FRIEDRICH-ALEXANDER
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FACULTY OF ENGINEERING

Generation of Synthetic Image Data for the Evaluation of Brain Shift Compensation Methods

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Outline

- Motivation
- Compensation Strategy for intraoperative Brain Shift
- Data Simulation
  - Overview
  - Methods
  - Simulation Result
- Conclusion and Outlook

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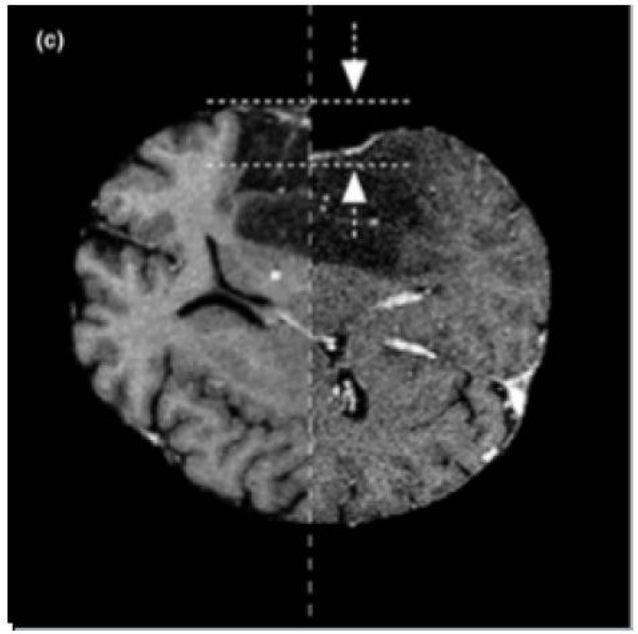
Motivation

Motivation

- **Brain shift**: also know as **brain distortion** or **brain deformation**.
- Observed as a relative motion of brain tissue w.r.t. the skull after craniotomy or tissue manipulation.
- Can be categorized into surface shift and subsurface shift.
- Caused by various factors:
  - Gravity,
  - Loss of cerebrospinal fluid,
  - Tumor size,
  - Operation time,
  - Medication etc.

Motivation

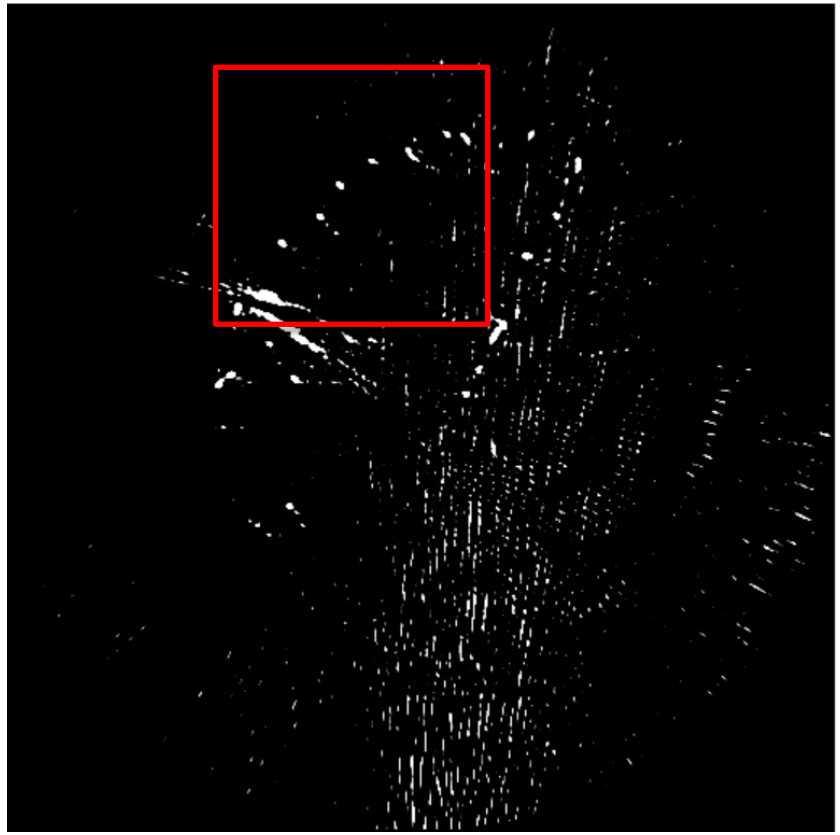


(a) (b) (c)

(a) Preoperative MR data.
(b) Same slide intraoperative MR data.
(c) The comparison of pre- and intraoperative MR data (left side pre-, right side intraoperative).

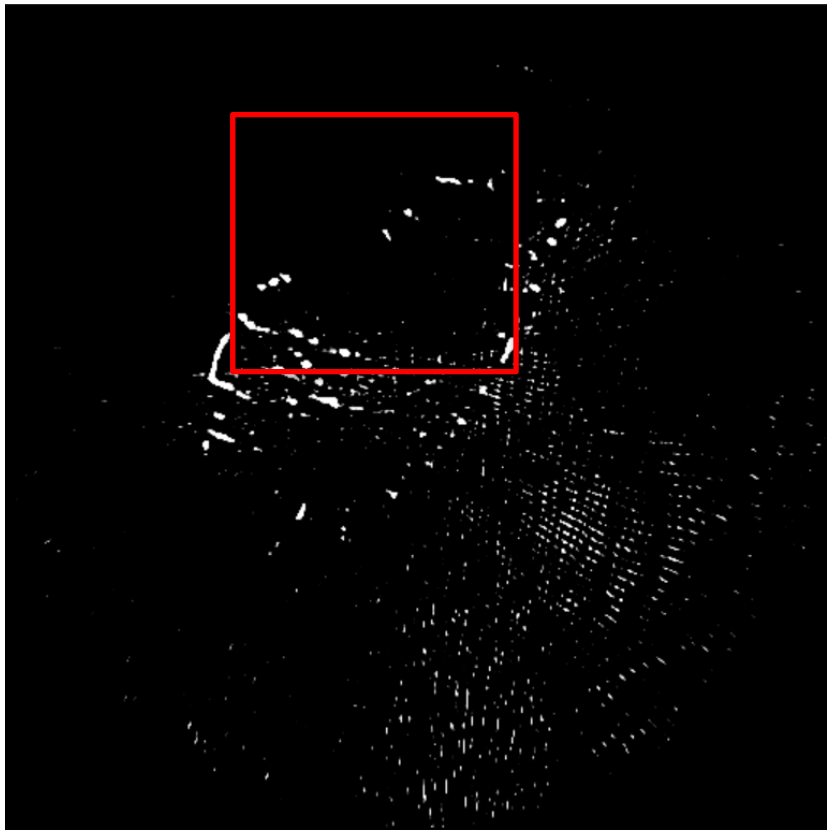
Image source: Hastreiter, P.; Rezk-salama, C.; Sofa, G.; Bauer, M; Greiner, G; Fahlbusch, R.; Ganslandt, O. & Nimsky, C. Strategies for brain shift evaluation. Medical Image Analysis, 2004 8, 447.

Motivation



(a)

(a) Preoperative 5s DSA image.



(b)

(b) 5s DSA image, after resection, same axial slice.

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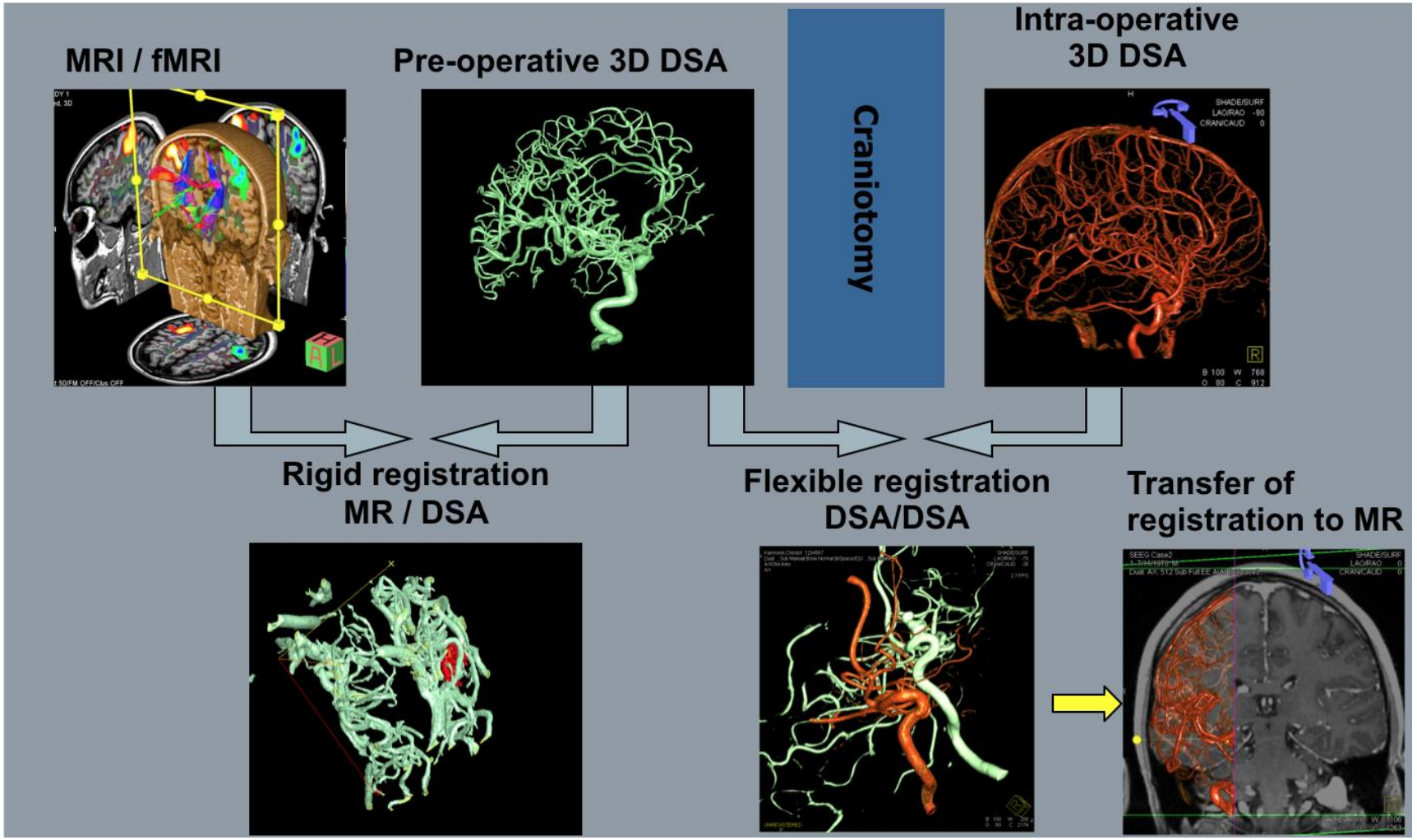
Compensation Strategy for Intraoperative Brain Shift

Compensation Strategy for intraoperative Brain Shift



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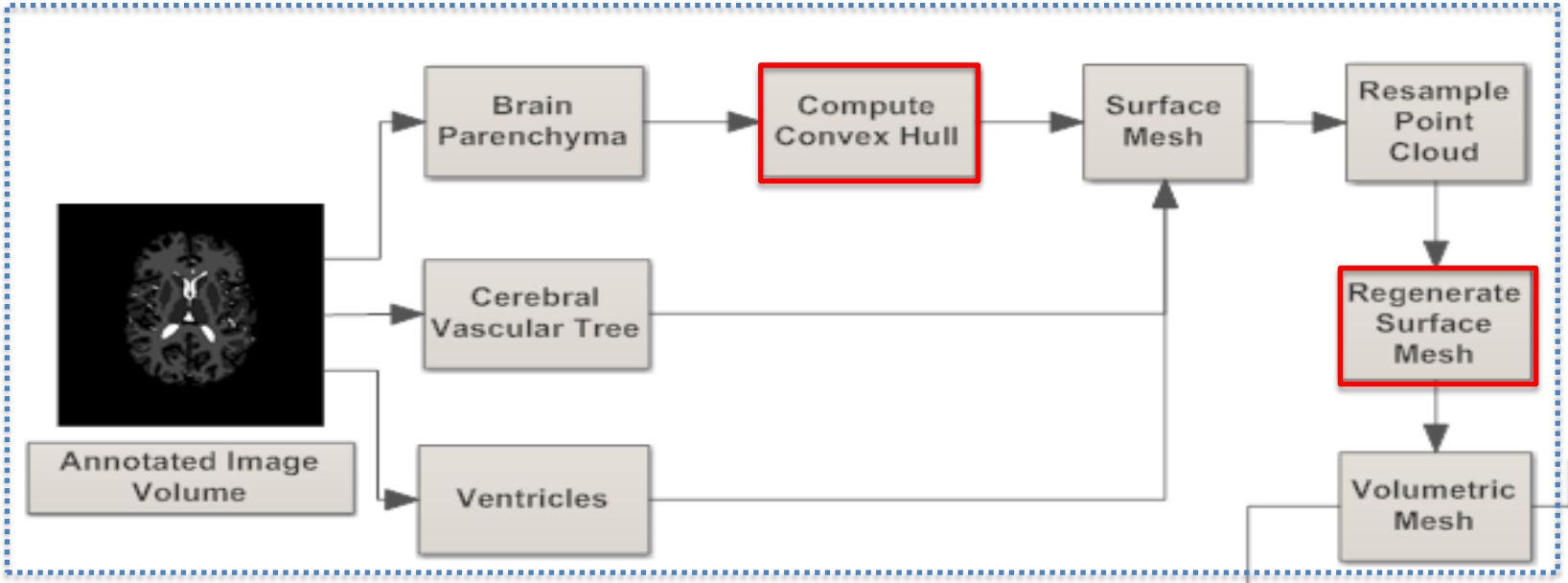
Data Simulation

Overview



Mesh Generation

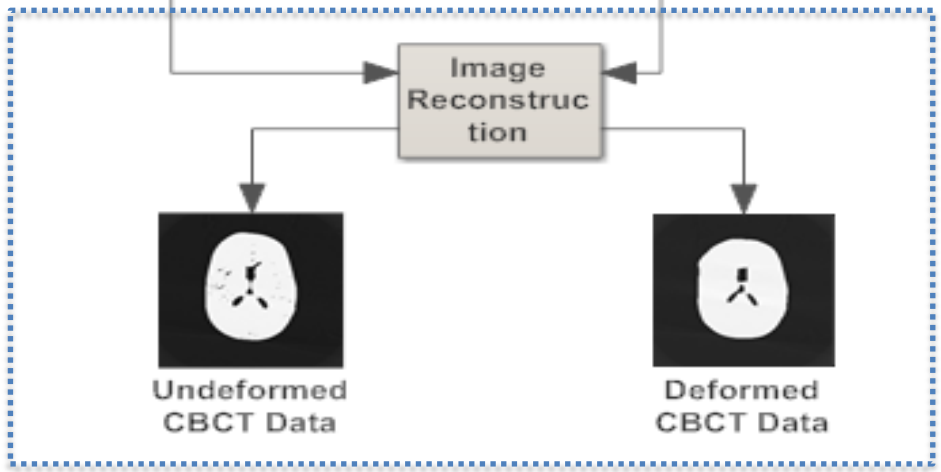
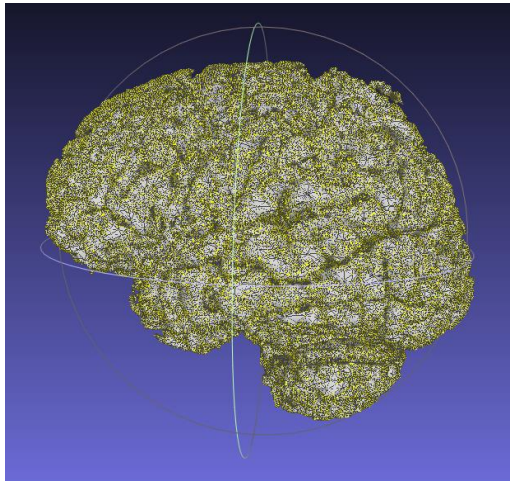
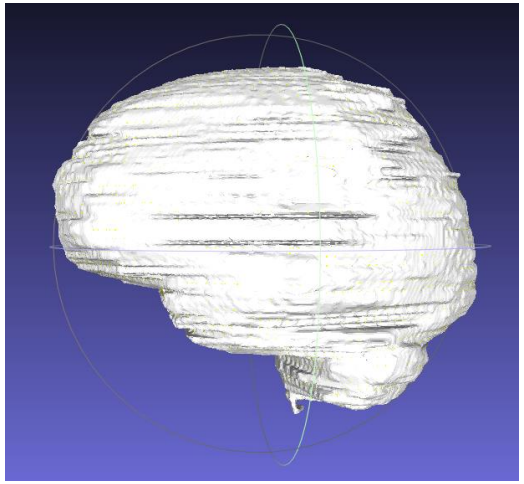


Image Reconstruction

Methods



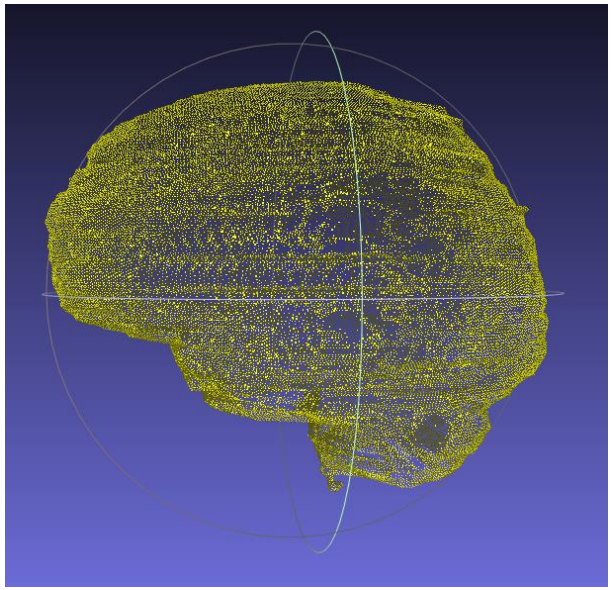


- Aim to generate **a simple realistic deformable model** of brain including vessels and ventricle, but **not** a **patient specific model** of the brain.
- Use this model to evaluate different deformable registration approaches.
- Considering FEM is very time consuming, a simplified surface structure of brain is beneficial.

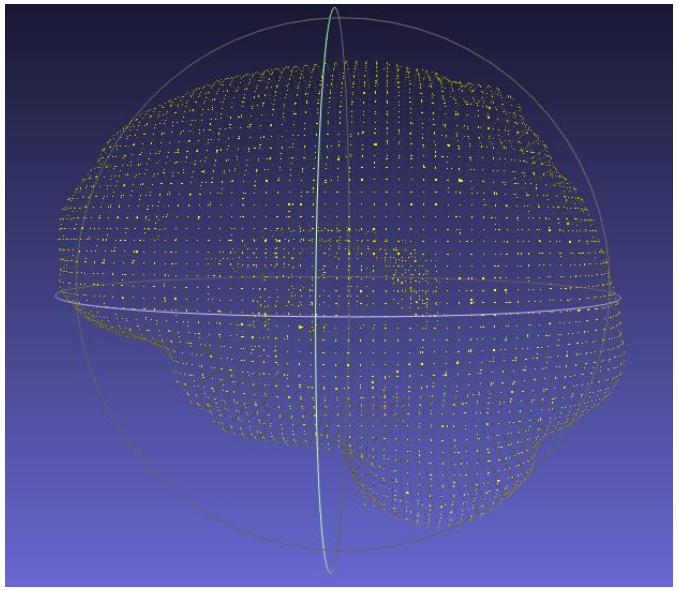
==> Compute the **convex hull** of the segmented brain tissue slice by slice and generate a surface model.

Methods

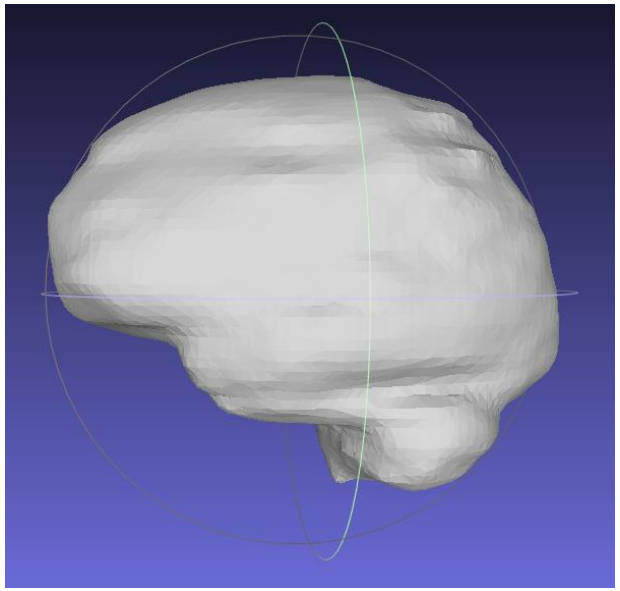
- The point cloud is randomly distributed, therefore the surface is not „smooth“ enough.
- Use Poisson Disk Sampling and re-generate the surface mesh.



(a)



(b)

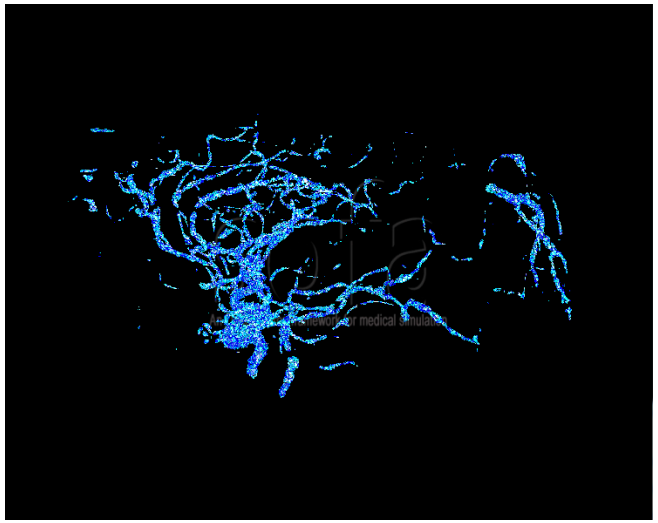


(c)

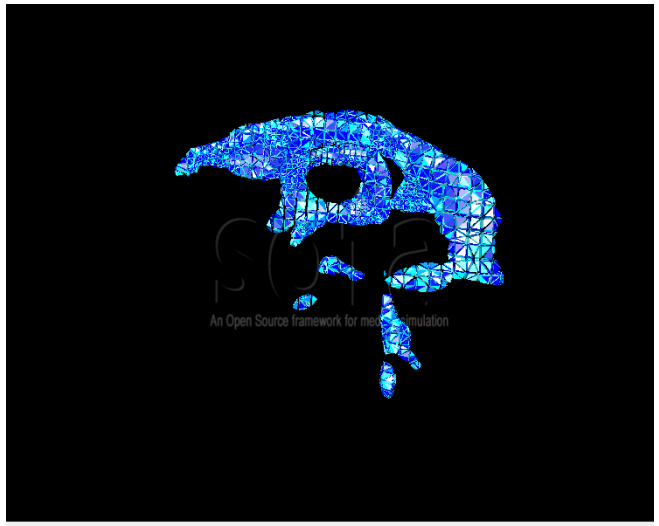
(a) Randomly and (b) uniformly distributed point cloud. (c) Reconstructed surface

Methods

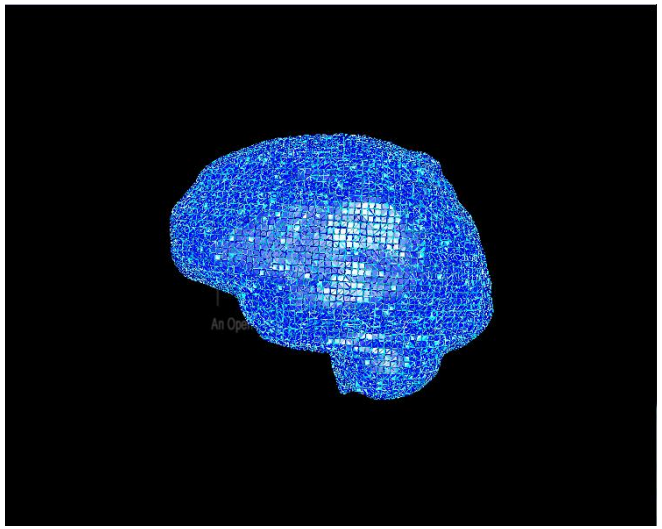
- Compute volumetric meshes:



(a)



(b)



(c)

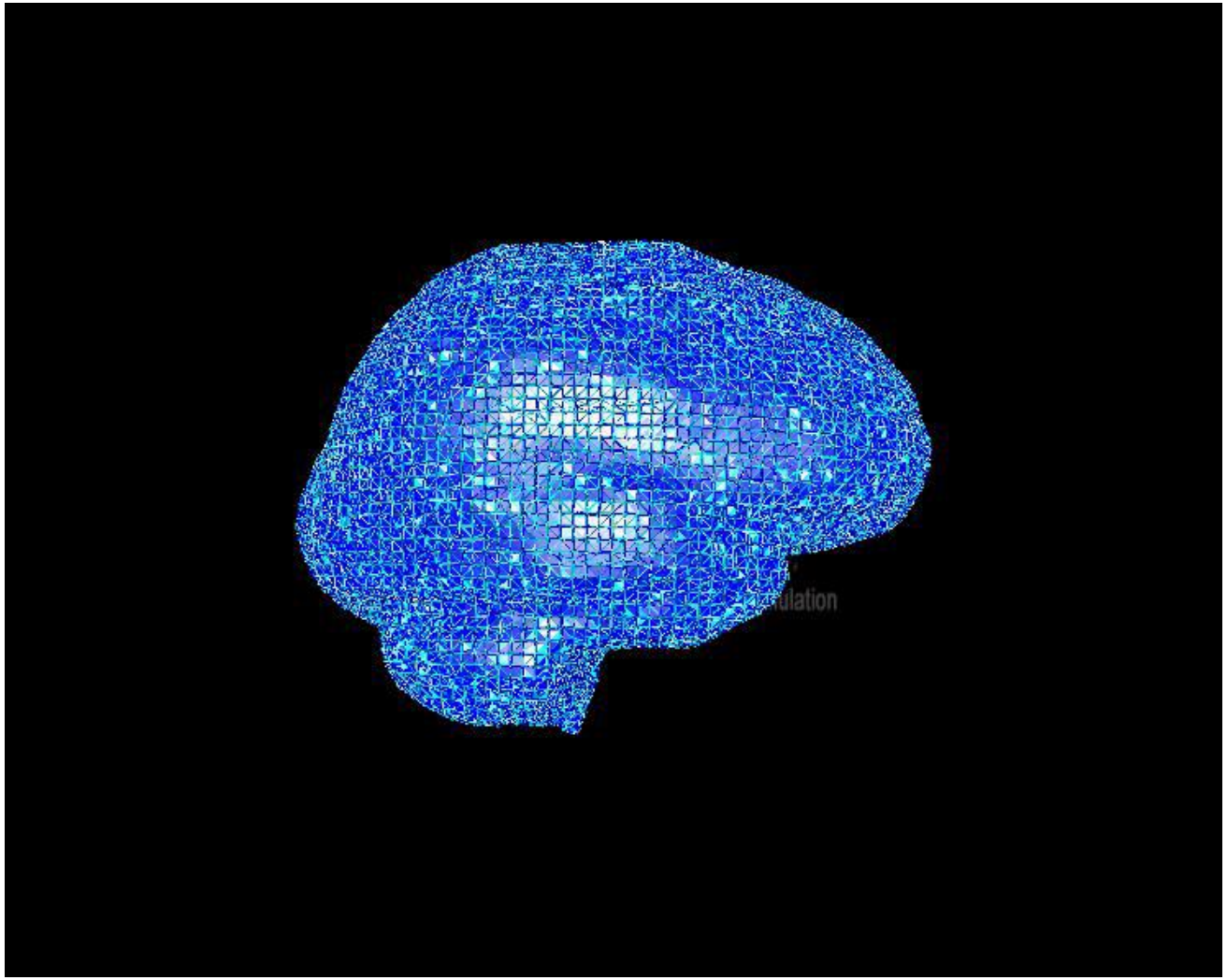
Volumetric mesh of (a) cerebral vascular tree (b) ventricles (c) simplified brain parenchyma

Methods

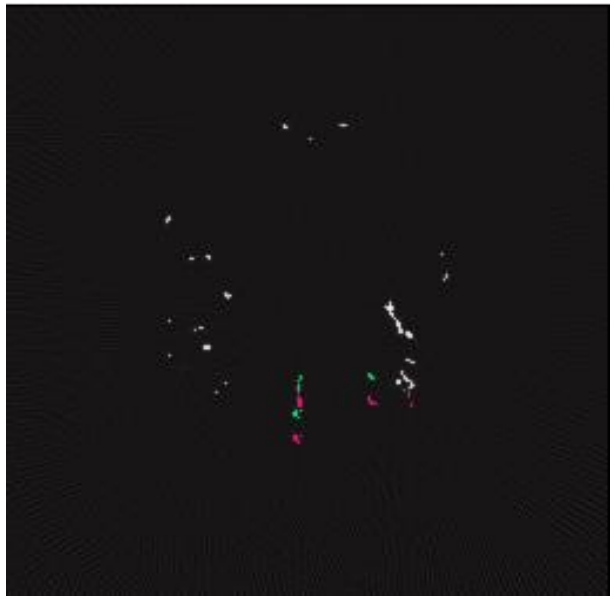
- Use **SOFA** (Simulation Open Framework Architecture) to perform Finite Element Analysis.
- Choose **linear elastic** model as constitutive law.
- Brain tissue, ventricle and vessels are modeled separately.
- Brain tissue is **soft but almost incompressible** (Poisson Ratio = *0.45* and Young´s Modulus = *2.1kPa*).

- Use **VTK** to convert the volumetric mesh to binary image volume
- Use **CONRAD** to forward project the binary data to get realistic CBCT image data.

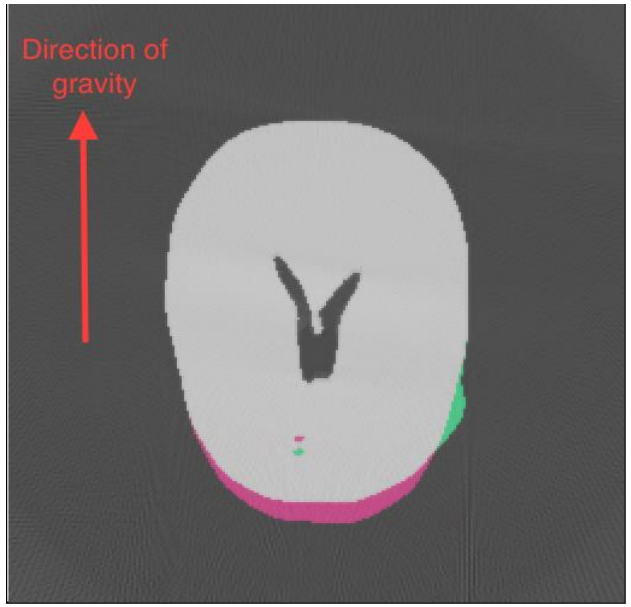
Simulation Result



Simulation Result



(a)



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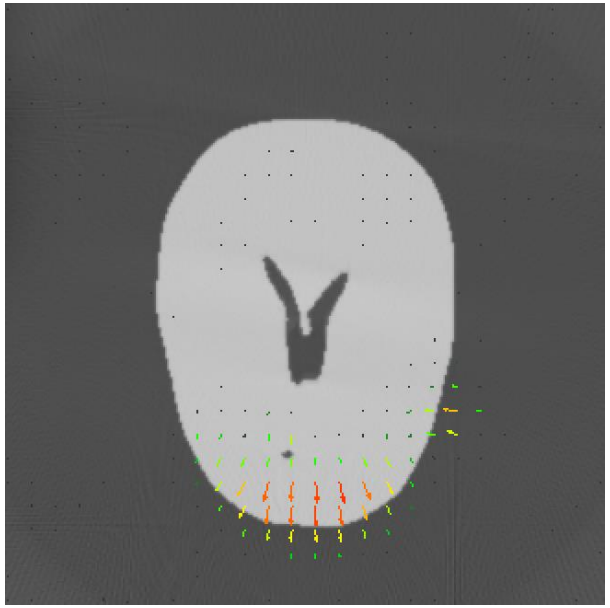

(c)

Comparison of the synthetic (a) vessels and (b) brain parechyma images. **Red**: before deformation. **Green**: after deformation.

(c) shows the displacement field. The max. displacement of this example is 10.8cm.

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Conclusion and Outlook

Conclusion and Outlook

- Conclusion
  - Generated simplified surface and volumetric meshes of brain based on segmented MRI data.
  - Performed deformation by using Finite Element Analysis on the volumetric meshes.
  - Reconstructed image volumes of brain tissue and vessels before and after deformation.
  - Realistic deformation: in the same range of clinical experience.

- Outlook
  - Construct another deformable model based on the chainmail approach.
  - Model the CSF and blood as fluid but not as solids.
  - Perform tissue resection on the model.
  - Use other constitutive laws (e.g. visco elastic, biphasic).
  - Reconstruct intra-operative MR images.

Thank you for your attention!

Questions?