Biomedical Engineering/Physiology 6460
Conduction Simulation Lab

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1 Purpose and Background

1.1 Purpose

The goal of this computational lab is to develop a basic understanding of electrical conduction in tissue and approaches to model it. Several programs allow simulation and visualization of electrical conduction in cardiac and neuronal tissue. We will apply software developed by Drs. Leonid Livshitz, Yoram Rudy and Anders Peter Larsen to simulate and analyze cardiac conduction in a one-dimensional tissue strand. Each of the specific tasks below aims at familiarizing you with modeling and simulation of tissue conduction as well as with effects of variations of cellular and tissue parameters on conduction.

1.2 Background

Most of the background on electrical conduction and stimulation of tissue is covered in the notes from our previous BE6460 lectures. Also, the general physiological and biophysical background comes from your lectures to date. In addition, the books written by Plonsey and Barr, "Bioelectricity–A Quantitative Approach" and Sachse, "Computational Cardiology" provide background information on mathematical and computational modeling of conduction, which is required for understanding the exercises. The applied model of myocyte electrophysiology is the Luo-Rudy model published in 1991 (PMID: 1709839). The conduction model was developed by Livshitz and Rudy in 2009 (PMID: 19720014). Background information on the safety factor and electrical coupling is provided in the articles attached to the lab instructions.

2 Lab Procedure

2.1 Lab Preparation

1. Ensure that you have access to a functional version of Matlab.
2. Download the simulation software on your computer and read through the code.
3. Download and read the articles attached to the lab instructions.

2.2 Lab Day Setup

1. Come prepared with a laptop with Matlab software.
2. Familiarize yourself with the Matlab software. If you are not familiar with Matlab, go through tutorials at http://www.mathworks.com/academia/student_center/tutorials/launchpad.html.
3. Explore the simulation software. Once familiar with the operation of the program, run simulations with the software and visualize the results.
4. Carry out the specific exercises in Section 2.3 below.

2.2 Capturing images

Matlab allows you to produce figures with high quality for your report. Alternatively, you could use a screen capture utility to grab images. After capturing, the screen shot is copied to the clipboard as an image. You can paste then image directly into your text processing program as well as most photo editing and image processing programs.

2.3 Lab Exercises - Modeling of Electrical Conduction in the Heart

Objective: Gain insights into electrical conduction under various conditions.

Assignment:

1. Perform simulations using the program sim_wrapper with the parameters listed in table 1. Note that each simulation might take a few minutes on your computer. On my computer (Mac Pro, 3 GHz 8-Core Intel Xeon E5, Matlab 2019b) a single simulation required 26 s.
2. Provide a table with conduction velocity and maximal upstroke velocity for each simulation.
3. Create figures to illustrate simulations relevant for your report. One figure should summarize results from simulation 1-7 varying intercellular coupling. Another figure should summarize results from simulation 4, 8-11 varying amplitude of the stimulus current I_{Stim}. A further figure should summarize results from simulation 4, 12-17 varying the sodium current I_{Na} underlying myocyte activation.

Simulation#	I_{Stim} (μA/μF)	Coupling (cm²/ms)	I_{Na} Scale
1	120	7e-5	1
2	120	1e-4	1
3	120	2e-4	1
4	120	7e-4	1
5	120	1e-3	1
6	120	2e-3	1
7	120	3e-3	1
8	110	7e-4	1
9	100	7e-4	1
10	90	7e-4	1
11	80	7e-4	1
12	120	7e-4	2
13	120	7e-4	0.75
14	120	7e-4	0.5
15	120	7e-4	0.4
16	120	7e-4	0.3
17	120	7e-4	0.25

Table 1. Simulation parameters

3 Lab Report

Introduction (30 pts): Begin the report with introducing cardiac electrical conduction and its biophysical basis. Introduce computational simulation of conduction and explain why these simulations can help to understand relationships between cellular activity, intercellular coupling and tissue conduction. Also, explain the concept of electrical sources and sinks in cardiac tissue. Provide examples of source-sink mismatches and describe how they might develop. Furthermore, explain the concept of "Safety factor". (Length: ~1.5 pages)

Methods (20 pts): In the Methods section, introduce the simulation software and its major building blocks. Describe briefly what you did to use the program and produce the figures in the results section. Include any relevant settings you had. Always keep in mind, the directions should be detailed enough to allow the instructors or someone with the background of your classmates to replicate your experiments. Find the correct balance between specific and general instruction and try not to replicate either the lab description (this document) or other materials. (Length: ~1 page)

Results (20 pts): Provide the material requested and address the questions in section 2.3. Make sure to use both images and text to describe all your results. The emphasis is on quantitative description, but also find ways to qualitatively describe the results where possible. (Length: ~1 page without figures and tables)

Discussion and Conclusion (30 pts): What do you conclude from the computed relationships between cardiac cellular activity, intercellular coupling and tissue conduction? In the computer model, every cell is connected only to its up- and downstream neighbor along the strand. Describe how this is different from real three-dimensional cardiac tissue. What is the advantage of the situation in real tissue? How does this relate to a source-sink mismatches and the safety factor of conduction? (Length: ~1,5 pages)

Please work independently on the lab report. Submit lab reports in PDF format via canvas at the specified deadline. Write the lab report as if you would write a paper for submission to a scientific journal. Lab reports are due in PDF via canvas. Follow standards for scientific writing and citation of literature, for instance

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(use single column format)