Nr.:

Masterarbeit am Lehrstuhl für Mustererkennung

A Chainmail-Based Brain Shift Model to Generate Realistic Digital Phantom Data

(Eine Chainmail-Basierte Brain Shift Model zur
Erzeugung Realistischer Digitaler Phantomdaten)

Brain shift is the change of the position and shape of the brain during a neurosurgery procedure e.g. an open skull surgery. This intraoperative brain deformation limits the use of neuroanatomical overlays that were produced prior to the surgery. With non-rigid registration algorithms, the brain shift can be measured on fast acquisitions of intraoperative 3D DSA images. Since C-arm CT is currently not established for open skull surgery, an adequate deformable brain model simulation is necessary to produce realistic deformable digital phantom data in order to evaluate various image registration methods.

Because of its accuracy, reliable behavior and its ability to model the different physical characteristics of the heterogeneous structure of the brain, finite element model (FEM) became the golden standard of surgical planning and model-based brain shift compensation. However, FEM-based brain shift model is highly complex, time consuming and requires multiple pre-processing steps such as image segmentation and mesh generation. Another possible approach to simulate heterogeneous soft tissue deformation is the chainmail concept [1]. It has been used to model the respiratory motion [2]. An extended version [4] of the enhanced chainmail algorithm for inhomogeneous tissue [3] has been adopted recently to model the head and neck motion.

In this thesis a chainmail-based soft tissue deformation algorithm should be developed and implemented in order to generate realistic digital phantom data for the evaluation of brain shift compensation methods. In particular, this thesis has to include the following aspects:

- Summary of related chainmail-based deformable model simulation
- Implementation of a chainmail-based brain shift simulation method
- Evaluation of the chainmail-based method with regard to accuracy and runtime, i.e. comparison to result of an existing FEM-based simulation method.
- Implementation should be done in Python or C++

Digital phantom data is available in our lab. If possible, existing software should to be reused (SOFA, ITK, VTK, CONRAD)

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Bearbeiter:
Beginn: from now on

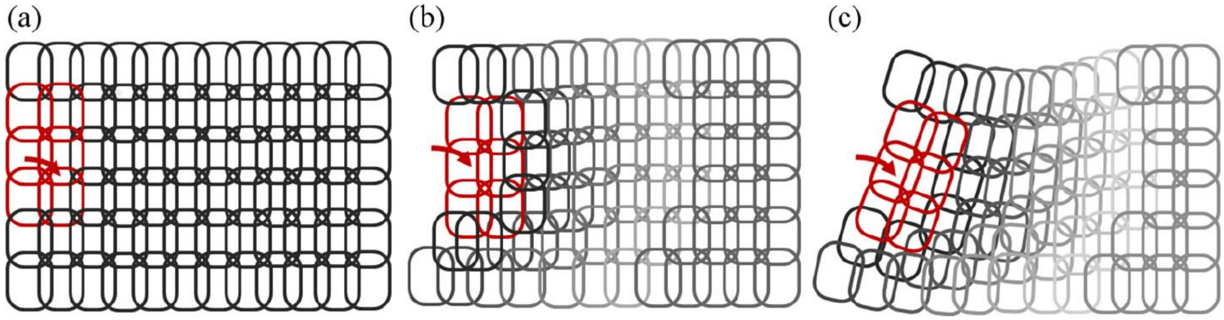

Figure 1: Illustration of the 2D chainmail concept: an initial deformation (a) of coupled rigid elements (red) is propagated to the neighboring soft tissue elements (grey) allowing only translational degrees of freedom (b) and also including rotational degrees of freedom (c).

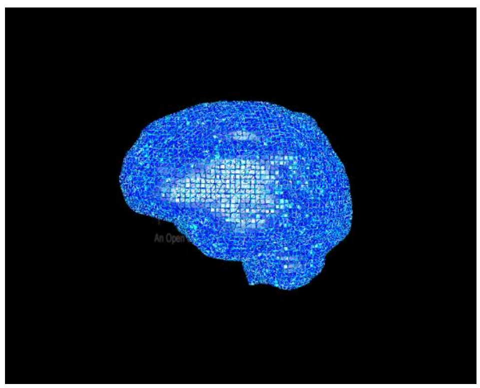

Figure 2: Finite element model to simulate the brain shift. Dark blue: soft tissue, light blue: ventricle and blood vessels

Reference:

[1] Gibson. S. F. 1997. *A Fast Algorithm for Deforming Volumetric Objects*. Proc. Symp. Interactive 3D Graphics, pp 149-154.

[2] Villard. P. F, Vidal. P-F. 2016. *Development and Validation of Real-Time Simulation of X-Ray Imaging With Respiratory Motion*. Comput. Med. Imaging Graph, 49, pp 1-15.

[3] Shill. M. A, Gibson. S. F, Bender. H-J and Männer. R. 1998. *Biomechanical Simulation of the Vitreous Humor in the Eye Using an Enhanced Chainmail Algorithm*. MICCAI 98' Lecture Notes in Computer Science (LNCS, 1496), pp 679-87.

[4] Teske. H, Bartelheimer. K, Meis. J, Bendl. R, Stoiber EM, Giske. K. 2017. *Construction of a Biomechanical Head and Neck Motion Model as a Guide to Evaluation of Deformable Image Registration*. Phys. Med. Biol. 62, N271-N284.