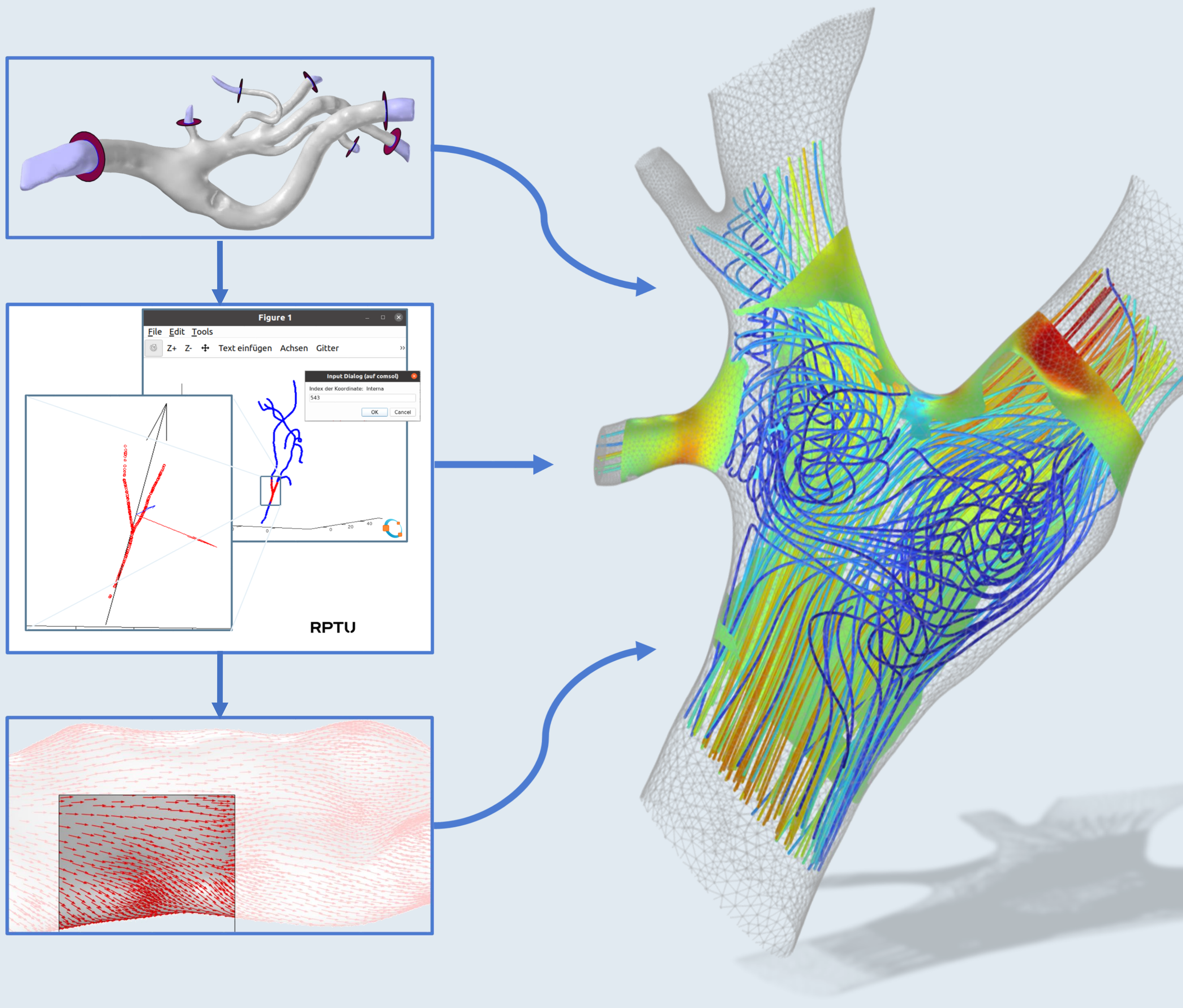

Utilizing COMSOL® in a Workflow to Assess Stroke Risks in a Large Set of Patient's Carotid Arteries

Optimizing the work routine with COMSOL® and large sets of patient arteries

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Abstract

The risk assessment of strokes caused by pathological irregularities in the carotid artery area plays a great role for the best patient's treatment decision. This process can be significantly improved with accurate flow field data obtained from simulations in patient-specific geometries. We developed an automated workflow for numerical data generation utilizing the COMSOL Multiphysics® software for a large set of 110 individual geometries to speed up the work routine. The exported datasets can serve as a hemodynamic database for visual atlases and comparative analysis.

Our automated workflow consists of (a). geometric preprocessing and simulation parameter setup, (b) simulation and (c) postprocessing and data export. Starting with geometric preparations of simulation- and export-parameters we use the centerline of each individual's vessel tree to determine parameters for cutting the in- and outlets. We also analytically define areas around the bifurcation and the internal carotid branch and set up slicing planes to extract field variables in reduced representation. In addition, we calculate a three-dimensional vector field on the vessel surface, which is integrated in COMSOL® to evaluate the longitudinal wall shear stress (WSS) discussed in [1] in the postprocessing step. The segmented carotid artery mesh is imported with the CAD Import Module and cropped in the geometry node according to our preprocessed parameters. The blood flow is simulated by solving the incompressible Navier-Stokes equations for laminar flow with a pulsatile inlet velocity condition which mimics the volumetric flow in the carotid artery during a cardiac cycle. The resistance boundary conditions, enabling the regulation of realistic flow split into the branches without affecting the flow patterns, are implemented at the outlet surfaces. In step (c) of our workflow, we evaluate and export simulated and derived data. Beside the flow variables we are interested in evaluation of surface risk descriptors as the wall shear stresses and their temporal and directional oscillations. The obtained hemodynamic database has been used for an explorative visual analysis of stroke risk based on flow patterns in the best match carotid morphology [2].

Automated Simulation Workflow

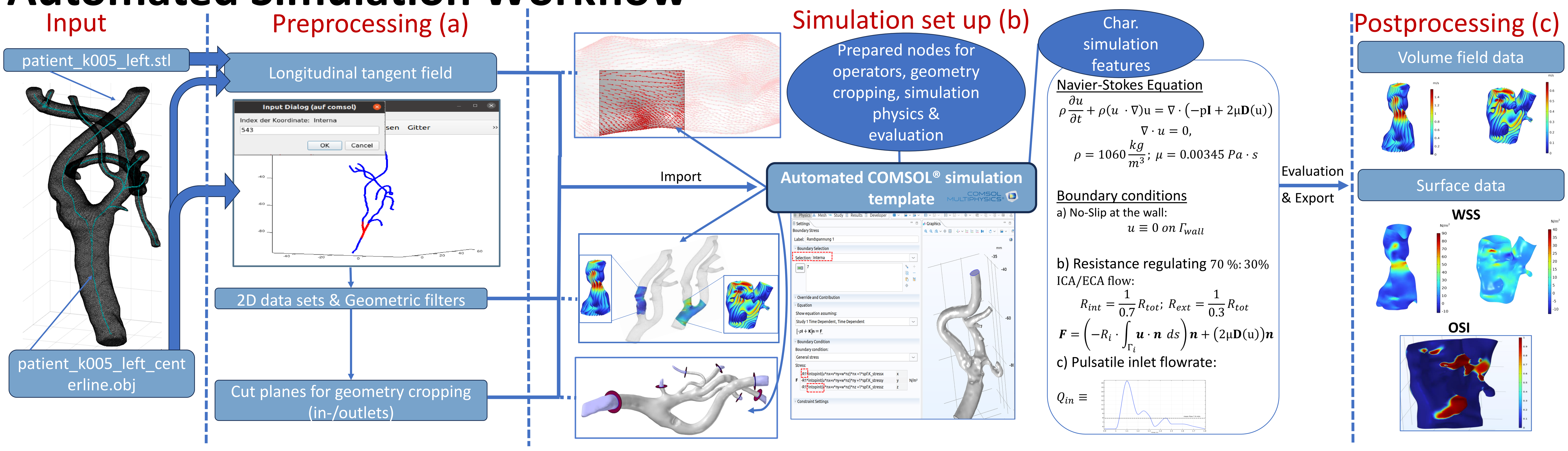


Figure 1. (a) Preparation of patient specific simulation parameters, evaluation filters & tangential field. (b) Automated COMSOL® template. Importation of preprocessed data with min. manual adjustment is needed for simulation (c) Results with filters applied.

Results: Hemodynamic Database

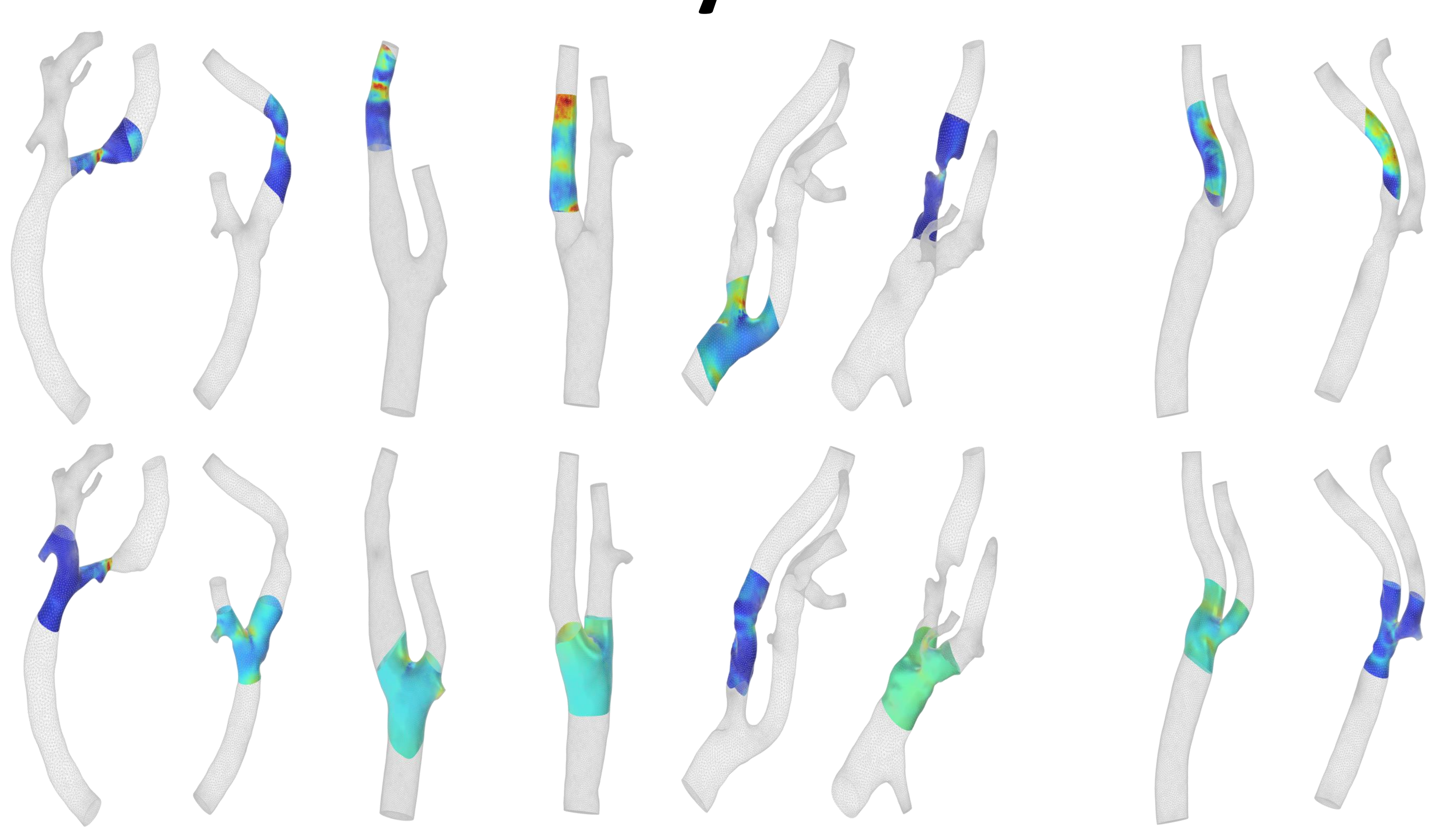
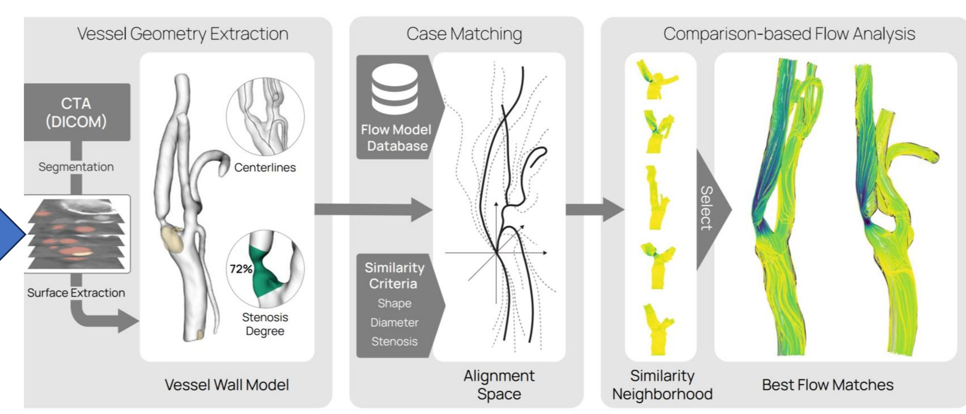


Figure 2. Visualization of a part of the generated hemodynamic database.

Usage similarity based:

visual analysis [2]



Statistics

Preprocessing	30 min
Indiv. Correction	10 min
Mean Computation time	4h 50min
Data export and upload	2h
Total	**7h 30min**

Overall time cost 34 days, 9 hours

Figure 3. Overview of needed time for single workflow steps.

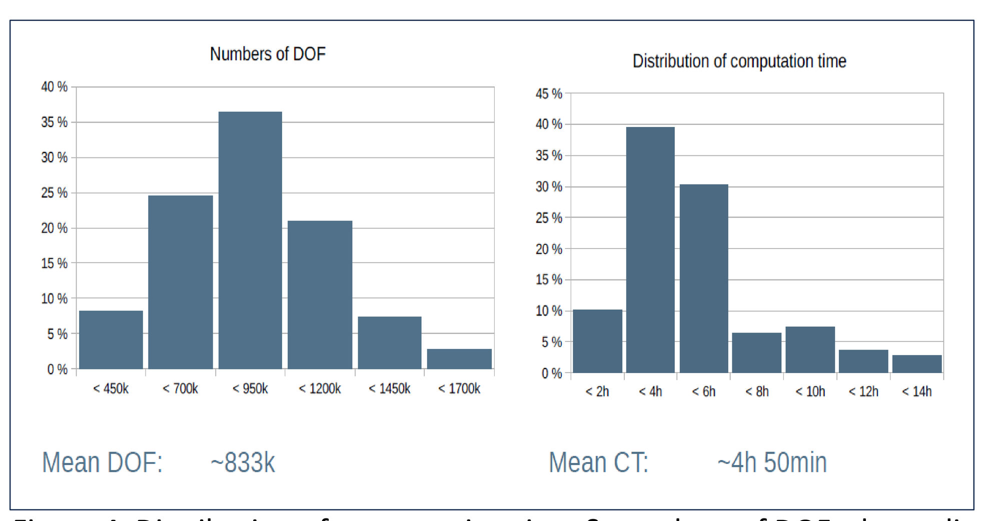


Figure 4. Distribution of computation time & numbers of DOFs depending on the complexity of the individual geometries

REFERENCES

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2. P. Eulerz, K. Richter, K. Lawonn, A. Hundertmark, „Instantaneous Similarity-based Visual Analysis of Blood Flow in Stenoses", - submitted 2023

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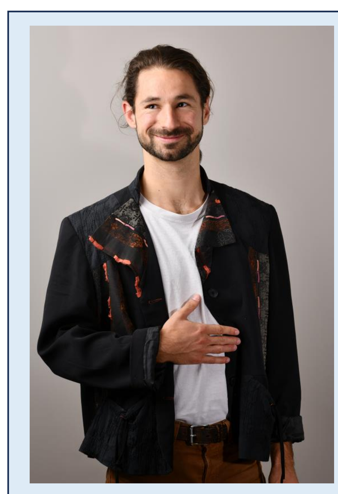

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