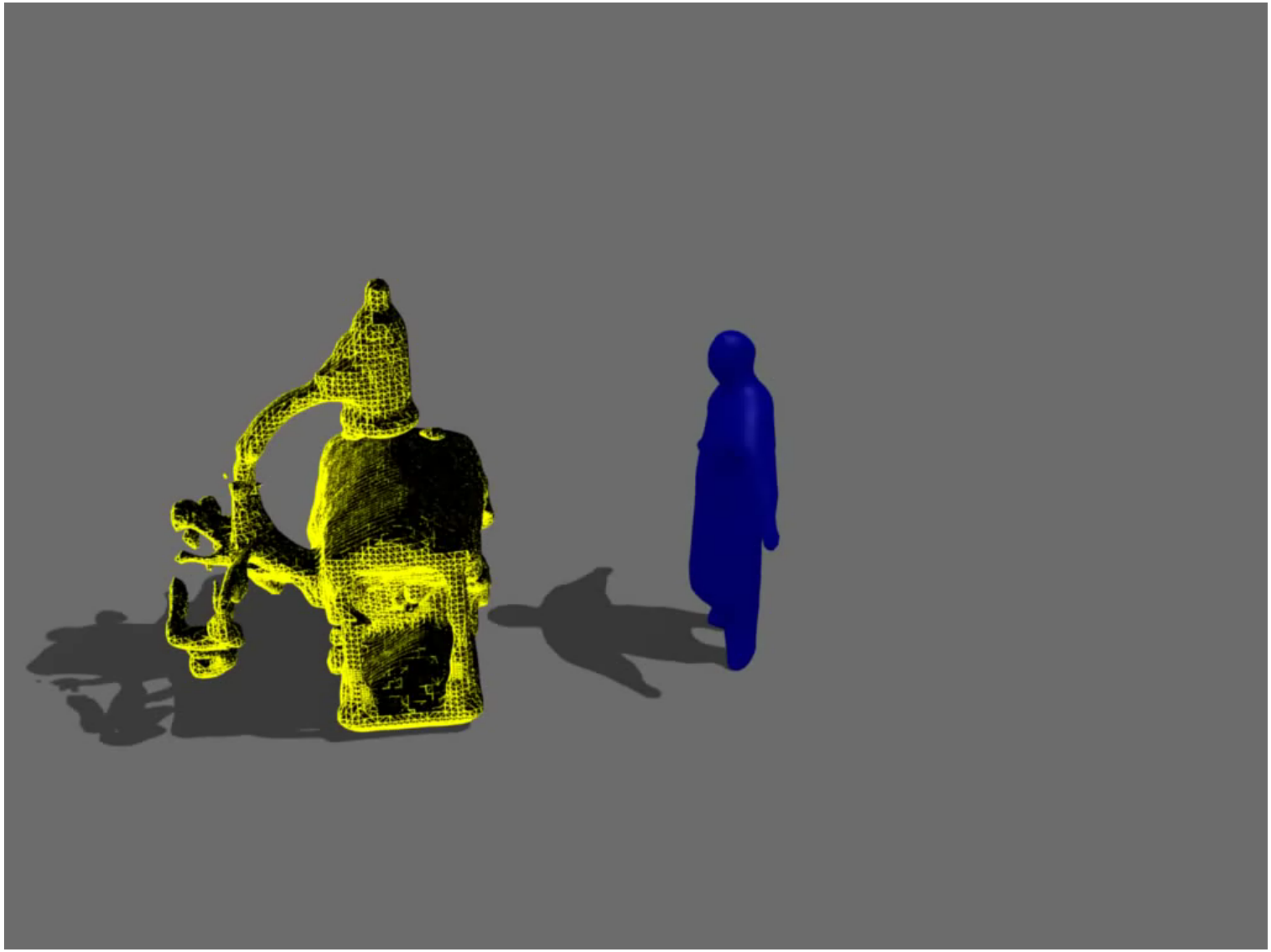
+

Radiation distribution and scattering modeling/estimation

+

Estimation of individualized accumulated radiation to body parts





Additional Applications of real-time 3D reconstruction: Recovering and monitoring surgical workflow for predicting the need and triggering/controlling events

Acquisition of training data

+

Recovery of workflow based on signals (see next talk)

+

Recovery of workflow based on 3D flow

+

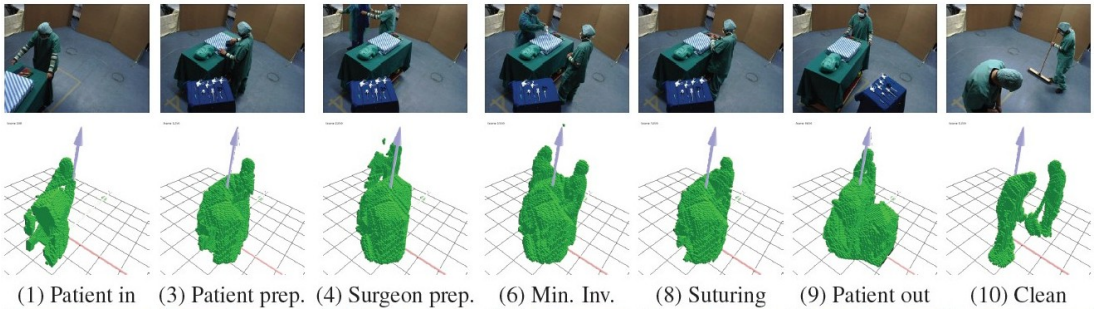
Monitoring of workflow and use for UI & robot control (see next talk)


Workflow Monitoring based on Multi-view Reconstruction
Nicolas Padoy, Diana Mateus (CAMP, TUM, Munich)
Daniel Weinland (CVLAB, EPFL, Lausanne)

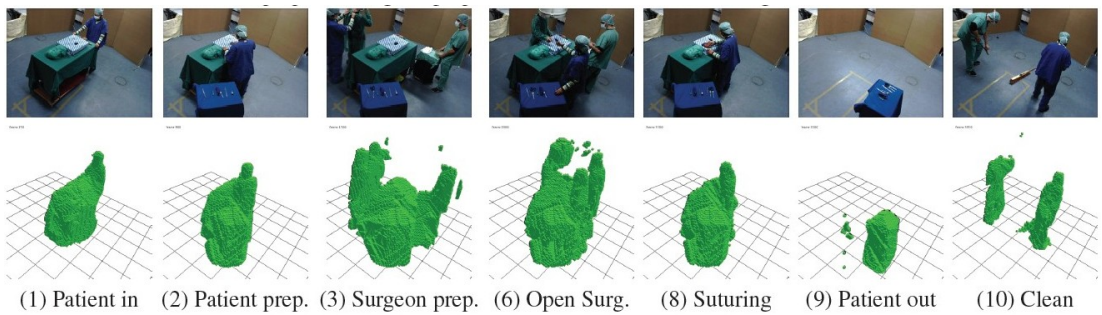
Scenario & Data

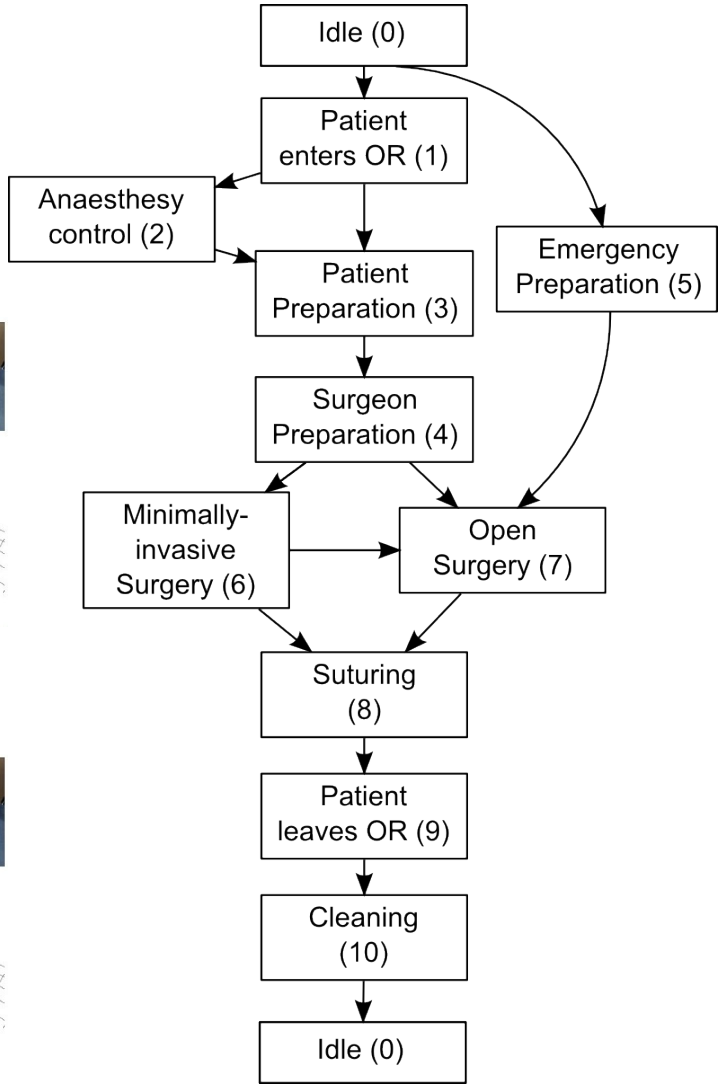
- Dataset of 22 sequences

Endoscopic



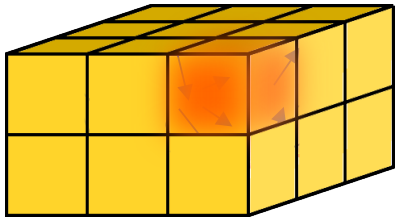
Open



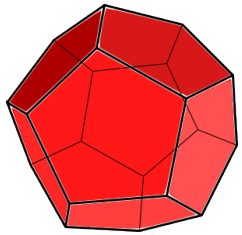


Methods: 3D-flow

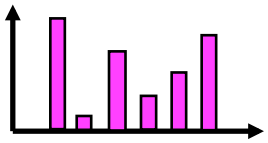
- Capture global activity pattern
- Lucas-Kanade in 3D
- Spatial histograming
  - Smooth voting with RBF
- Orientation quantization
  - Uniformly in 12 directions
- Observation vectors
  - Size 216
  - Dimensionality reduction



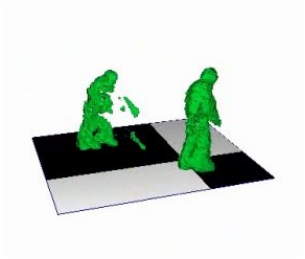
3x3x2

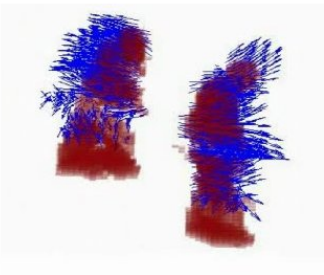


dodecahedron



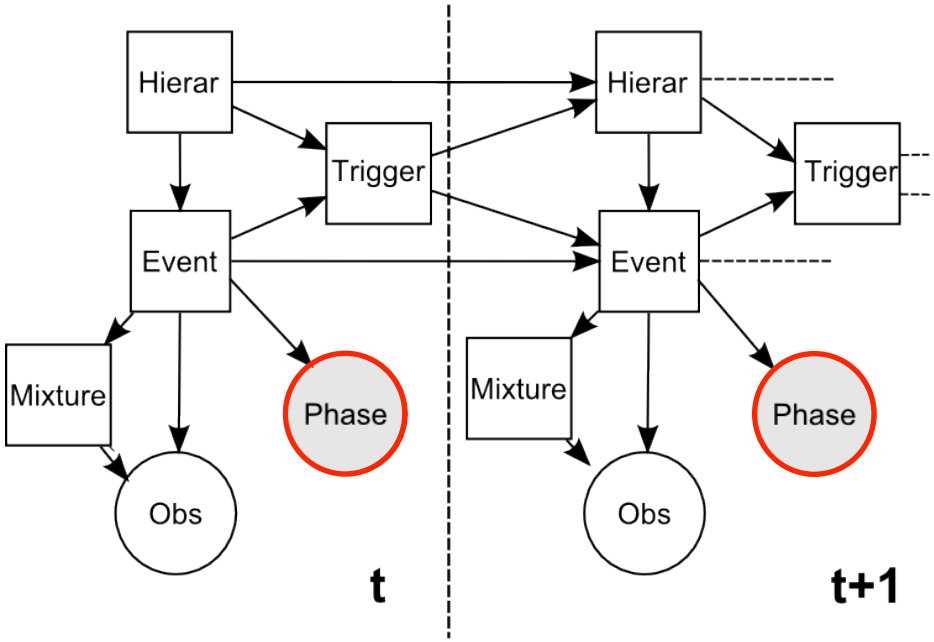
feature vector



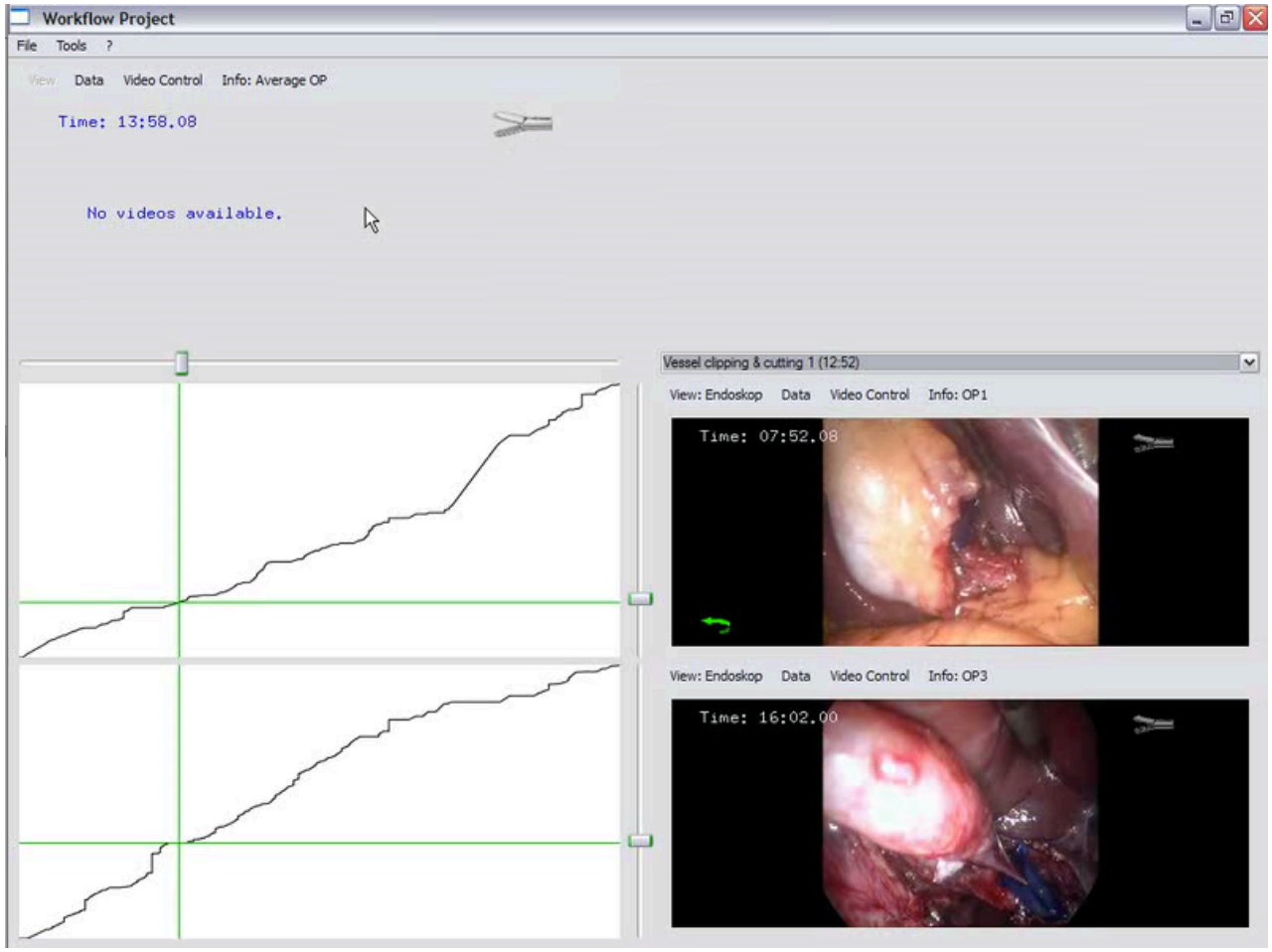


Methods: Workflow-HMM

- Temporal process modeling
- Hierarchical HMM with 2 levels, augmented with phase probability variables
- Dynamic Bayesian Network representation:



Recovery of workflow based on signals



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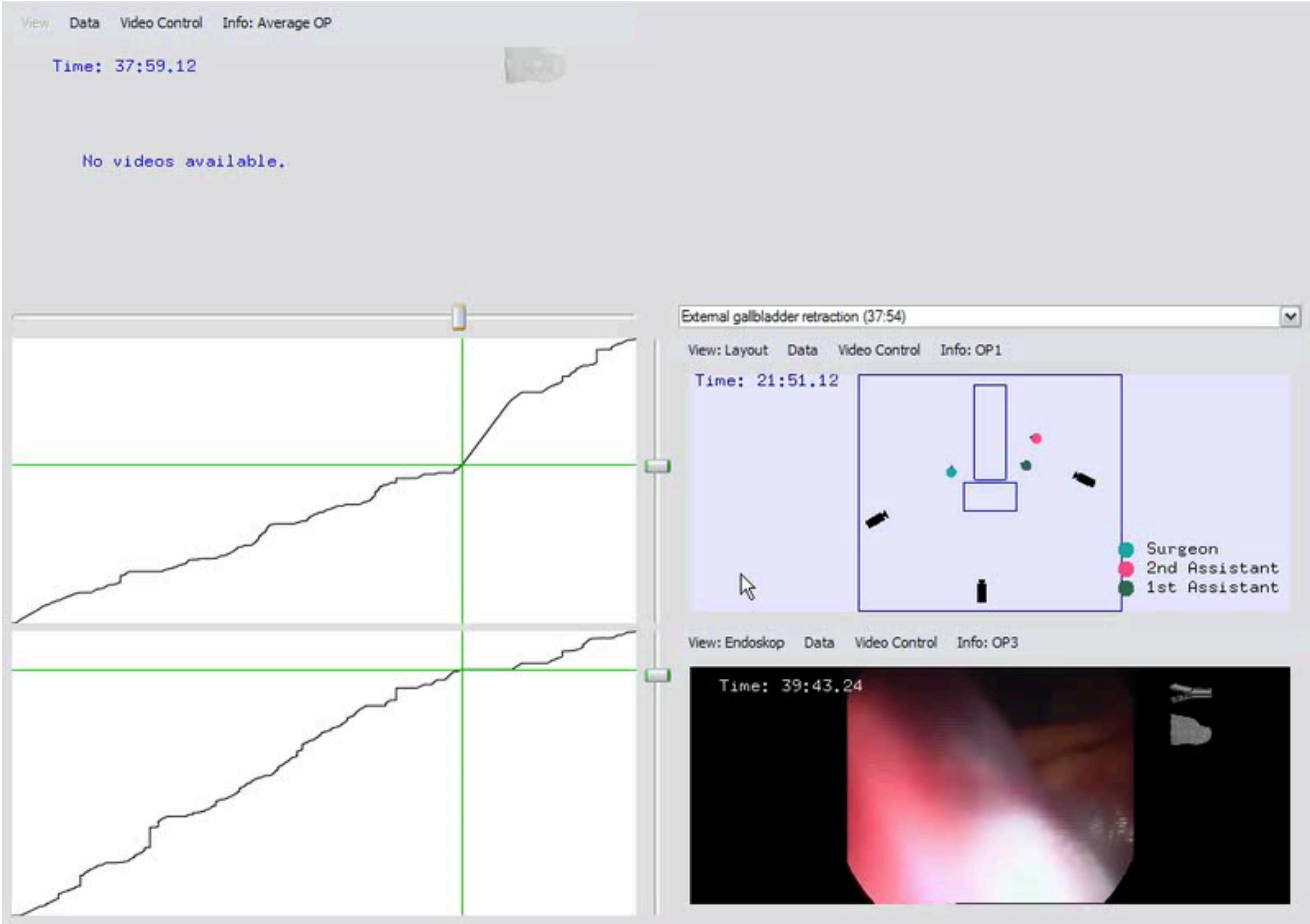

Follow up project at TUM:

- Joint DACH project with:
  - EPFL (P. Fua, V. Lepetit)
  - TU Graz (H. Bischof)

- Five researchers over three sites
- Multi-camera systems in OR
- + Kinect, TOF, Inertial Sensors, …
- *Development of advanced workflow based Surgical interfaces …*

Looking forward to national and international research collaboration …

Thanks to CAMP@TUM

2009/11pubs : 9 TMI, 4 MedIA, IJCV, PAMI, 29 MICCAI, 12 CVPR, 3 ICCV, 3 ECCV, 9 ISBI, 7 ISMAR, 8 BMVC, 2 IPMI, 2 IPCAI, …

Thank You

For more information

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campar.in.tum.de