Numerical Modeling and Large–Scale Simulation of the Electro–Mechanics–Fluid Problem for the Heart Function

L. Dedè[♯,*], D. Forti[†], A. Gerbi[†] and A. Quarteroni[†]

[♯] MOX – Modeling and Scientific Computing, Mathematics Department
Politecnico di Milano
P.zza Lonardo da Vinci 32, 20133 Milano, Italy
e-mail: luca.dede@polimi.it, web page: https://mox.polimi.it/

[†] Chair of Modelling and Scientific Computing (CMCS) – MATHICSE
École Polytechnique Fédérale de Lausanne
Av. Piccard, Station 8, 1015 Lausanne, Switzerland
e-mail: {davide.forti, antonello.gerbi, alfio.quarteroni}@epfl.ch - Web page: http://cmcs.epfl.ch

ABSTRACT

The simulation of the heart function is a challenging task from the mathematical, numerical, and computational points of view. Indeed, the full cardiac model features a multiphysics nature as it is comprised of several components – electrophysiology, mechanics (both active and passive), and fluid dynamics – each of them intrinsically complex; moreover, these involve a wide range of spatio–temporal scales which need to be properly represented to capture the mutual interactions of all the heart components [4].

In this talk, we focus on the mathematical and numerical modeling of the left ventricle by integrating state–of–the art models for the electrophysiology of the tissue, the activation mechanisms at the cellular level, the passive mechanical responses of the muscle, and the fluid dynamics of the blood in the chamber, thus yielding a coupled electro–mechanics–fluid problem describing the heart function [1, 4]. We consider its spatial approximation by means of the Finite Element method and we propose a fully coupled approach with a semi–implicit scheme for its time discretization based on Backward Differentiation Formulas. For modeling the fluid dynamics of the left ventricle within the ALE framework, we use the Variational Multiscale method with LES modeling [3] in order to capture the transitional, or nearly turbulent nature of the blood flow. The large–scale problem arising from our discretization approach is solved by the GMRES method with a preconditioning strategy based on the extension of the FaCSI (Factorized Condensed SIMPLE) concept [2]. We present and discuss numerical results obtained in the high performance computing framework for patient–specific, left ventricle geometries.

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