Karlsruhe Institute of Technology

Institute of Biomedical Engineering

Beyond Myocytes: Benchmarking Microstructural Heterogeneity in Cardiac Electrophysiology

Bachelor/Master Thesis

Motivation

Heart muscle contraction is determined by excitation waves traveling through its tissue. While traditionally attributed solely to cardiomyocytes (CM), **fibroblasts (FB) are increasingly recognised to electrically couple to CM and thus modulate excitation spread**.

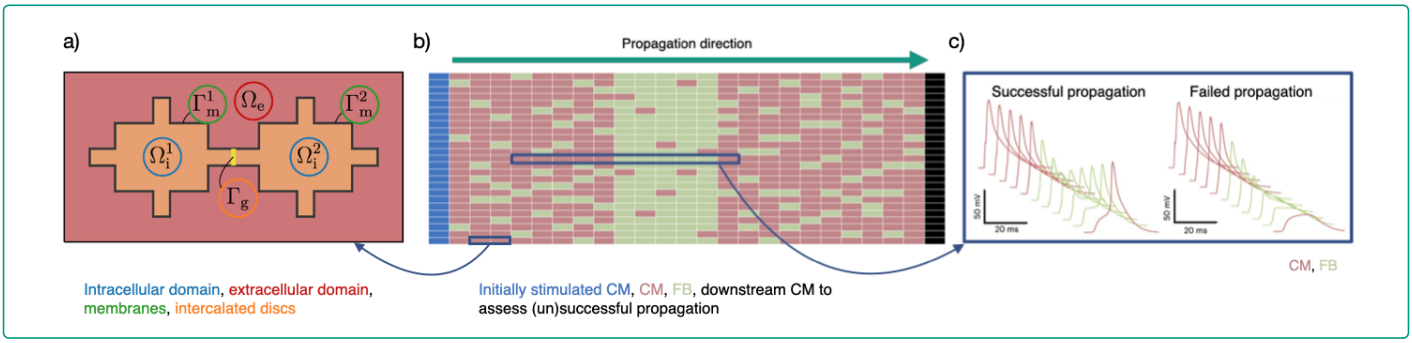

Figure 1: a) Schematic representation of the EMI model with two neighbouring, explicitly represented CM, their interfaces and surrounding extracellular space [1], b) **Schematic setup of the thesis project**, which is a spatially extended version of the setup shown in c) which shows transmembrane voltages for (un)successful excitation propagation via a chain of FBs [2].

Student Project

We employ the **extracellular-membrane-intracellular (EMI) model** [1], which explicitly resolves CM and their membranes within the computational mesh to capture the micro-structural behavior of excitation spread. The aim of this thesis is to **extend EMI-based simulations**, using the cardiac electrophysiology simulator openCARP [3], **to investigate CM-FB interactions in spatially extended tissue** and thereby **investigate how FB presence modulates excitation propagation** in cardiac tissue. To this end, we will:

a) vary the **CM/FB ratio** (sweep over the number n of FB),
b) vary the **spatial distribution** of FB (sweep over where these n FB are placed),
c) vary the **microstructural arrangement** (CM-FB coupling types and FB distribution patterns)

Your **tasks** will include:

- Literature research on the spatial organization of FB in cardiac tissue (e.g. using histological studies),
- Construct meshes accounting for this spatial organization starting from a given single-CM geometry,
- Assess under which conditions (variations in FB presence) excitation spread succeeds or fails

[1] Tveito et al. *Modeling Excitable Tissue: The EMI Framework. Simula Springer Briefs on Computing*. Springer (2020)
[2] Giardini et al., *Nat Cardiovasc Res* (2025), doi: 10.1038/s44161-025-00728-9
[3] `https://opencarp.org`

Software & Tools

Python, openCARP, bwUniCluster3.0, ParaView

Research Area

Cardiac Electrophysiology, Cardiac Microstructure, Computational Methods, Finite Element Methods

Course of Studies

Electrical Engineering, Biomedical Engineering, Physics, Computer Science, Mathematics

Starting Date

As soon as possible

Posted Date

05.08.2026

Contact Persons

Joshua Steyer, M.Sc.
joshua.steyer@kit.edu
+49 721 608-47184

Jan-Erik Duhme, M.Sc.
jan-erik.duhme@kit.edu
+49 721 608-47299

www.ibt.kit.edu

CaMo