The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

A novel Machine Learning method for accurate and real-time numerical simulations of cardiac electromechanics

Luca Dede'[1], Francesco Regazzoni[1], Matteo Salvador[1], and Alfio Quarteroni[1,2]

[1] MOX - Dipartimento di Matematica, Politecnico di Milano, P.zza Leonardo da Vinci 32, 20133 Milano, Italy.
[3] Mathematics Institute, École Polytechnique Fédérale de Lausanne, Av. Piccard, CH-1015 Lausanne, Switzerland (*Professor Emeritus*).

Keywords: *Cardiac Electromechanics, Numerical Simulations, Machine Learning, Sensitivity Analysis, Uncertainty Quantification*

The cardiac function is the result of the concerted action of several physical processes, ranging from the cellular scale to the organ level. A crucial role in heart modeling is accounting for the coupling between electrophysiology and active and passive mechanics, leading to the so called electromechanical models. Performing fast and reliable electromechanical simulations is increasingly becoming important in computational cardiology and precision medicine. With this aim, we propose a novel Machine Learning method that enables real-time numerical simulations of cardiac electromechanics. We derive a reduced-order model (ROM), written as a system of Ordinary Differential Equations, in which the right-hand side is represented by an Artificial Neural Network (ANN) that possibly depends on a set of parameters associated with the model to be surrogated. This method is non-intrusive, as it only requires a collection of pressure and volume transients obtained from the full-order cardiac electromechanics model (FOM). Once trained, the ANN-based ROM is coupled with circulation models that account for the cardiovascular system external to the heart, as for the original electromechanical model, but at a dramatically reduced computational cost. We show the effectiveness of the proposed strategy on two relevant contexts in cardiac modeling. We employ the ANN-based ROM to perform a global sensitivity analysis on both the electromechanical and the hemodynamic models. Then, we perform a Bayesian estimation of some parameters starting from noisy measurements of scalar outputs. By replacing the FOM of cardiac electromechanics with the ANN-based ROM, we are able to perform in a few hours of computation the numerical simulations, which would otherwise be unaffordable if carried out with the FOM. We show that our ANN-based ROM is able to speedup the numerical simulations by more than three orders of magnitude.

This work has received funding from ERC under the European Union's Horizon 2020 program: grant agreement No 740132, iHEART, P.I. Prof. A. Quarteroni.

REFERENCES

[1] F. Regazzoni, M. Salvador, L. Dede' and A. Quarteroni. A machine learning method for real-time numerical simulations of cardiac electromechanics. *arXiv* 2110.13212, 2021.

[2] A. Quarteroni, L. Dede', A. Manzoni, C. Vergara. *Mathematical Modelling of the Human Cardiovascular System: Data, Numerical Approximation, Clinical Applications*. Cambridge University Press, 2019.