Framework for Fluid-Structure Interaction with Contact and its Applications in Biomechanics

Johan Jansson[1, 2], Jeannette Spühler[1], Niyazi Cem Degirmenci[1*], Van Dang Nguyen[1], Johan Hoffman[1, 2],

[1]Department of High Performance Computing and Visualization, KTH Royal Institute of Technology
Lindstedtsvagen 3, 10044 Stockholm, Sweden
{jjan,spuhler,ncde,jhoffman,vdnguyen}@kth.se

[2]Basque Centre for Applied Mathematics
Mazzaredo 14, 48009 Bilbao, Basque Country, Spain
jjansson@bcamath.org

ABSTRACT

In this contribution we present a computational technique based on a Unified Continuum (UC) model of Fluid-Structure Interaction (FSI) discretised by an Arbitrary Lagrangian-Eulerian (ALE) finite element method [1]. The implementation in our parallel finite element framework Unicorn[2]/FEniCS-HPC[3] is described together with its applications in biomechanics, including benchmark problems for verification and validation of the mathematical model and its implementation.

The applications that we plan to be present and discuss are:

Verification and validation of the 3D FSI method through the CHeart FSI Benchmark [4],

Validation of the Contact model with comparisons to the 2D test problem discussed in the paper [5].
Validation of the FSI-Contact model for self oscillating vocal folds against experimental measurements where the work is performed as part of the EUNISON FP7 project.
Application of FSI-Contact with realistic Human Vocal Folds geometry with coupled aeroacoustic simulations.
Application of FSI-Contact for heart valves.

The new advances that will be brought into focus in the method development is a variant of the GLS-stabilization with stabilization parameter proportional to h^3/2, with improved accuracy for smooth solutions, which we use for the CHeart 3D FSI benchmark, and preliminary results with a fixed-mesh variant of the ALE UC model activated in regions of extreme mesh deformation.

References

[1] J. Hoffman, J. Jansson, M. Stckli, Unified continuum modeling of fluid-structure interaction, Mathematical Models and Methods in Applied Sciences, Vol.21(3), pp.491-513, 2011.
[2] J. Hoffman, J. Jansson, R. Vilela de Abreu, N. C. Degirmenci, N. Jansson, K. Mller, M. Nazarov and J. Hiromi Sphler, Unicorn: parallel adaptive finite element simulation of turbulent flow and fluid-structure interaction for deforming domains and complex geometry, Computers and Fluids, Vol.80, pp.310-319, 2013.
[3] http://www.fenicsproject.org
[4] David Nordsletten, Oliver Röhrle, Johan Hoffman, Ralph Sinkus, and Thomas J. R. Hughes FSI Benchmark: Techniques and Validation, Minisymposium 10, 4th International Conference on Computational and Mathematical Biomedical Engineering – CMBE2015
[5] David Doyen, Alexandre Ern, Serge Piperno, A Semi-Explicit Modified Mass Method for Dynamic Frictionless Contact Problems, Trends in Computational Contact Mechanics, Volume 58 of the series Lecture Notes in Applied and Computational Mechanics pp 157-168