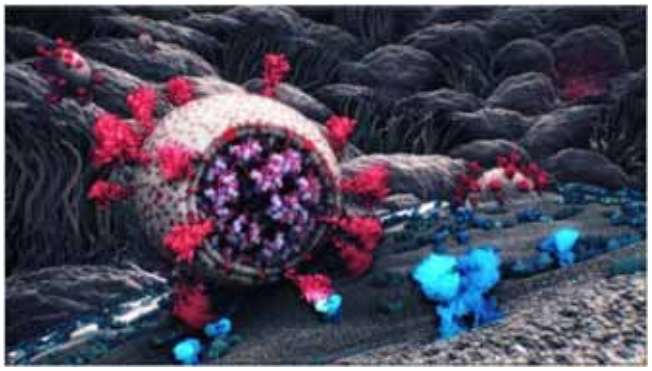
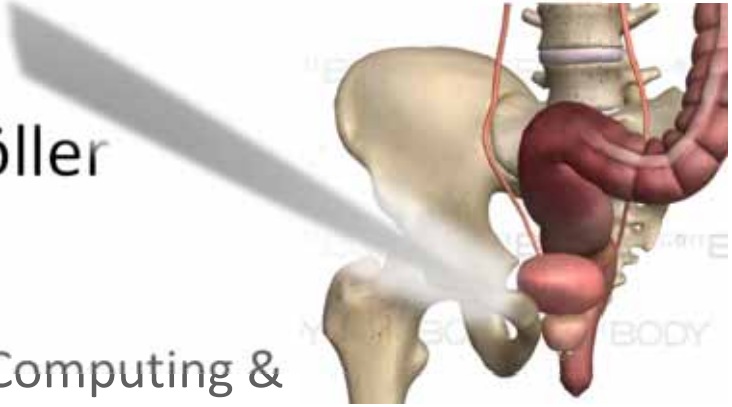
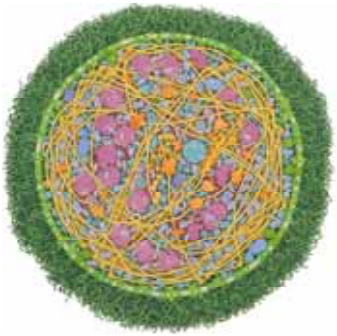
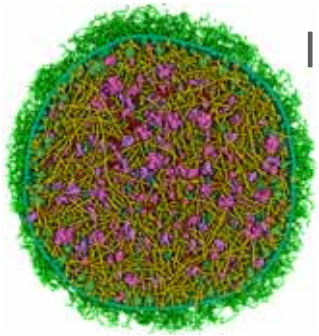


Medicinae Notitia Visibilis Fac – Quo Vadis?

Eduard Gröller

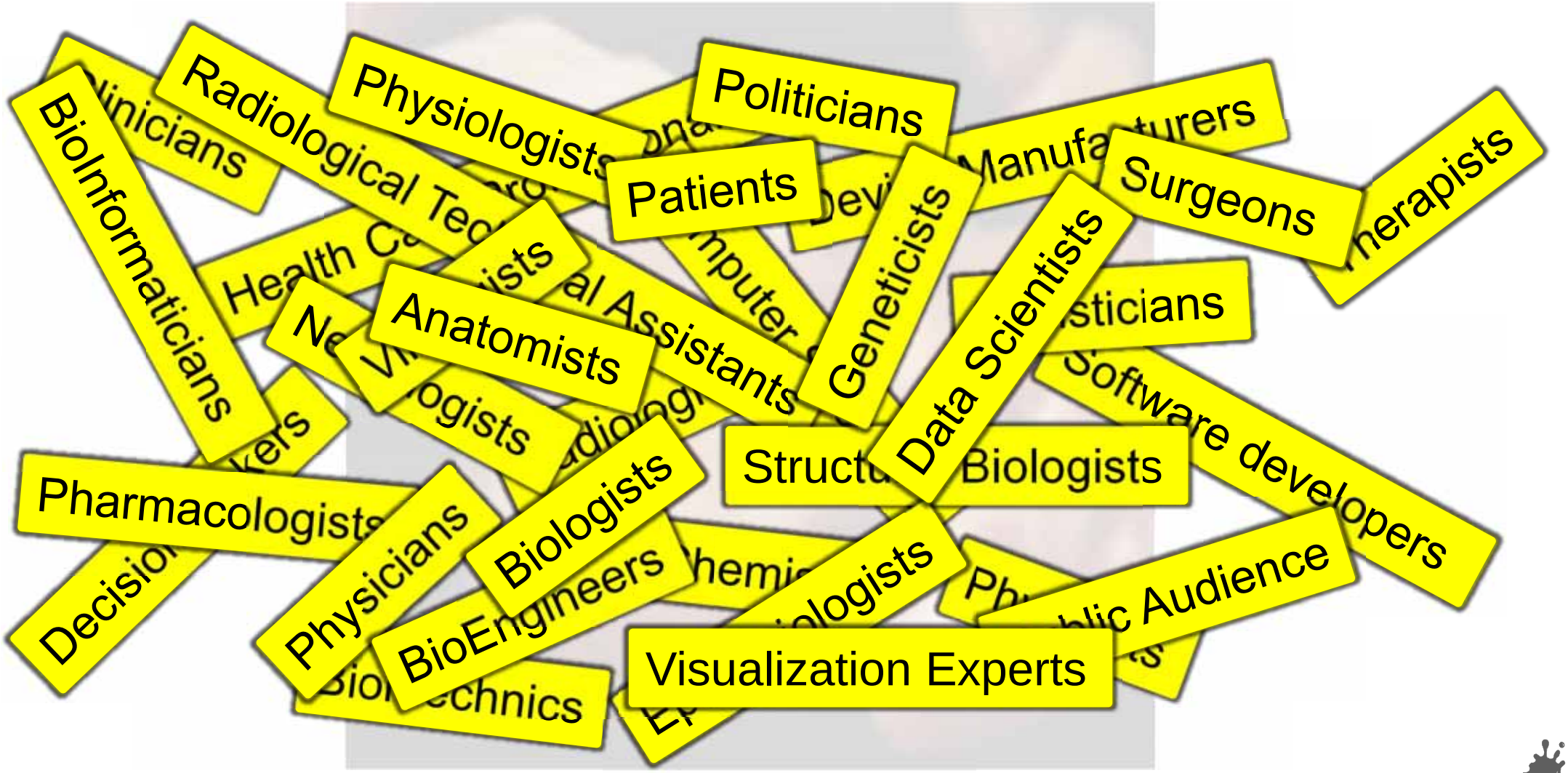






Institute of Visual Computing &
Human-Centered Technology,
TU Wien, Austria

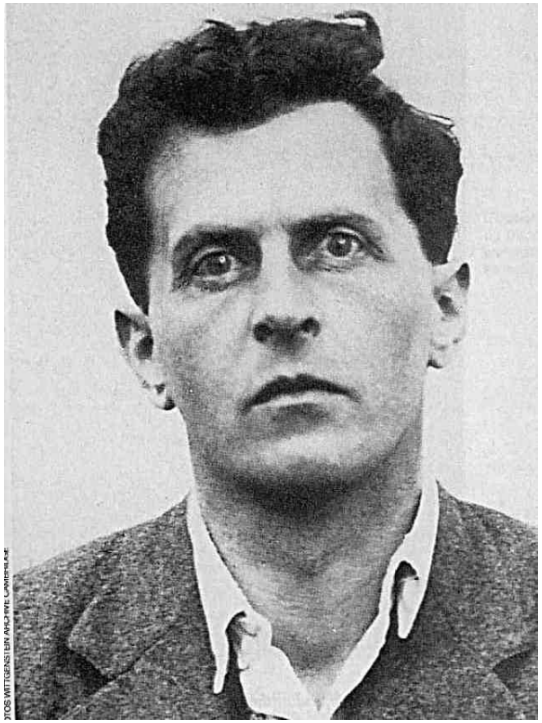
Stakeholders in (Bio)medical Visualization



What is it all about?

Die Grenzen meiner Sprache bedeuten die Grenzen meiner Welt

[Ludwig Wittgenstein]



Is medical visualization using the right language?

Organizers‘ Request

We would ask you for a 10 minute presentation, describing open challenges that you see in medical visualization, answering the following questions:

- Why is this a challenge?
- Are there any approaches to tackle this problem so far?
- What would be required to solve the problem?
- Is the VIS ecosystem part of the problem?

Of course you would be able to supplement this with your own ideas.

Informal Ad Hoc Opinion Poll

Short version: What do you consider as important open challenges in medical visualization?

Long version: For each of the open challenges in medical visualization that you mentioned could you briefly answer

- Why is this a challenge?
- Are there any approaches to tackle this problem so far?
- What would be required to solve the problem?
- Is the VIS ecosystem (IEEE Vis, EuroVis, …) part of the problem? [if you are familiar with this ecosystem]

Additional questions:

- Can you name success/failure stories of medical visualization. Why did they succeed/fail?
- What are novel application domains for medical visualization (novel imaging, diagnosis, and treatment techniques)
- How important is medical visualization as compared to medical imaging?
- What do you consider obstacles (legal, technical, commercial) to bring research results in medical visualization to clinical use?
- Unrelated to visualization, what do you consider the greatest open challenges in your area?

Feedbackees

Wolfgang Birkfellner

MEDICAL UNIVERSITY OF VIENNA

Marcel Breeuwer

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Katja Bühler

vrvis

Dominik Fleischmann

Stanford MEDICINE

Florian Ganglberger

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Bernhard Kainz

Imperial College London

Gabriel Mistelbauer

OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

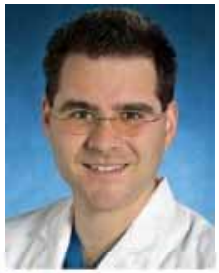
Christian Nasel

KARL LANDSTEINER XL

Renata Raidou

university of groningen

Rüdiger Schernthaner



MEDICAL UNIVERSITY OF VIENNA

Gerald Schröcker

GE Healthcare

Maurice Termeer

Philips Healthcare

Rainer Wegenkittl

AGFA HealthCare

Wolfgang Weninger

MEDICAL UNIVERSITY OF VIENNA

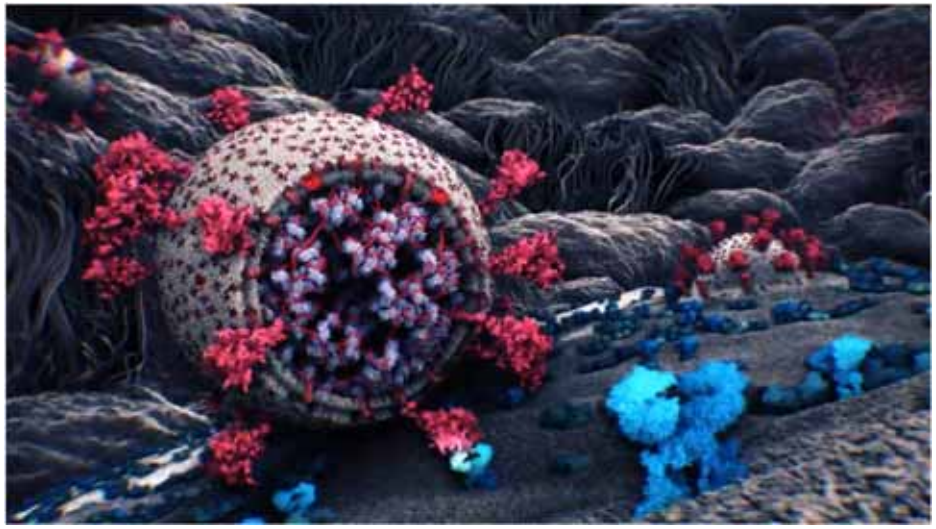
Ad Hoc Feedback Summarization

- Artificial Intelligence, Deep Learning {6}
- Comprehensive Visualization {3}
- Uncertainty Calculation & Visualization, Quantitative Results {3}
- Intuitive User Interfaces, Intuitive Visualization Solutions, Complexity Reduction {7}
- Visualization Speed/Efficiency {7}
- Trust in Visualization Results {6}
- Standardization, Harmonization {9}
- Clinical Application Driven Visualization {3}
- Interdisciplinary, Integrative Research {7}
- Data Preparation, Data Handling, Big Data {8}
- Data- and Application-wise: Stop doing “old” stuff {6}
- User-wise: Opening up our Target Groups {1}
- Domain-wise: Bridging BioVis and MedVis {3}
- Stumbling Blocks, Issues with VisEcoSystem {11}

Visualization Success/Failure Stories {6}

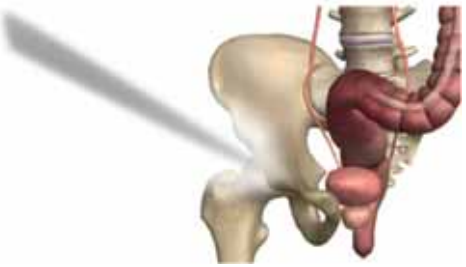
[Kanitsar et al.]

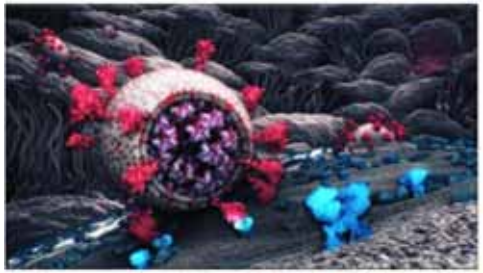
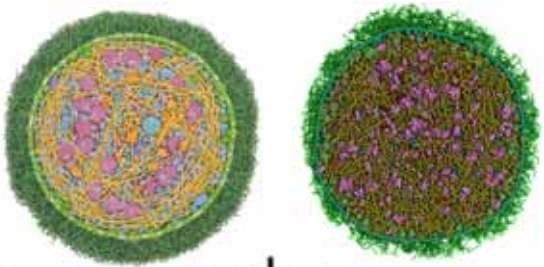
[Bruckner, Varchola, Karimov, Schröcker, et al.]



[Mindek, nanographics, 2020]

Questions? Comments?



“Medicinae Notitia Visibilis Fac – Clara Futura In Vobis”

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Gerald Schröcker
Maurice Termeer
Reiner Wegenkittl
Wolfgang Weninger
…

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Open Challenges – (Bio)medical Visualization {9}

- Visualization of difficult data
- Multi-scale, multi-modal visualization
- Unifying framework to incorporate many small solutions
- Funding for community building
- Extract meaning from data (What to visualize ↔ How to visualize)
- Publicly available data sources + annotations
- 3D fabrication – physicalization
- From diagnosis/treatment to prediction/prevention (e.g., Visual Analytics, e.g. aortic dissection)
- Screening, personalised diagnoses, prognoses
- Visualization in the wild
- Modelitics, data assimilation
- Patient briefing, storytelling: P4 medicine, precision medicine
- VR/AR, visual analytics, immersive analytics, ensemble visualization
- Progressive, guided visualization + analytics in real-time
- Data preparation + curation
- AI many approaches in diagnosis, but clinically applicable?
- Education
  - How to make medical visualization interesting to students?
  - Narrow specialists vs. Interdisciplinary education (computer scientist or physicist vs bioengineer or data scientist)

Medical Imaging ↔ Medical Visualization {5}

- Medical imaging basis of medical visualization
- Medical imaging, biomedical applications more dynamic, larger?
- Both equally important
- Medical imaging increasingly needs medical visualization
- How comparable to hot topics: machine learning, autonomous systems, internet of things, data science, …?

Medicinae Notitia Visibilis Fac - Quo Vadis?

- Title: Medicinae Notitia Visibilis Fac - Quo Vadis?
- Abstract: Medical Visualization is a scientific field that takes advantage of human vision and perception to amplify cognition and gain insight in (complex) medical data. The interdisciplinarity and the diversity of stakeholders and their greatly varying expertises and expectations, make it a demanding area with many overlapping, but distinct domains. Collaboration and communication is challenged by: “Die Grenzen meiner Sprache bedeuten die Grenzen meiner Welt“ (Ludwig Wittgenstein). This talk reflects on the feedback from an ad hoc and random sampling of my professional network with comments, e.g., from basic and applied visual and medical computing experts, commercial developers of medical software, clinical researchers and practitioners.

Artificial Intelligence, Deep Learning {6}

- Large amount of data required
- Data comprehensive/general enough
- Patient-specific accuracy/precision
- Bias: data, gender, age, geographic distribution
- Generalizability
- Control on data acquisition, generation, annotation
- “black boxes” – lack of trust in automated methods
- Explainable AI, interaction & visualization
- Clinically applicable solutions
- AI is tool not solution

Comprehensive Visualization {3}

- Multitude of data
- Multiple sources/modalities
- Convey essential information to clinician
- Many solutions published, few in clinical practice
- Switching between modalities
- Accommodating many modalities
  - Confidence
  - Reliability
  - Robustness

Uncertainty Calculation & Visualization, Quantitative Results {3}

- Accuracy & precision of image analysis results
- Patient-specific way – precision medicine
- Easily understandable for the clinical user
- “black boxes” – lack of trust in automated methods
- Required: clever solutions
  - Close cooperation of clinical users
  - Validated
  - Broadly adopted
  - Preferably standardized

Intuitive Interfaces+Visualizations; Complexity Reduction {7}

- Clinicians: few interactions with simple visualizations without training
- Complexity reduction of imaging systems (e.g., US)
- Static presets, dynamic parameter adjustments
- Most Visual Analytics Systems not applicable in clinical practice
- Navigation in 3D space with multiple views is difficult
- 2D vs 3D and similarity to gold standards
- Solutions should
  - be intuitive
  - fit into existing workflow
  - be similar to what user is familiar with
- Balance complexity of data ↔ complexity of user interfaces

Visualization Speed/Efficiency {7}

- Real-time interaction with rich visualizations
- Integrate interactive visualization with data analysis (and pre-processing)
- Make big data accessible
- Online diagnosis (e.g., US)
- Real-time visualization of parameter variations
- HW/SW in clinical use: sometimes not latest technology
- Solutions characterized by
  - Parallel computing, multi-core PCs, GPUs
  - Run on all types of architectures and hardware
  - Cloud-based, out of core, streaming, insitu
  - Progressive, incremental analysis

Trust in Visualization Results {6}

- How to estimate accuracy & precision (patient specific)
- „black boxes“ (deep learning) require guarantees and failure modes
- PCA, T-SNE, UMAP almost standard, not reliable as representation
- Transformation to normalized space may fail
- Data (resolution) loss
- Arteficial data, interpreting artefacts
- Quantitative vs. Qualitatitive results
- Precision medicine
- Reproducibility/stability of algorithms

Standardization, Harmonization {9}

- Standardized solutions in close collaboration with clinical users
- New data formats (DICOM goes back 40 years)
- Early communication with data producers and annotaters
- Static presets
- Certification, legal approval, disproportionate regulations
- Stable and reproducible assessment
- Integrated diagnostic environment (plug-ins?)
- Web-based visualization
- Open-source frameworks

Clinical Application Driven Visualization {3}

- Avoid „I have a solution – where is your problem“
- Many visualizations developed – only a few made it into clinical practice
- Machine learning: just a tool not a solution
- Domain expertise required
- Plethora of available data – relevance determined by tasks

Interdisciplinary, Integrative Research {7}

- Interdisciplinary way of thinking necessary
- Data curation costly and critical
- Plethora of data (-omics), data integration
- Switching between modalities/visualizations
- Close interweaving: interaction + visualization + machine learning
- Training of interdisciplinary researchers vs. narrow specialists
- Spatial/institutional association between user and basic researcher
- Software integration
- Collaboration of many experts necessary (e.g., aortic dissection)

Data Preparation, Data Handling, Big Data {8}

- Scanning difficult (subgroup of patients) – improve raw data quality
- Complex signal processing involved („garbage in – garbage out“)
- Data curation costly and critical
- Communicating gap between raw data and visualization
- Making big data accessible
  - in life sciences
  - Example: UK biobank
  - Electronic Health Record (EHR)
- Real-time browsing, search, exploration, visualization
- Avoid data (resolution) loss
- Generative maching learning models
- In-situ techniques (simulation+visualization)
- Standardization
- Interdisciplinary collaboration (e.g., aortic dissection)

Data- and Application-wise: Stop doing “old” stuff {6}

- Avoid solutions for simple data
- Go beyond easy problems
- From diagnosis/treatment to prediction/prevention (e.g., Visual Analytics)
- Heterogeneous data integration (digestible, usable)
- Reliable visualizations
- Interdisciplinary collaborations (domain expertise, industry, visualization, machine learning expertise, biomedical expertise, lots of statistics)
- Automatic techniques (machine learning)
- Screening, personalised diagnoses, prognoses

User-wise: Opening up our Target Groups {1}

- Patient communication and information
- Communication of medicine and biology to laymen/general audience
- Engagement of public ↔ scientific accuracy
- Virtual Reality / Augmented Reality solutions
- 3D printing
- Data physicalization
- Education, museums, dissemination (e.g., nanographics)
- Multidisciplinarity needed
- Collaboration with artists/illustrators
- Good knowledge of background science
- Focus group: kids

Domain-wise: Bridging BioVis and MedVis {3}

- BioVis ↔ MedVis
  - Important subfields of life sciences
  - Speak different languages (Shonan seminar “Formalizing Biological and Medical Visualization”)
  - Work on different scales
  - Collaboration: domain/medical/biology experts, industry
- Communicating the gap between raw data and the visualization
- Making big data accessible
- Balance between complexity of data and complexity of user interfaces
- Visualization is seen as given in interdisciplinary research
- Life Sciences
  - Hugely interdisciplinary
  - Plethora of data
  - Visualization in the wild
  - Modelitics

Stumbling Blocks, Issues with VisEcoSystem {11} (1)

- Many problems solved but not applied in clinical use
  - Simple cases
  - Scalability
  - Reliability
  - Evaluation
  - Reproducibility / stability
- Scientific orginality vs. relevance
- Interdisciplinary work difficult to „sell“
- Bringing vis. technology to clinical practice not rewarded
- Data curation
- Need of interdisciplinarity
- Danger of becoming extended workbench
- Visualization often a small part of the user problem

Stumbling Blocks, Issues with VisEcoSystem {11} (2)

- Long cycles: visualization research → commercial product, clinical application
- Technical papers – application papers – (applied papers)
- Medical visualization is a special application domain
- Certification/approval, standardization, data rights
- Access do domain experts, industrial partners
- What to visualize ↔ How to visualize
- Funding interdisciplinary initiatives: spatial/institutional association between user and basic researcher
- Difficult to formulate sound scientific hypotheses
- Individual solutions with limited market potential
- Software development and integration
- Big players: hospital networks, national health services, large instrument manufacturers, insurance companies, large software frameworks