ETH
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isprs

Advanced visualization issues

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Content

- Introduction
- Basic visualization techniques
- Virtual reality tools
- Simulation
- Clinical application examples

Clinical visualization targets

- Communication of information
- Visual perception channel is very broad
  about half of the brain is devoted to visual processing
- Perception is a limiting factor in understanding
  procedures have to be adapted
- Maximizing the transmitted information
  - but our perception can be overloaded
  - danger of distraction
  - there is an optimum

Medical usage I

- Diagnostic support
  - Providing basically all information
  - Presentation style has great influence: experience
- Communication of quantitative information
  - Making the invisible visible
  - Access to abstract information
  - Supporting insight and understanding
- Pre-operative planning
  - Exploration of patient-specific data
  - Simulation of interventions
    - Actual execution
    - Prediction of short/long-term outcome

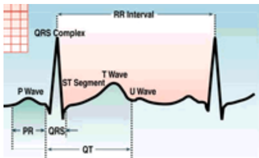
Medical usage II

- Therapy support
  - Navigation tools
  - Integrating all available information
    be careful: too much information may endanger the health of the surgeon (and therefore of the patient)
  - Psychotherapy
- Training and education
  - Teaching anatomy (and physiology)
  - Training of residents (surgical training)
  - On the long term combination with patient specific pre-operative planning

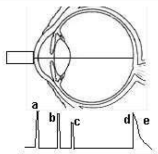
Medical usage III

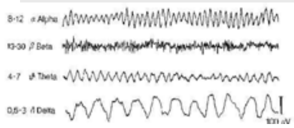
- Accompanying therapy
  - Prophylaxis and screening
  - Post-operative followup
  - Rehabilitation
- Research, development and design tools for
  - Novel implants
  - New surgical procedures
  - Basic understanding of healthy and pathological processes

1D visualization

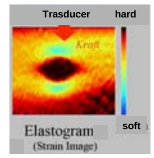


- Quite traditional signal visualization
- In several areas still the best way for presentation
  - EKG
  - EEG (multi-channel)
  - A-mode ultrasound





2D visualization

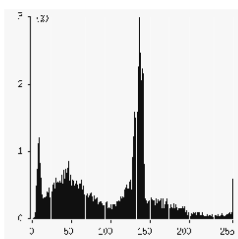


- Little help can be offered the human visual system is too good for us
- Some standard elementary functionality
  - Interactive contrast adjustment
  - Noise reduction
  - Tools for measurement/quantification
  - Image/data fusion
- Nevertheless we can do a lot of harm

  histogram equalization

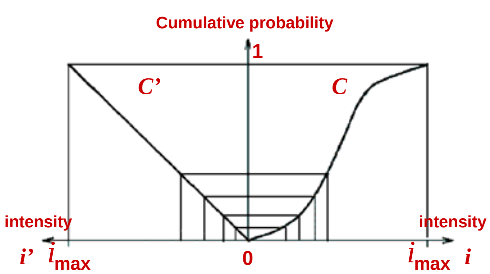
Why to temper with histograms

Usually poor usage of available intensity values



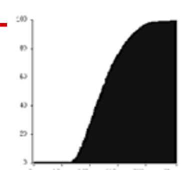
Histogram equalization example

Sketch of histogram equalization

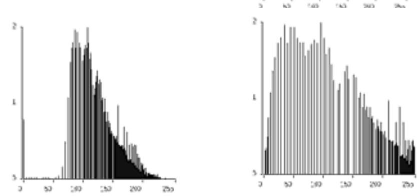


Change of histogram

cumulative histogram

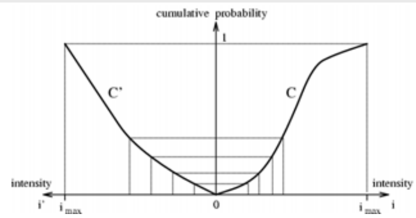


original and flattened histograms



Generalization

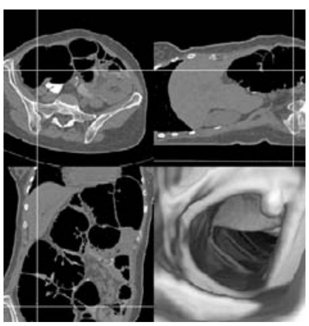
- Enforcement of any histogram
- Can be quite useful: equalizing differences in acquisition compensating for slice thickness differences in TEM images
- No use in radiology



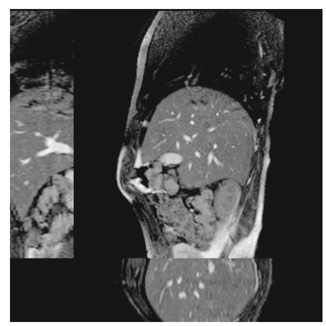
3D visualization

- The human visual system is not trained to perceive volumetric data
- Tools are needed for optimal presentation
- Originally: presenting slices in a clever way
  - Oblique slices
  - Curved reconstructions
  - Multiplanar reconstruction
- 4th dimension can be incorporeted (dynamics)
- Simplifying the data in a way radiology usually does: projection
  - Simulated radiographs (DRR)
  - Generate phisically non-realizable contrast: maximum intensity projection (MIP)
  - Combination with motion parallax

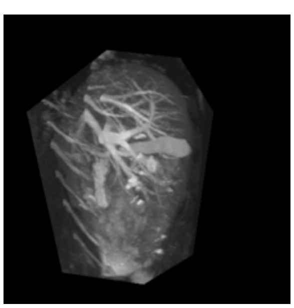
Multiplanar reconstruction (MPR)

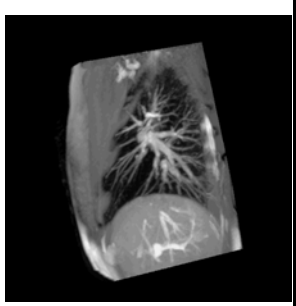


MPR of 4D data



Maximum intensity projection of 4D MRI data

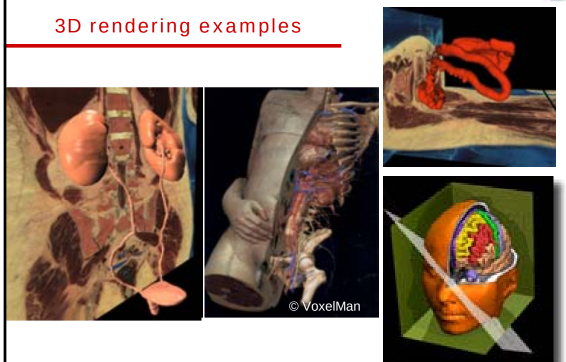




Simulated 3D appearance

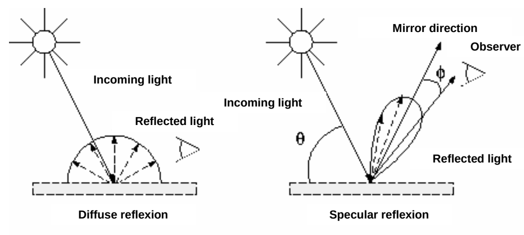
- Attack against radiologists
  Emulates their core competence (and quite successfully)
- The most spectacular recent development in computer science
- Driven by the entertainment industry
- Basically a simulation of interaction between light and matter
- Full photorealism is possible
  - Is expensive (at least today)
  - Hardly possible real-time
  - Do we need it in clinical applications?

3D rendering examples

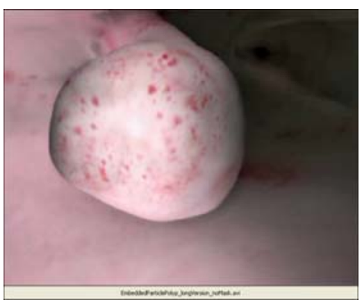


Surface rendering

Basically simulating reflexion phenomena



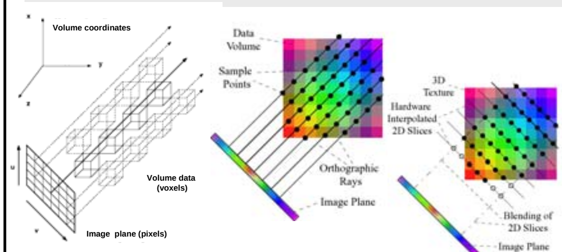
Texture mapping



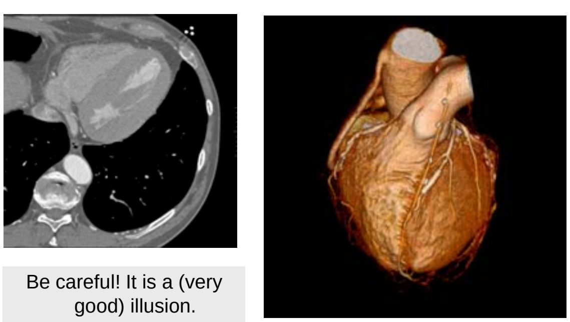
- Describing all tiny details lead to extremely complex models
- Complexity reduction: mapping real images to virtual surfaces

Volume rendering

- Simulating transmission and reflection through the data
- Can be implemented as (3d) texture mapping



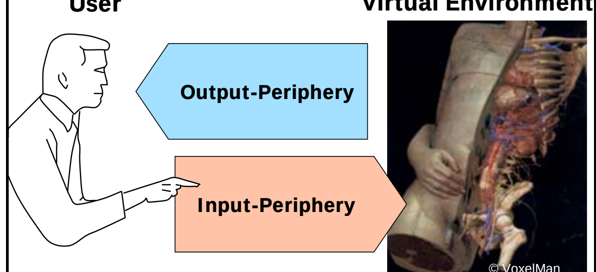
Volume rendering example



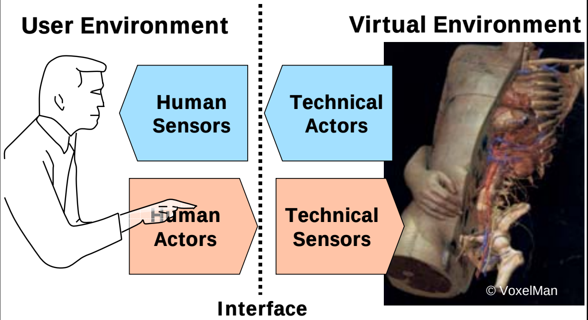
Be careful! It is a (very good) illusion.

The principle of virtual reality

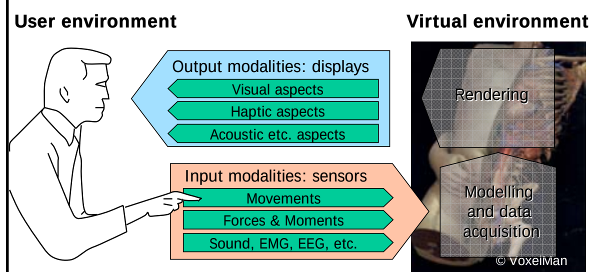
User **Virtual Environment**



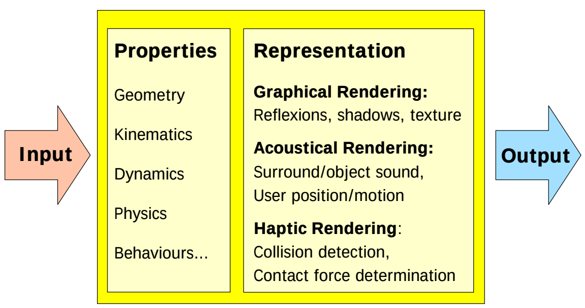
Real and virtual environments



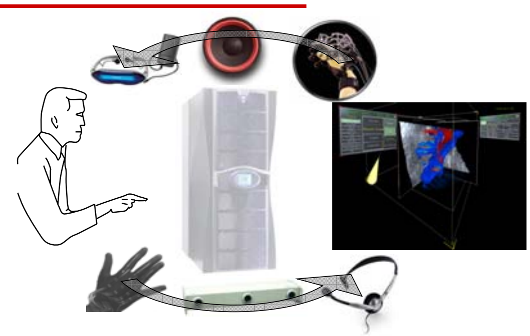
Actual implementation



The virtual environment



Prototypical VR setup

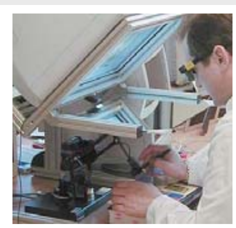


Audiovisual display technologies

- Auditive feedback: fully relying on consumer electronics
- Visual displays: different degrees of immersion
  - Display
  - Worbench
  - Cave
- Stereoscopy is still not comnpletely satisfactory
  - Goggles (active/passive): obtrusive
  - Stereoscopic displays: limited viewing angle
  - Holography: not yet really operational
- Combination of display and user observation
  Blue-C

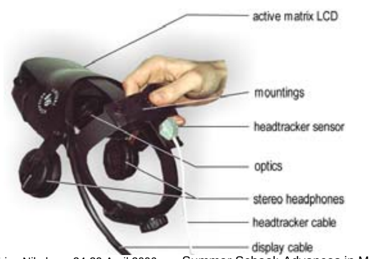
Displays and workbenches

- Active: the glasses change transparency
  quite expensive
- Passive: selectively polarized glasses
  cheap but sensitive to head tilt



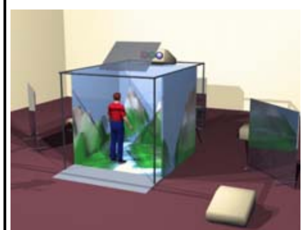
Head-mounted displays

Separate display for each eye
- Limited field of view
- Stereoscopy is automatically guaranteed




Caves

Stereoscopic technology the same as for displays




The Blue-C

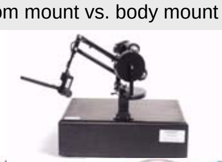
- Combination of immersive display with user observation
- An I/O device

Multi-modal environments

- Vision is our most important sense, but not the only one
- For realistic immersion other perceptional channels should also be used
  - Hearing
  - Touch: haptic feedback
  - Vestibular
  - Olfactory
  - (Taste?)
- Free movement on a limited environment (real walk-through)

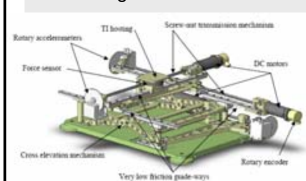
Kinesthetic (force) feedback

- Usually inverse robotic technology
- From simple 3D force reflecting pointers to exoskeletons room mount vs. body mount

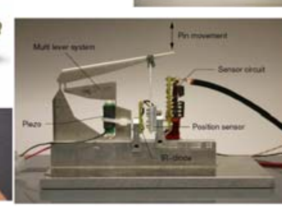



Tactile displays

Generating the sense of touch: tactile texture







Virtual reality technology

Vestibular feedback

Motion platforms (e.g. Flight simulators)

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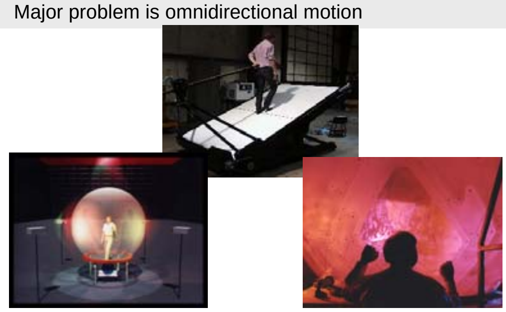
Virtual reality technology

Walking platforms

- Allowing non-constrained motion in a limited space
- Major problem is omnidirectional motion



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Virtual reality technology

Augmented reality

- One further step: mixing the real and augmented world
- Quite complex: everything needed as in VR but in addition coherence with the real world must be ensured

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Virtual reality technology

How far is VR useful in medicine

- The more immersive the environment the more obtrusive it is for the user
- In surgery one cannot accept this
  the workflow cannot be disturbed
- In many cases immersion is useful or even required
  - Education
  - Training
  - Psychotherapy
- Optimal solution has to be found for every application
- Select the simplest from all acceptable solutions

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Simulation

Simulation technologies

- Cannot be separated from visualization
- Provides significant part of the information to be presented
- Two major directions
  - Simulation for training
    - No connection to a real patient
    - Not necessarily true but looks reasonable
    - Needs real-time response
  - Simulation for planning and supporting understanding
    - Has to be patient specific
    - Must be as correct as possible
    - Can rely on batch processing

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Simulation

Surgical training simulation

- The user is not just an observer, but interacts with the scene
- The reaction of the scene must be predicted
  - Biomechanics (deformation, cutting)
  - Fluid behaviour (bleeding)
  - Eventually more complex physiological responses
- Simulation of very complex multi-physics systems
- Usually rough approximations are needed to stay real-time
- Parallel computing plays a decisive role
  not just computing, but also communication (bandwidth and latency)
- In most cases both visual and haptic feedback requested

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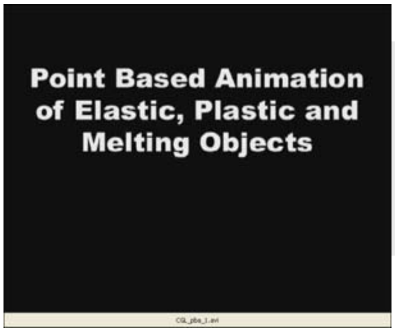
Simulation

Biomechanical tissue models



CGL_pba_1.avi

Multitude of possible approximations:
- mass-spring models
- Finite Element modelling
- particle systems

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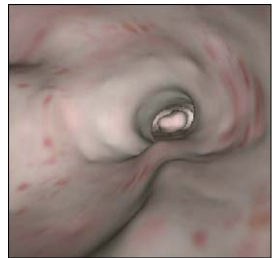
Simulation

Flow simulation

Bleeding in hysteroscopy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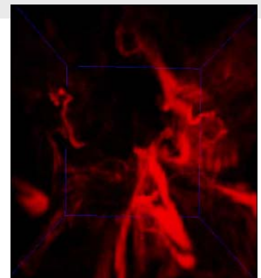
Metaxas_closeView2_divx30fps.avi

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Simulation

Providing force feedback

- Realistic instrument handling is important


Haptic.avi

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Simulation

Diagnostic and therapeutic simulators

- Diagnostics
  - Additional information for diagnostic decision
  - Example: handling aneurisms
    - Today decisions based on morphology and clinical experience
    - Does not directly address the underlying physiology
    - Knowledge about pressure and wall strain/stress relations would allow much more reliable decisions
- Therapy
  - The basic target is to predict outcome
  - Supports both individual planning and design of new therapies
  - Older than computer aided medicine: radiotherapy and stereotactic neurosurgery

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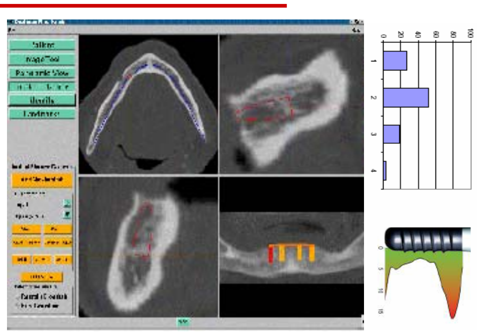
Functional planning of dental implantation



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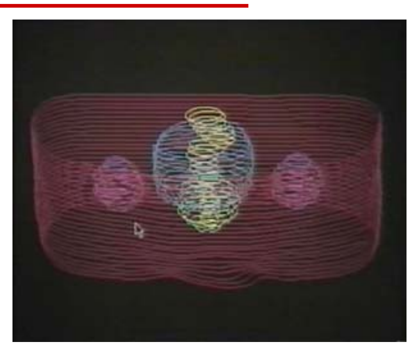
Simulation

Planning in radiation therapy



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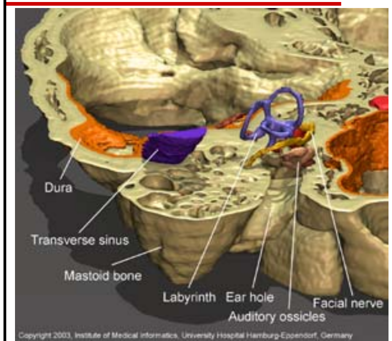
Simulation

Planning in stereotactic neurosurgery

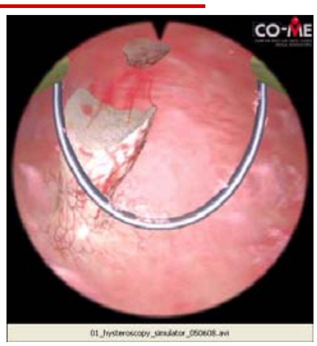
Application examples

VoxelMan middle ear surgery simulator



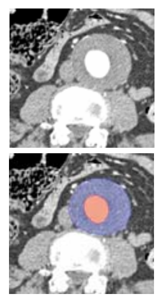
Application examples

Hysteroscopy training simulator



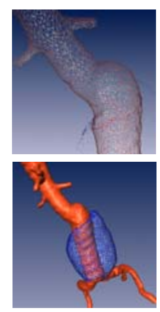
Application examples

Flow simulation for diagnosis and treatment of anorisms



CT angiography

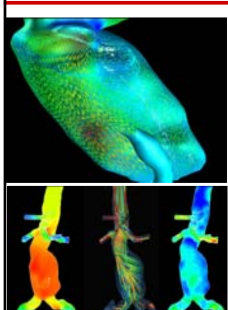
Segmented model



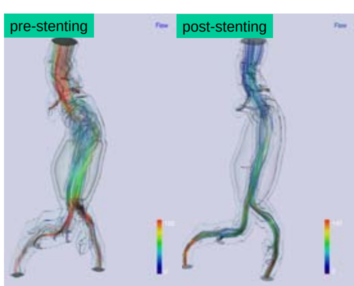
FEM mesh

Application examples

Flow simulation results

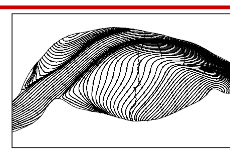


Wall pressure Streamlines Wall shear stress

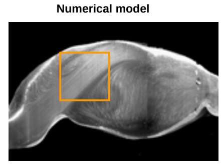


Application examples

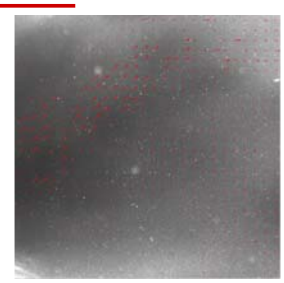
Validation of simulation results



Numerical model

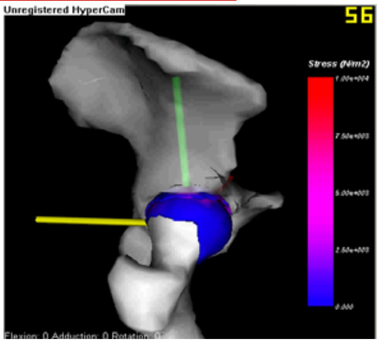


Silicon model
Laser flowline visualization

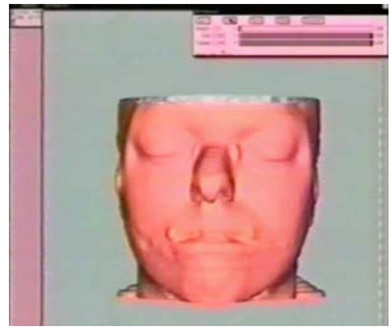


Particle Image Velocimetry measurement

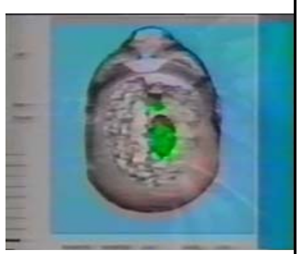
Investigation of joint motion



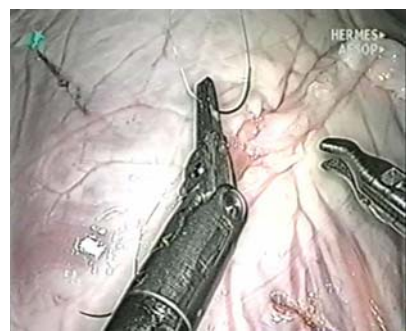
Prediction of CMF surgery results



AR for navigation during surgery



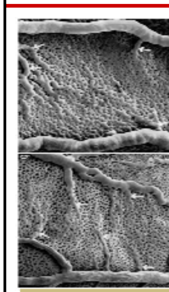
Immersive telesurgery



The next step: understanding body function

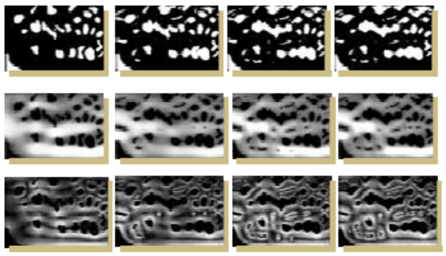
- Using simulation technology to model tissue behaviour
  - Tissue formation
  - Pathology development
  - Reaction to external influence (physical, chemical, biological)
- We have to understand the underlying mechnisms
  - Transport
  - Signalling
  - Mechanobiology
  - Programming (genetics)
  - Dependencies and interactions
- We know a lot on subcellular level: this is not a clinical question!
- How to use it to understand a tissue/organ/organism

Modeling blood vessel formation

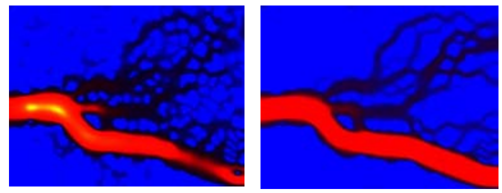


- Models of angiogenesys
- Influence of flow
- Capillary bed formation
  - Flow calculation
  - Tissue remodeling
- Testbed: intussusceptive angiogenesis
- Shear stress in endothelial cells as driving factor

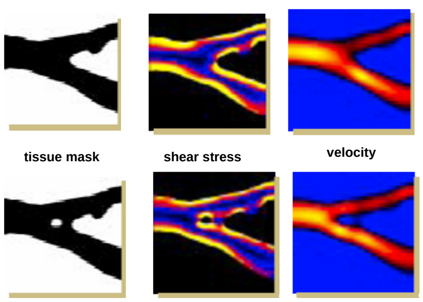
Remodeling example



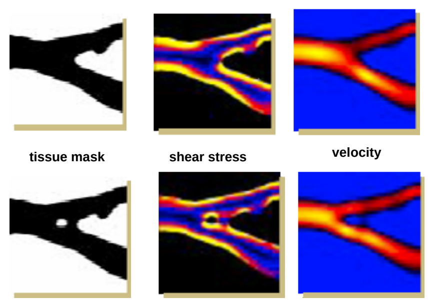
Bifurcation formation



Tissue pillar appearance



Bifurcation remodelling



Summary

- It is more and more difficult to separate methodological components of a clinical system
- Integration is the key
  - Image analysis
  - Visualization
  - Simulation
  - Instrumentation
- The stock on technology is huge and ever growing
  - As a developer, temptation is high to use all gadgets and more
  - Should be avoided, the clinician is quickly overwhelmed while he/she should stay in the driver's seat
- Procedural and individual simulation will converge
- We need a bit different parallel HPC than today; balance between computation and communication

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