Illustrative Particle Visualization of 4D MRI Blood-Flow Data

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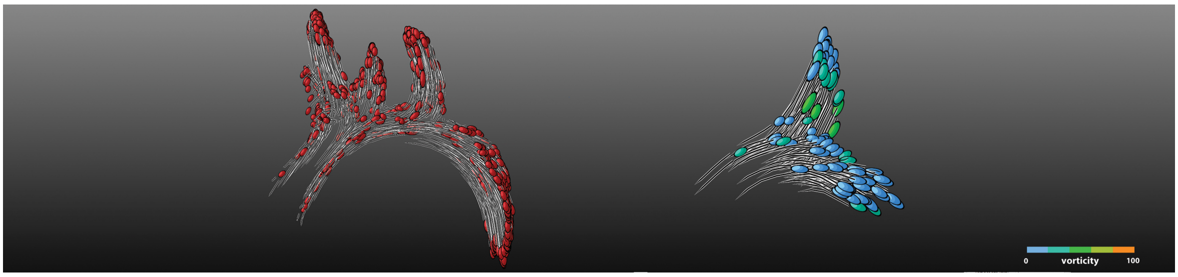

Figure 1: Illustrative particle tracing of 4D PC-MRI blood-flow in the aorta and pulmonary artery.

1. Introduction

Morphology of cardiovascular tissue is significantly influenced by the unsteady behavior of flowing blood. Insight into the hemodynamics potentially reveals valuable diagnostic information for a wide range of cardiovascular diseases (CVD). This group of conditions is currently the leading cause of death in the western world. At present, diagnosis and prognosis of CVD is primarily based on morphological information, possibly enriched by functional information from cine scans. In the near future, blood-flow dynamics might become a vital source of diagnostic information.

Blood-flow information can be measured non-invasively, ruling out approximative model assumptions that are found in fluid simulations. For our work, we depend on 4D phase-contrast magnetic resonance imaging (PC-MRI) for the acquisition blood-flow velocity information. This technique provides quantitative 3D-cine velocity fields of the blood-flow for a full cardiac cycle.

Before conducting in-depth analysis of the blood-flow characteristics, it is worthwhile to qualitatively explore the hemodynamics, such that clinicians can interactively inspect the flow field for abnormalities. To that end, we employ an interactive particle system.

In previous work, particle systems were readily applied to blood-flow fields. Particles are commonly depicted as spheres, with a color mapping of the local speed. Alternatively, particles may be depicted by small integral lines.

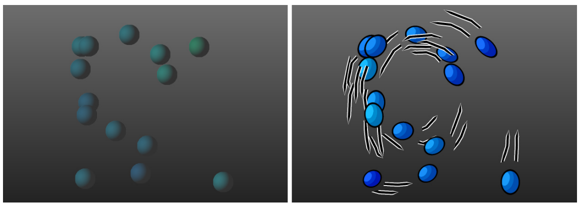

Figure 2: Comparison between conventional particle depiction (left) and our illustrative depiction (right)

2. Our Approach

Based on previous work [vPBB*10], we were inspired by illustrative techniques, typically found in cartoons [JR05]. Therefore, we extend common sphere or integral line renderings. Our approach enhances perception of speed and direction within the blood-flow field (figure 2).

First, spheres are deformed to ellipsoids, conveying blood-flow velocity. This technique is often applied in comics, mimicking a ball in high-speed motion.

Second, we enhance the perception of direction by means of speed lines, capturing the particle trajectory. We apply two lines per particle, similar to comics depicting motion. Whenever speed-lines are parallel, the particle fully resides within the flow field. Otherwise, the particle dwells near the vessel wall. The speed lines are reversed pathline-traces, rendered as tapered line strips with halos for additional depth perception [EBRI09]. The thickness of the speed lines is adjusted according to the local speed.

The combination of ellipsoids and speed lines captures local speed and direction of the blood-flow. Color coding of speed information is superfluous, saving color information to convey more elaborate flow characteristics, such as vorticity or particle residence time.

Our particle system is implemented using modern consumer graphics hardware. Integration of particles is performed on the graphics hardware using Runge-Kutta 4 integration. Particle are rendered through imposter ellipsoids. Seed positions of particles can be updated interactively, facilitating exploration.

References

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