Virtual and Augmented Reality techniques embedded and based on a Operative Microscope. Training for Neurosurgery.

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Project:

Marie Curie action:

COMPU SURGE

Institute for Process, Control and Robotics
University of Karlsruhe

University Hospital of Heidelberg
Dept. Neurosurgery
Dept. Cranio-Maxillo-Facial

Image processing, Modelling, Visualization, Simulation,
Registration, Navigation,
Calibration, 3D-Measuring, Surgical Robot, Operation Planning, Augmented and Virtual Reality
Overview

- Computer Assisted Neurosurgery Workflow and needs
- Background: A.R. Microscope prototype
- Training System
- Conclusion
Virtual Reality (VR): completely replaces the real world.

Augmented Reality (AR): User sees real environment; combines virtual with real. It supplements reality, instead of completely replacing it.

**Mixed Reality**

Continuum reality-virtuality (by Millmann ‘94)

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Computer Assisted Neurosurgery workflow

Image Acquisition (CT, MRI)

Image Processing (segmentation, classification, 3D modeling)

Patient Registration, Tracking (instruments, microscope, patient)

Visualization, Navigation
AR in operating room
3D Augmented Operating Microscope

Oculars view
Traditional methods to learn in medicine (past)

The Anatomy Lecture of Dr. Nicolaes Tulp (Rembrandt, 1632)
Surgery: traditional methods to learn (now)

Other ways to trainee surgery are requested

Courtesy of Yoshihiro Kuroda
Training Systems

Virtual environment + Haptic interface

= Training Simulator System

Motivation:

- Benefits for student, surgeon.
- Avoid the use of cadaver or animal.
- It’s a tool more efficient than classic methods.
State of the Art in Neurosurgical Trainings

Endoscopic third ventriculostomy

Dept. of Electrical Eng. and Computer Sc., Case Western Reserve University and Dept. of Neurosurgery, Rainbow Babies’ and Children’s Hospital

Human ventricle puncture

Department of Health Science and Technology
Aalborg University

Interaction between Spatula and brain tissue
Neurosurgical Training System

Real Microscope

Haptic Interface
(Sensible technologies)

3D Navigation
(3D Slicer)

Neurosurgical Training System
Image Processing and Navigation

Image Processing and Navigation (Video)
3D acquisition by laser scanning

Faro Arm

Faro Arm. 3D acquisition. (Courtesy of LDI.)
Physical Modeling

Methods:
- Mass Spring Damper
- Long Elements
- Finite Elements

Accuracy or Computation time?

\[
m_i \ddot{x}_i + c_i \dot{x}_i + \sum_{j \in \sigma(i)} \vec{F}_j(\vec{x}_i, \vec{x}_j) = m_i \vec{g} + \vec{F}_{ext}^i
\]

where \( \vec{x}_i \) is the coordinate vector of the node \( N_i \), \( \vec{v}_i \) and \( \vec{a}_i \) are its velocity and acceleration vectors, respectively, \( m_i \vec{g} \) is the gravitational force, \( c_i \) is the damping coefficient and \( \vec{F}_{ext}^i \) is the total external force applied to \( N_i \) and \( \sigma(i) \) is the set of the indices of the nodes adjacent to \( N_i \) in the 3D mesh of the model.
Collision Detection and Response

Bounding boxes structure Collision Detection

Collision Response
Keywords

- Image processing
- Physical modeling
- Collision detection
- Collision response
- Haptic interface (force feedback)
- Tracking system
- Camera calibration
- Patient registration
- Stereoscopy
- Real time
Conclusion and next steps

- We presented the state of art about the first mixed reality system embedded and based on a real microscope.

- We are extending the AR platform adding haptics, a complex virtual environment and integrating all with 3DSlicer.

- Next simulation step: an interaction between spatula and brain tissue

- We are giving emphasis to the balance between accuracy and computational load (real-time constraints)
Thank you for the attention

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