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Aufgabenstellung Advanced Design Project

Title: Physically informed neutral networks to estimate wall shear stresses from Magnetic Resonance Imaging

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Wall shear stress (WSS) is an important hemodynamic quantity associated with the development and progression of cardiovascular diseases. Magnetic resonance velocimetry (MRV) provides non-invasive access to flow fields, but the reconstruction of WSS from MRV data remains challenging due to limited spatial resolution, measurement noise, and the high sensitivity of near-wall velocity gradients. Physics-informed neural networks (PINNs) offer a promising framework to combine MRV measurements with the governing equations of fluid flow and thereby improve the reconstruction of near-wall quantities. This project therefore aims to reconstruct WSS directly from MRV velocity data using a PINN and to assess the robustness and accuracy of the resulting estimates.

Project Tasks

The objective of this project is to reconstruct wall shear stress (WSS) from magnetic resonance velocimetry (MRV) data using a physics-informed neural network (PINN). Previous work has investigated the accuracy and limitations of WSS estimation from MRV measurements [1]. Building on this work, Bauer et al. [2] provide a publicly available dataset of pulsatile flow through a generic abdominal aneurysm, including time-resolved 3D MRV measurements and corresponding reference data. This dataset [3] will serve as the experimental basis for the project.

1. Import and preprocess the MRV velocity data and extract the vessel geometry and wall locations.
2. Implement a physics-informed neural network combining the MRV measurements with the incompressible Navier–Stokes equations and appropriate boundary conditions.
3. Reconstruct a physically consistent velocity field, with particular focus on the near-wall region.
4. Determine the wall shear stress from the reconstructed near-wall velocity gradients.
5. Compare the PINN-based WSS reconstruction with the available reference data and assess its accuracy and robustness with respect to relevant MRV and PINN parameters.

References

[1] A. Bauer, S. Wegt, M. Bopp, S. Jakirlic, C. Tropea, A. J. Krafft, N. Shokina, J. Hennig, G. Teschner, and H. Egger, “Comparison of wall shear stress estimates obtained by laser Doppler velocimetry, magnetic resonance imaging and numerical simulations,” *Experiments in Fluids*, vol. 60, Art. 112, 2019. doi: 10.1007/s00348-019-2758-6.

[2] A. Bauer, M. Bopp, S. Jakirlic, C. Tropea, A. J. Krafft, N. Shokina, and J. Hennig, “Analysis of the wall shear stress in a generic aneurysm under pulsating and transitional flow conditions,” *Experiments in Fluids*, vol. 61, Art. 59, 2020. doi: 10.1007/s00348-020-2901-4.

[3] A. Bauer et al., MRV dataset for pulsatile flow through a generic aneurysm, TUdatalib, Technische Universität Darmstadt. doi: 10.25534/tudatalib-113.2.

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