

**Berne University  
of Applied Sciences**

Engineering and  
Information Technology



**Fraunhofer**

# *Haptic Osteosynthesis Virtual Intra-operative Surgery Support Environment (HOVISSE)*

***Hasler MMI Workshop, Appenberg, 1. - 2. March 2007***

**HASLERSTIFTUNG**

Call for Proposal 2005  
Man-Machine Interaction

***A research collaboration between the  
Berne University of Applied Sciences, the  
University Hospitals of Basel and Zurich and the  
University of Basel Computer Science Department***

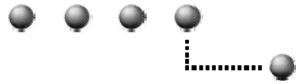


## *Presentation Overview*

- **HOVISSE Project Overview** (U.Künzler, UASB)
- **Work Package C Medical Requirements** (D.Hoigné, CARCAS)
- **Work Package C Simulation** (S.Fischli, UASB)
- **Work Package C Optimization** (J.Eckerle, UASB)
- **Project Summary and Outlook** (U.Künzler, UASB)



# HOVISSE Project Partners



## **Berne University of Applied Sciences**

- Computer Science and Mechanical Engineering Department



## **CARCAS Research Group of University Hospitals of BS and ZH**

- Computer Aided Radiology and Computer Aided Surgery Group (CARCAS)



## **University of Basel Computer Science Department**

- Computer Science Department (Prof. Dr, Thomas Vetter)



Fraunhofer

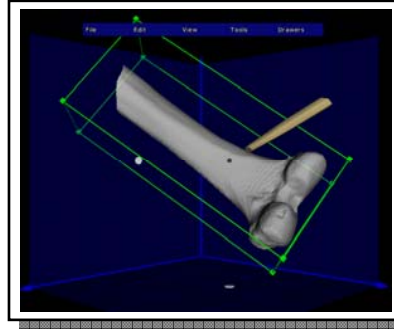
## **Fraunhofer IPA Institute**

- Institute for Manufacturing Engineering and Automation, Stuttgart (D)

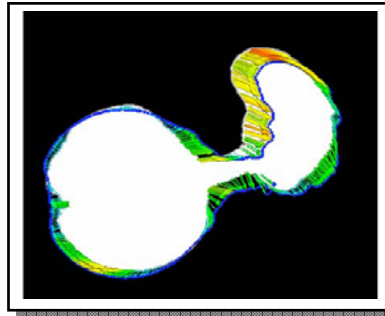
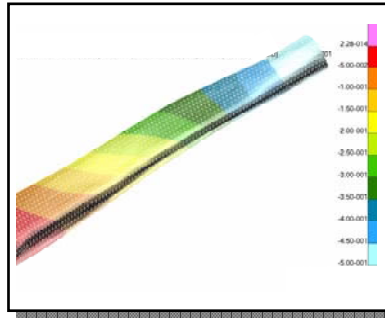


# HOVISSE Research Plan (Work Packages)

## Haptic Osteosynthesis Planning

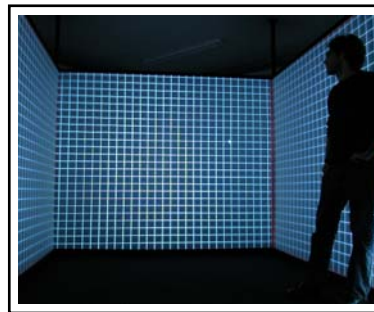
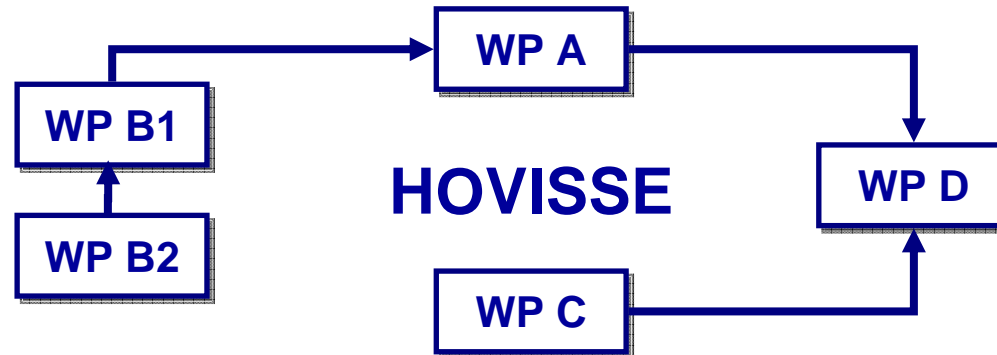


## FEA Optimized Implant Selection and Positioning

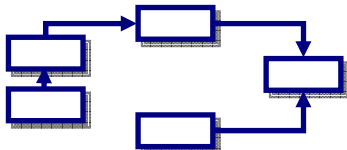


## Statistical Modelling of 3D Bone Morphology

## AR Intra-operative Information System



## VR Simulation of Operation Room Workflow



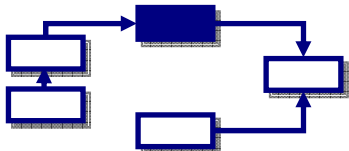




# *WP-A: Haptic Osteosynthesis Planning*

## **Haptic Osteosynthesis Planning**

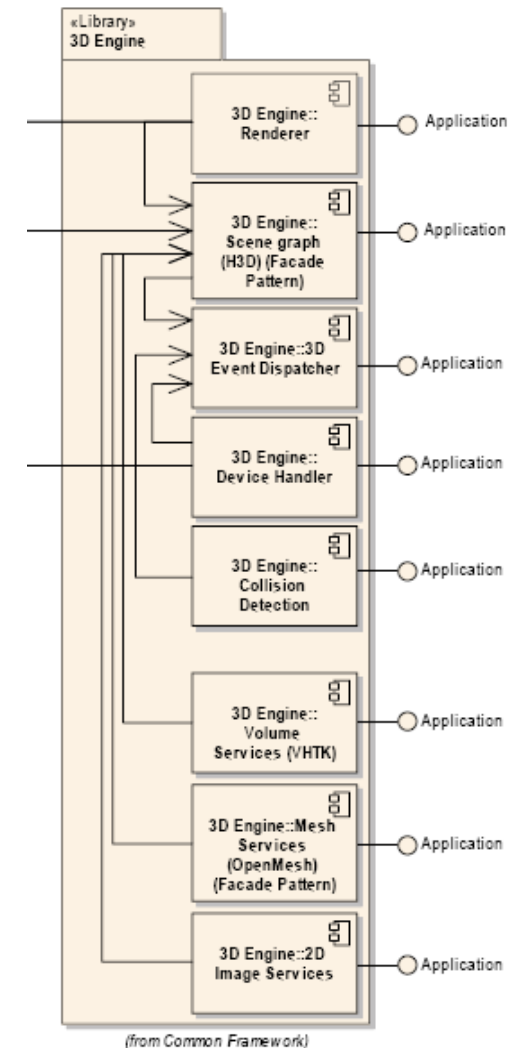
- **Work Package Research Goals**
  - Improvement of current state of the art 2D/3D visual only Osteosynthesis planning tools
  - Modelling of haptic feedback during pre-operative planning and implant fitting procedure
  - Development of an immersive 3D stereoscopic and haptic pre-operative planning environment
  - Development of advanced multi-modal visual-haptic man-machine interaction techniques





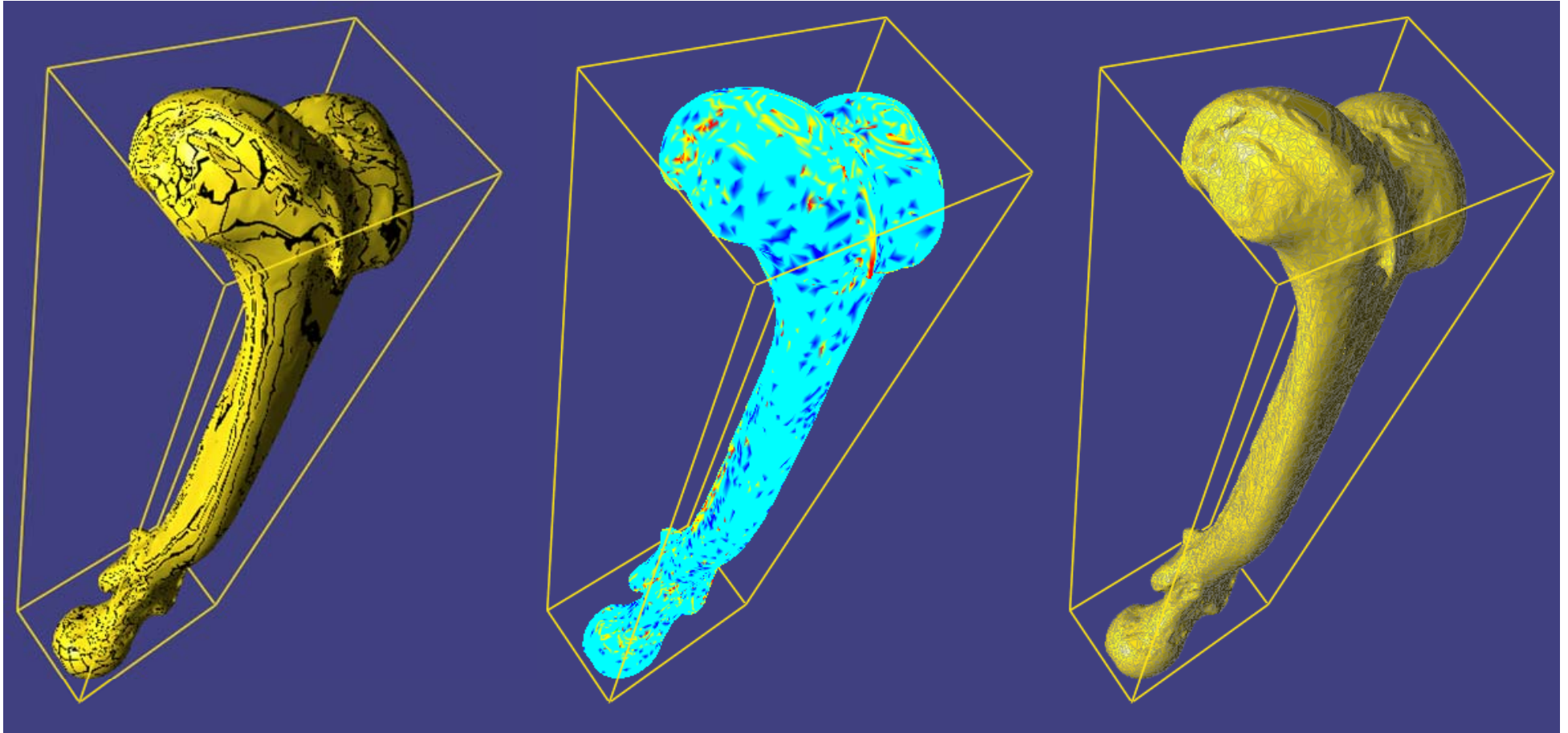
# WP-A: Technical Progress

- **HOVISSE Software Architecture Design Goals**
  - Common Software Architecture for all HOVISSE WPs
- **I3D - Immersive 3D Software Framework**
  - Platform independent rendering engine implemented with C++/OpenGL
  - GLUT based window context as foundation for 3D UI
  - Unified scene graph based rendering for geometry, volume and haptics data
  - OpenSource base distributed rendering framework for CAVE visualization (Chromium)



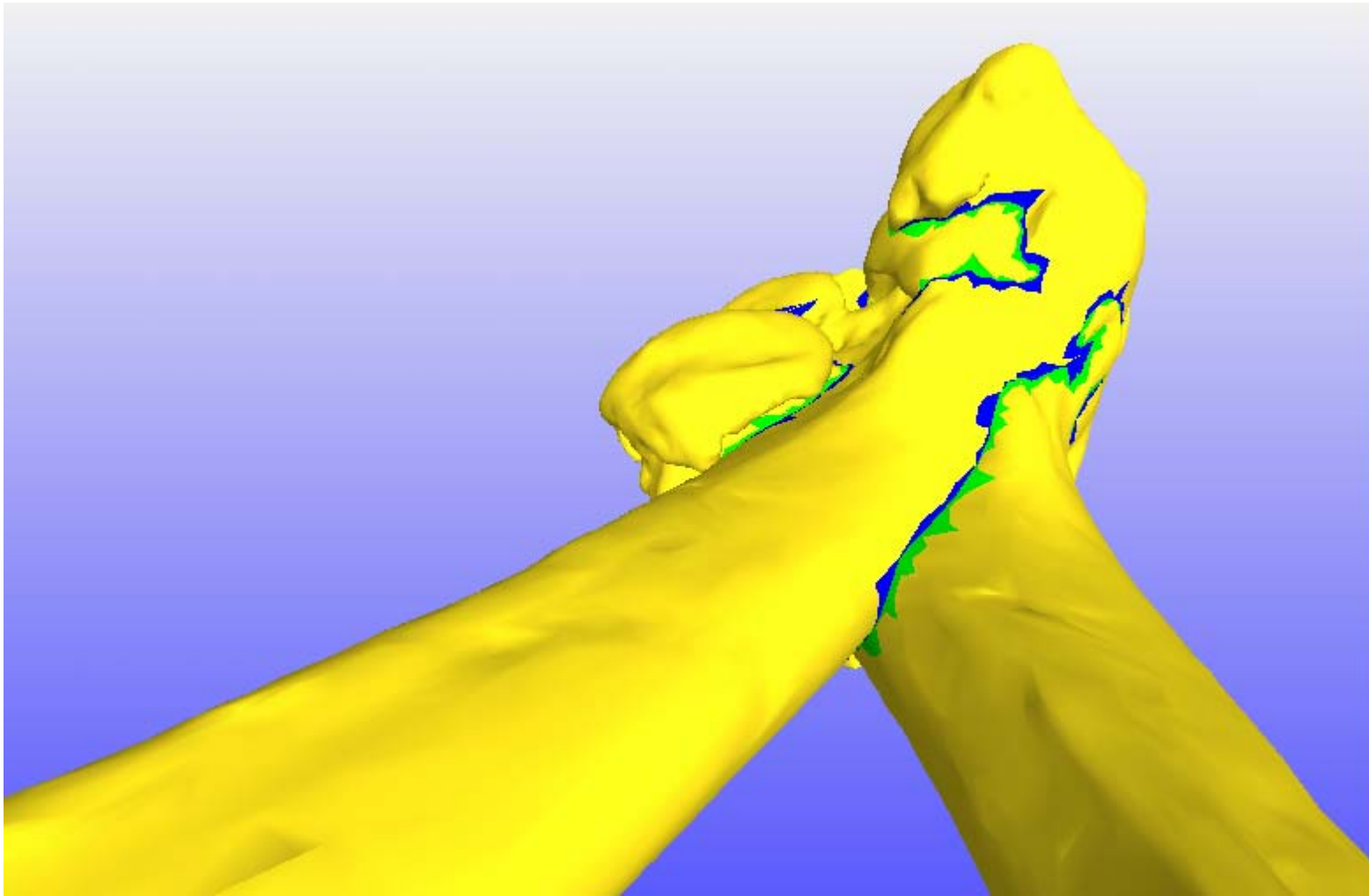


# *WP-A: Mesh Surface Analysis*





## *WP-A: Collision Detection Prototype*

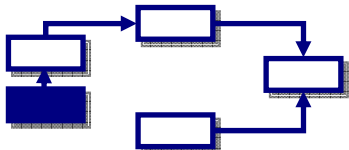
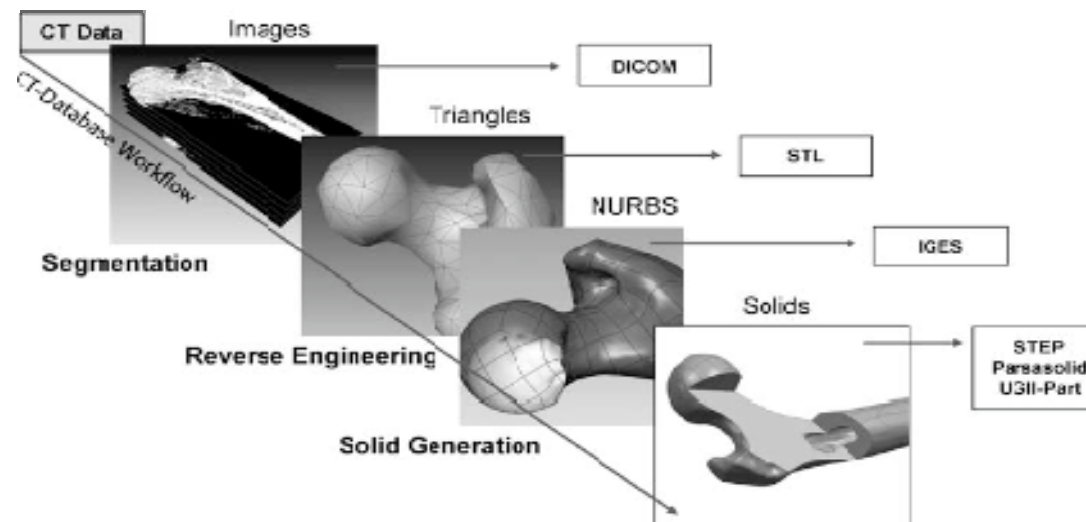




# WP-B2: Statistical Modelling of Bones

## Statistical Modelling of 3D Bone Morphology

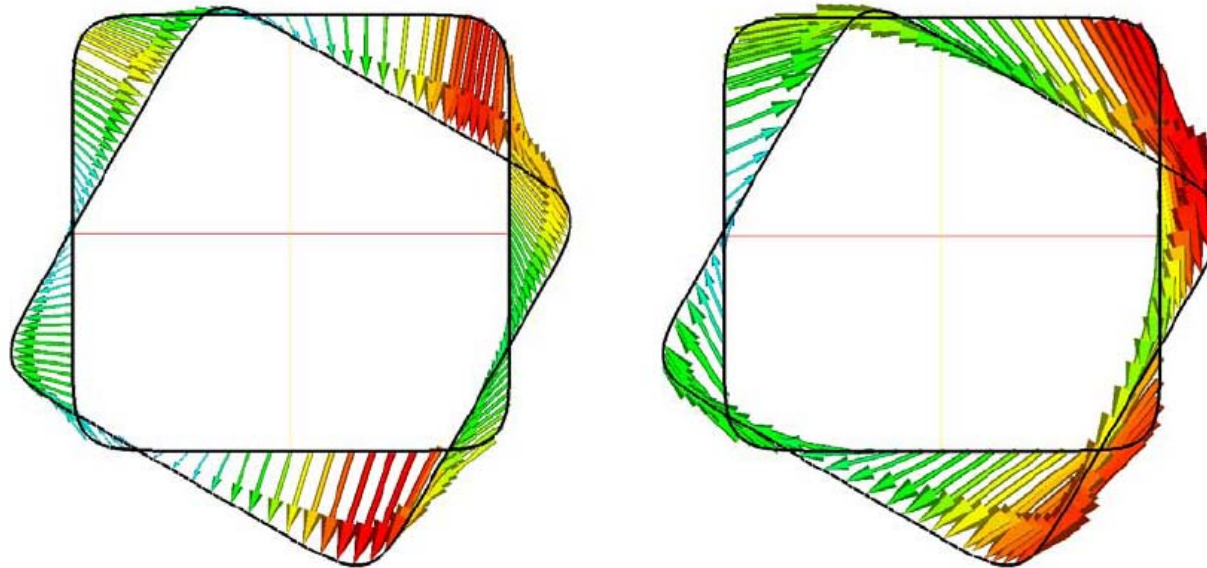
- **Work Package Collaboration Partner**
  - University of Basel Computer Science Department
- **Work Package Research Goals**
  - Generalized 3D statistical bone model to map shape and density distribution
  - Human Bone Repository (26 Femora)





## *WP-B2: 3D Morphable Model of the Femur*

- **Goal: Building a statistical shape model of the femur**
  - Mapping high resolution 3D bone structure (spongiosa) to low resolution data
  - Investigating possibilities of shape prediction for missing parts
- **Task: Development of non-rigid registration algorithm**
  - Non-rigid registration method to put many example shapes into correspondence

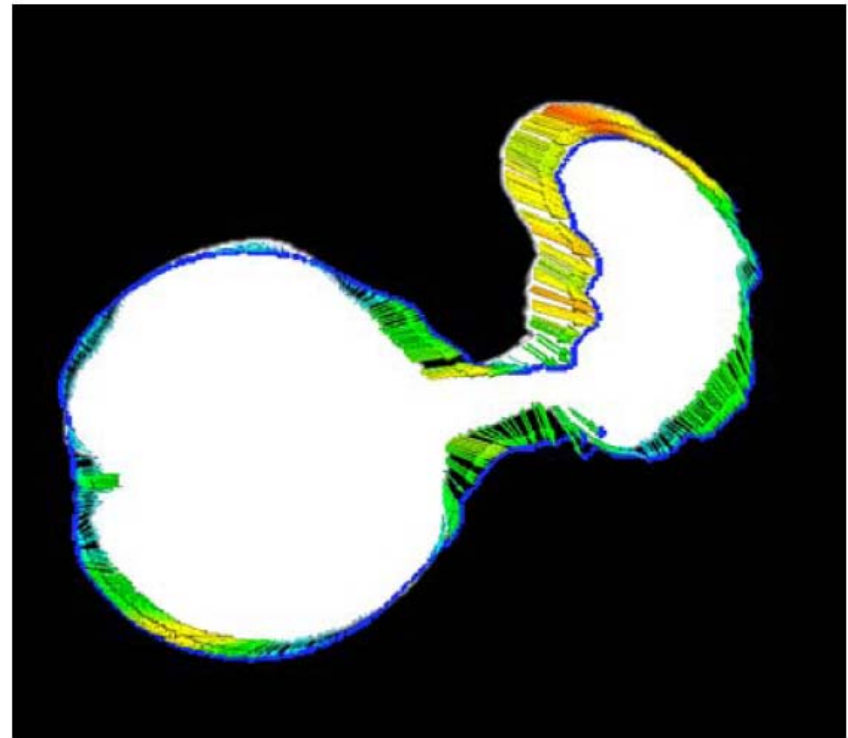
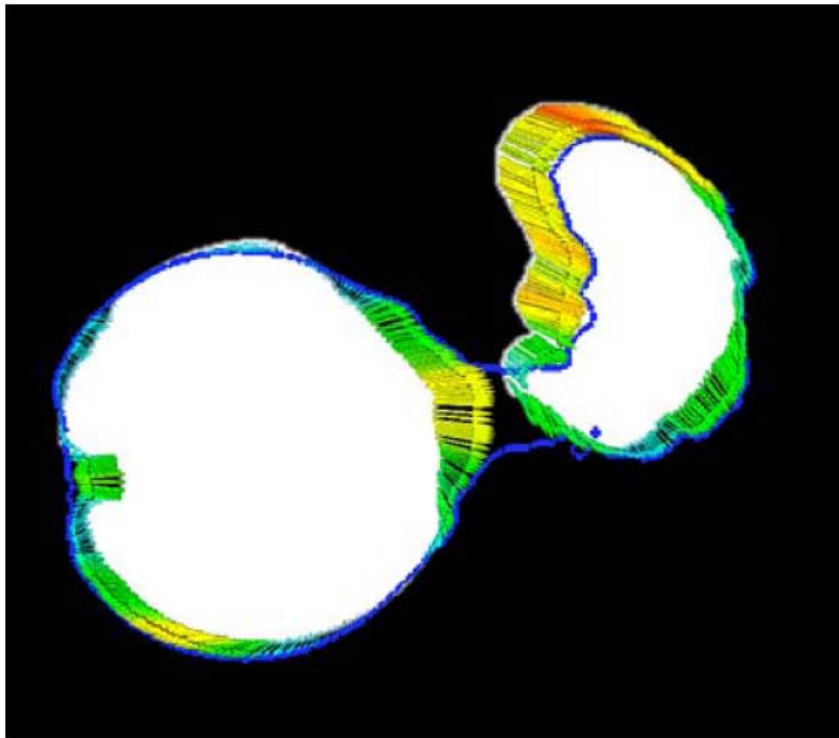


- Comparison between a standard- (left) and curvature-sensitive registration (right)



## *WP-B2: Non Rigid Registration*

- **Registration of two 2D slices with different topology**







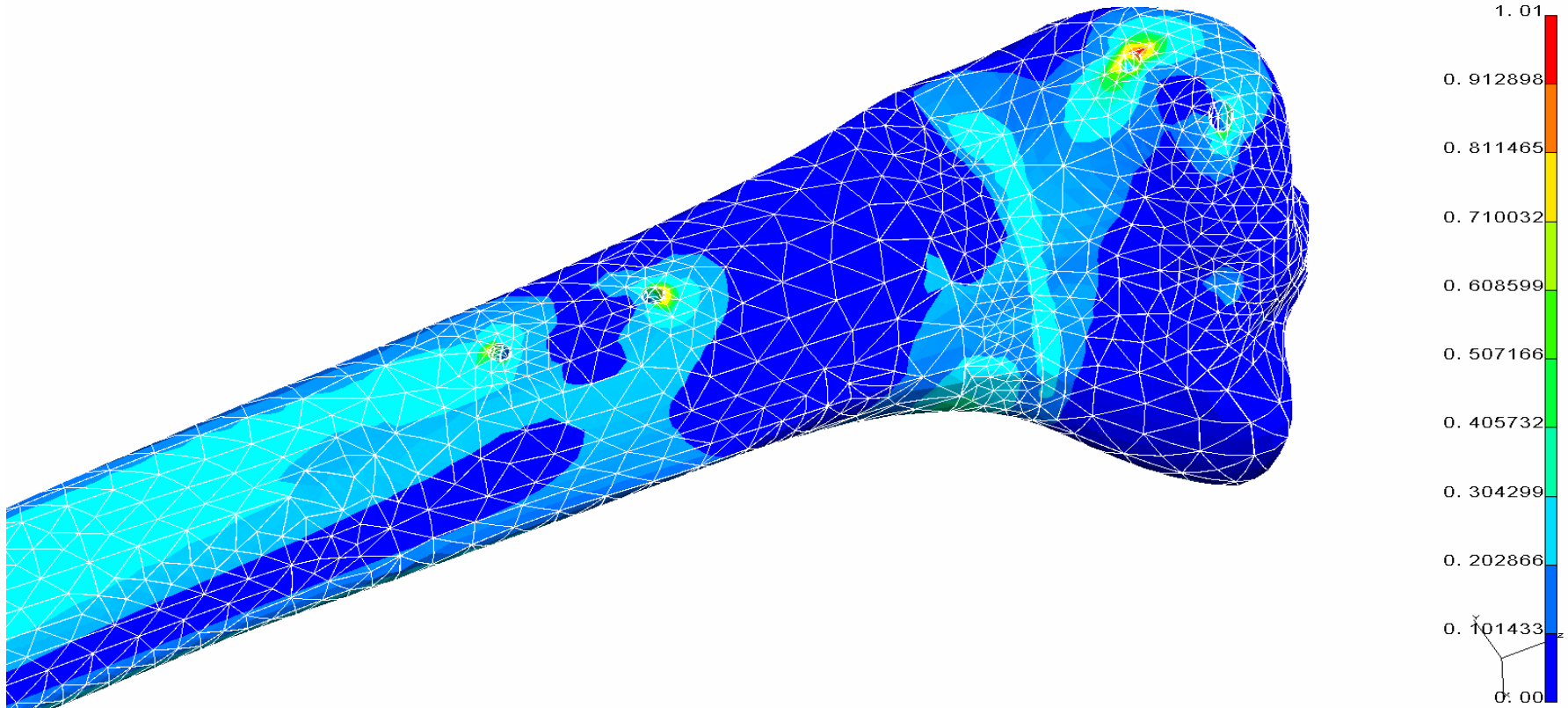
# WP-B2: Bone Models

- **Geometry Transformation: STL -> Nurbs -> FEM**

RESULTS: 3- B. C. 1, STRESS\_3, LOAD SET 1  
STRESS - VON MISES M N: 0.00 MAX: 1014.33  
FRAME OF REF: PART  
SCALE: 3

MODEL\_SOLUTION SOLVE

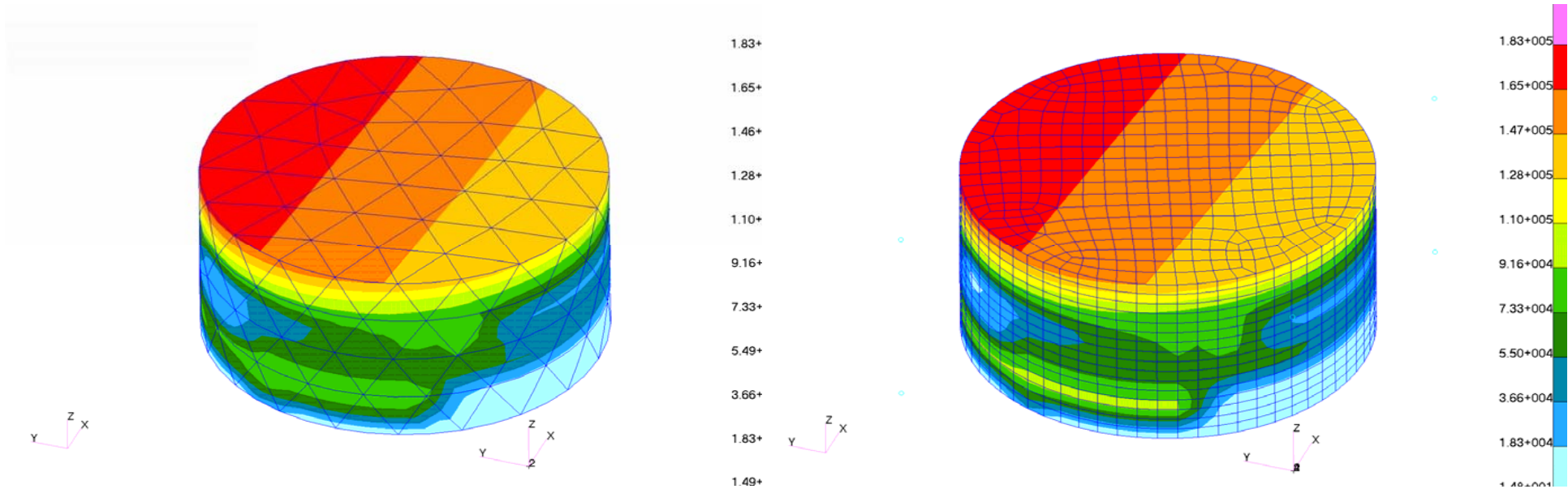
VALUE OPTION: ACTUAL





# WP-B1: Inhomogeneous Material Properties

- **Changed Geometrical Topology - Constant Material Distribution**



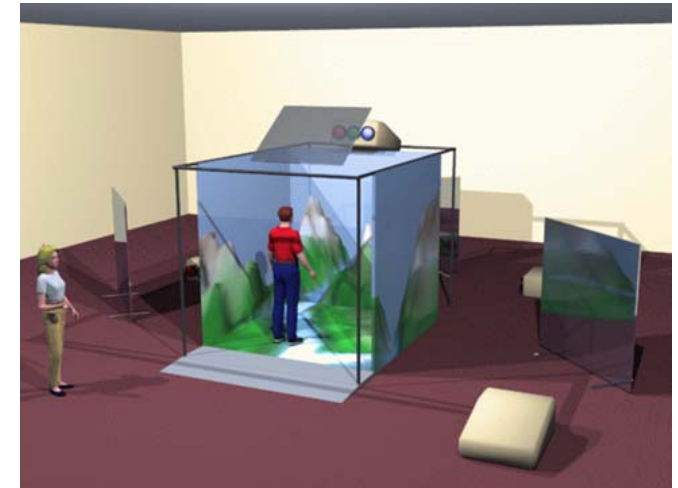




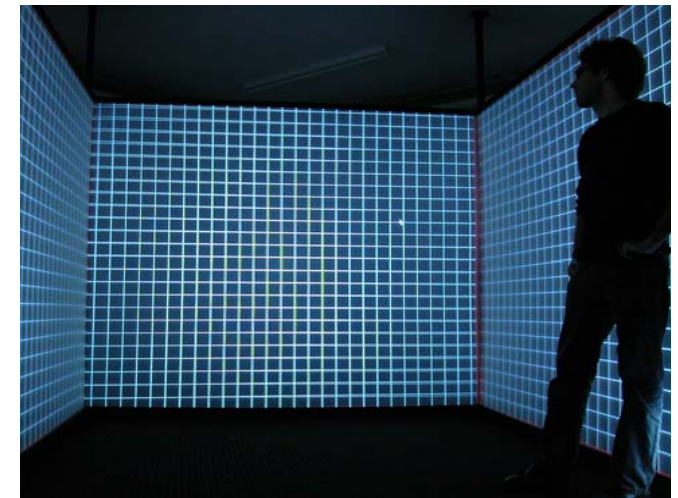
# WP-C: VR Simulation of OR Workflow

## Operation Room Interactive Surgery Workflow Simulation

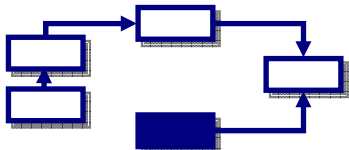
- **Collaboration Partner**
  - Fraunhofer Institute for Manufacturing Engineering and Automation (IPA)
- **Work Package Research Goals**
  - Simulation and optimization of intra-operative surgery workflows within a CAVE environment
  - Optimization of medical equipment placement and device setup within virtual operation room
  - Environment for Training of OR Teams



CAVE (Cave Automatic Virtual Environment)

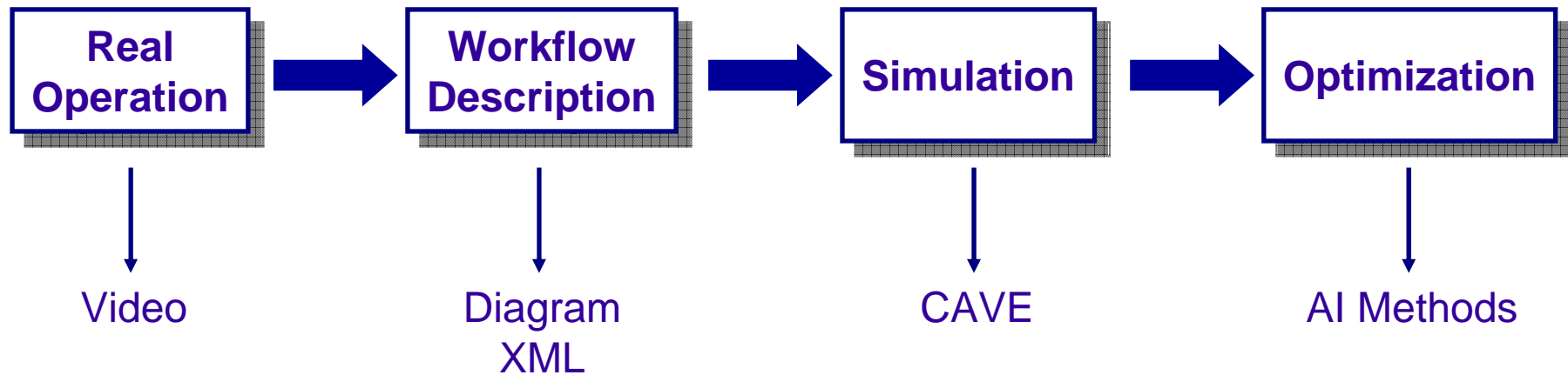


UASB 3 Wall Passive Stereo CAVE





## *WP-C: Development Steps*



# Insight



# OR workflow



**Requirements  
for an operation?**

**Shopping List**



# *Operating Room Shopping List*

- 1. Patient**
- 2. Operating Room**
- 3. OR-Attendant (Lagerungspfleger)**
- 4. Anaesthesiologists (2)**
- 5. Instruments**
- 6. OR-Nursees (2)**
- 7. Surgeons (2)**





**Reduction of Costs**  
**(1 min OR = 80 SFr)**

**Reduction of Radiation**

## **Video: Osteosynthesis of a Leg Fracture**





# *WP-C: Workflow Definition*

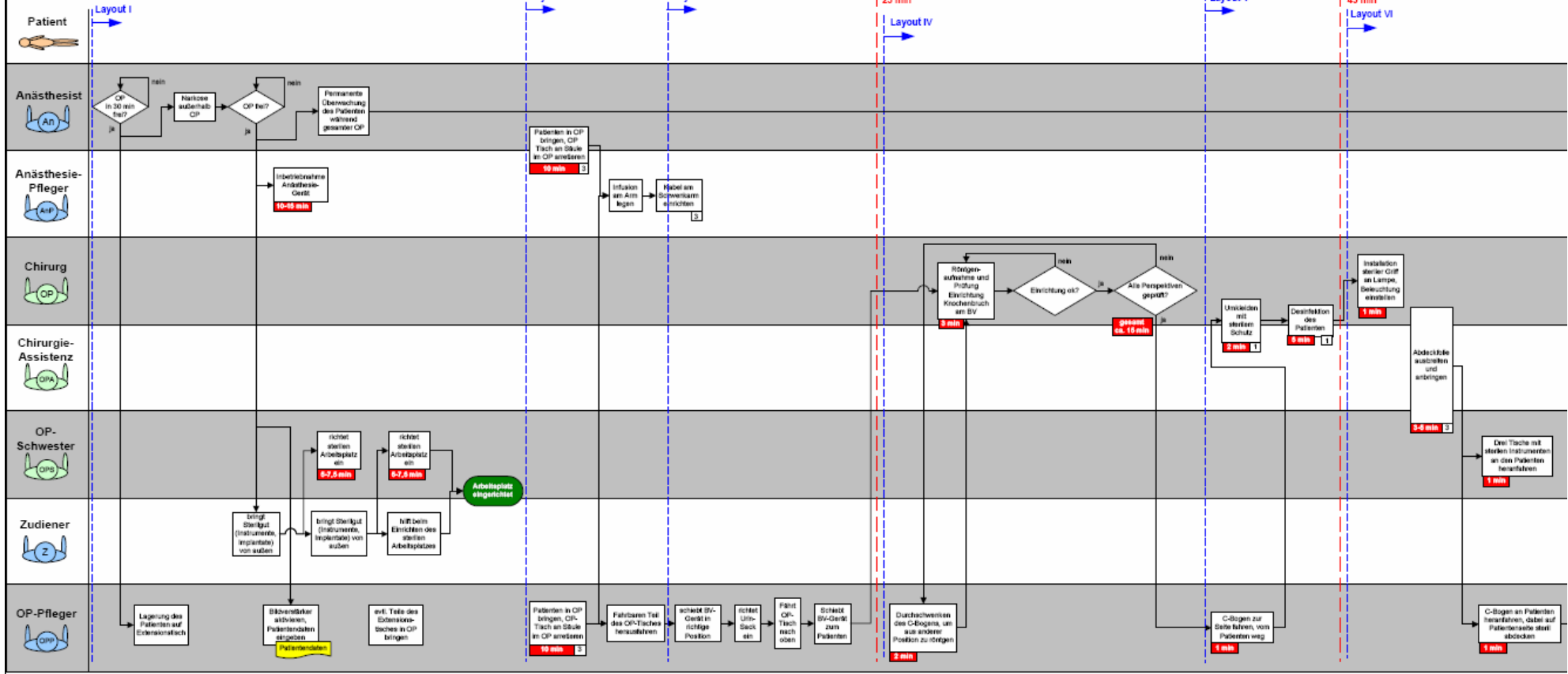


## **OP Workflow Definition Workshop**



# WP-C: Workflow Description

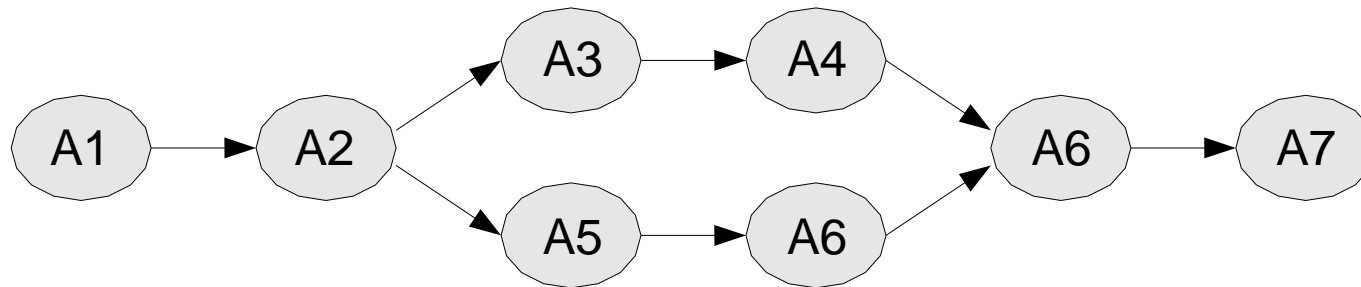
## Hovisse-Prozessaufnahme



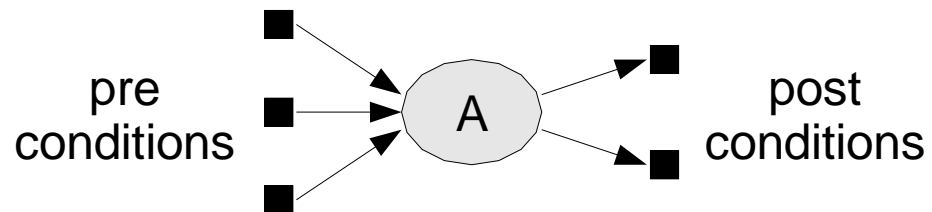


# WP-C: Workflow Description

- Approach I



- Approach II



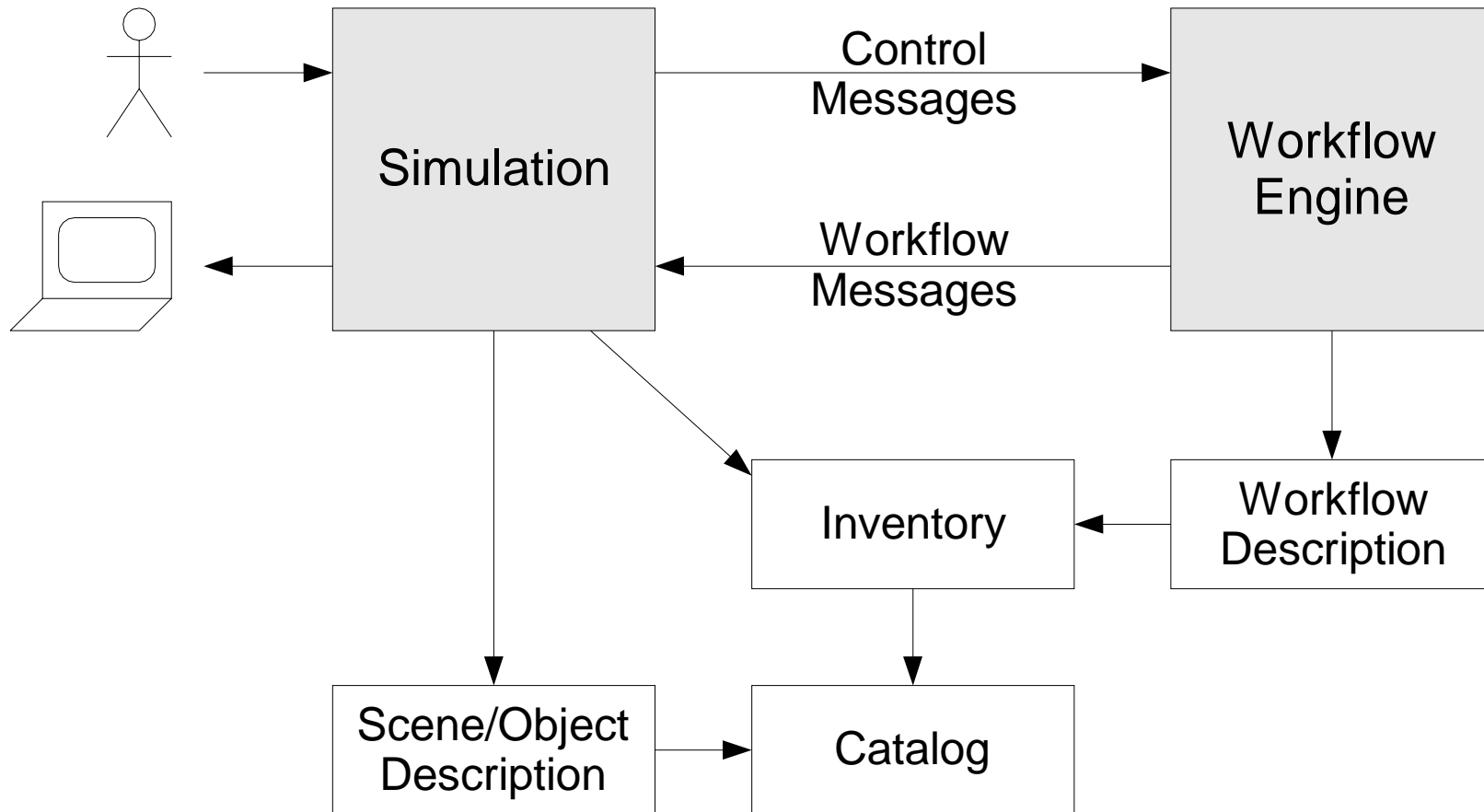


## *WP-C: Workflow Description*

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<workflow id="w1">
  <inventory invRef="i1"/>
  <conditions>
    <has id="c1">
      <actor invRef="a1"/>
      <object invRef="o1"/>
    </has>
    ...
  </conditions>
  <actions>
    <action id="a1" catRef="x1">
      <precondition ref="c4"/>
      <postcondition ref="c2"/>
      <actor invRef="a2"/>
      <object invRef="o1"/>
    </action>
    <action id="a2" catRef="x2">
      <precondition ref="c5"/>
      <postcondition ref="c1"/>
      <actor invRef="a2"/>
      <actor invRef="a1"/>
      <object invRef="o1"/>
    </action>
    ...
  </actions>
</workflow>
```



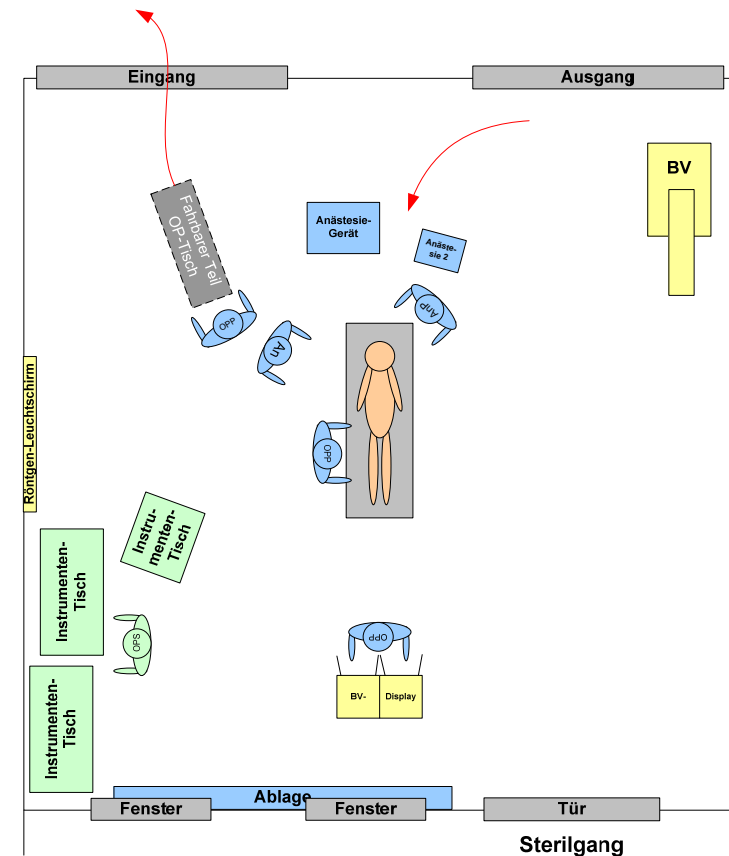
# WP-C: Software Architecture





## WP-C: Workflow Simulation and Optimization

- A snapshot of the operation: The male nurse has got the patient. Now he puts away the mobile part of the operation table.
- Refine this action by a sequence of primitive actions for simulation.
- As a result, we have to solve a path finding problem.





## *WP-C: Simulation*





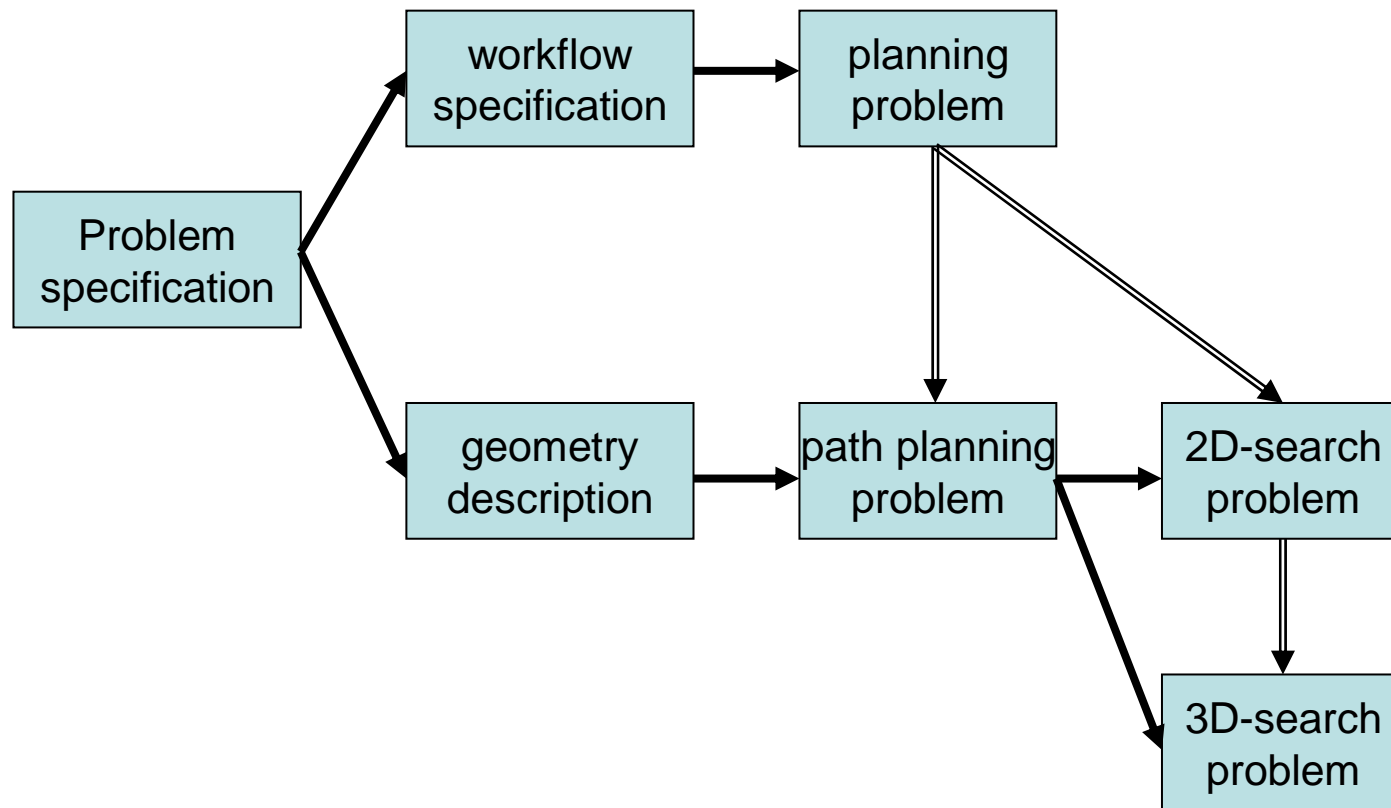
## **Optimization**

- **Optimality criterion: Time, radiation dosis, personel costs.**
- **Problem: Generate all the possible schedules of this operation and compute that one which is optimal with respect to the selected optimality criterion.**
- **Solution: This can be done by planning.**
- **Specify the workflow as planning problem given by**
  - a set of actions,
  - an initial state and a goal state, and
  - and solve it by a planning algorithm.
- **However, it is a non-classical planning problem.**



## *WP-C: Workflow Simulation and Optimization*

- **The complete problem solving process:**





## *Project Summary and Outlook*

- **Excellent Project Spirit among Project Partners**
  - Efficient and productive project start
  - Highly motivated team and inter-disciplinary collaboration
  - Unique pooling of complementary know-how and expertise
- **Source for Diploma Theses**
  - Excellent source for interesting and popular thesis topics (8 students, 6 theses)
- **Hasler-Foundation - A Catalyst for UASB Research**
  - Otherwise no approved research resources for UASB lecturers
  - Otherwise no UASB inter-departmental research collaboration
  - Otherwise no collaboration between UASB and University of Basel
- **Project Outlook**
  - 2007: Continuation and Completion of WP-A and WP-C
  - 2008: Focus on implementation of WP-D using result from previous WPs