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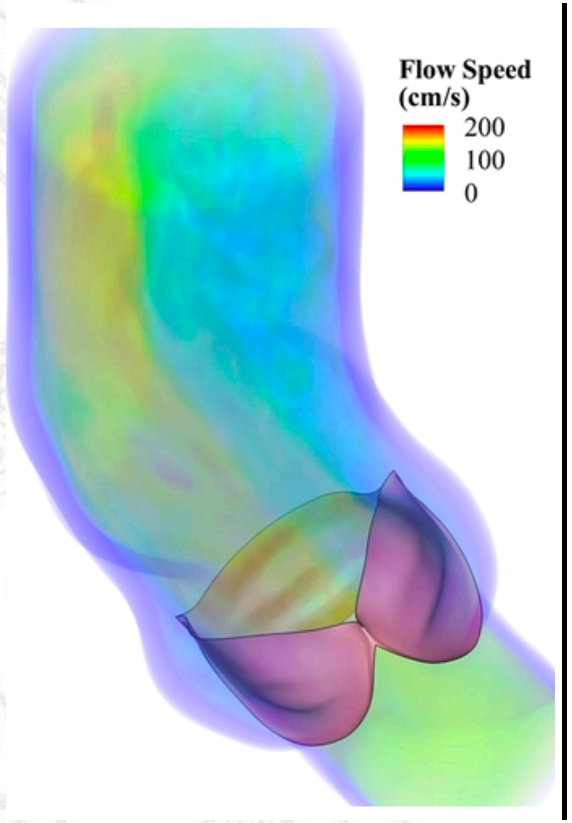
A Framework for Patient-Specific Heart Valve Design and Analysis

In this work, we present a framework for designing patient-specific bioprosthetic heart valves using recently proposed immersogeometric fluid–structure interaction (FSI) analysis. The patient-specific aortic root geometry is reconstructed from the medical image data and is represented using non-uniform rational B-splines. We then parametrically design bioprosthetic heart valves (BHVs) based on the aortic root, using a Rhino/Grasshopper-based interactive geometric design platform. The FSI simulations are carried out using our hybrid immersogeometric/arbitrary Lagrangian–Eulerian methodology, which allows us to efficiently perform a computation that combines a boundary-fitted, deforming-mesh treatment of the artery with a non-boundary-fitted treatment of the leaflets. We simulate the coupling of the deforming, patient-specific aortic root and parametrically designed BHVs, and the surrounding blood flow under physiological conditions through several cardiac cycles. The attachment edge of the leaflet is coupled with the arterial wall motion using a penalty formulation. The results demonstrate the effectiveness of the proposed framework in practical computations with greater levels of physical realism. A parametric study is carried out to investigate the influence of the geometry on heart valve performance, indicated by the effective orifice area during the opening and the coaptation area during the closing. Finally, the FSI simulation of the optimal BHV design is compared with the phase-contrast MRI data to demonstrate the qualitative similarity of the flow patterns in the ascending aorta.



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April 3rd, 3:00pm
DICAr MS1 Meeting Room
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Virtual Modeling and Additive Manufacturing for Advanced Materials

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