`life`[x]: a high-performance simulator of the cardiac function

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Abstract

Modeling the whole cardiac function involves the solution of several complex multi-physics and multi-scale models describing a wide range of different processes, such as the propagation of the trans-membrane potential and the flow of ionic species in the myocardium, the deformation caused by the muscle contraction, as well as the dynamics of the blood inside the heart chambers and flowing through the valves, as schematized in Figure 1. Therefore, whole-heart fully-coupled simulations are computationally intensive and call for simpler yet accurate, high-performance computational tools (see, *e.g.*, the geometrical complexity of the computational mesh shown in Figure 2).

In this work we introduce `life`[x] (`https://lifex.gitlab.io/`, pronounced /ˌlaɪfˈɛks/, official logo shown in Figure 3), a finite element numerical solver for multi-physics and multi-scale problems, aimed at cardiac applications. It is written in `C++` using the most modern programming techniques available in the `C++17` standard and is built upon the `deal.II` (`https://www.dealii.org/`) finite element core.

The goal of `life`[x] is twofold. On the one side, it aims at making *in silico* experiments easily reproducible and accessible to the wider public, targeting also users with a background in medicine or bioengineering, thanks to an extensive documentation and user guide. On the other hand, being conceived as an academic research library, `life`[x] can be exploited by scientific computing experts to explore new mathematical models and numerical methods within a robust and friendly development framework.

`life`[x] has been developed with a modular structure, incorporating packages for the simulation of cardiac electrophysiology, mechanics, electromechanics and blood fluid dynamics models.

Recently, the first module of `life`[x] (fiber generation, `https://doi.org/10.5281/zenodo.5810268`) has been made publicly available: in the near future, it will be gradually followed by other core models for

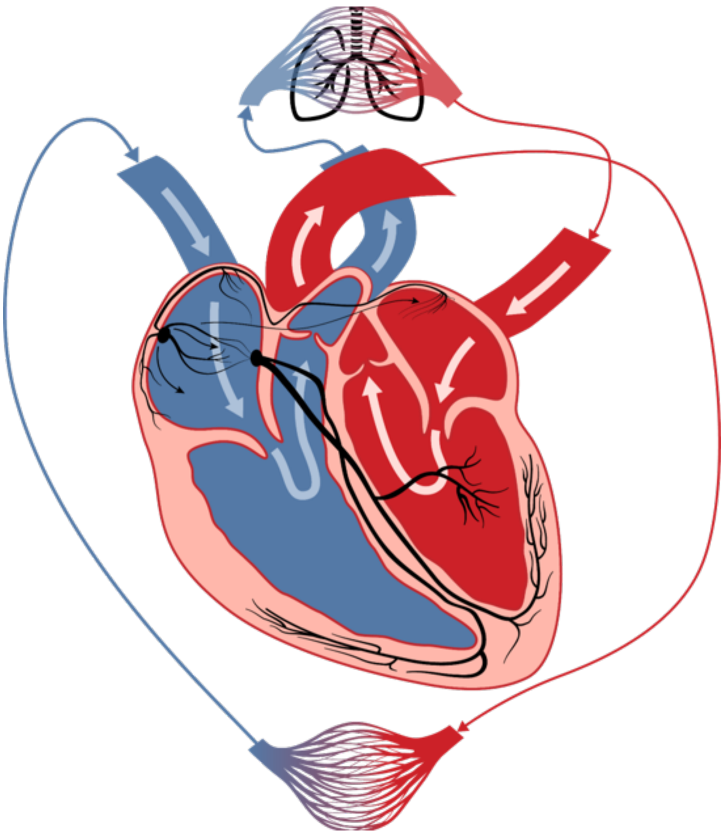

Figure 1: Schematization of the multi-physics and multi-scale processe involved in the cardiac function.

> the cardiac function (electrophysiology, mechanics, electromechanics, fluid dynamics, ...), to be released under an open-source license.

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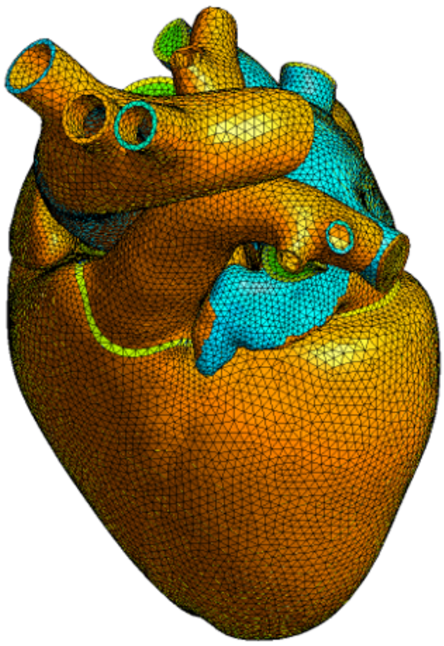

Figure 2: A computational mesh representation of the whole-heart.

Figure 3: `life`^{x} official logo.