Computational Fluid Dynamics of Human Cerebral Circulation Systems

Figure 1: Example of reconstruction via Magnetic Resonance Imaging of a human cerebral circulation system. A specific region of interest is extracted and the cerebral flow is solved. On the right panels an example of wall shear stress computation in a cerebral arteria in the presence of an aneurysm, performed with the present CFD algorithm.

**Background.** A recent and promising application of Computational Fluid Dynamics (CFD) regards the study of vascular flow systems in humans. The combination of powerful numerical tools for the flow prediction and the precise measurement and reconstruction of complex real vascular systems permits to investigate the impact of flow behaviour on diseases initiation and progression. In fact, the development of several pathologies is strictly connected to the vascular flow behaviour (hemodynamics). Therefore, the possibility of solving the complex vascular flow in real vascular geometries via CFD is of enormous interest for several medical applications.

**Problem Description and Goals.** The main goal of the project is to assess the medical risk of a human disease on the basis of the flow characteristics, by means of CFD. For instance, both high and low flow velocities and stresses in the veins have been found to be correlated with intracranial aneurysm growth and rupture. More generally, cerebrovascular diseases are known to be strictly connected with wall shear stresses in the circulation system. Students will identify a particular region in the circulation system, on the basis of the targeted disease of interest. Then, they will investigate the flow characteristics which can affect the diseases initiation, progression and/or spreading. A special focus will be given to the importance of the pulsatile nature of human cerebral blood flow and its relation with diseases initiation.

**Method and Implementation**

1. First stage: from open-source datasets of *in vivo* medical images, the real geometry of the human vascular system will be reconstructed. A specific region of interest will be identified. This stage will be performed with specific algorithms provided by the supervisor to be run in Matlab.

2. Second stage: the reconstructed geometry of the specific region will be used as input for three-dimensional flow simulations. The flow will be solved by means of an innovative CFD technique, the Lattice-Boltzmann Methodology (LBM). The software is ready and will be provide by the supervisor (in Matlab), as well as instructions to run it.

3. Third stage: analysis of the flow characteristics and quantification of the risks related to the diseases, for instance by quantifying the flow velocities and stresses in the veins with the presence of a pulsatile flow.

4. Fourth stage: summary of the work and dissertation of the results.

**Special Admission Requirements, Target Group and Group size.** To know Matlab software is required. The student group can be from courses: TKMAS, TKBIO, TKDAT, TKKEF, TKKMT, TKTFY, TKDES, TKTEM, TKAUT, TKATK, TKELT, TKITE. The group size is from 3 to 6 persons. The project can be doubled.

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