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OPTIMIZED PATIENT–SPECIFIC IMPLANTS

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Today fractures of the long bones, i.e. tibia or femur, are treated surgically. This means that implants are used that allow early post operative weight bearing and physiotherapy of the injured limb. However, the implants currently used in orthopaedic trauma surgery do not account for individual specificities of the patient and of the fracture.

A personalized approach to fracture therapy necessitates the integration of knowledge and techniques from mechanics, orthopaedic trauma surgery, computer science and image processing. Here, we will merge the relevant knowledge from these disciplines into an integrated workflow.

Routinely acquired computed tomography data sets are subjected to an automated segmentation procedure using edge–enhancing nonlinear anisotropic diffusion (EED) filtering. Thereafter, a volume mesh is generated using an adaptive, octree based scheme that allows a locally heterogeneous resolution exploiting the concept of hanging nodes.

Mechanical FEM simulations are used to compute the stresses and strains arising in the implant and the bone structure. Based on the results of the FEM simulations, new therapeutic approaches for revision surgery are developed. With the help of optimisation algorithms, a blue print of the mechanically optimal configuration of the cancellous bone transplantation is computed to achieve fracture fusion.

Using these results the surgeon will be able to use a targeted approach with surgical intervention only in those areas of the non union where load peaks of the bone–implant system occur. With iterative automated optimisations and mechanical simulations we generate also an patient specific implant model. The process integrates the biomechanical needs,

i.e. optimal neutralisation of torsion loads, and the anatomical needs, i.e. minimally invasive surgical technique, into the implant.

The resulting FEM model represents the individual patient fracture including the implant that have been used to fix the fracture initially. This model will support the surgeon in answering the key questions of a personalised therapeutic concept:

- How much fusion area is necessary for the fracture?
- Is the implant suitable for the fracture?
- Does the patient need a customised implant?

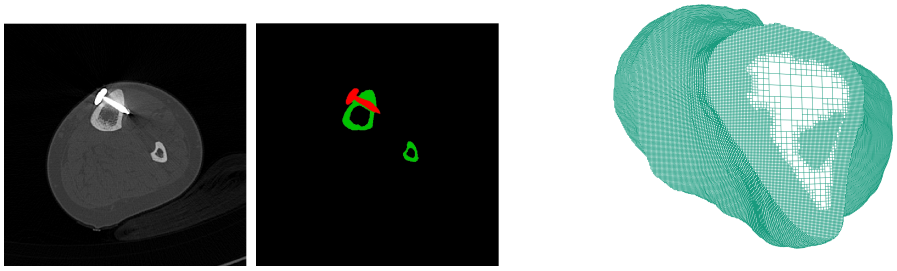

Figure 1: Individual slice of the original computed tomography image (left); results of the segmentation process of the same slice (middle); cut through the octree based volume mesh with hanging nodes structure (right).

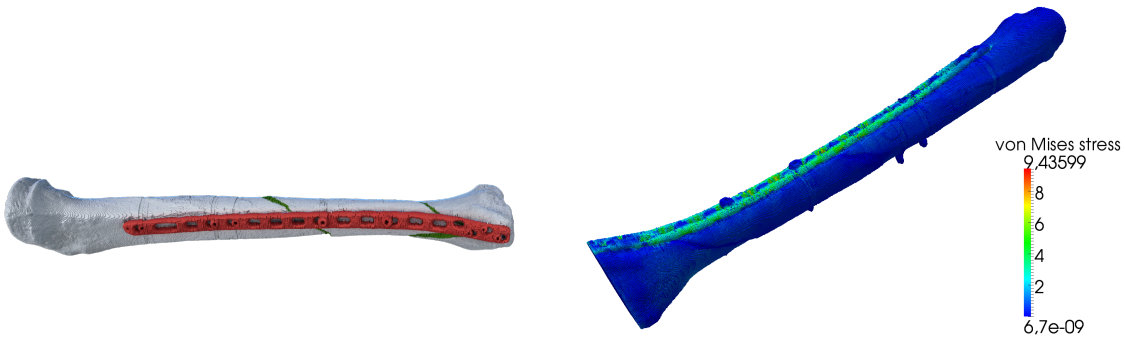

Figure 2: patient–specific volume mesh with implant and fracture area (left); von Mises stress of the bone–implant system (right).

REFERENCES

[1] J. Weickert. Anisotropic Diffusion in Image Processing. Teubner, 2005.

[2] J. Möbius and L. Kobbelt. OpenFlipper: An Open Source Geometry Processing and Rendering Framework. volume 6920 of *Lecture Notes in Computer Science*, Springer Berlin / Heidelberg, 2012.