A machine learning-based reduced order model for the investigation of the haemodynamics in coronary artery bypass grafts

P. Siena[1], **C. Balzotti**[1], **M. Girfoglio**[1], **A. Quaini**[2], **and G. Rozza**[1]

[1]*SISSA, International School for Advanced Studies, Mathematics Area, mathLab, via Bonomea 265, 34136, Trieste, Italy.*
[2]*University of Houston, Department of Mathematics, 3551 Cullen Blvd, 77204, Houston TX, USA.*

The diffusion of coronary artery diseases and the increasing demand from the medical community for quantitative and patient-specific investigations are the main motivations which gave a strong impulse in recent time to the development of fast and accurate numerical models. The final goal is a better understanding of the blood flow behaviour in grafts and graft junctions so as to aid in surgical planning of grafting and improve the lifetime of grafts.
In this work, a machine learning Reduced Order Model (ROM) is employed in order to ensure rapid computations of the blood flow patterns in patient-specific configurations of Coronary Artery Bypass Grafts (CABGs) for variable physical and geometrical parameters of clinical interest. An expensive and time consuming offline phase performs a large number of parameter and time dependent high-fidelity solutions and generates the reduced basis from them. Then, during an online stage, the behaviour of the system in the parameter space can be investigated at a considerable reduced time.
In this scenario, we consider two different applications:

- Firstly, the ROM is implemented and its performance is tested for the reconstruction of pressure, velocity and wall shear stress computed by the Navier-Stokes equations for a patient-specific geometry, where the bypass is performed with the left internal thoracic artery on the Left Anterior Descending artery (LAD). The inlet flow rate and the severity of the stenosis are considered as parameters in the reduced framework [2].
- Then, the ROM approach is used within an optimal control problem in order to match measured clinical data with numerical outcomes at varying of the Reynolds number. This approach is introduced to overcome the issues arising from unrealistic outlet boundary conditions, which can lead to doubtful predictions. Here, we consider a bypass performed with the right internal thoracic artery on the LAD.

In both cases, we show that the data-driven ROM is able to provide a computational speed-up significantly greater than the one provided by classic projection-based strategies [1, 3].

References

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