COUPLING STRATEGIES FOR ELECTRO–MECHANICS IN THE HEART

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ABSTRACT. Heart failure (HF) is one of the major challenges in modern cardiology. An effective treatment for HF patients can be cardiac resynchronisation therapy (CRT). Unfortunately, current diagnostic tools are clinically insufficient to guide clinicians in the optimal application of CRT, as testified by the high percentage of non–responding patients to the therapy (in some cases up to 30%).

Over the last decade, several research groups have been working on modelling CRT by combining patient–specific geometrical, electrical and mechanical information. Such models can potentially improve the diagnosis. On the other hand, modelling the heart dynamics is a complex multiphysics problem, spanning several temporal and spatial scales. Thus it is not a trivial task to build consistent mathematical models and robust numerical schemes.

Strongly coupled electromechanical models are known to show unstable behaviour under many circumstances [3]. Besides possible mathematical inconsistencies in the model which may lead to instability [4], also the numerical discretisation is challenging, for at least two reasons: first, the spatial scale required for the electrophysiology and mechanics are significantly different, and second, the operator–splitting strategy to solve the coupled nonlinear system is generally unstable.

In this talk we present some preliminary results on a novel strategy to solve the coupled problem with a monolithic approach, and we compare this to staggered approaches proposed in the literature by others. The basic idea is to keep the nonlinear system fully coupled with the possibility to have basis functions defined on different meshes, and possibly not nested.

As part of work of the Center for Computational Medicine in Cardiology in Lugano, we implemented HART, a novel front–end for the open source general purpose C++ finite element framework MOOSE, see [2]. This library allowed for major acceleration of the software development process. Although only a few months old, coupled simulations of electrocardiology and cardiomechanics are now possible with HART.

Making use of the very modular formulation of MOOSE, HART is easily extendible to incorporate additional material laws and cell membrane models. For parallelization, the code relies on the widely used and well developed solver library PETSC. We will present and discuss scaling benchmarks for the coupled problem on both a Linux cluster and a state-of- the-art Cray supercomputer. Finally, further directions of development for HART will be outlined.

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