BME 355 Assignment 3: Cardiovascular Modelling

Due 11:59pm, March 20, 2020.

This assignment should be completed in groups of two or three. Submit a PDF document (not a Word document) that includes the names of the group members, answers to questions, and requested plots. Also submit your Python code in a zip file. You are advised to use the partially completed code on Learn.

This assignment is based on a model from Ferreira, A., Chen, S., Simaan, M. A., Boston, J. R., & Antaki, J. F. (2005). A nonlinear state-space model of a combined cardiovascular system and a rotary pump. *Proceedings of the 44th IEEE Conference on Decision and Control, and the European Control Conference, CDC-ECC '05*, *2005*, 897–902.

1) Complete the unfinished sections of the code (circulation.py) based on the Ferreira et al. paper and the lecture slides. The Circulation constructor requires several arguments. Use values from the paper, $E_{max} = 2.0$, $E_{min} = 0.06$, and heart rate 75 beats/min.
2) Simulate the model for five seconds. Plot the atrial pressure, ventricular pressure, arterial pressure (i.e. x_3), and **the aortic pressure just outside the aortic valve** (i.e. between D2 and R4). Start the simulation with all the blood in the atrium, so that the initial ventricular blood volume is the slack volume.
3) Write a method to accurately calculate left ventricular blood volume given results from a simulation of the cardiovascular system model. Assume a slack ventricular volume of 20ml. In addition to writing the code, briefly describe your approach in the PDF document.
4) Plot ventricular pressure (vertical axis) versus ventricular volume (horizontal axis) to produce a pressure-volume loop for a few cardiac cycles. Omit the first five cycles to avoid the transient response when the simulation starts. Increase R1 to 2Ω (or mmHg s/ml) and plot another pressure-volume loop (in the same plot as the first one, so they are easily compared). Finally, with R1=.5Ω, simulate aortic stenosis by increasing R3 to 0.2 and plot another pressure-volume loop. Explain the differences in these loops. Use a legend to label the loops, *normal*, *high systemic resistance*, and *aortic stenosis*.