Course on Virtual Reality

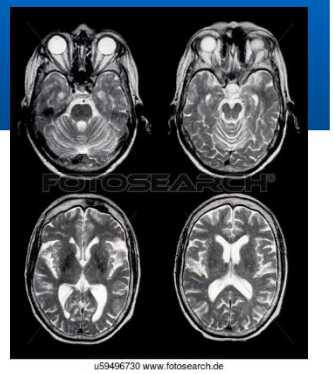
Applications in Science & Industry

Motivation for Virtual Reality

- Flight and drive simulators
- Computer games
- Product development: Virtual Prototyping
- Factory planning
- Architecture
- Cultural heritage
- Data analysis in Computational Engineering Science
- Medical simulation
- Psychatric therapy
- VR as the better user interface
- VR as a goal in it’s own right

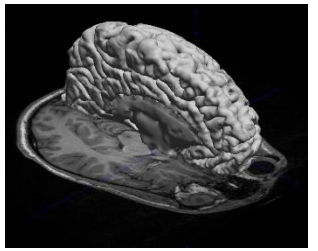
VR-based Medical Simulators

Virtual Reality in Medicine



Complexity

VR as a tool for diagnosis: 3-D vis of CT(MRI)-data



↓ Segmentation

VR as a tool in education: Anatomy

↓ Interaction, Plausibility

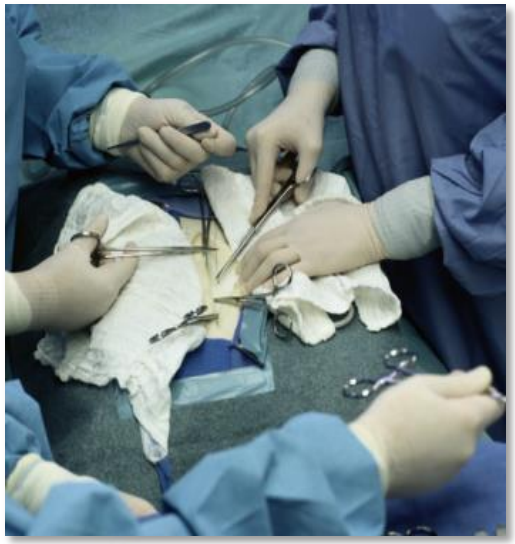
VR as a tool in education: Virtual Surgery

↓ Authenticity

VR as a tool to prepare surgical operations

Virtual Reality Simulators for Medical Procedures

- Training of medical procedures
  - Apprenticeship: “see one, do one, teach one”
  - Mannequins, animals, corpses, real patients
  - Virtual reality-based medical training



- Challenges
  - Physics-based simulation for deformation
  - Real-time simulation & interaction
  - Visual and haptic feedback
  - Evaluation

VR-based Regional Anesthesia Simulator

RA complex/error-prone, few training opportunities

→ **Virtual Reality training simulator**

Bimanual Procedure:

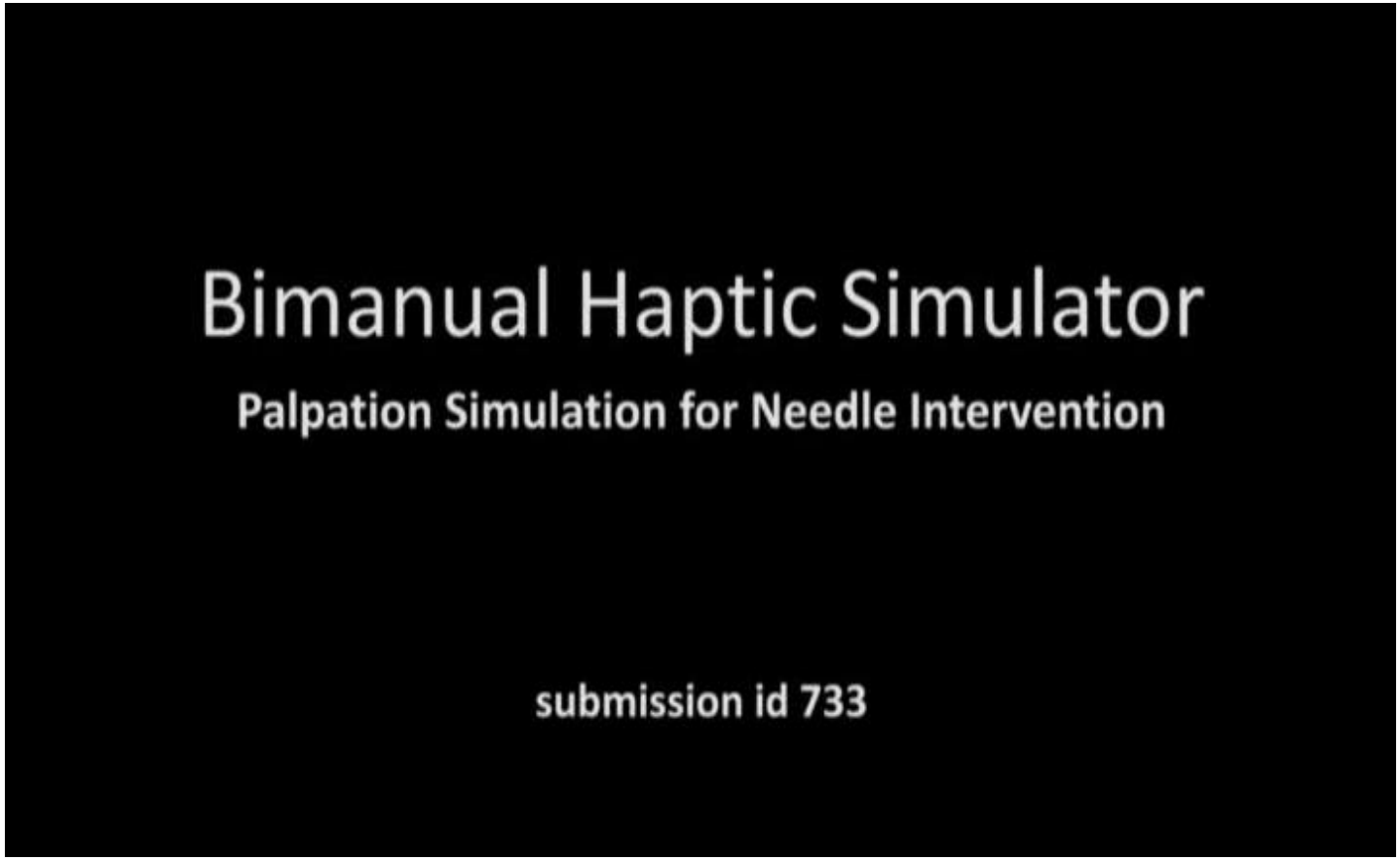
- identify insertion site by palpation
- needle intervention:
  - locate nerve via electric impulses
  - apply anesthetics

DFG Project, Partners:

- Klinikum Aachen, Anästhesiologie, Prof. Rossaint, Dr. Grottke
- Klinikum Aachen, Med. Informatik, Prof. Deserno
- RWTH VR Group

[BVM 2008, BJA 103(4) 2009, CARS 2009, MMVR 2009, VCBM 2010, EGVE 2011, TVCG 18(4) / IEEE VR 2012 Best Paper Award]

The RASim Prototype



→ YouTube

The EU Project RASimAS

Partners:
- Klinikum Aachen, Anästhesiologie, Prof. Rossaint
- Klinikum Aachen, Med. Informatik, Prof. Deserno (Coordinator)
- Klinikum Aachen, Clinical Trial Center, Dr. Greindl
- RWTH VR Group
- Bangor Univ., INRIA, KU Leuven, URJC Madrid, …
- Sensegraphics AB

[CARS 2011, VCBM 2012, SpieMed 2014, VCBM 2015, …]

RASimAs

Funded by the European Union

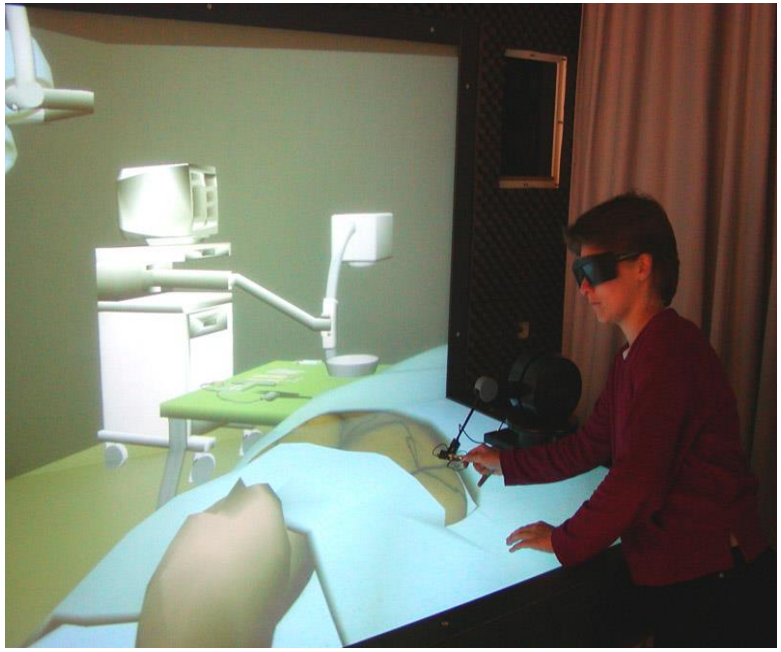
Ultrasound Simulation

- Employs geometrical acoustics
  - Ultrasound wave as rays
  - reflections, reverberation and shadowing
- Emulates the actual image formation process
- Multiple scattering models

→ YouTube

Virtual Surgery

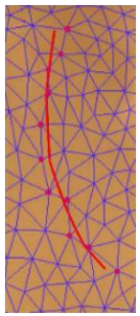
- Long term goal:
  VR Environment for training of standardized plastic surgery interventions with force feedback
  - First operation: breast reduction

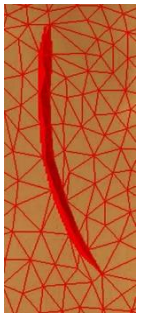


Klinikum Aachen (Plastische Chirurgie), VRGroup

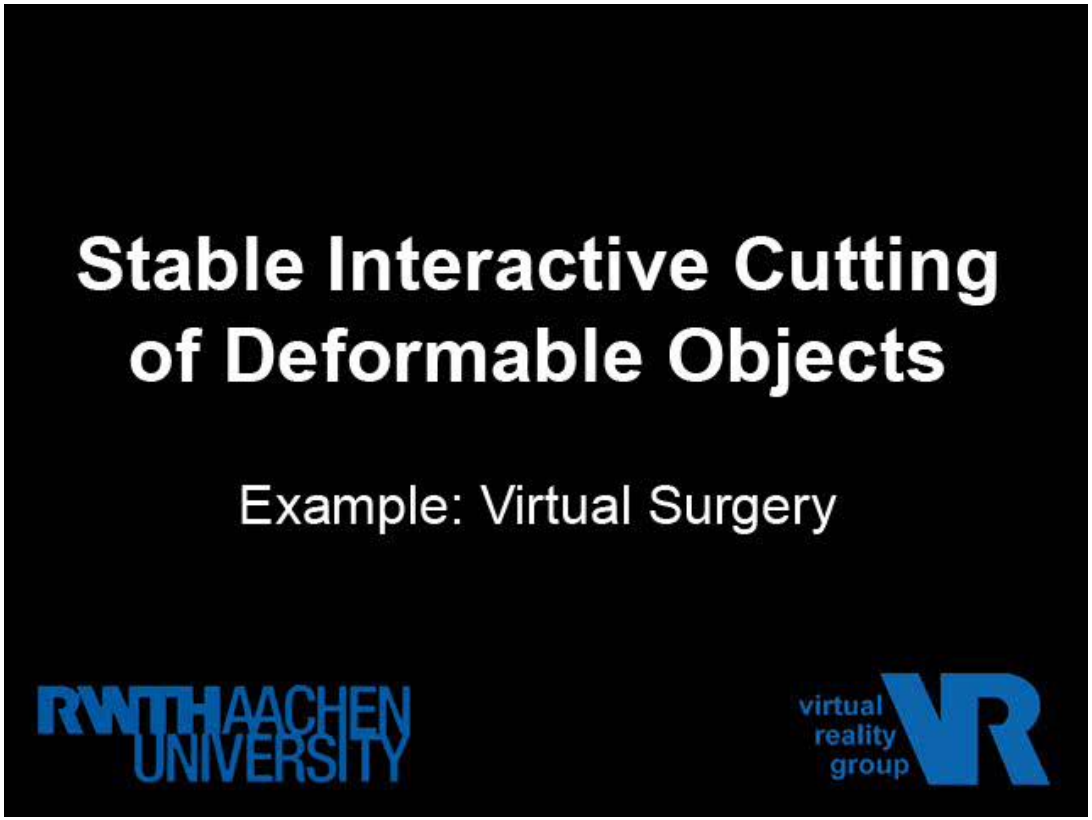
Simulation of Soft Tissue Cutting

- Cuts create structural changes → Discretization has to be adapted
- Finite Element Method → Remeshing needed
- Extended Finite Element Method (XFEM) → Enrichment of elements





→ YouTube



START Nachwuchsförderung 2003

Partners:

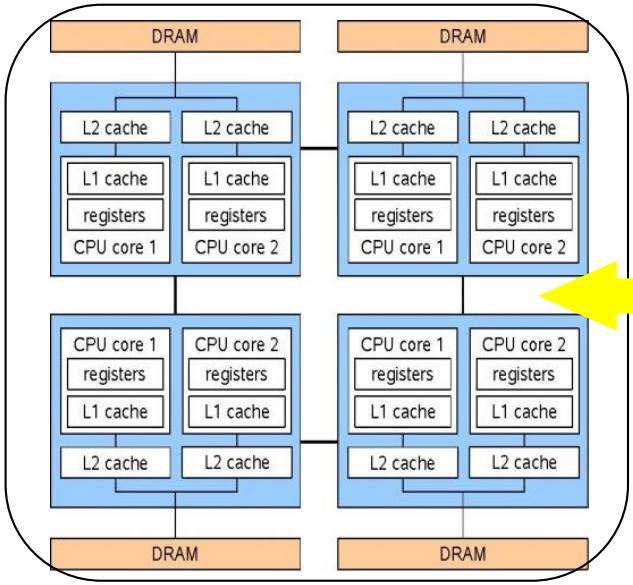
- Klinikum Aachen, Klinik für Plastische Chirurgie, Hand und-Verbrennungschirurgie, Dr. Wolter
- RWTH VR Group

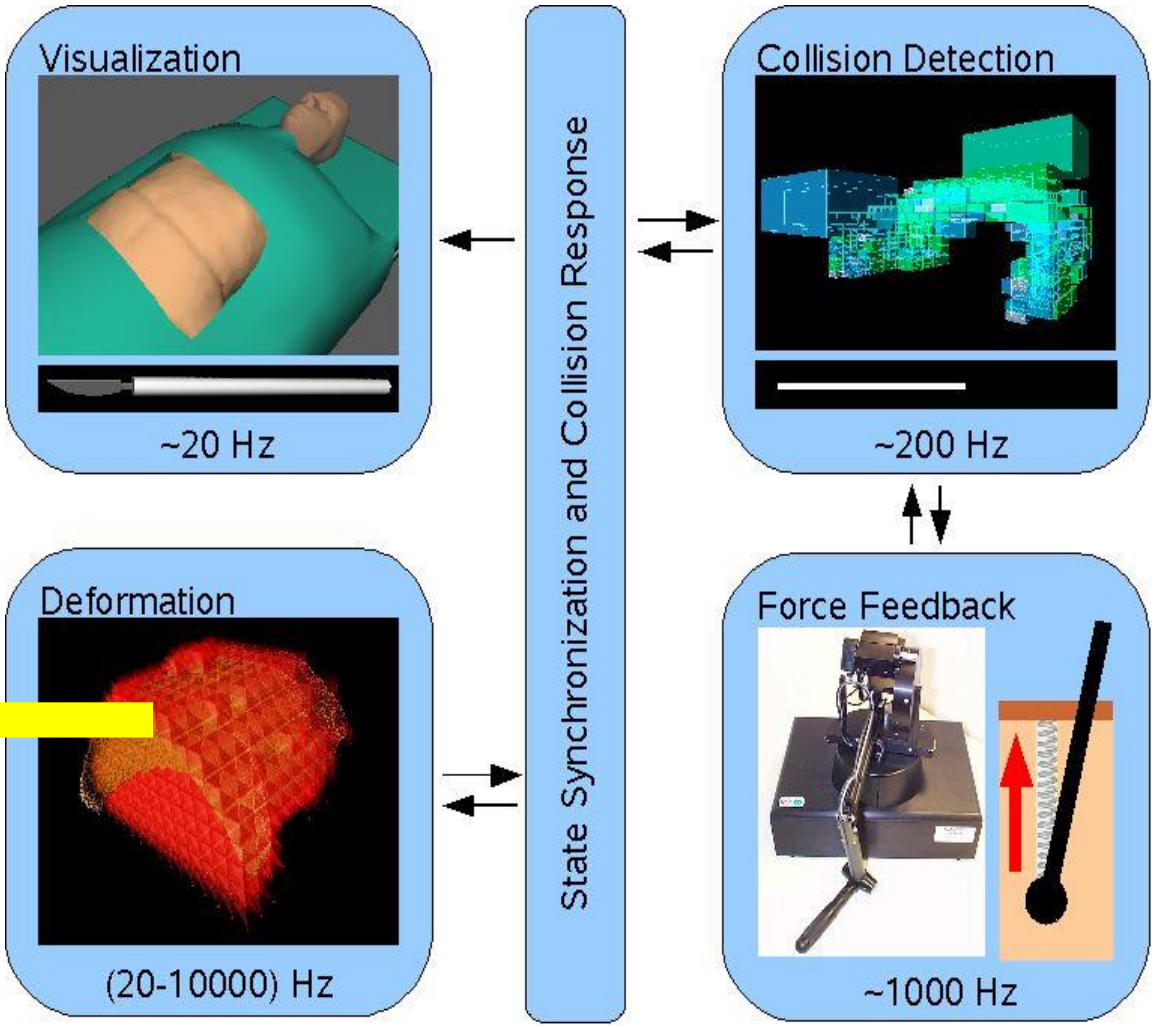
[VRST 2004, MMVR 2005, BVM 2007, MMVR 2007, CGA 29(2) 2009]

Performance is a Challenge!

HPC Competence @

IT Center | RWTH AACHEN UNIVERSITY





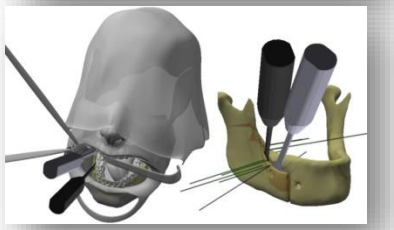
BSSO – Bilateral Sagittal Split Osteotomy Simulator

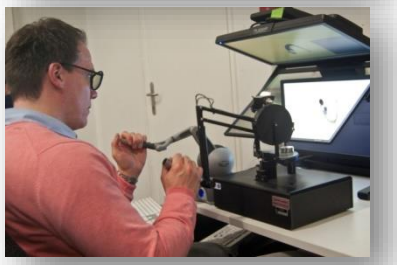
DFG Project, Partners:

- Klinikum Aachen, Klinik für Zahn-, Mund-, Kiefer- und Plastische Gesichtschirurgie, Dr. Gerressen
- AICES Graduate School (XFEM Research Group), Dr. Fries
- RWTH VR Group

[CARS 2010, CURAC 2010, MedRobCAS 9(1) 2013, EuroHaptics 2014, ISBMS 2014, EGVE 2015, VRIPHYS 2015 Best Paper Award]

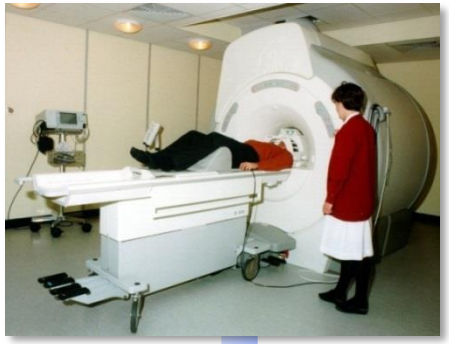
→ YouTube



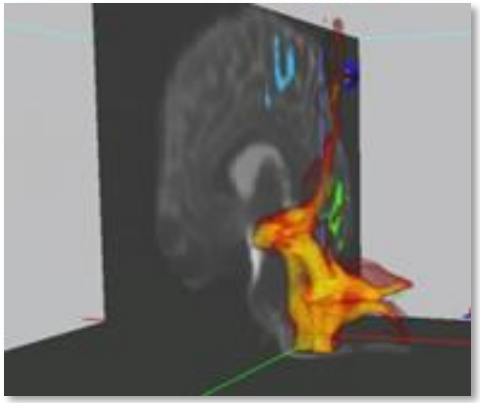


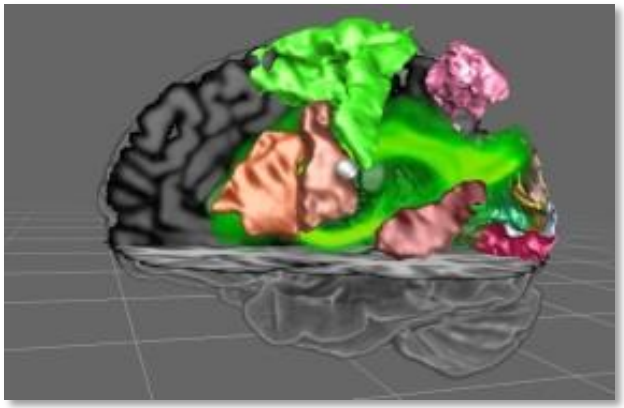
Virtual Reality in Neuroscience

Visualization of Imaging Data



CT, (f)MRI, PET, EEG, …





Profs. Amunts, Zilles, Caspers, Kuhlen JARA Jülich Aachen Research Alliance

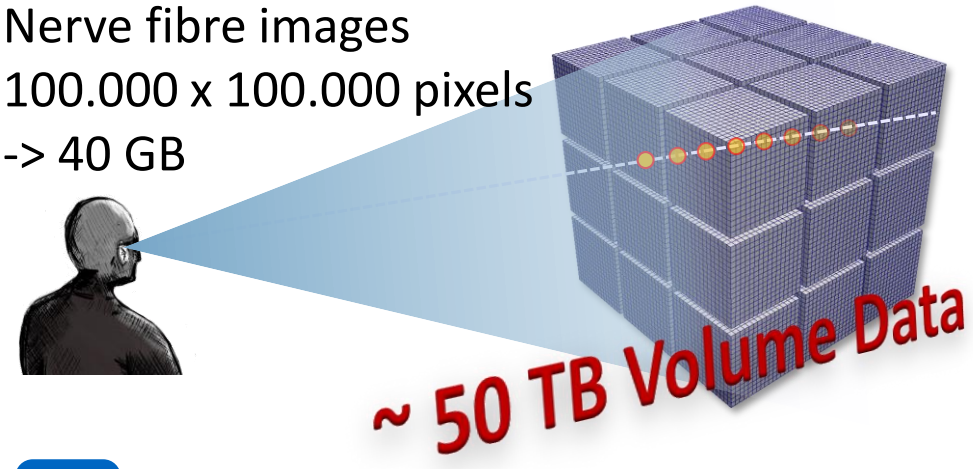
Visualization of PLI Data

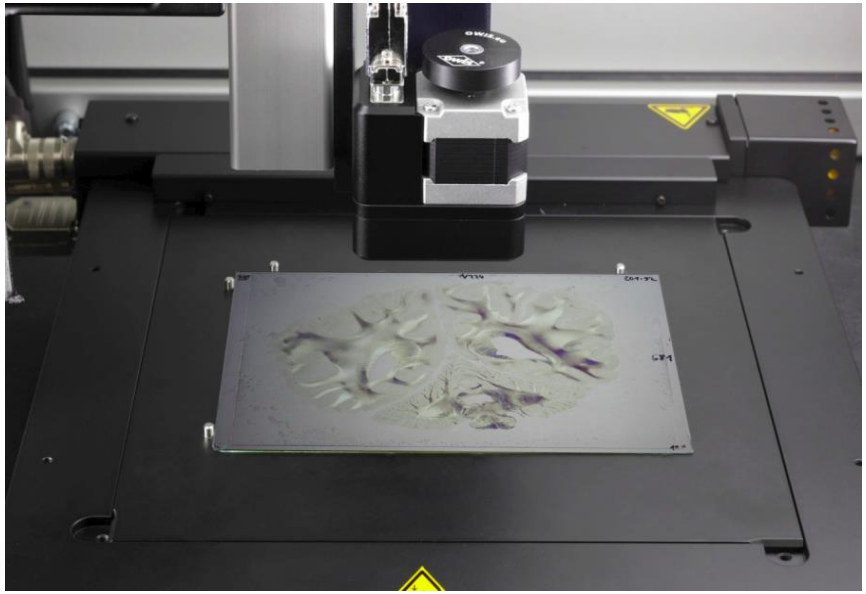
Partners in this HBP/SMHB/JARA Activity:

- FZ Jülich. INM-1, Prof.. Amunts, Dr. Axer
- FZ Jülich, JSC, Profs. Lippert, Pleiter
- RWTH VR Group & European Vis Groups

[IEEE VR 2016]

Nerve fibre images
100.000 x 100.000 pixels
-> 40 GB





3D - Polarized Light Imaging

The Human Brain Project

Human Brain Project

- EU FET Flagship Project, started in 2013
- ~ 1 Billion € funding over 10 years
- ~ 80 universities as partners in this project
- Public website at www.humanbrainproject.eu
- Goal of the project:
  - Collaborative effort towards understanding the human brain
  - ICT platform to emulate the brain's computational capabilities
  - ➢ Simulate the human brain via supercomputers

The Human Brain Project

Human Brain Project

Mouse brain

~70 M ($7x10^7$) nerve cells

~40 M glial cells

O(10^{12}) synapses

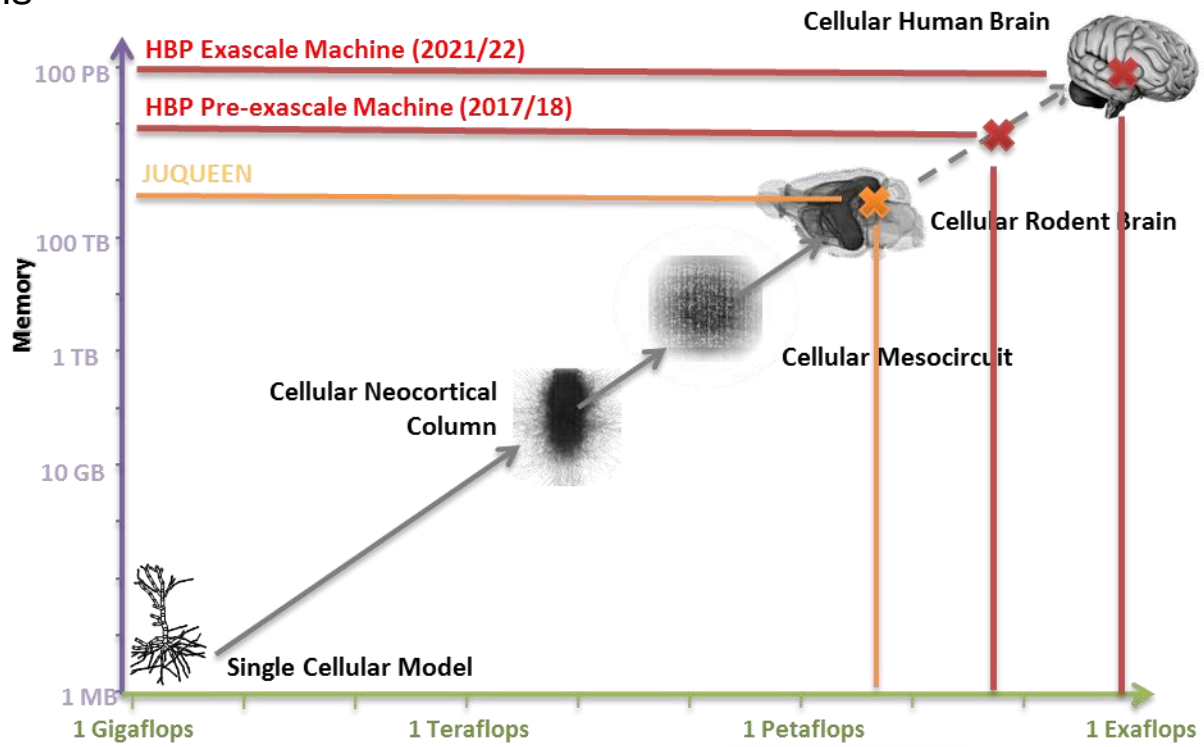
Human brain

~90 B (10^{11}) nerve cells

~90 B glial cells

O(10^{15}) synapses

Santiago Ramón y Cajal, 1894

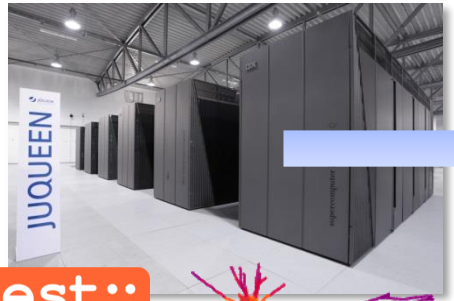


nest:: simulated()

NEURON

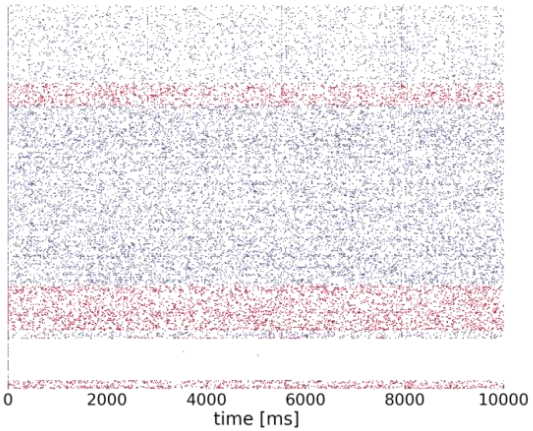
[Schürmann/EPFL]

The Human Brain Project



nest:: simulated()

NEURON



[S. Grün, M. Diesmann et al.]

Courtesy of
José M. Peña,
Universidad Politécnica
de Madrid

Human Brain Project

Blue Brain Project
EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Cajal BLUE BRAIN

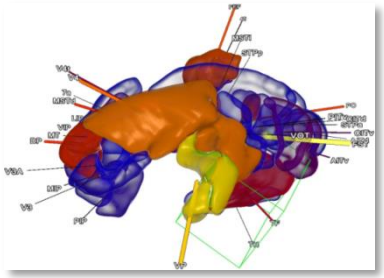
Visualization of NEST Simulations

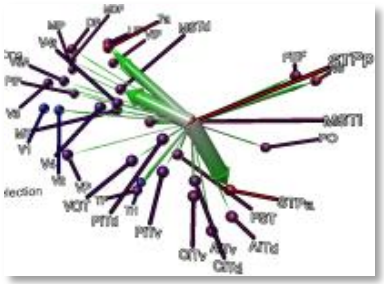
Capabilities

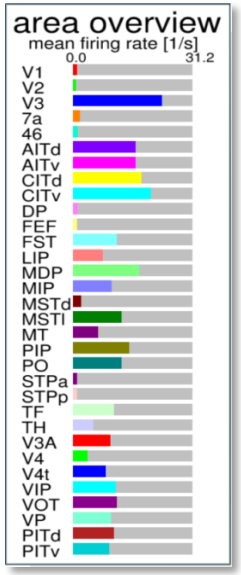
- Multi-view (geometrical / abstract)
- Virtual Reality support
- Multi-scale (from spiking of single neurons up to area activities)

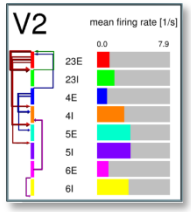
Partners in this HBP/SMHB/JARA Activity:
- FZ Jülich. INM-6, Profs. Diesmann, Grün
- RWTH VR Group & European Vis Groups

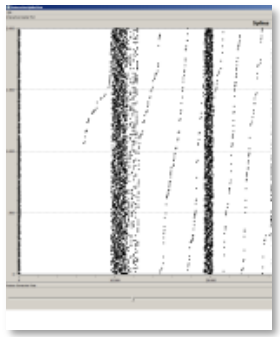
[BioVis 2012, Front.Neuroinform 9(29) 2015]









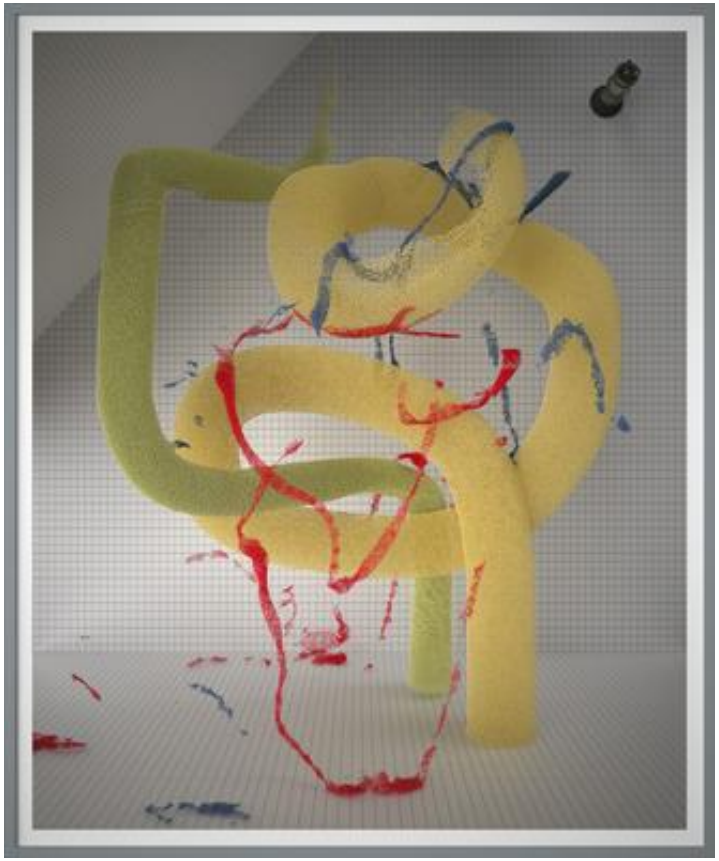


→ YouTube

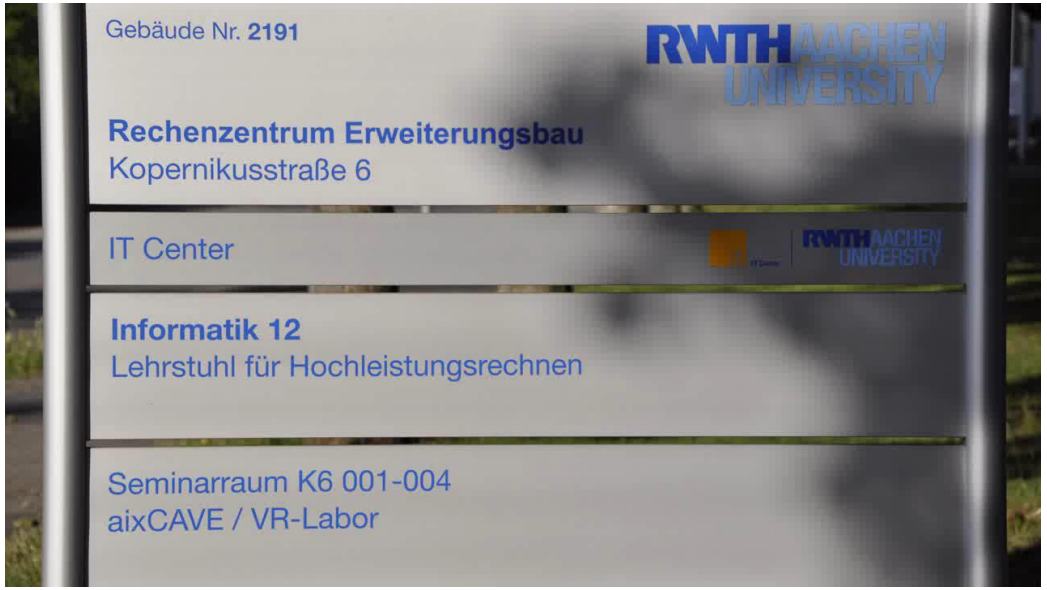
“Phantastic” Virtual Worlds

Virtual Reality in Arts: “Tarnen & Täuschen II”, Tim Berresheim

- Exhibition Ludwig Forum, October – December 2015



→ YouTube



VR is a Complex & Interdisciplinary Research Field!

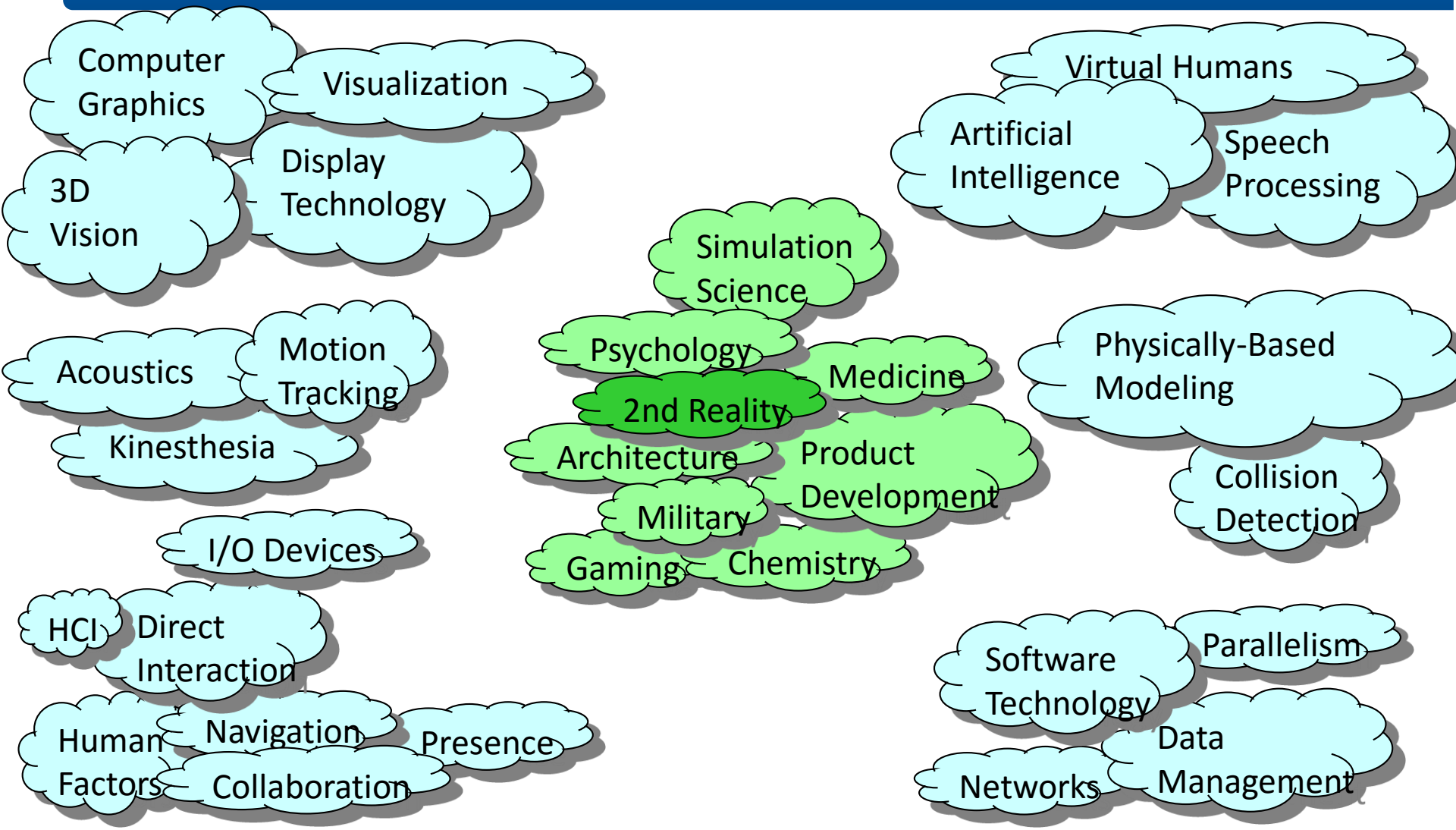
- **VR/AR as an object of research:**
  - Inherently interdisciplinary
    - Software Technology, HCI, Computer Graphics, Vision, Acoustics, Haptics, Motion Tracking, Collision Detection, Network Technology, Parallelism, Display Technology, I/O, PBM, Kinematic Structures, Human Factors, Visualization …

➢Teamwork within and across disciplines!

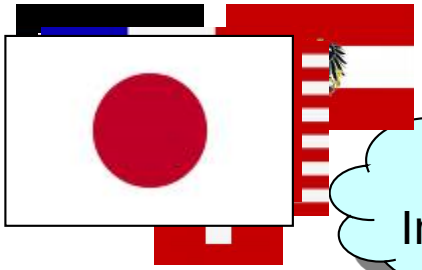
- **VR/AR as a tool in research**
  - Manifold application areas
    - Mechanical & Electrical Engineering, Simulation Science, Robotics, Product Development, Materials, Medicine, Life Science, Chemistry, Biology, Psychology, Architecture, Entertainment, …

➢Collaboration between VR researchers and users!

VR is a Complex Network of Multiple Disciplines!



VR is a Complex Network of Multiple Disciplines!



Computer Graphics
Visualization
3D Vision
Display Technology
Virtual Humans
Artificial Intelligence
Speech Processing
Simulation Science
Physically-Based Modeling
Acoustics
Motion Tracking
Psychology
Medicine
Kinesthesia
2nd Reality
Architecture
Product Development
Collision Detection
I/O Devices
Military
Parallelism
HCI
Direct Interaction
Gaming
Chemistry
Software Technology
Human Factors
Navigation
Presence
Collaboration
Networks
Data Management

Course on Virtual Reality: Outline