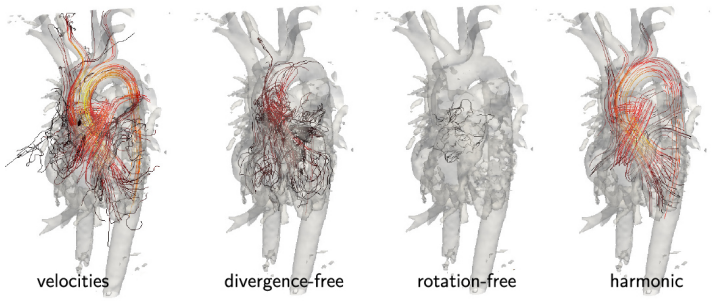
Bachelor Major Project: Helmholtz Decomposition of 4D MRI Blood-Flow Data



Introduction:
Measurements from a wide variety of modalities are used to diagnose cardiovascular diseases. Magnetic Resonance Imaging (MRI) is often used for complex cases. Diagnosis of cardiovascular disease in clinical practice is largely based on anatomical MRI scans, while more advanced MRI scanning protocols provide quantitative blood-flow information.

Clinical research takes a large interest in finding correlations between blood flow and the progression of vascular diseases. Until recently computational fluid dynamics (CFD) simulations delivered the main source of information. Nowadays also quantitative blood-flow data can be acquired with MRI; providing a measurement of the blood flow, as opposed to a simulation of the blood-flow velocities.

The flow measurements provide large data sets, which are hard to interpret on a slice-by-slice basis. Mental reconstruction of vascular structures can be challenging, even for a skilled radiologist. The flow measurements add a velocity field that changes over time to these complex structures, resulting in a data set which becomes exceptionally hard to understand.

Problem Statement:
To facilitate the analysis of the blood-flow, we aim for simplified representations of the velocity fields. In the past, methods have been proposed to decompose vector fields into simplified separate fields. For instance, the 'Helmholtz decomposition' separates the flow field into a rotation-free, a divergence-free and an additional harmonic field (e.g., Petronetto et al. [1]). Since the blood-flow is incompressible, the field should be free of divergence. In practice however, this is not the case due to imperfections of the measurements.

In recent work, we have investigated the Helmholtz decomposition to 4D MRI blood-flow data, decomposing the time-resolved blood-flow velocity field. Using the Helmholtz decomposition, a divergence-free representation of the measured blood-flow data can be obtained, which is of interest to physicians who investigate the blood-flow acquisition. However, different approaches exist to perform the decomposition. Therefore, differences between these techniques need to be evaluated.

Goal:
The goal of this project is to evaluate different Helmholtz decomposition techniques for 4D MRI blood-flow data, based on previous research on this topic.

Execution:
Execution of the project comprises the following aspects:

- Implementation
  Implementation of the different techniques using Matlab or Mathematica. Previous research provides a basis for solid starting point.

- Evaluation study
  Investigate the drawbacks and benefits of the different approaches. This involves a quantitative comparison of the different approaches using suitable error measures.

References:
[1] *"Meshless Helmholtz-Hodge Decomposition'*, Fabiano Petronetto, Afonso Paiva, Marcos Lage, Geovan Tavares, Hélio Lopes, and Thomas Lewiner in Proceedings of IEEE Visualization (2010)