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


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)
The HOVISSE Project Partners include:

- **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 IPA Institute**
  - Institute for Manufacturing Engineering and Automation, Stuttgart (D)
HOVISSE Research Plan (Work Packages)

- WP A: Haptic Osteosynthesis Planning
  - WP B1: FEA Optimized Implant Selection and Positioning
  - WP B2: Statistical Modelling of 3D Bone Morphology
  - WP C: VR Simulation of Operation Room Workflow
  - WP D: AR Intra-operative Information System
**Work Package Team Members**

**Haptic Osteosynthesis Planning**

**WP-A: U. Künzler**
- R. Witschi (SW)
- A. John (SW)
- C. Furrer (SW)
- D. Hoigne (Med)

**Management Board**
- U. Künzler (UASB)
- P. Messmer (CARCAS)
- T. Vetter (Uni Basel)
- U. Josi (UASB)

**WP-B1: M. Züger**
- U. Josi (FEA)
- D. Hoigne (Med)

**WP-B2: T. Vetter**
- T. Albrecht (PhD, SW)
- F. Matthews (Med)
- D. Hoigne (Med)

**WP-C: U. Künzler**
- R. Hauck (SW)
- P. Messmer (Med)
- D. Hoigne (Med)
- B. Amrhein (Workflow)
- S. Fischli (Workflow)
- J. Eckerle (Simulation)
- F. Decker (VR)
- C. Runde (VR)

**WP-D: U. Künzler**
- R. Witschi (SW)
- R. Hauck (SW)
- P. Messmer (Med)
- F. Matthews (Med)
- D. Hoigne (Med)
- A. John (SW)
- R. Cattin (Tracking)

- **FEA Optimized Implant Selection and Positioning**
- **Statistical Modelling of 3D Bone Morphology**
- **Intra-operative Planning Information System**
- **Operation Room Interactive Surgery Workflow Simulation**
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
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: 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
Finite Element Analysis (FEA) Optimized Implant Selection and Positioning

- **Work Package Collaboration Partner**
  - Mechanical Engineering Dept. (U. Josi, M. Züger)

- **Work Package Research Goals**
  - Integration of FEA simulation results into the pre-operative planning environment for optimized fracture suitable implant selection and positioning
WP-B2: Bone Models

- Geometry Transformation: STL --> Nurbs --> FEM
WP-B1: Inhomogeneous Material Properties

- Changed Geometrical Topology - Constant Material Distribution
Augmented Reality (AR) Intra-operative Planning Data Information System

• **Work Package Research Goals**
  – Unified display and access to 2D/3D pre- and intra-operative information (data and images)
  – Development of an Augmented Reality information system for in-situ access of surgery planning data
  – Design of novel non-manual (e.g. eye-tracking, voice, etc.) multimodal man-machine interaction techniques for usage during surgical interventions
**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

- Real Operation
  - Video
- Workflow Description
  - Diagram
- Simulation
  - XML
- Optimization
  - CAVE
  - AI Methods
Insight

OR workflow
Requirements for an operation?

Shopping List
Operating Room Shopping List

1. Patient

2. Operating Room

3. OR-Attendant (Lagerungspfleger)

4. Anaesthiologists (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**

- **Approach I**

  ![Approach I Diagram]

- **Approach II**

  ![Approach II Diagram]

  - pre conditions
  - post conditions
<?xml version="1.0" encoding="UTF-8"?>
<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

Simulation

Control Messages
Workflow Engine
Workflow Messages

Inventory

Scene/Object Description
Catalog
Workflow Description
• 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 dose, personnel 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.
• 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