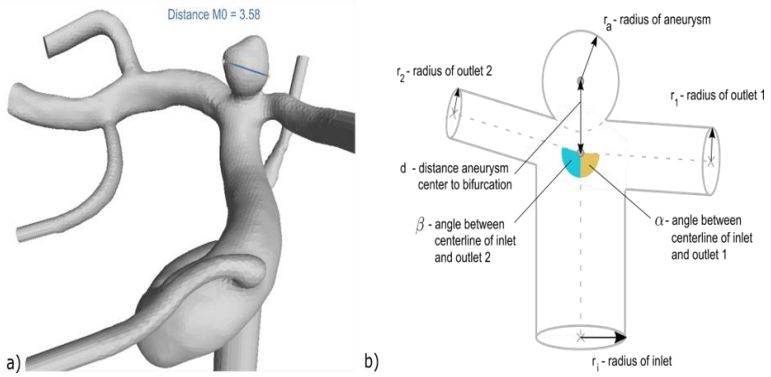
Towards deep learning-based wall shear stress prediction for intracranial aneurysms

Annika Niemann[12], Lisa Schneider[1], Berhard Preim[1], Samuel Voß[23], Philipp Berg [23], Sylvia Saalfeld[12]
Department of Simulation and Graphics, Otto-von-Guericke University Magdeburg, 2 Forschungscampus STIMULATE 3 Department of Fluid dynamics and technical flows Otto-von-Guericke University Magdeburg contact:annika.niemann@ovgu.de

Artifical aneuryms creation

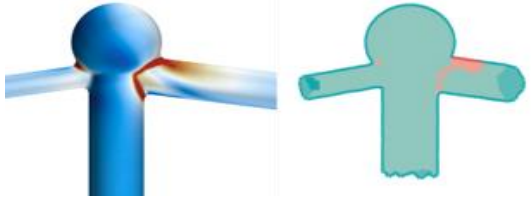
- Artifical bifurcation aneurysms created with CAD
- Consist of three cylinders (inlet + two outlet vessels) and a sphere (aneurysm)
- 7 parameters: inlet and outlet radii (r_i,r_1,r_2), aneurysm radius (r_a), distance between aneurysm center and bifurcation (d), angle between inlet and outlet (α,β)
- Parameter values based on 13 reference cases from a database with 200 patient-specific 3D aneurysm models



	ri	r1	r2	ra	d	α	β
average	2.53	1.87	1.75	2.09	3.67	97.31	93.77
min	1.81	0.96	1.04	1.11	1.65	64	60
max	3.38	2.48	2.58	3.44	6.15	167	120

Hemodynamic simulation

- Hemodynamic simulations of 145 artifical aneurysms
- Discretized into volumetric cells (1.2 to 2.4 million cells each)
- Blood modelled as incompressible, laminar fluid, density 1055kg/m³, viscosity 0.004 Pa s
- Inflow: constant velocity 0.3 m/s
- Rigid vessel walls with no-slip condition
- Zero-pressure assumption at the outlets
- 5s simulation time, average wall shear stress over 3-5s



Simulation result andground truth for deep learning

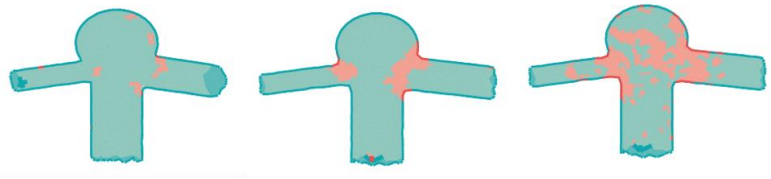
Deep learning mesh segmentation

- Binary segmentation based on simulation: normal and high wall shear stress (>0.4 * reference value)
- Reference value: median of maximal wall shear stress from each model
- Trained medMeshCNN and medMeshCNN with additional features (curvature, thickness)
- 123 meshes used for training

Acknowledgment

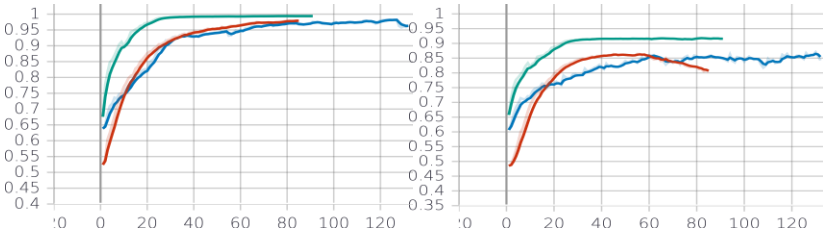
This work is partly funded by the German Research Foundation (SA3461/2-1, BE 6230/2-1) and the Ministry of Economics, Science and Digitization of Saxony-Anhalt within the Forschungscampus STIMULATE (grant number I 117).

Results



MedMeshCNN and | with curvature | with curvature thickness

- On average 43 seconds per mesh for wall shear stress prediction
- Including curvature improves results
- Weighted loss function needed
- Selected threshold and same basic geometry of artifical aneurysms might hinder training



Train and test accuracy (red: medMeshCNN, green: with curvature, blue: with curvature and thickness)

Reference

Lisa Schneider, Annika Niemann, Oliver Beuing, Bernhard Preim: MedMeshCNN – Enabling MeshCNN for medical surface models https://arxiv.org/pdf/2009.04893.pdf