Vis08 VIS • INFOVIS • VAST

Advanced Visual Medicine: Techniques for Visual Exploration & Analysis

Interactive Visualization of Multimodal Volume Data for Neurosurgical Planning

Felix Ritter, MeVis Research Bremen

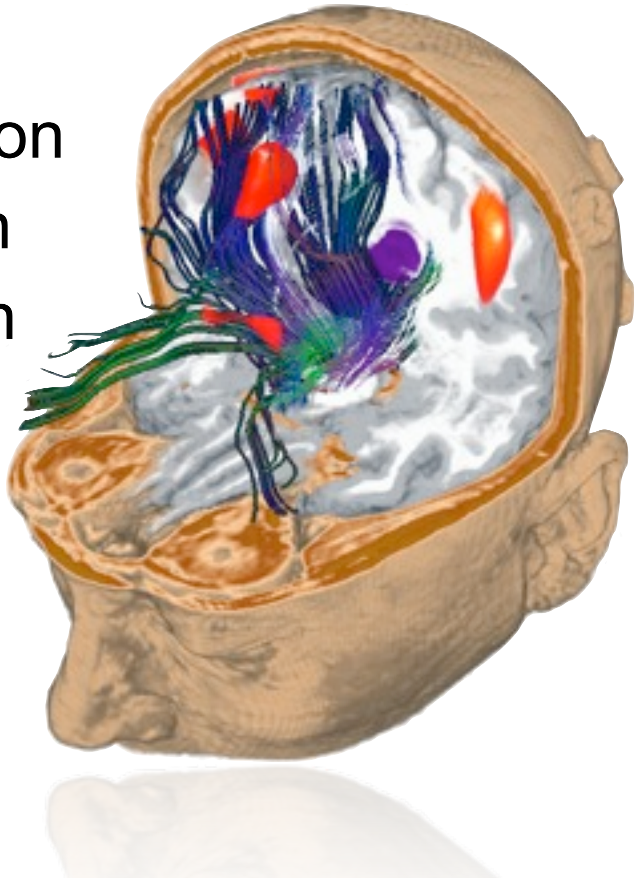
Multimodal Neurosurgical Planning

Multimodal Neurosurgical Planning

- Is a resection possible?
- What type of resection can be performed?
- What is the risk of the surgical intervention?
- What is an optimal access path to the lesion?

Topics to Work on

- Combining multimodal volume data
- Enhancement of risk structures
- Accentuation of spatial relations
- Reduction of interaction for exploration
- Visualization of access path to lesion
- Supporting brain-surface intervention



Medical Volume Data

Common medical volume data:

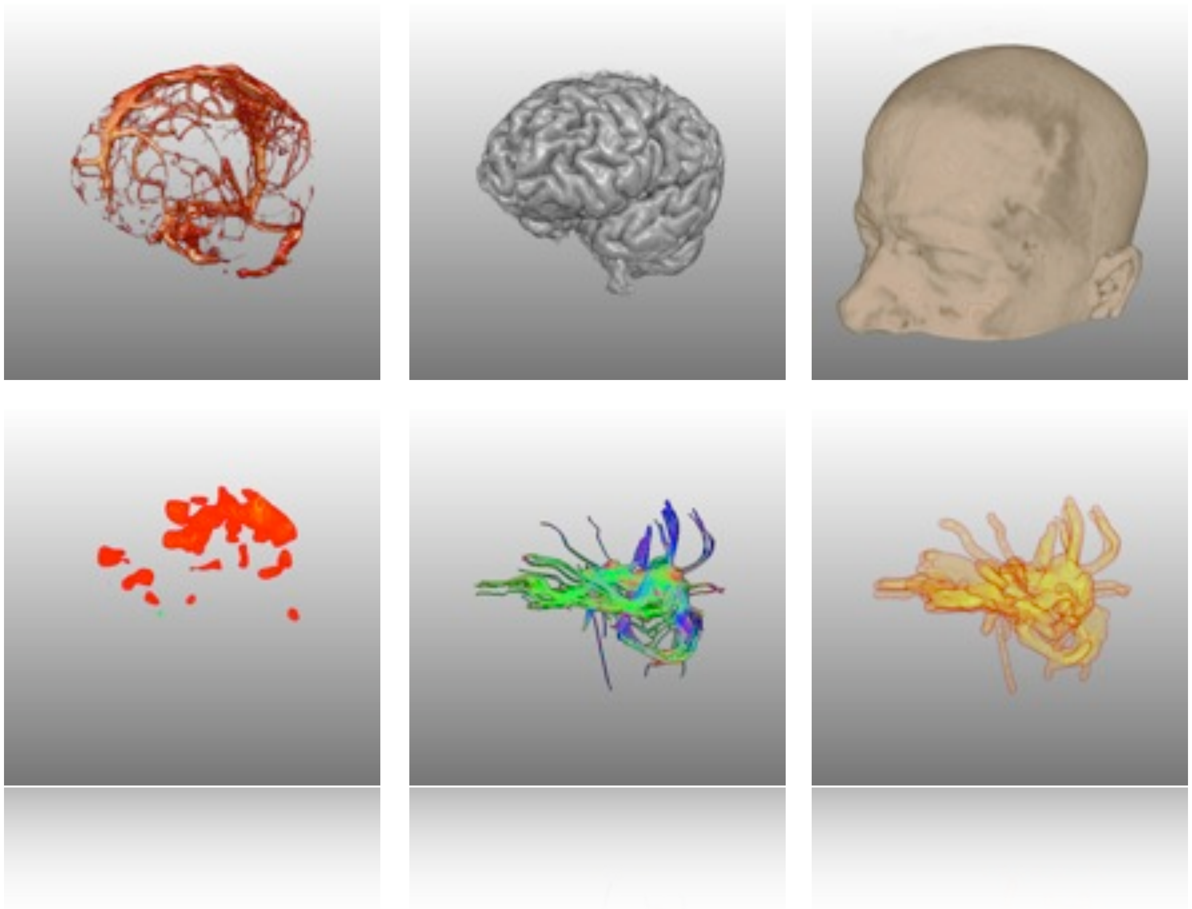
- *MRI* (magnetic resonance imaging), high soft tissue contrast for visualization of anatomical details
- *fMRI* (functional magnetic resonance imaging), for detection of the brain‘s activation areas
- *DTI* (diffusion tensor imaging), for reconstruction of the brain‘s nerve tracts
- *CT* (computer tomography), just used in special cases due the high radiation exposure, e.g. skull bone infiltrated by tumor tissue
- *PET* (positron emission tomography), nuclear imaging technique to detect functional processes

Multimodal Neurosurgical Planning

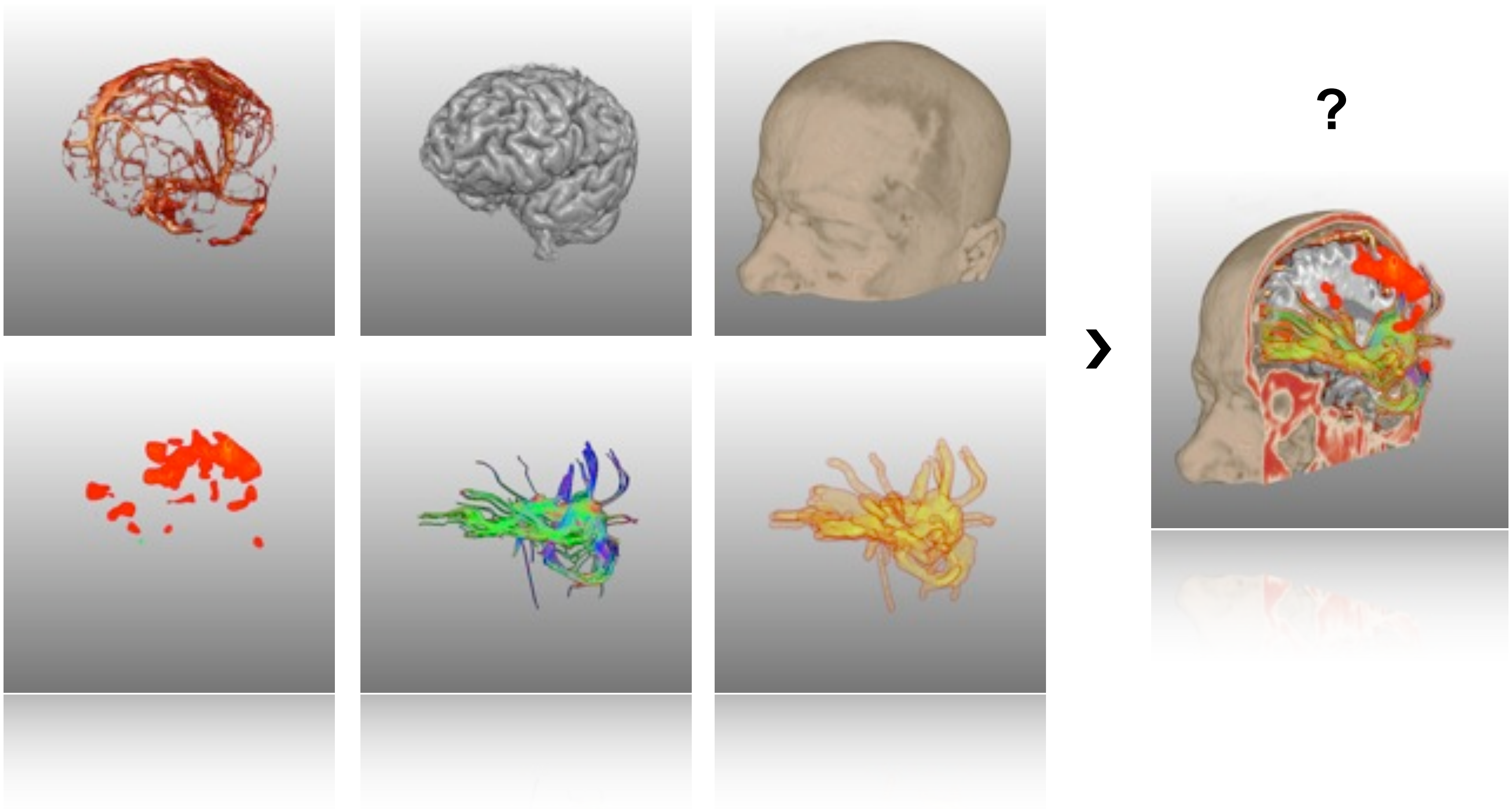
- A tempting assumption:
  - Combination of all available imaging modalities can identify all relevant structures!
- Limitations:
  - Models behind the involved techniques
    - fMRI can give hints about functional areas (Accumulation of oxygen)
    - Fiber-Tracking can give hints about axonal pathways (Diffusion of water)
  - Usefulness of combinations
- A better interpretation:
  - Combination of different images may give additional information but may also introduce limitations and additional complexity

Multimodality Visualization

Multimodality Visualization



Multimodality Visualization

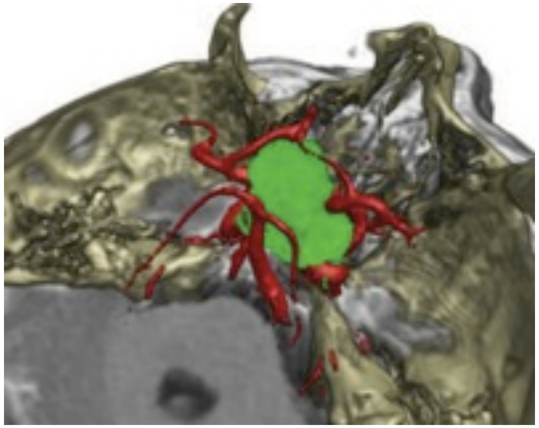


Multimodal Volume Rendering

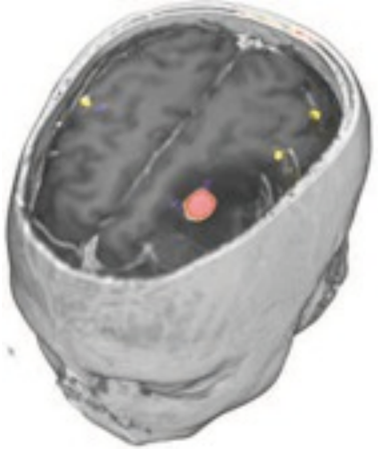
Visualization of CT & MR data for visualization of implanted electrodes for epilepsy surgery

Johanna Beyer et al., VIS 2007

CT, MR & MRA

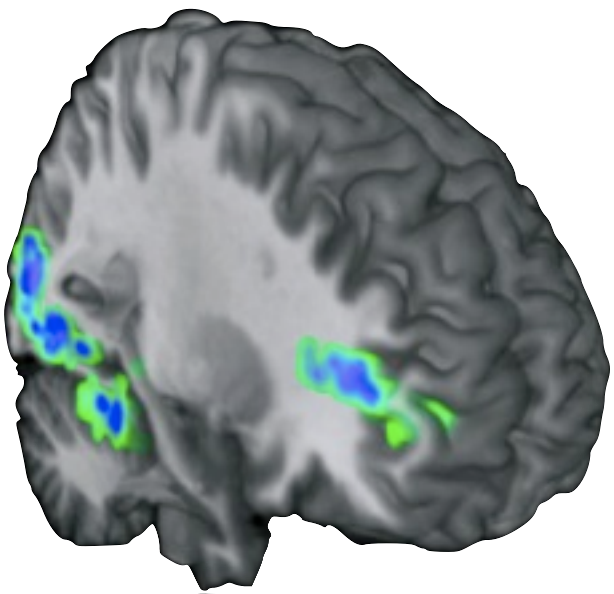


MR (black/white), PET (red) & fMRI (yellow and white)

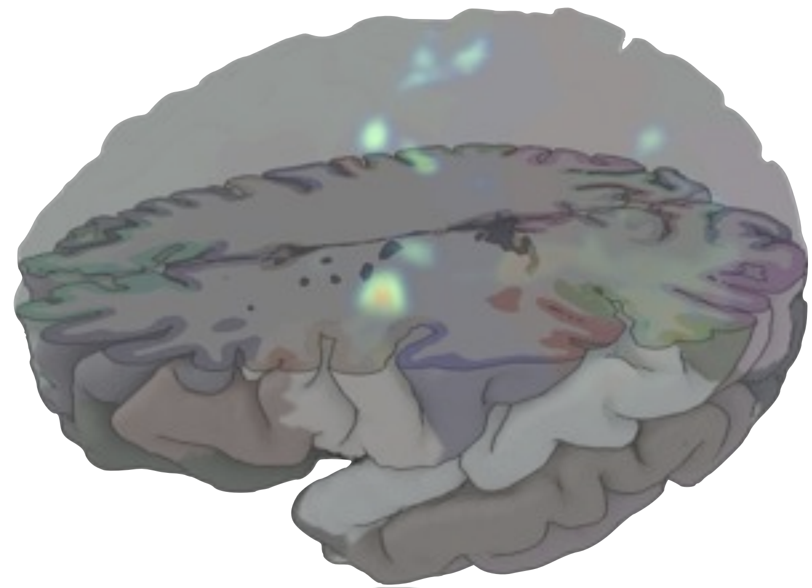


Multimodal Volume Rendering

Combined MRI, fMRI visualization



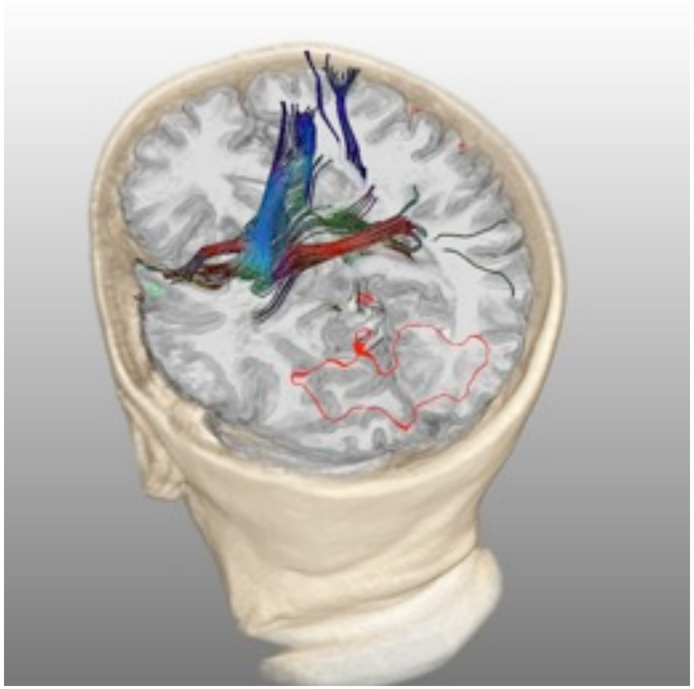
Friedemann Rößler et al., SimVis 2006

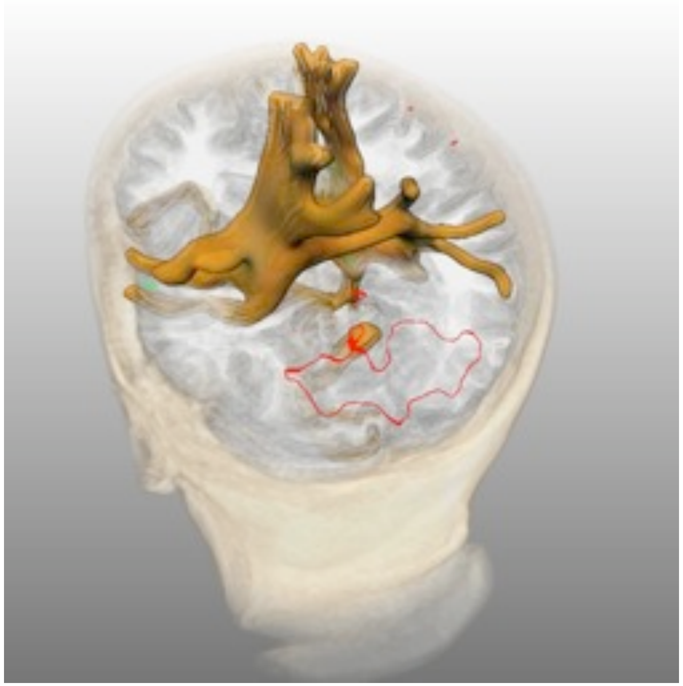


Werner Jainek et al., EuroVIS 2008

Multimodal Volume Rendering

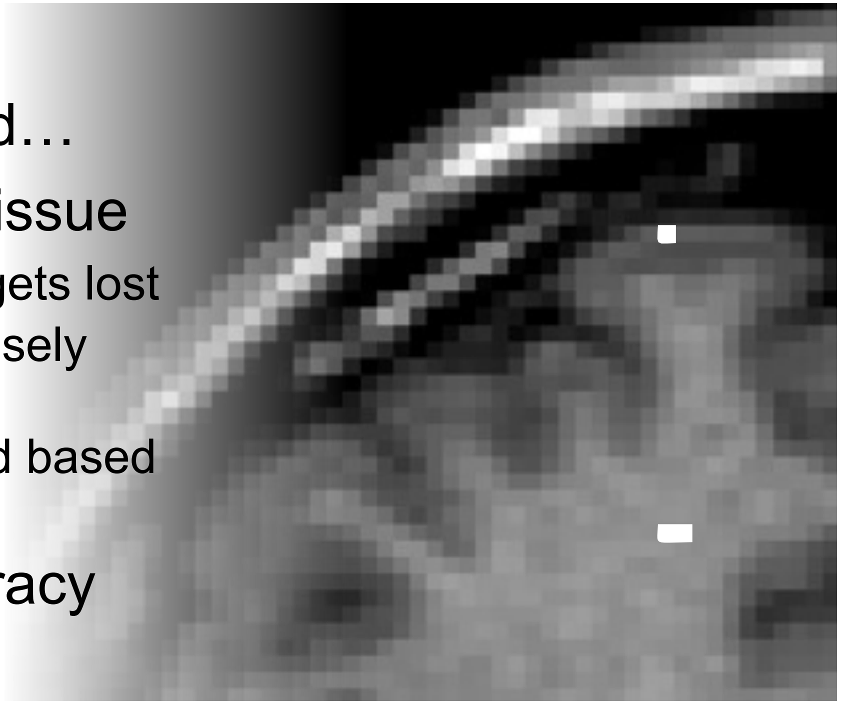
MRI, fMRI & DTI





Alexander Köhn et al., EG 07

Dealing with Inaccuracies in Multimodal Neurosurgical Planning

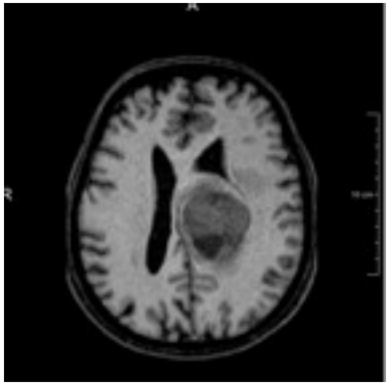


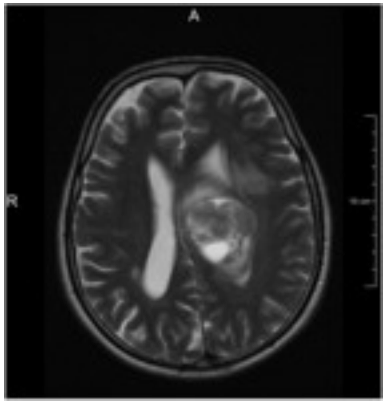
- Accuracy is limited!
- Sources for limitations are manifold…
- Limited accuracy may become an issue
  - If the awareness about the limitations gets lost
  - If the impression of high accuracy is falsely created
  - If decisions are made, that are not valid based on the given accuracy
- Limited accuracy turns into inaccuracy
- Inaccuracy is unavoidable

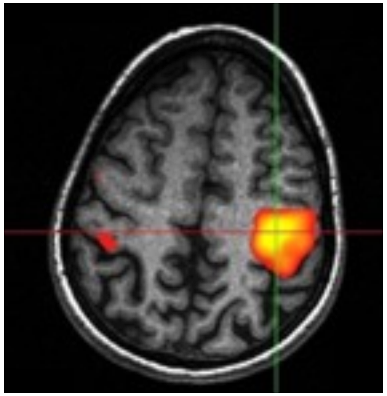
We must be aware of it !

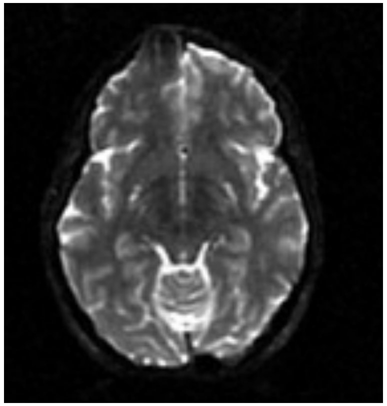
Sources of Inaccuracies

- Image registration
  - Spatial alignment is prerequisite for overlaying different images
  - Automatic rigid registration









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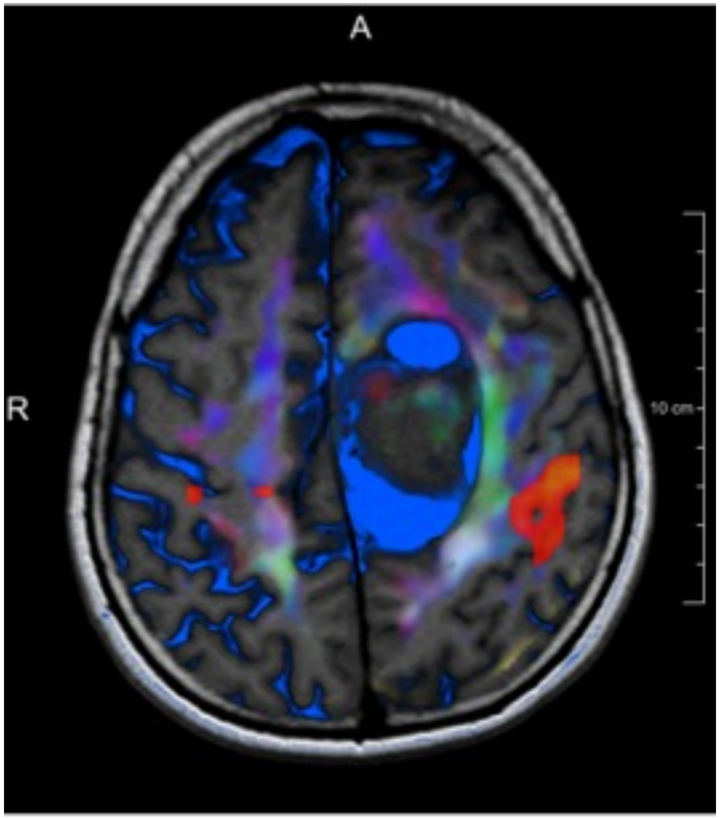

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- Problem:
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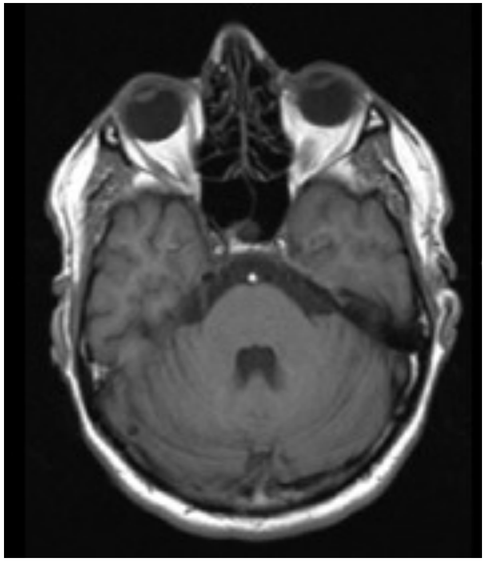

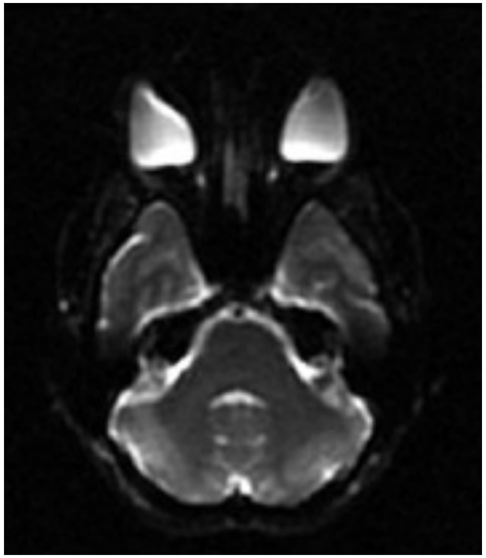

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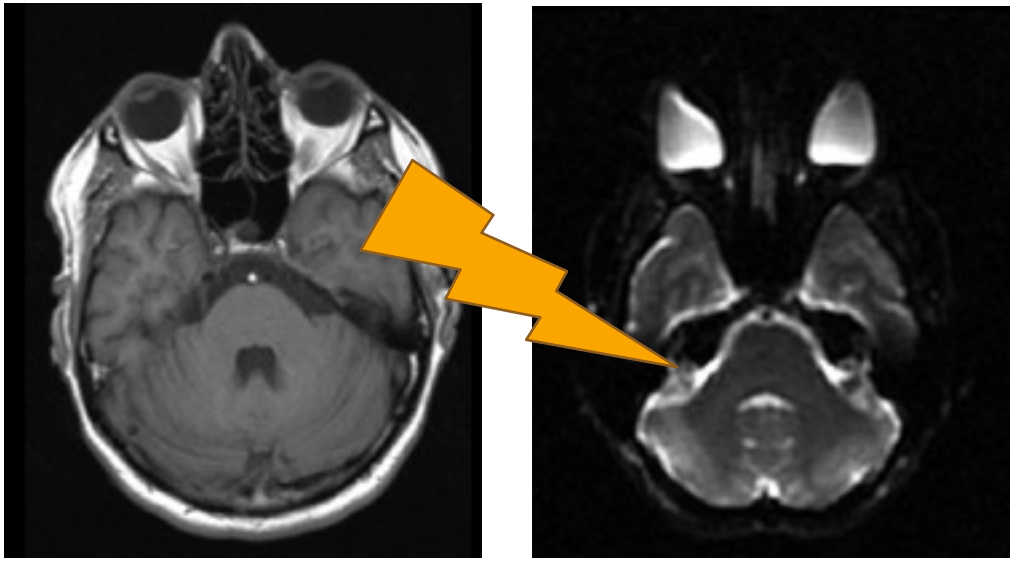

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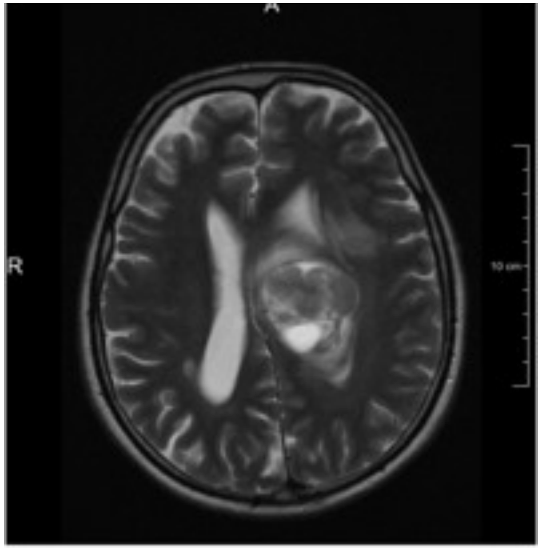

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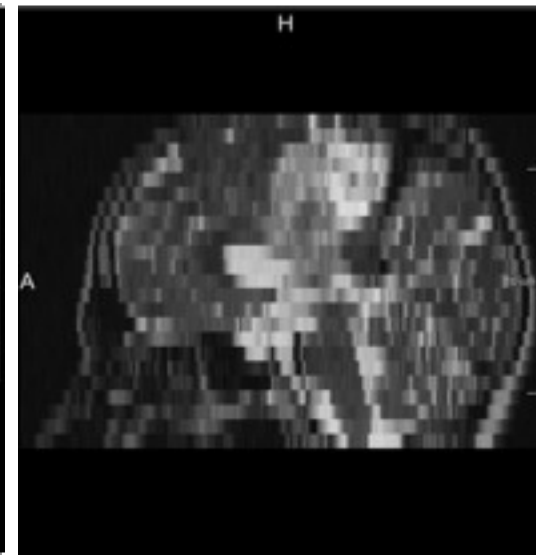
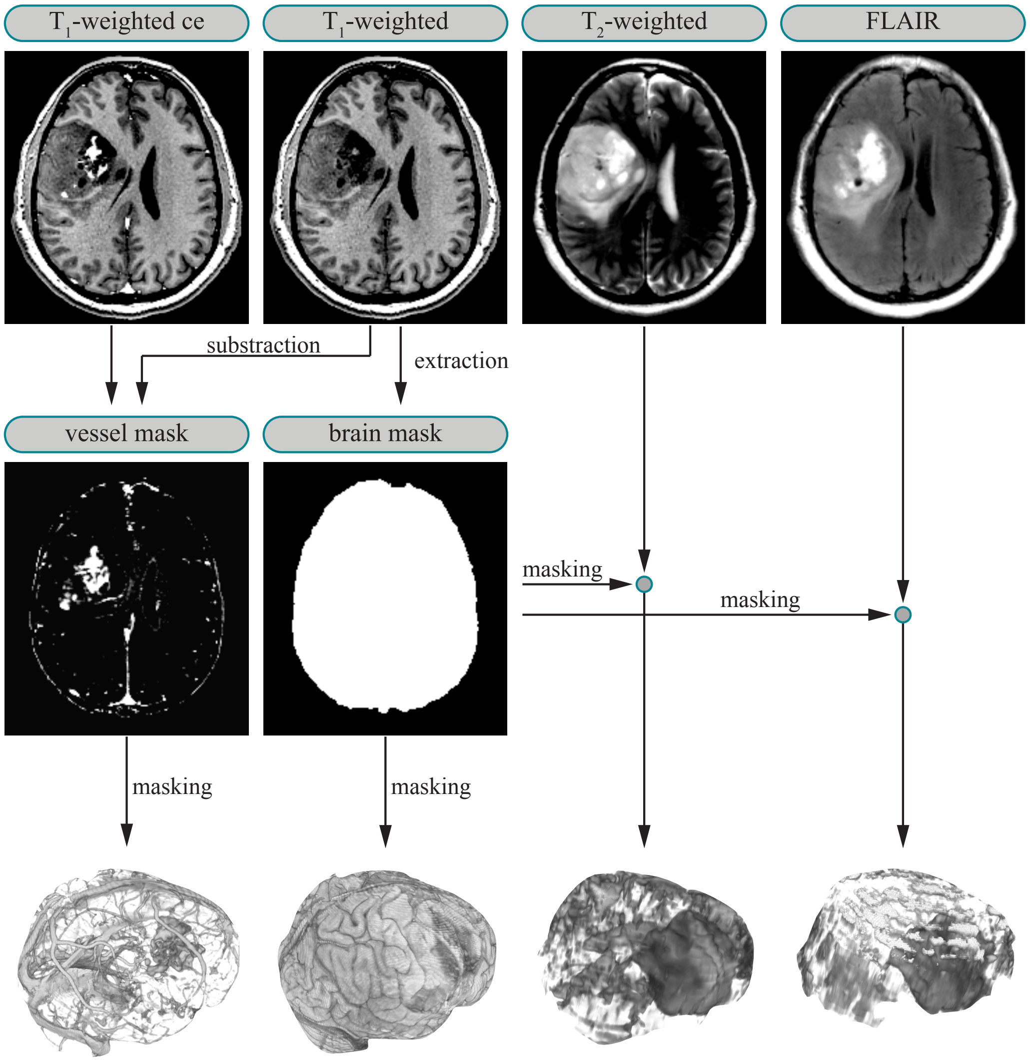
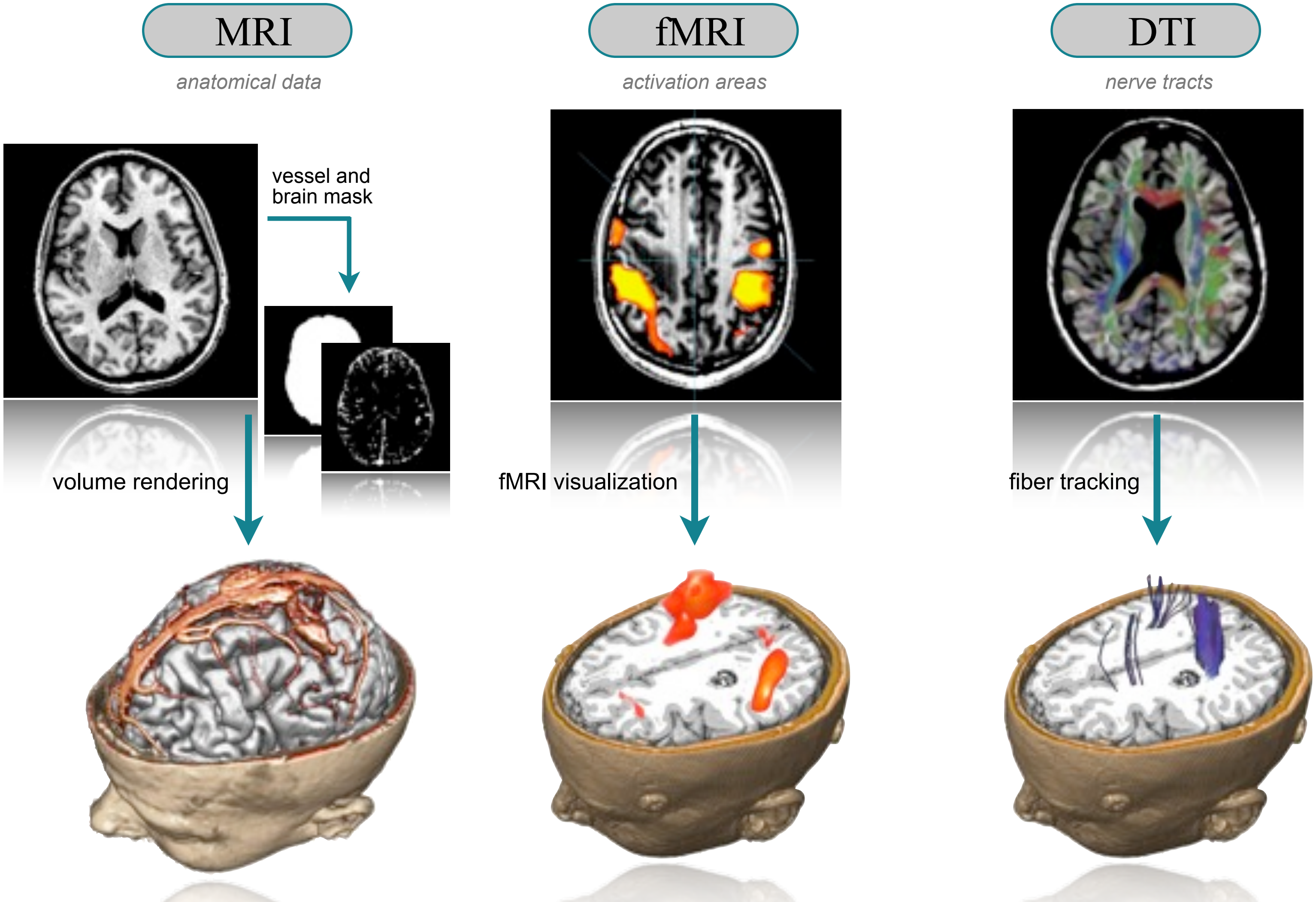


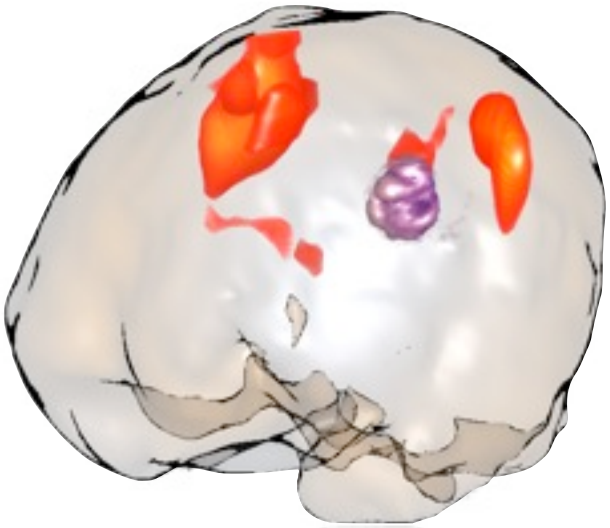
Extraction of Anatomical Structures



Risk Structures

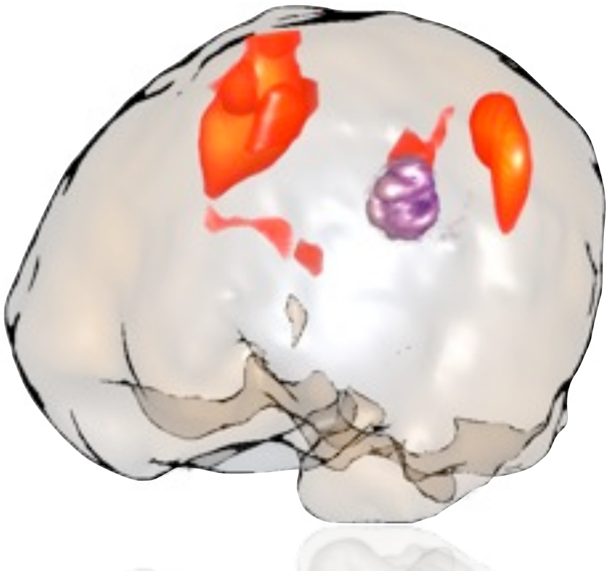


Multimodal Volume Visualization

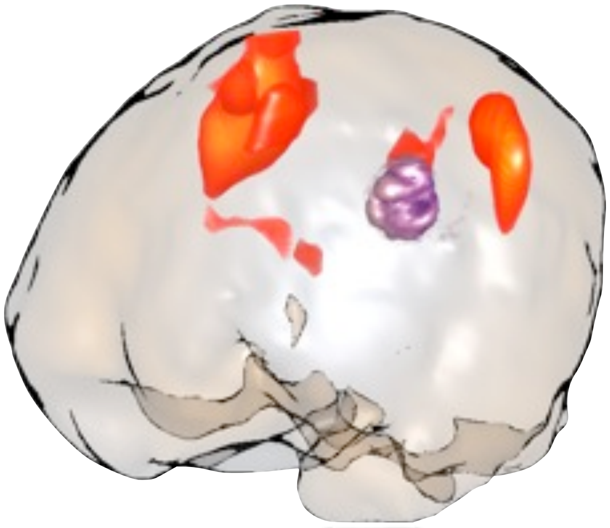


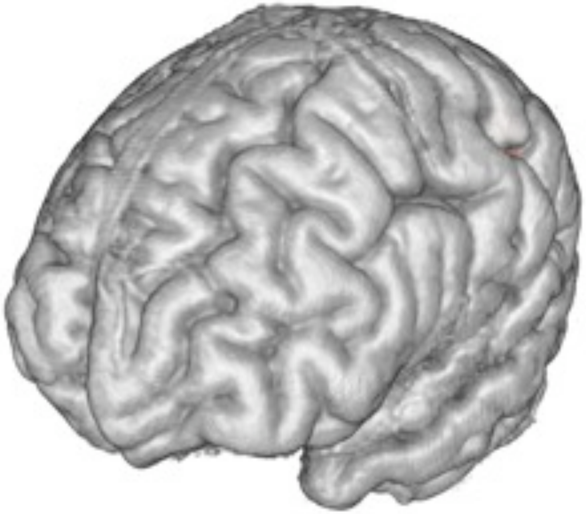
Multimodal Volume Visualization

- Combined exploration of inner risk structures and brain surface anatomy difficult



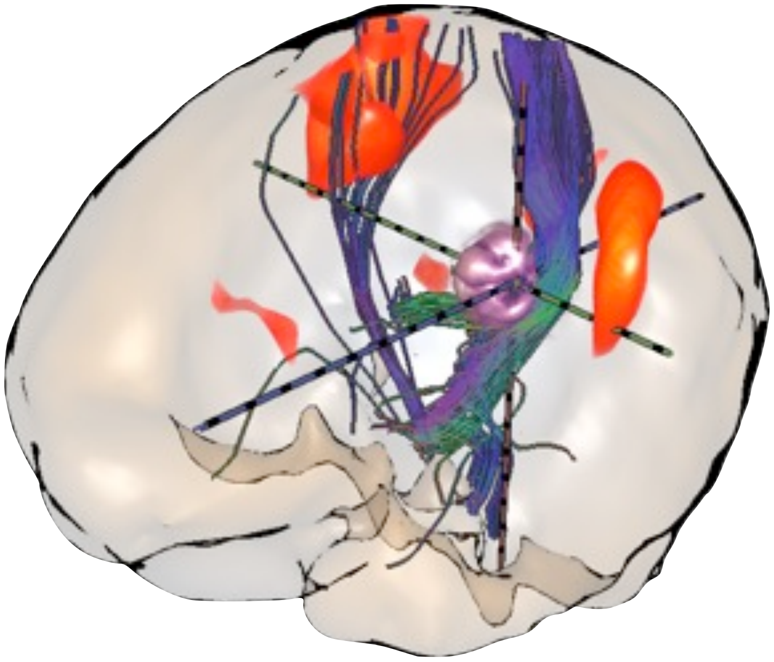
- Combined exploration of inner risk structures and brain surface anatomy difficult
- Simple solution: Dual views
  - *Internal view*: visualization of internal structures (risk structures, occluded by skull and brain)
  - *External view*: visualization of opaque anatomy (skull / brain). Requires cutting tools for exploration of inner structures.





Visualization Complexity

- Not all areas of the brain are of interest, e.g:
  - Fading of *color saturation* of fMRI areas far away of the ROI and trajectory
  - Fibers far away are just visualized as *outlined silhouettes*
  - Using distance-based selection of transfer function and shader



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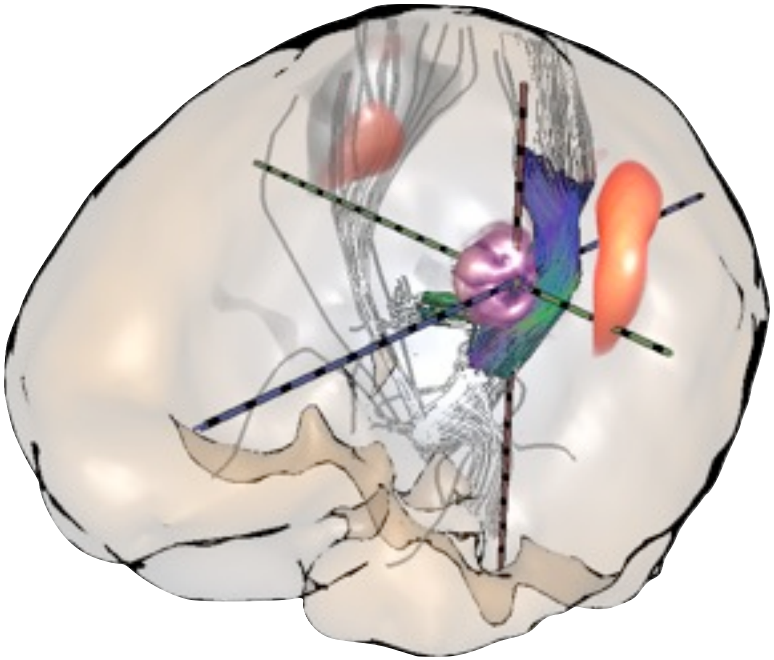
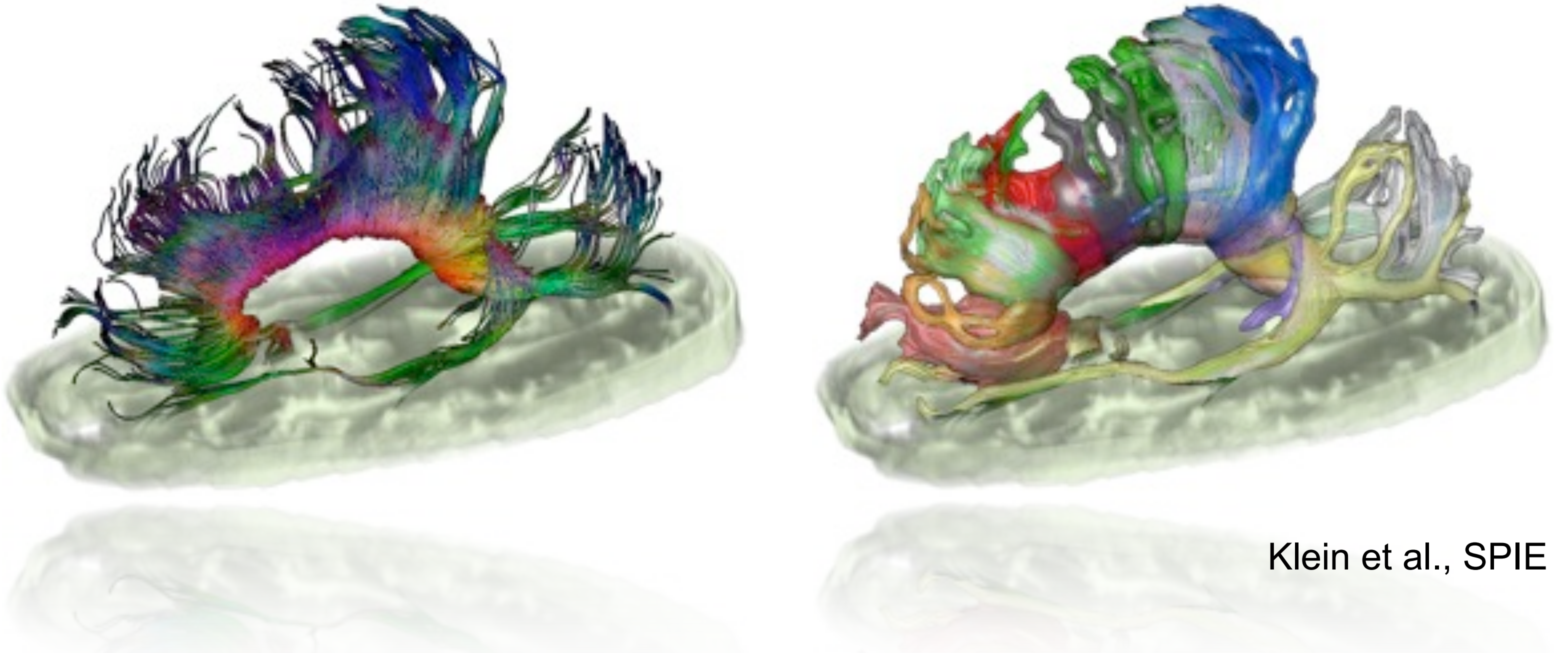


Fiber Clustering

Group geometrically similar or related fibers acquired by DTI.

- Improve perception of fiber bundles and connectivity.
- Improve interaction with fiber bundles.
- Avoid user-biased quantification results.



Klein et al., SPIE 2007

Improving Localization

- Depth perception of individual structures within the brain‘s hull difficult
- Visualizing the principal axes of the volume restricted by brain‘s hull improves localization

Distance Ring

- At some orientations one of the axes could be hidden or occluded by other structures
- „Distance Ring“ indicates location of ROI in view direction
  - *Minimal distance*: distance ring is completely open
  - *Maximal distance*: distance ring is completely closed

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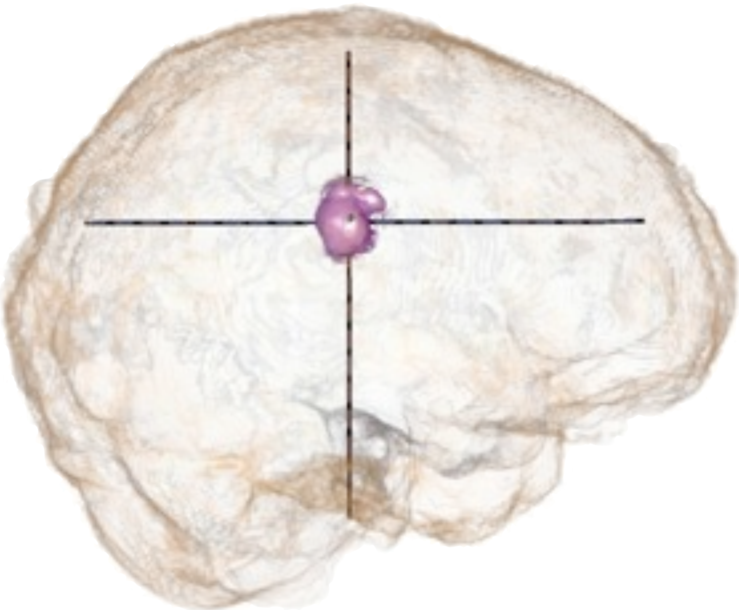
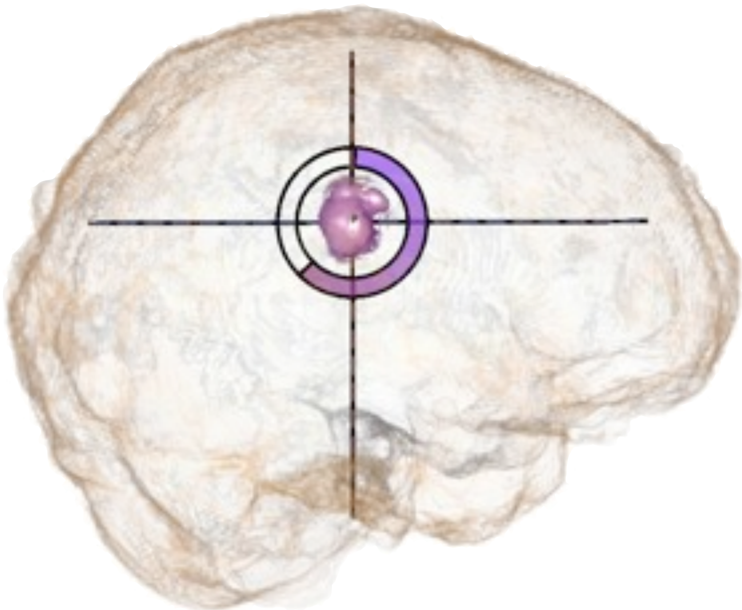
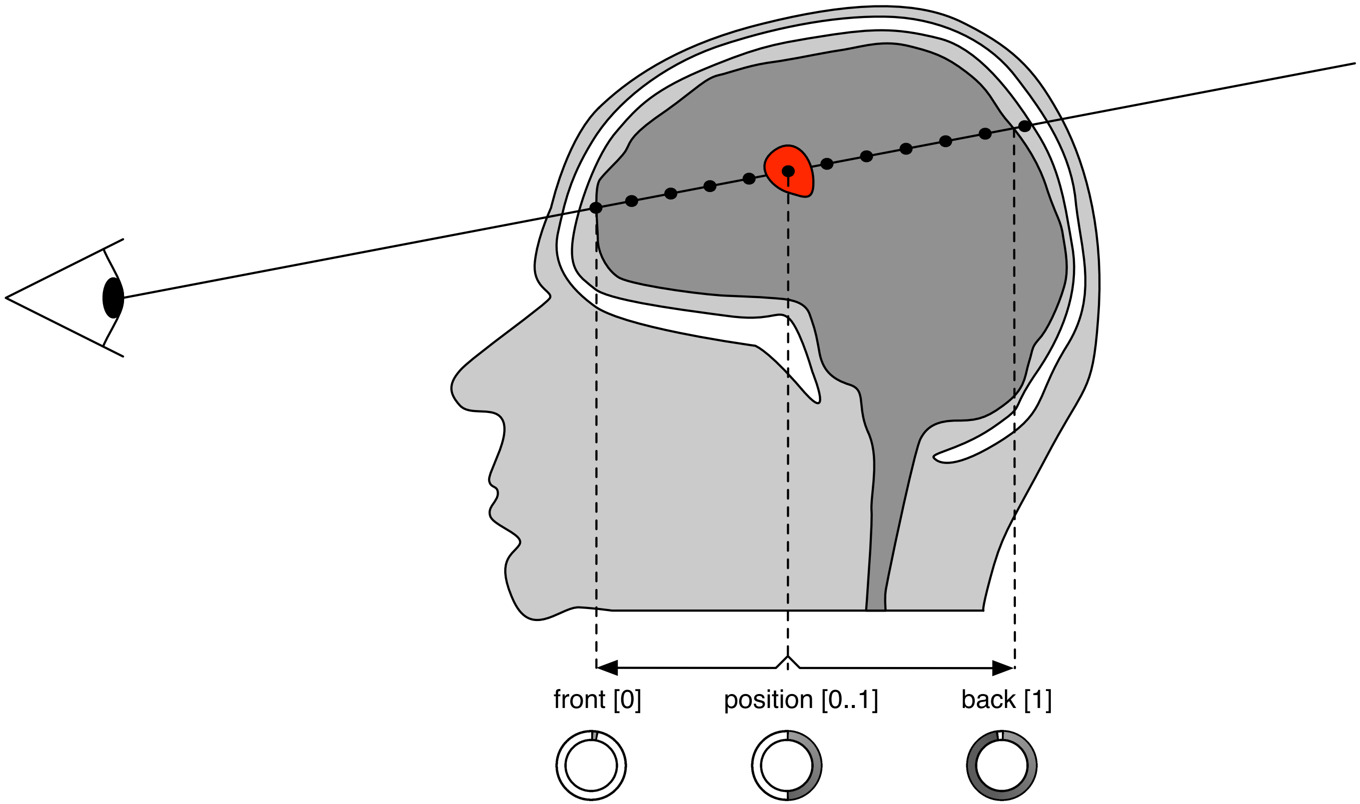




Distance Ring

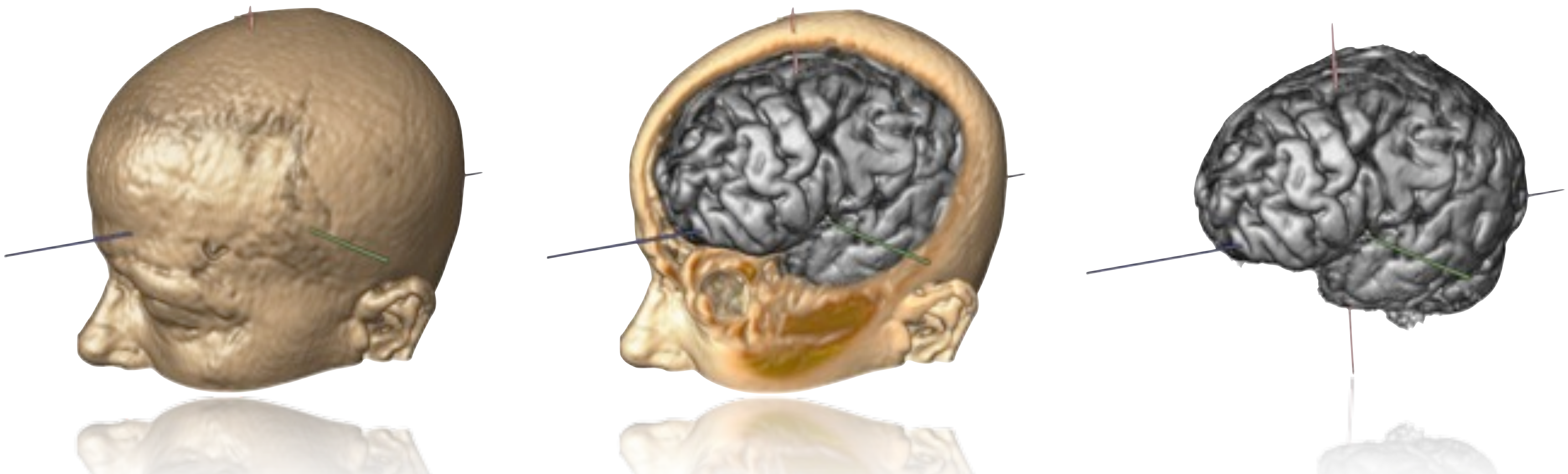
Tracing ray through brain mask



Superficial Landmarks

Superficial landmarks at surface of skull and brain to support navigation:

- Relate anatomical structures of head to those landmarks (e.g. nose, ears)
- Brain structures after opening the skull are known



Visualization of Contrast Enhanced Structures

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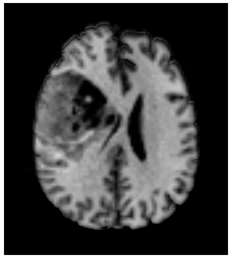

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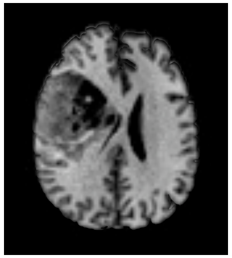

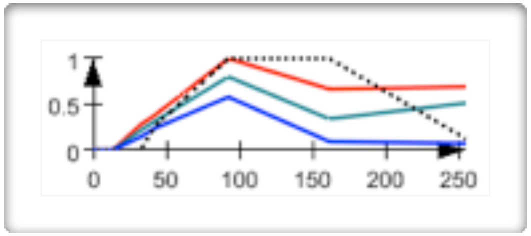

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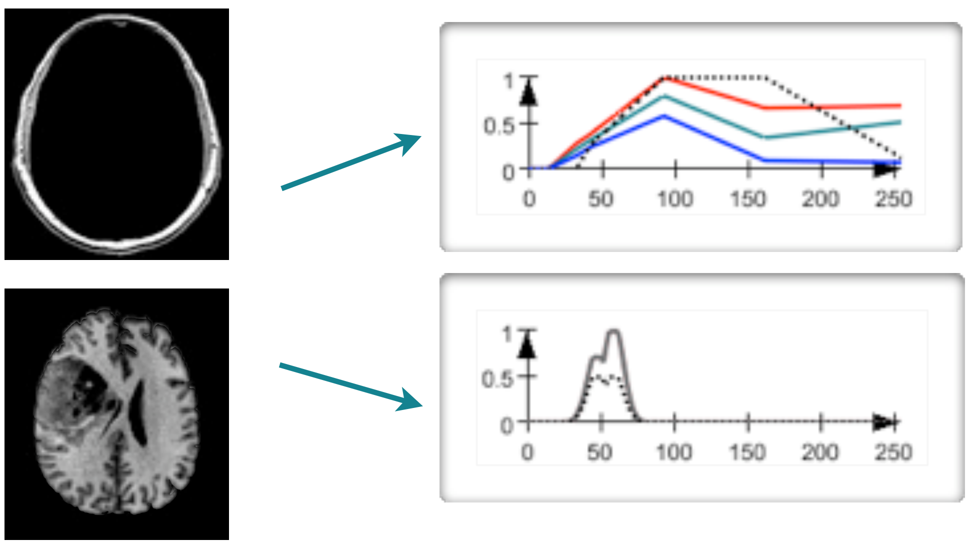

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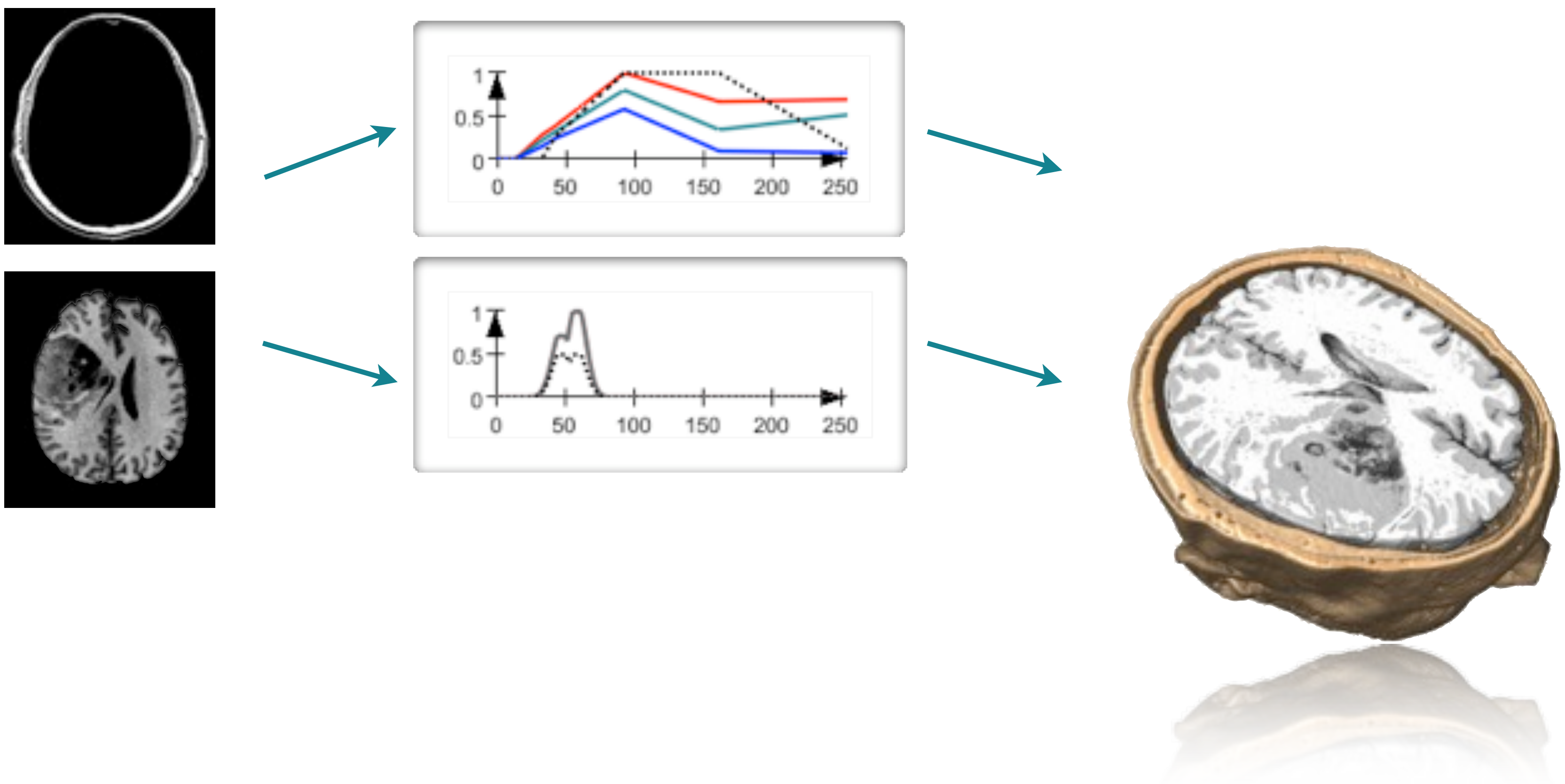

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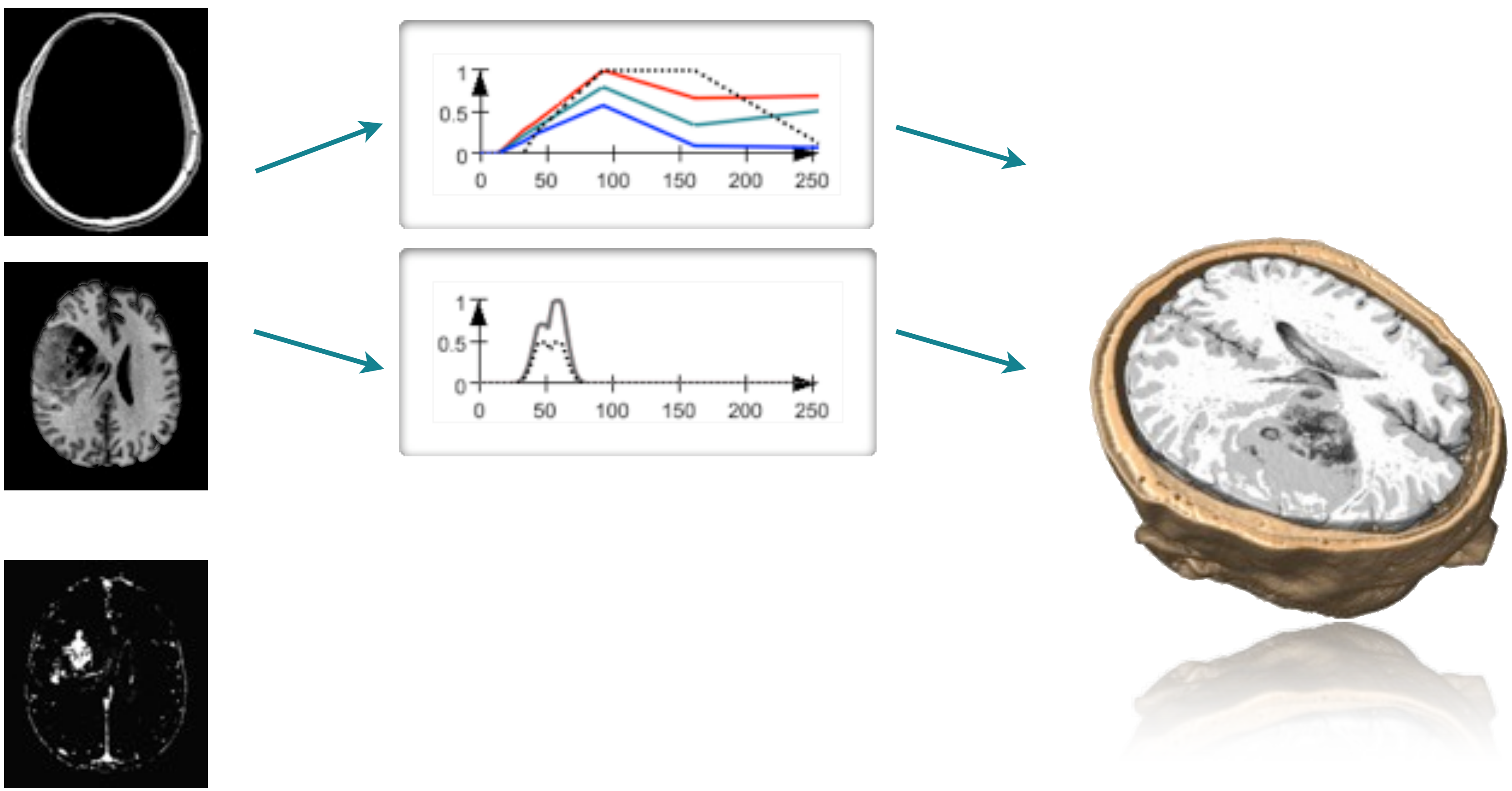

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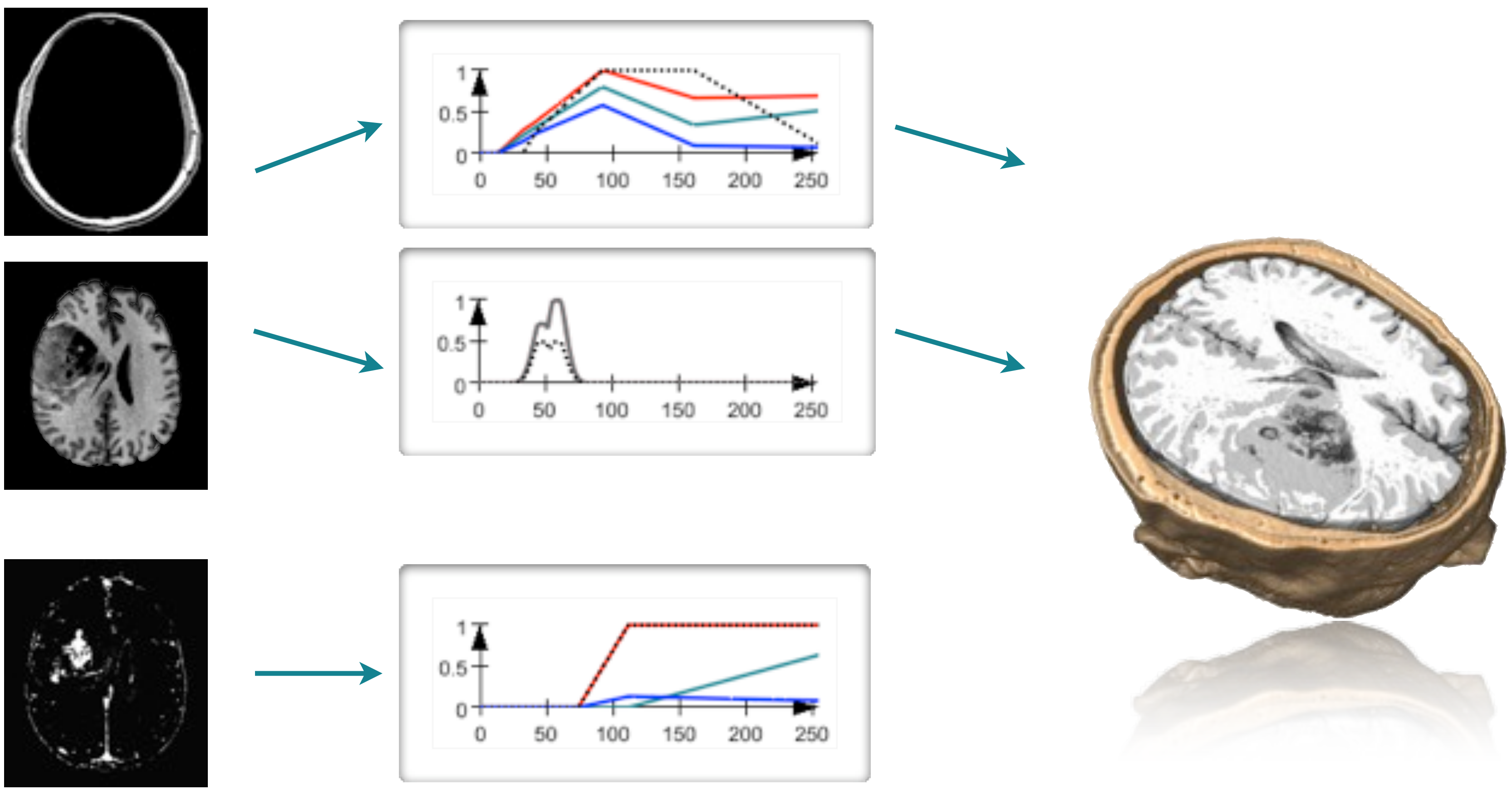

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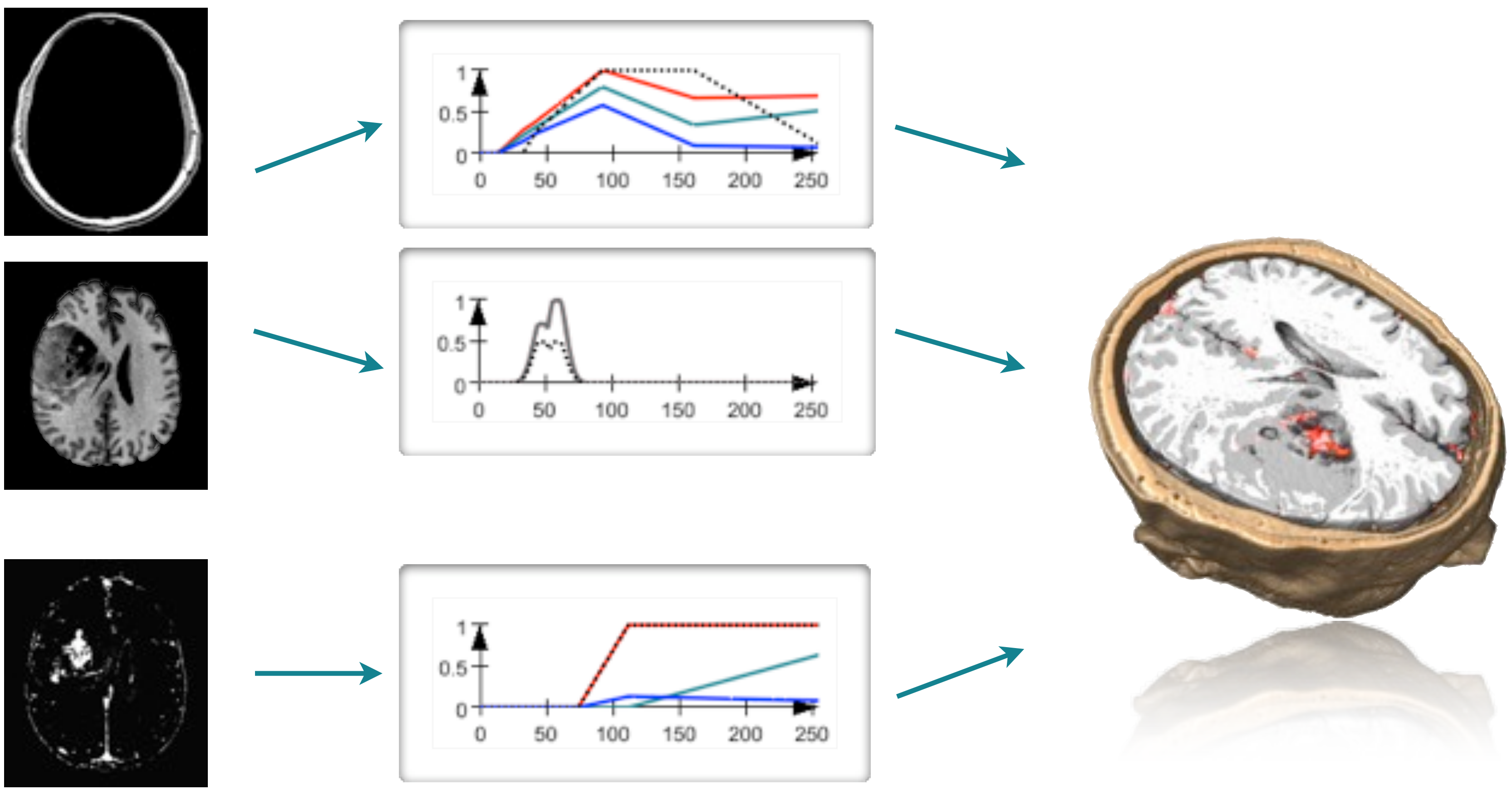

Automatic Transfer Function Adaptation of Diseased Tissue

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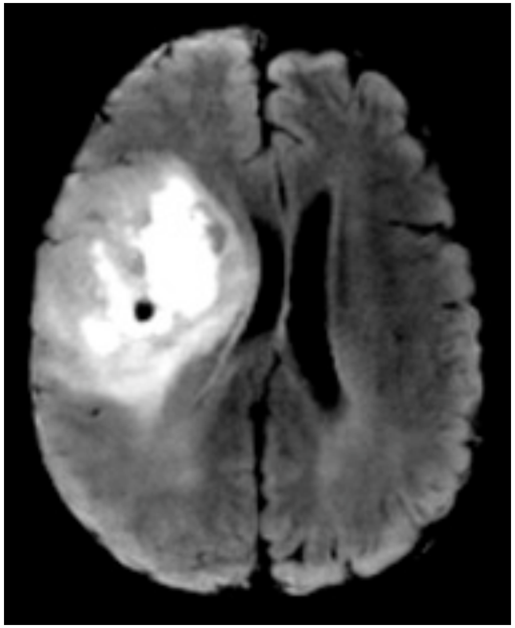

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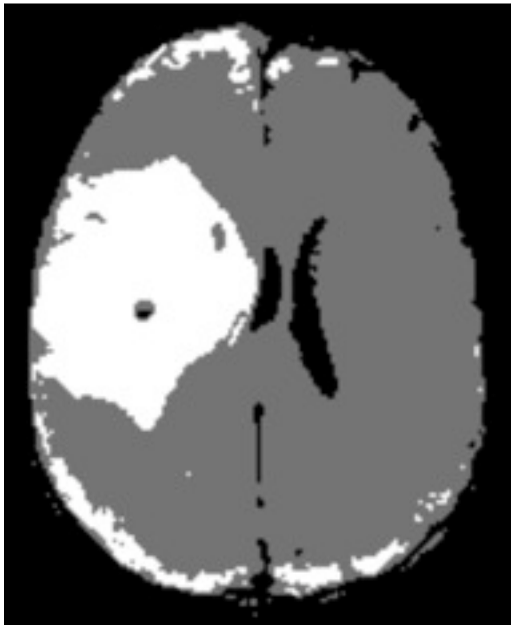

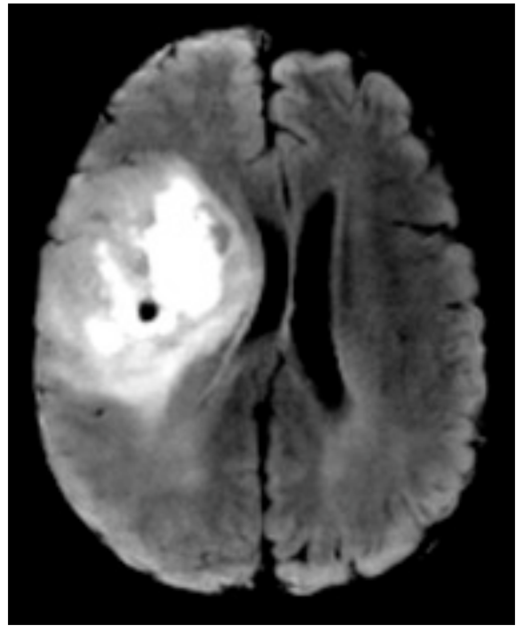

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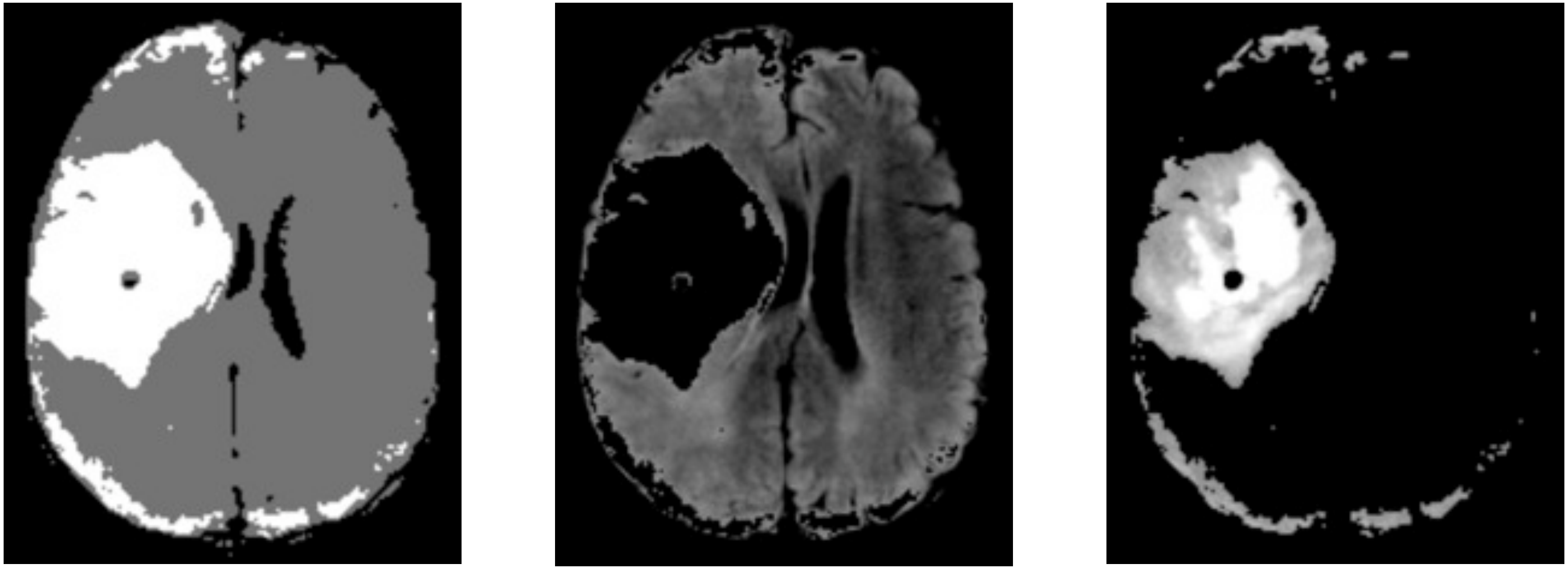

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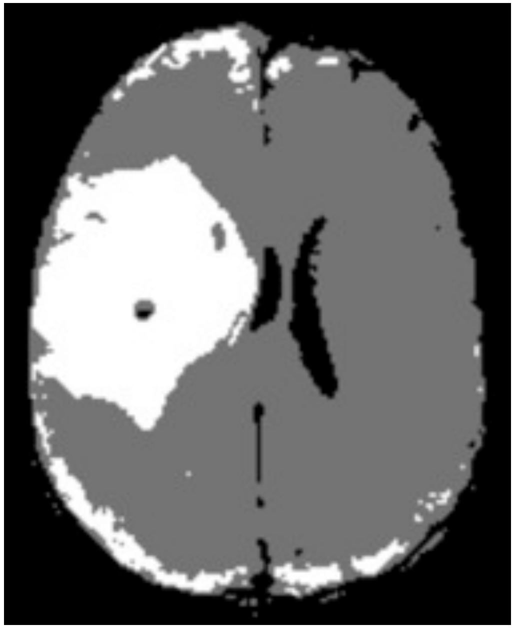

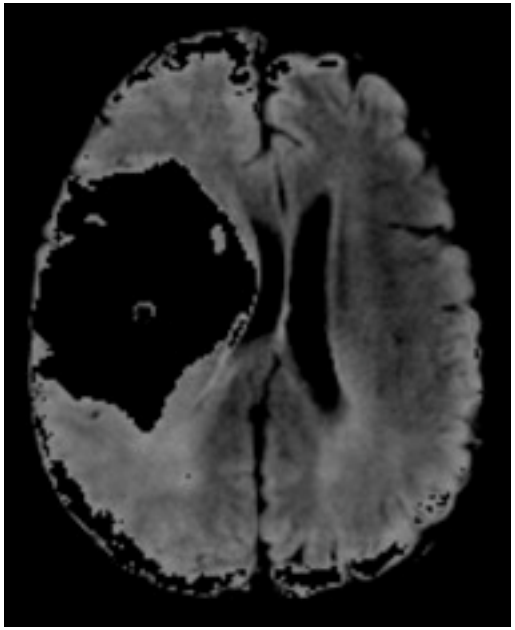

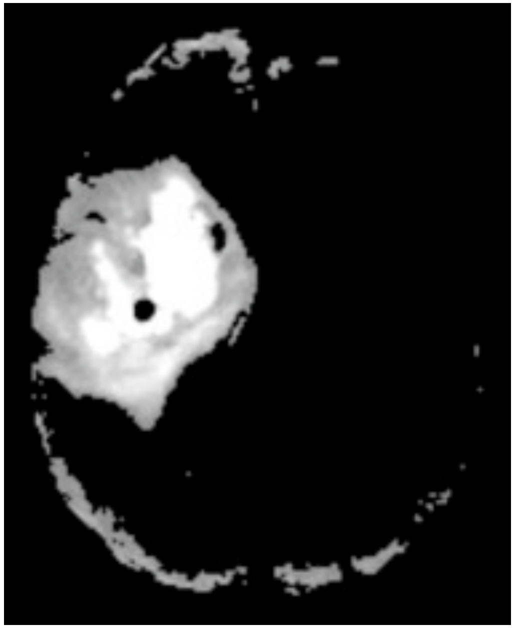

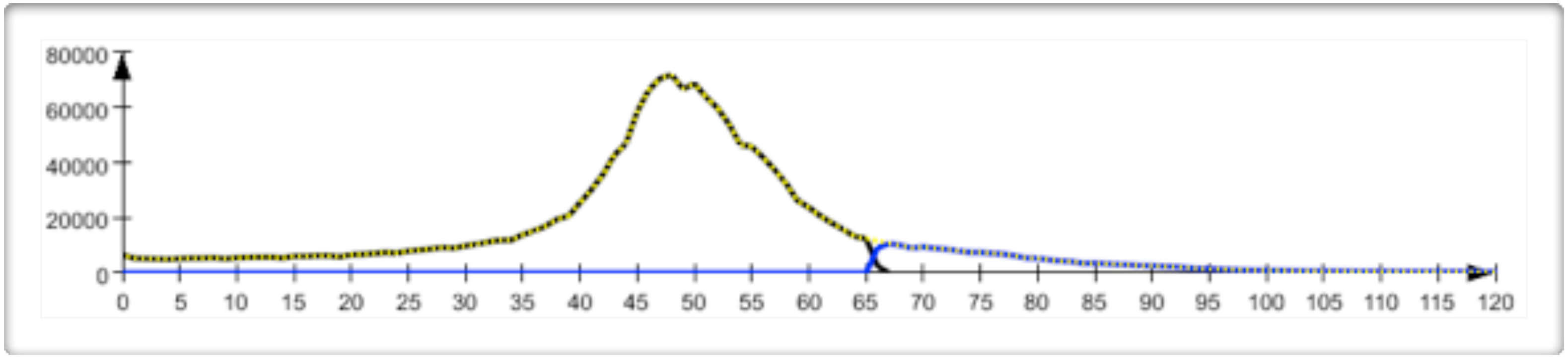

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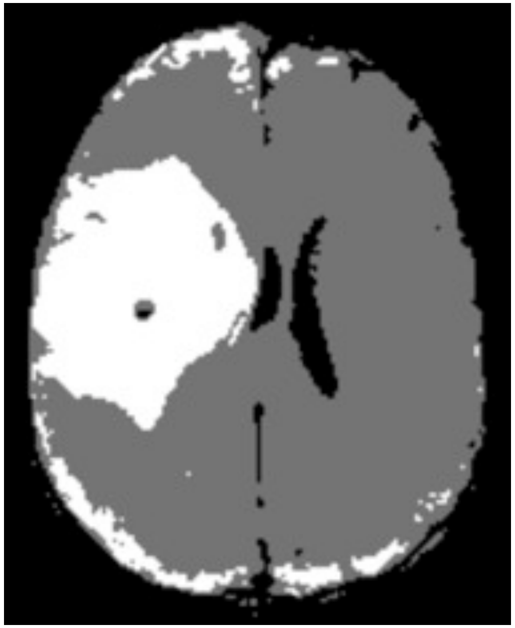

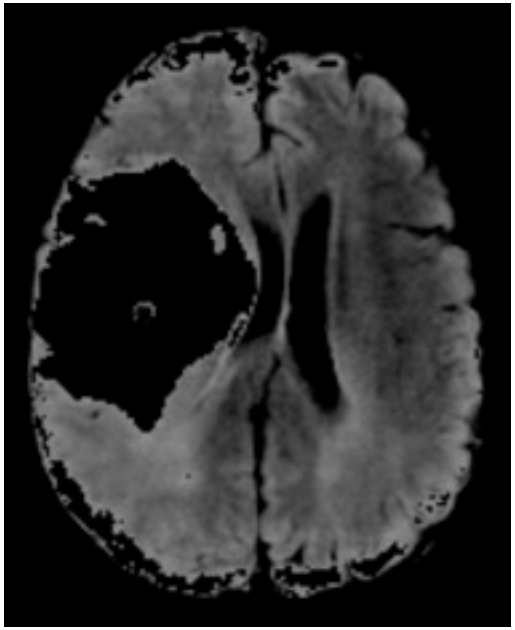

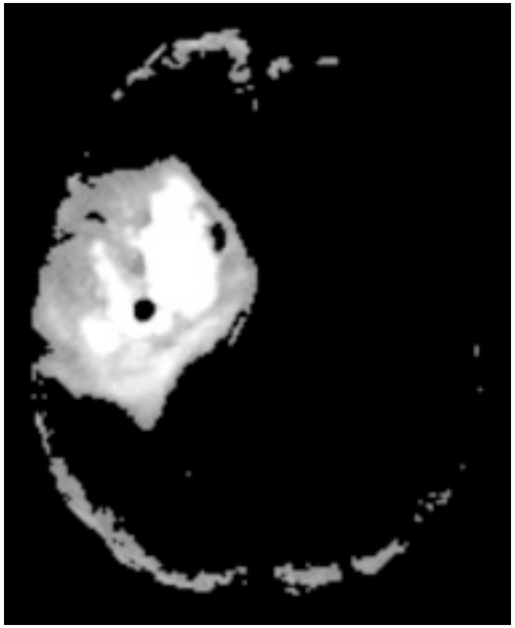

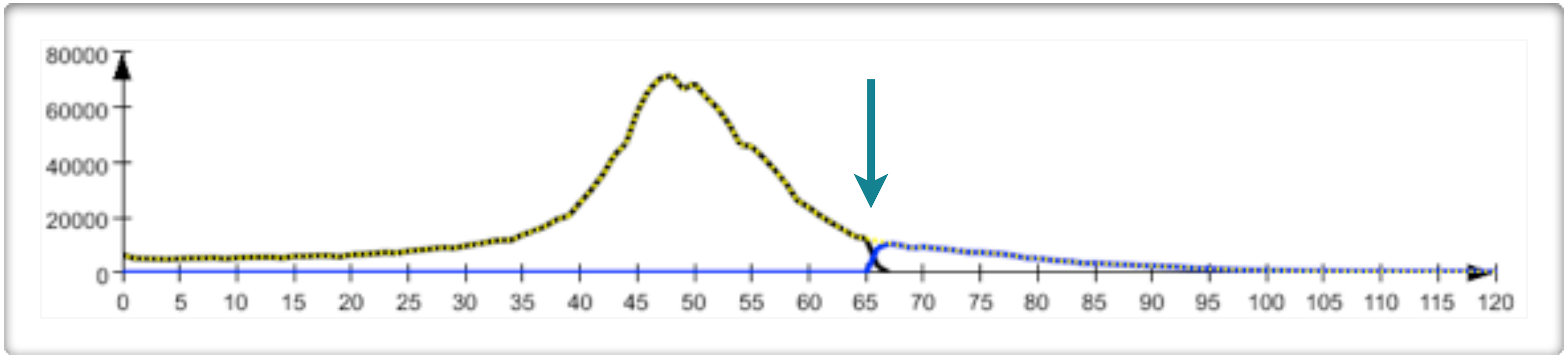

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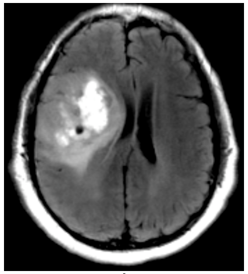

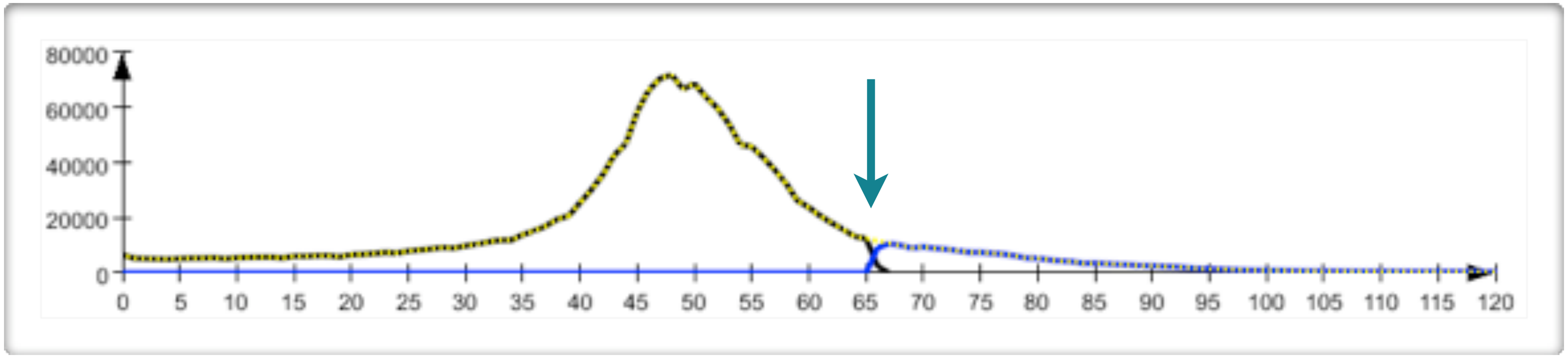

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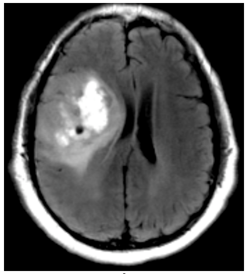

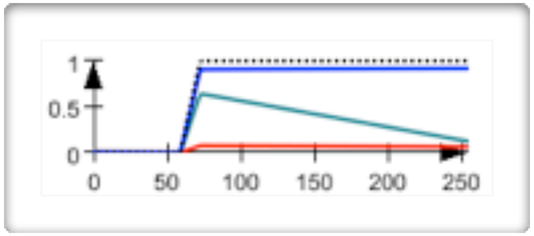

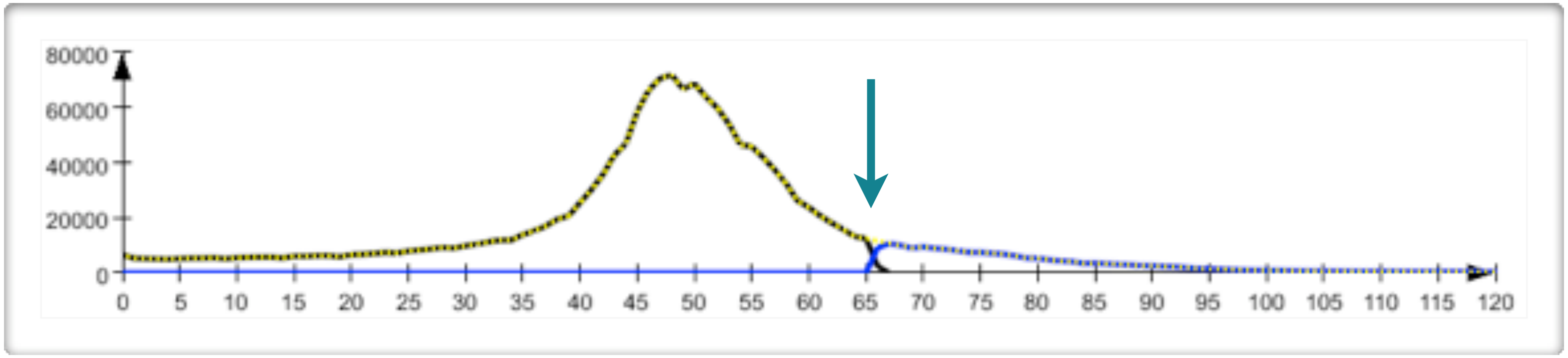

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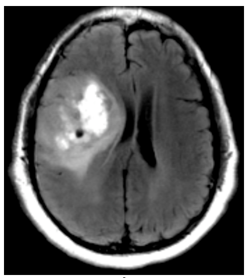
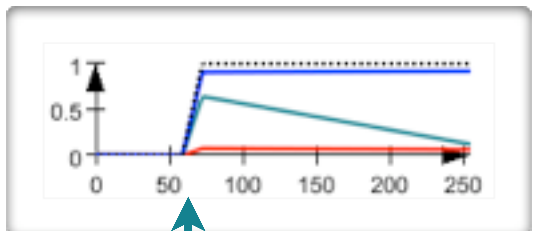
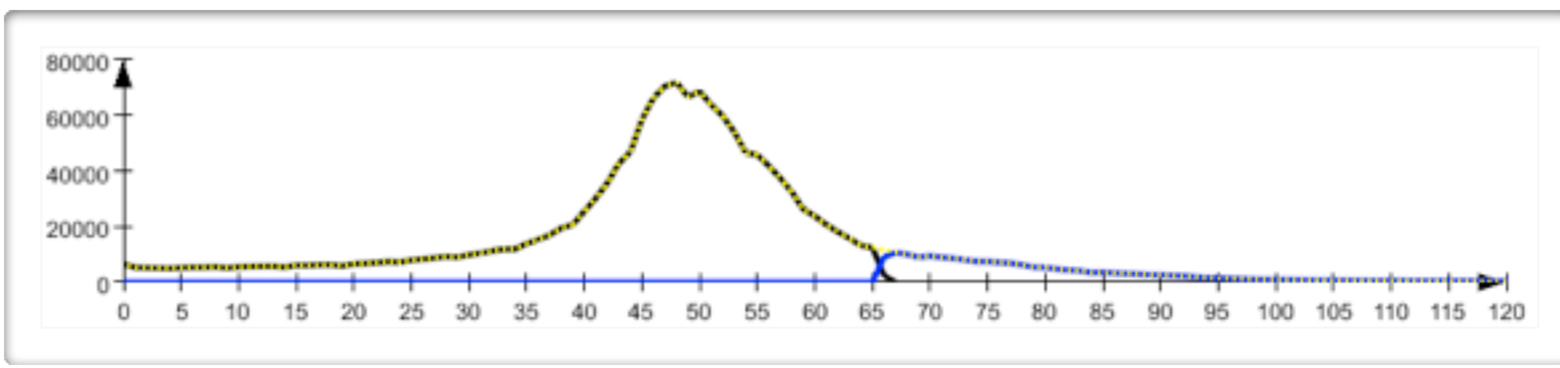
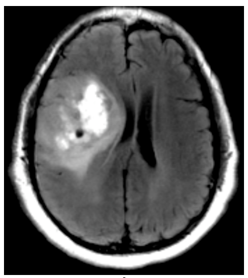
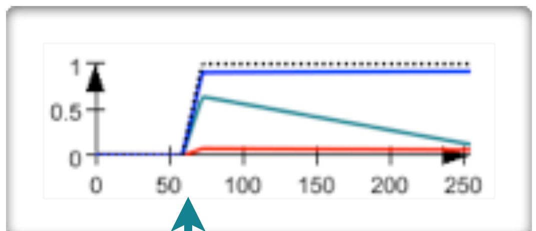


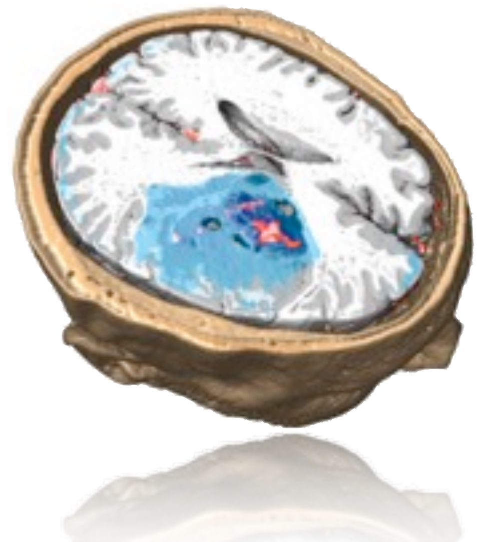


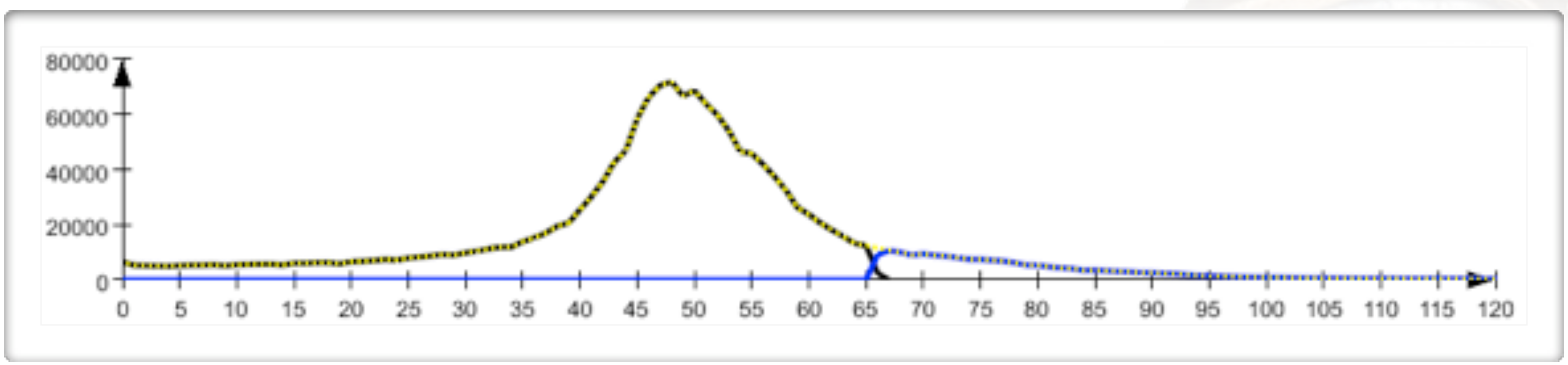


Automatic Transfer Function Adaptation of Diseased Tissue

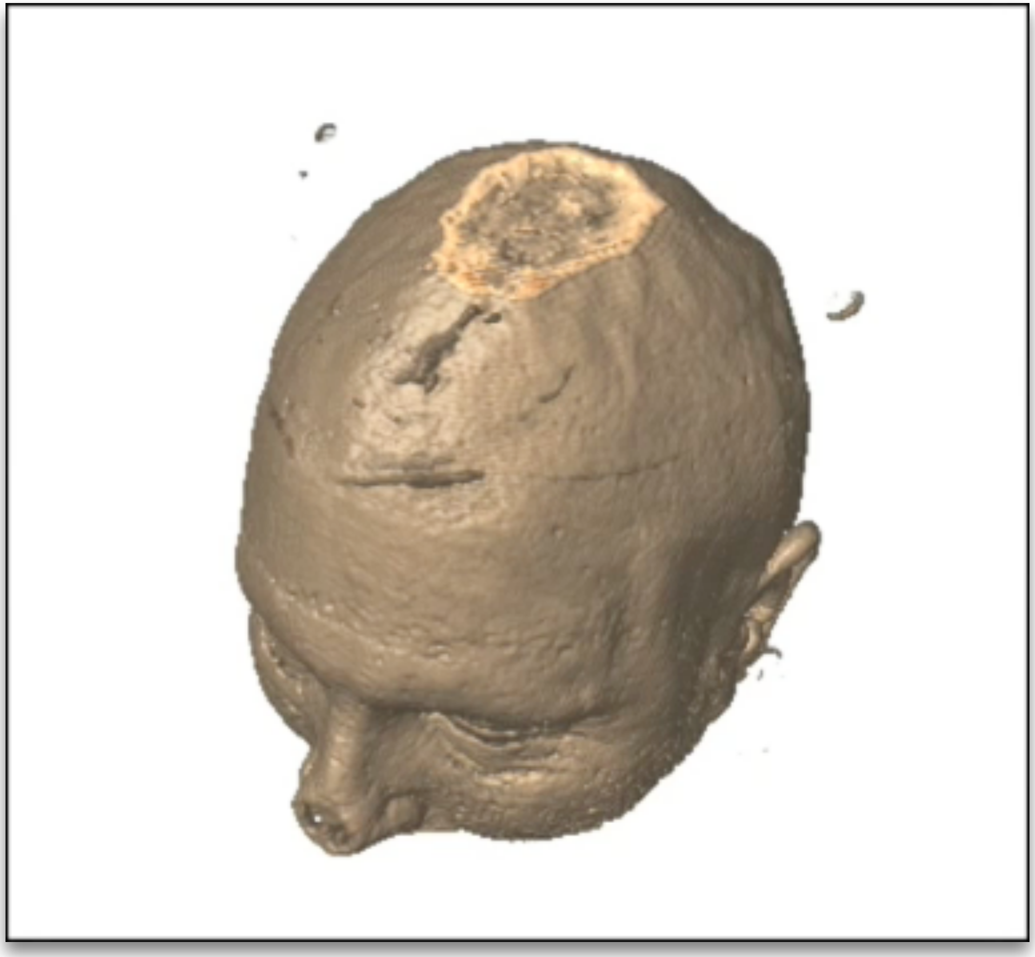








Two-stage Rendering Pipeline



Rieder et al., VCBM 2008

Automatic Axis-Aligned Clipping

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- How to reduce interaction required for exploration?

Automatic Axis-Aligned Clipping

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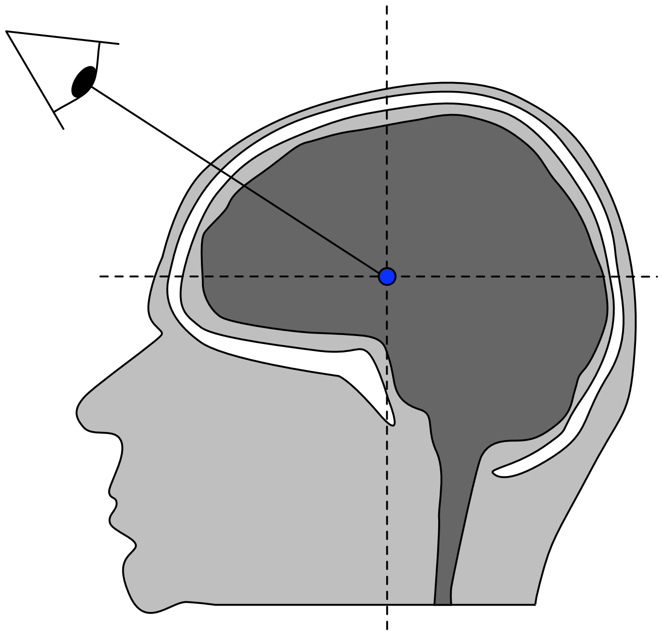
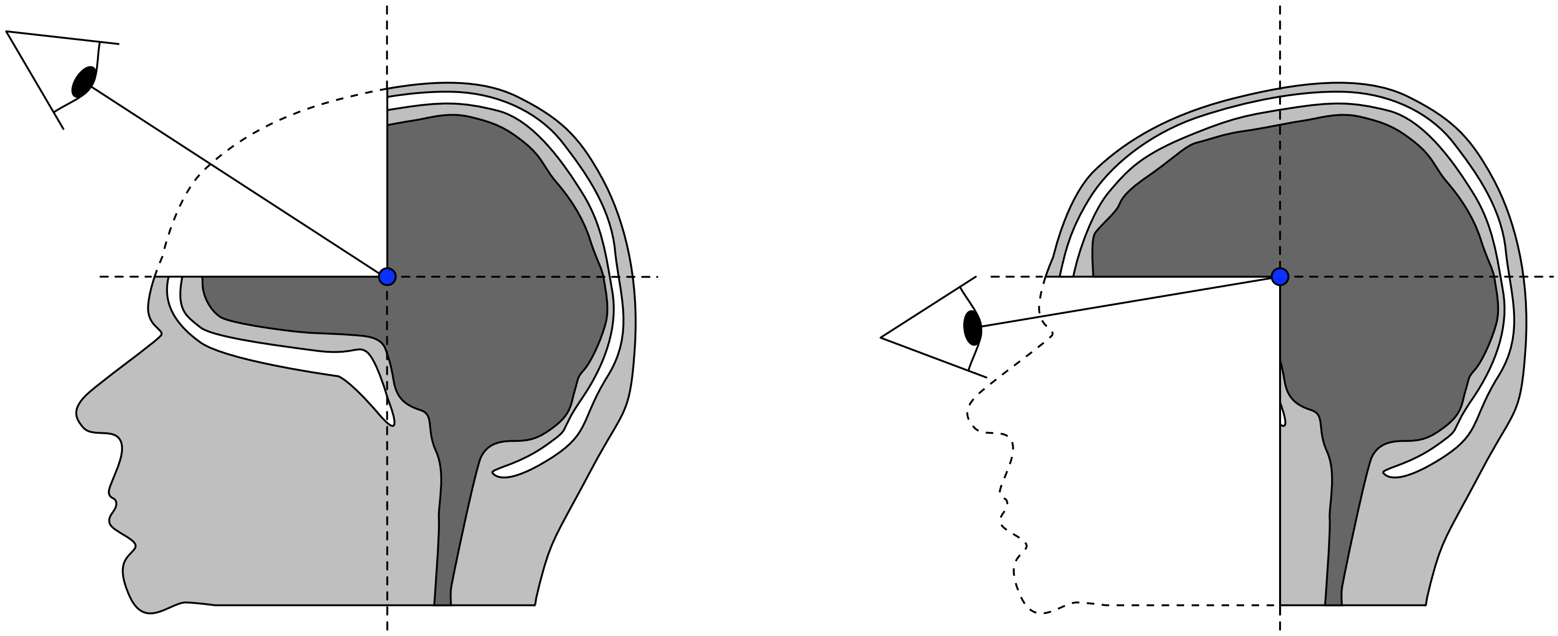
- Dividing rendered volume into octant sectors

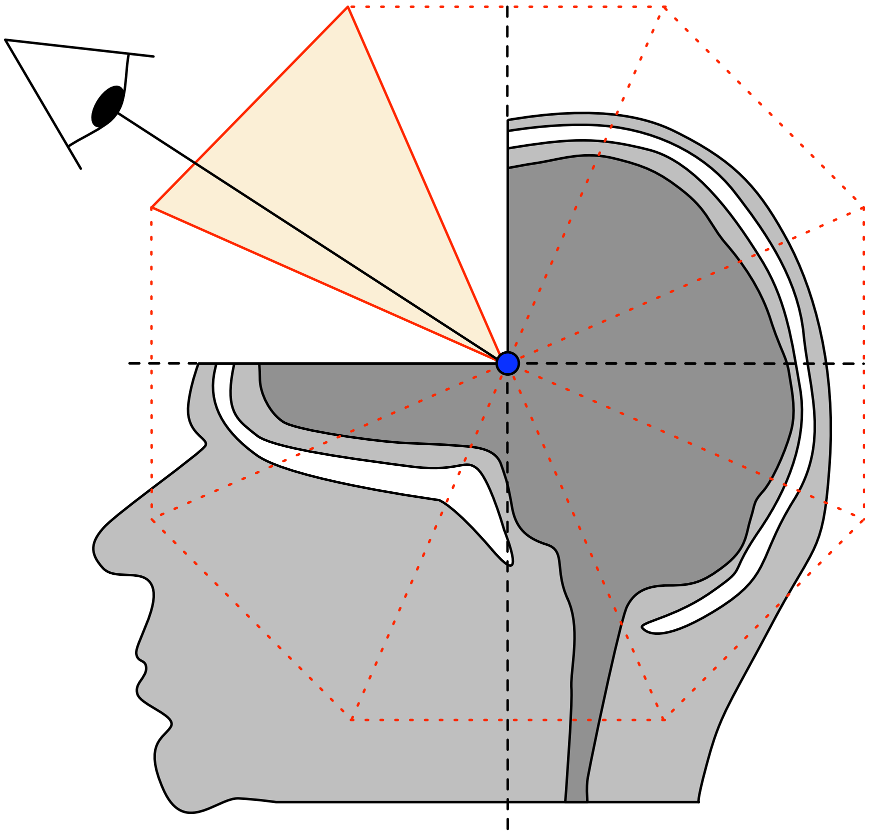


Automatic Axis-Aligned Clipping

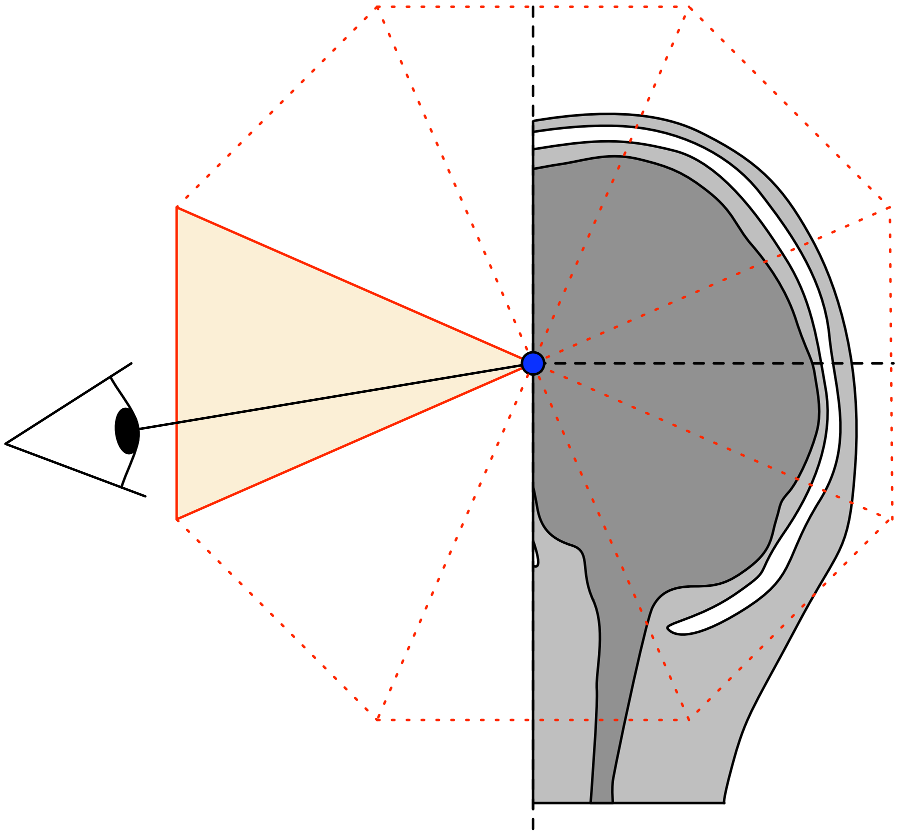
- How to reduce interaction required for exploration?
- Dividing rendered volume into octant sectors
- Automatically discard sector located between view point and center of some ROI



Automatic Axis-Aligned Clipping

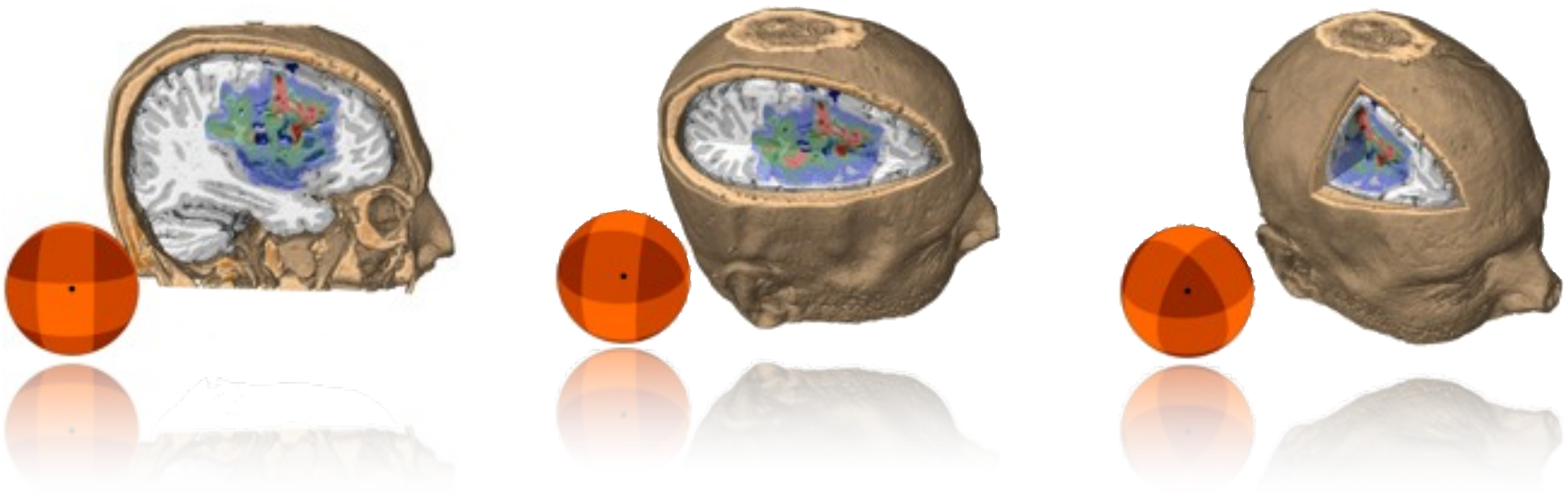


Automatic Axis-Aligned Clipping

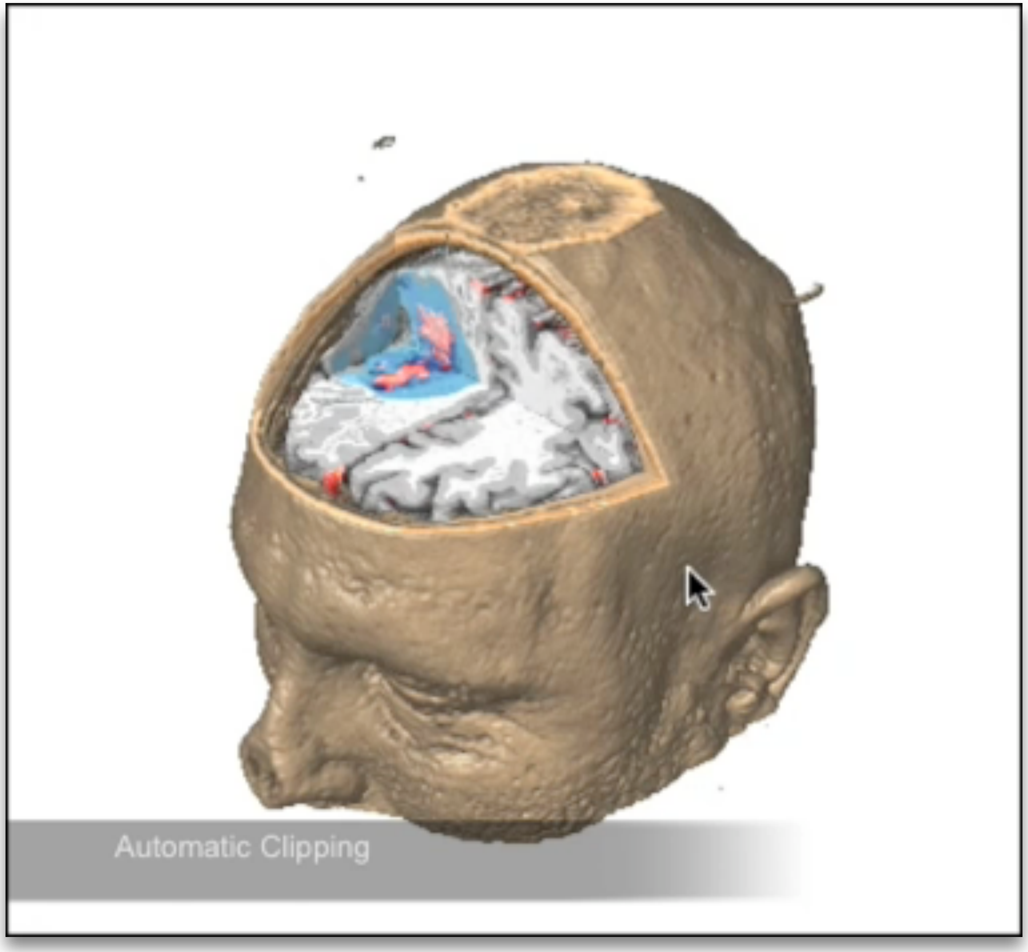


Automatic Axis-Aligned Clipping

Partitioning space into 26 different sectors



Automatic Axis-Aligned Clipping



Visualization of the Access Path

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- How to support planning of access to a deep-seated lesion?

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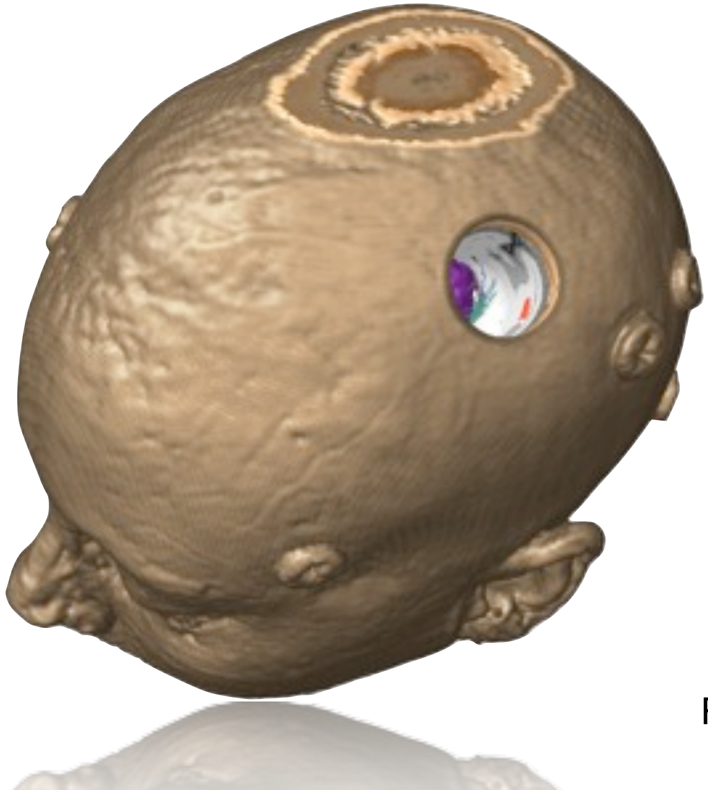
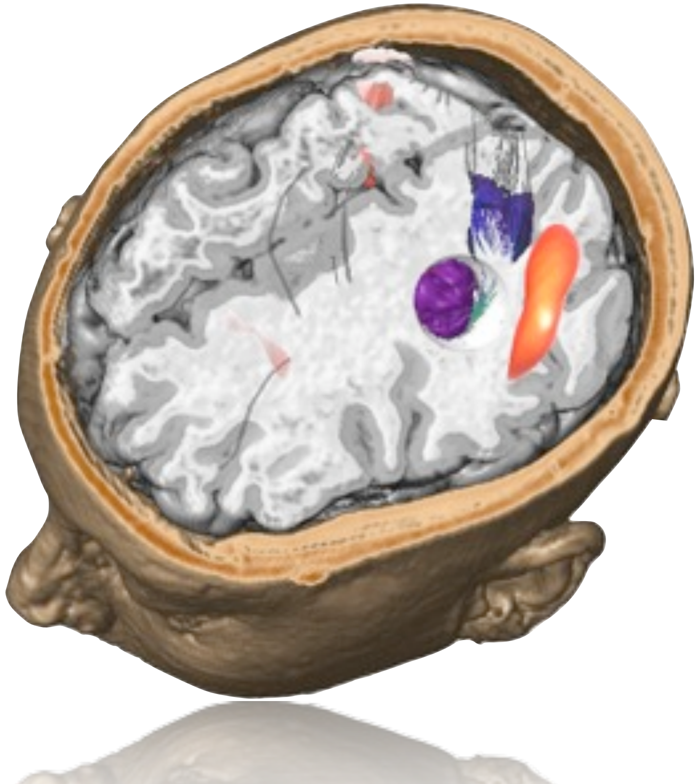
- How to support planning of access to a deep-seated lesion?
- Virtual access path from incision point to target



Rieder et al., EuroVIS 2008

Visualization of the Access Path

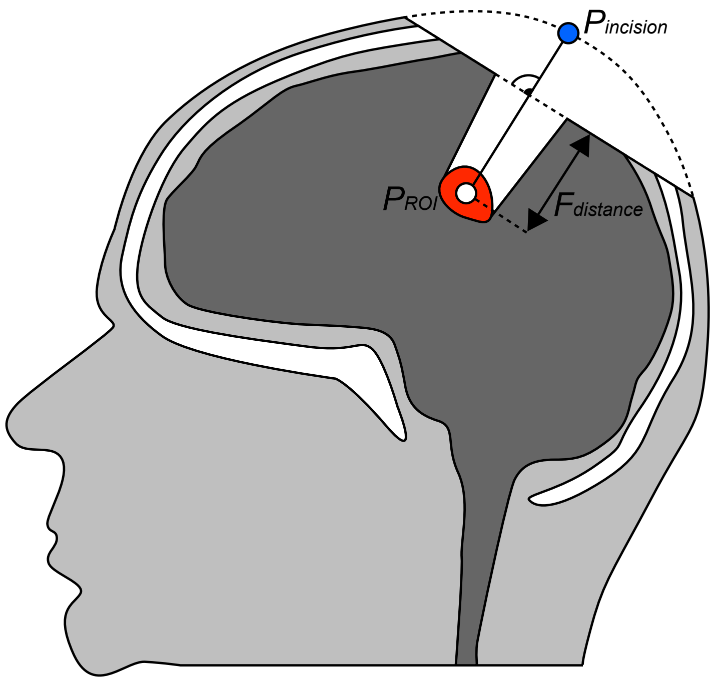
- How to support planning of access to a deep-seated lesion?
- Virtual access path from incision point to target
- Orthogonal cutting plane along the trajectory for detailed exploration



Rieder et al., EuroVIS 2008

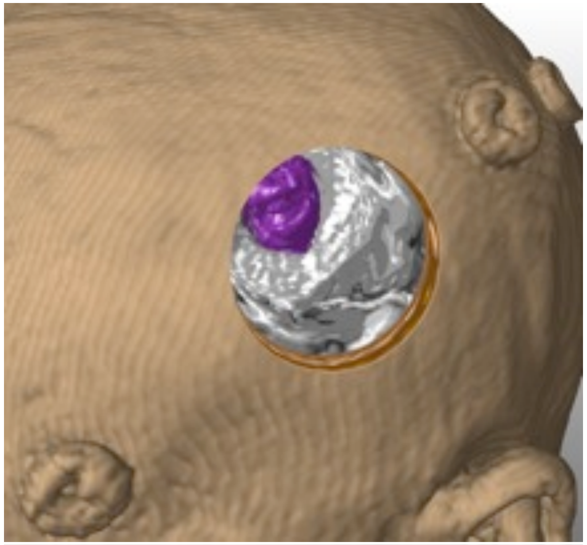
Visualization of the Access Path

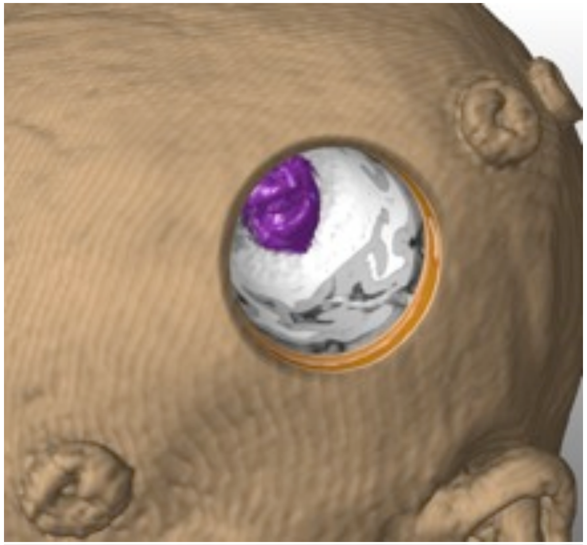
The virtual access path: simplified cylinder geometry from incision point to ROI for visualization



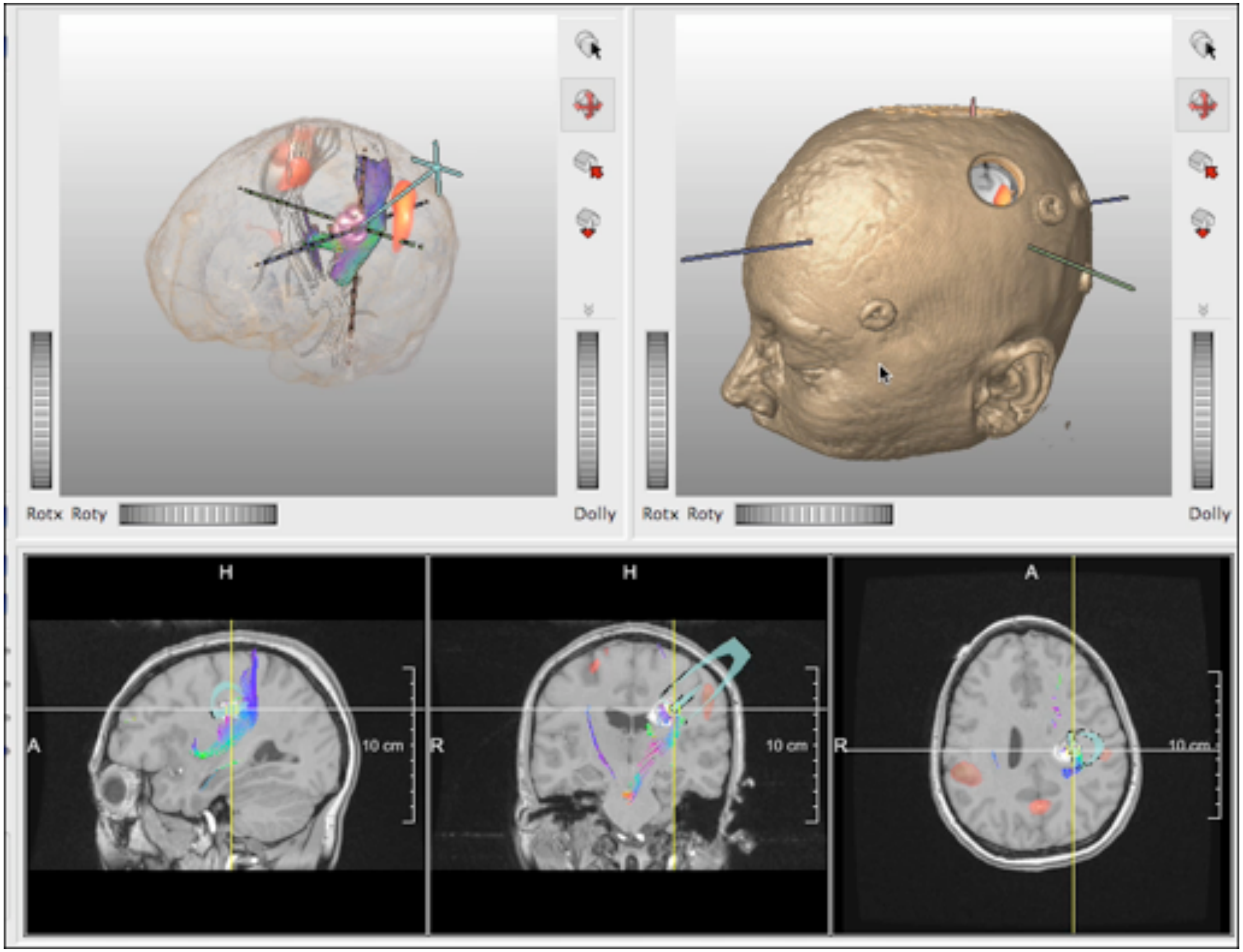
Visualization of the Access Path

- Problem: Incorrect illumination of homogeneous regions (white matter, grey matter) due to ill-defined gradients at cuts
- Solution: Transfer normals of cutting geometry into cutting surface of volume (consistent shading [Weiskopf et al., TVCG 2003])

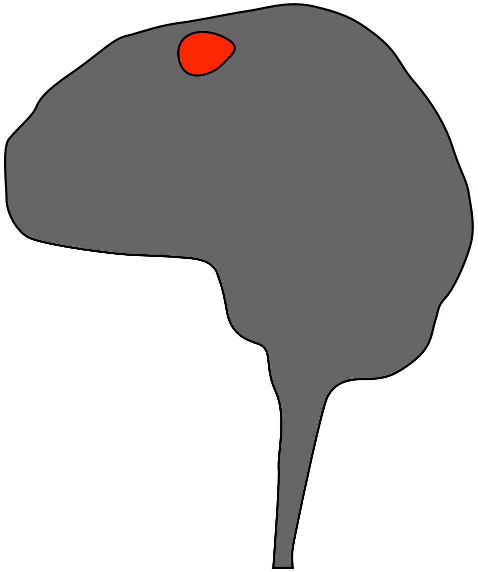




Visualization of the Access Path

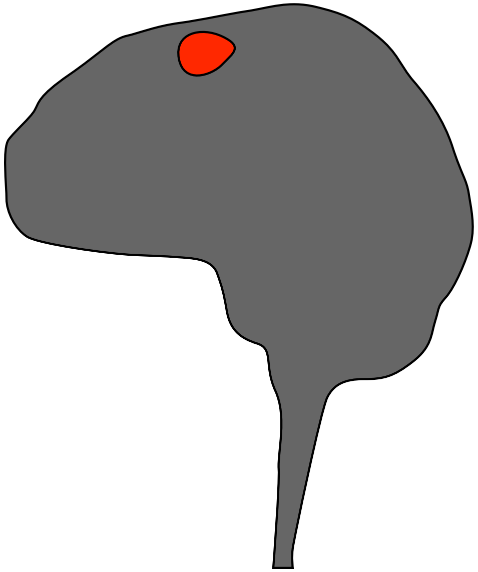


Brain Peeling



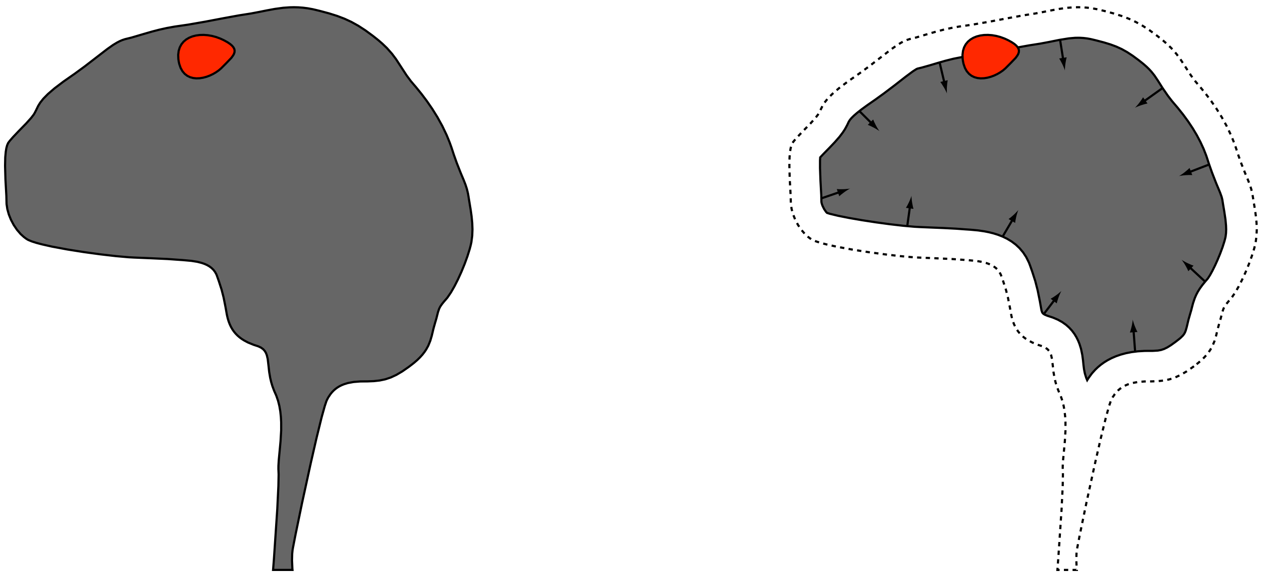
Brain Peeling

- How to explore anatomical details in the vicinity of the brain surface with cutting planes?

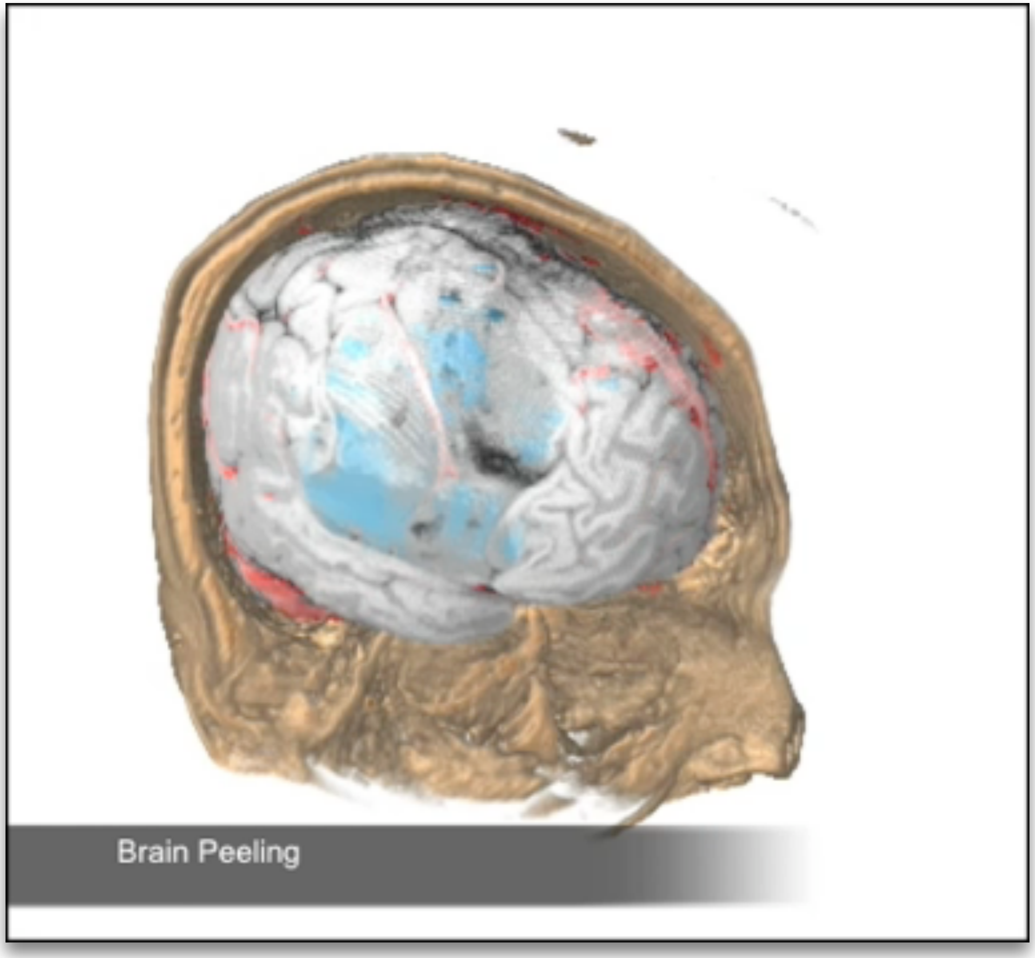


Brain Peeling

- How to explore anatomical details in the vicinity of the brain surface with cutting planes?
- Peel brain surface step by step:
  - Compute distance field (DF) from brain mask
  - Discard voxel if value in DF lower than distance threshold



Brain Peeling



Rieder et al., VCBM 2008

Conclusions

- Transfer function adaptation important for robustness
- Automated volume clipping facilitates exploration
- Virtual access path could become integral part of preoperative planning
- Trajectory aligned cutting plane supports inspection along access path
- Brain peeling allows the surgeon to inspect anatomical details in the vicinity of the brain surface
- Awareness about the limitations important!

Acknowledgments

This presentation would have been impossible without the support of my colleagues:

- Horst Hahn
- Jan Klein
- Alexander Köhn
- Christian Rieder
- Florian Weiler