**MA665: Introduction to Modeling and Data Analysis in Neuroscience (Fall 2019)**

**Instructor:** Mark Kramer (mak@math.bu.edu)

**Course Hours:** September 3, 2018 – October 24, 2018 [7 weeks]

Tuesday & Thursday, 12:30-1:45 PM, CAS 330

**Office Hours:** Math & Stats Room 224 by appointment

**Textbook:** None

**Course Website:**      https://github.com/Mark-Kramer/BU-MA665-MA666

**Prerequisites:** Graduate standing or consent of instructor.

This course is intended to introduce neuroscience graduate students to mathematical concepts in neuroscience. We will use experimental observations in neuroscience to motivate the study of mathematics, both to quantify the observed data and build computational models. The course will focus on five fundamental topics in mathematical neuroscience, with emphasis on quantifying neurophysiological time series and developing mathematical models of the activity observed. An important component of the course is an introduction to scientific computing. Completing the material in this course will provide you with the minimum requirements for an introduction to a subset of topics in computational neuroscience.

**Course goals**

To introduce mathematical concepts encountered in neuroscience research and more advanced neuroscience graduate courses. To teach basic programming skills. To think about neuroscience in quantitative ways.

**Course requirements**

The main requirement in this course is effort. I expect your full effort during our course meetings, and outside of the course, to meet the course objectives. As part of this course, you will work together in teams of 3. We’ll establish those teams during the first week of MA665. You will work with your team to complete a series of challenges in this course.

**Grades**

To earn an A in MA665, your team must complete challenges in five topics:

* Programming proficiency
* The integrate and fire neuron, and its extensions
* The Hodgkin-Huxley neuron
* The evoked response potential, and bootstrap resampling
* The power spectrum

We will begin each challenge in class. Challenge questions will include: basic facts, conceptual questions, and practical programming implementation. Upon completion of a challenge, I will select a team to present their results. The class and I will ask questions of the team and selected team members. Please do your best to answer each question. If your team successfully answers each question, then your team completes the challenge. If not, I will recommend topics for additional study. You may continue to complete a challenge after our in course discussion, and present the results at a later time (in class or during office hours).

**Schedule**

Please begin with Topic 1, and progress in the order of topics. Our goal is to complete all 5 topics by the end of MA665. I recommend viewing online lectures and completing readings outside of class. I recommend asking questions and working on challenges during class.

**Suggested Course Schedule**

Readings: These papers provide a general context and motivation for the application of mathematics and statistics to problems in neuroscience. Please read these papers at your leisure during the next 7 weeks.

* Gerstner, W., Sprekeler, H., & Deco, G. (2012). *Theory and simulation in neuroscience*. Science, 338(6103), 60–65.
* Marder, E. (2015). *Understanding brains: details, intuition, and big data*. PloS Biology, 13(5), e1002147
* Churchland, A. K., & Abbott, L. F. (2016). *Conceptual and technical advances define a key moment for theoretical neuroscience*. Nature Neuroscience, *19*(3), 348–349.

Advanced Reading: This paper provides a big-picture discussion of computational neuroscience and related topics. Important ideas to consider for your future career in neuroscience.

* Brain 2025: A Scientific Vision, 2014

Depressing reading:

* *Saving Science: Science isn’t self-correcting, it’s self-destructing*. Daniel Sarewitz, 2016.
* Button, K., et al (2013). *Power failure: why small sample size undermines the reliability of neuroscience.* Nature Reviews Neuroscience, 14(5), 365–376.

**Topic 1**

Sept 3: Introduction

Sept 5,10: Programming Proficiency

Materials

Readings: (pdf) **MATLAB**: Chapter 1 @ Kramer & Eden, *Case studies in neural data analysis*, 2016.

Code: (mat) Topic-1 Introduction/MATLAB on [BU-MA665-MA666](https://github.com/Mark-Kramer/BU-MA665-MA666)

(web) Introduction to **Python**

See Part 1 at: <https://mark-kramer.github.io/Case-Studies-Python>

**Topic 2**

Sept 12: Class discussion: The integrate and fire neuron, and its extensions

Sept 17,19: Conceptual and computer challenges

Materials

Reading: (pdf) Abbott, Brain Res Bull (1999) vol. 50 (5-6) pp. 303-4

(pdf) Chapter 8, pages 267-269 @ E. Izhikevich, *Dynamical Systems in Neuroscience*, 2007.

(pdf) Chapter 1, pages 5-12 @ C. Koch, *Biophysics of computation*, 1998.

(pdf) Chapter 14, pages 330-341 @ C. Koch, *Biophysics of computation*, 1998.

Videos: (lec) M. Kramer, *Introduction to the integrate and fire model* (Neural Spike Train Analysis 4)  
 NOTE: Slides available as PDF on [BU-MA665-MA666](https://github.com/Mark-Kramer/BU-MA665-MA666).

Link: <https://www.samsi.info/news-and-media/27-jul-drs-m-kramer-and-u-eden-samsi/>

(lec) W. Gerstner, *Passive membrane and Integrate-and-Fire model*

Link: (*Introduction to Neuronal Dynamics*) <https://youtu.be/uE9_1b4gE3A>

Link: (*Passive membrane*) <https://youtu.be/l3hvrx33lZc>

Link: (*Integrate-and-Fire model)* <https://youtu.be/gU9UzFeg8f4>

Code (pynb) [Integrate and Fire Model](https://github.com/Mark-Kramer/Case-Studies-Python/blob/master/content/A03/LIF.ipynb)

Code (mat) Topic-2 I&F/MATLAB on [BU-MA665-MA666](https://github.com/Mark-Kramer/BU-MA665-MA666)

**Topic 3**

Sept 24: Class discussion: The Hodgkin-Huxley neuron

Sept 26, Oct 1: Conceptual and computer challenges

Materials

Reading: (pdf) Chapter 2, pages 25-42 @ E. Izhikevich, *Dynamical Systems in Neuroscience*, 2007.

(pdf) Chapter 6, pages 142-159 @ C. Koch, *Biophysics of computation*, 1998.

(pdf) Hodgkin-Huxley 1-page cheat sheet

(web) W. Gerstner, *Detailed Neuron Models* (sections 2.1 & 2.2)

Link: <http://lcn.epfl.ch/~gerstner/SPNM/node12.html>

(pdf) Advanced: Hodgkin and Huxley, J Physiol (Lond) (1952) vol. 117 (4) pp. 500-44.

Videos: (lec) M. Kramer, *Introduction to the Hodgkin-Huxley neuron* (**Neural Spike Train Analysis 5**)

NOTE: Slides available as PDF on GitHub.

Link: <https://www.samsi.info/news-and-media/27-jul-drs-m-kramer-and-u-eden-samsi/>

(lec) W. Gerstner, *Detailed Neuron Model (a)*

Link: <http://klewel.com/conferences/epfl-neural-networks/index.php?talkID=4>

(lec) W. Gerstner, *Detailed Neuron Model (b)*

Link: <http://klewel.com/conferences/epfl-neural-networks/index.php?talkID=5>

Code: (pynb) [Hodgkin Huxley Model](https://github.com/Mark-Kramer/Case-Studies-Python/tree/master/beta%20versions/Hodgkin%20Huxley%20Model)

(mat)

**Topic 4**

Oct 3: Class discussion: The event-related potential

Oct 8,10: Conceptual and computer challenges: The event-related potential

Materials

Readings: (pdf) Chapter 2 @ Kramer & Eden, *Case studies in neural data analysis*, 2016.

Tutorial: (pynb) [The Event-Related Potential](https://github.com/Mark-Kramer/Case-Studies-Python/tree/master/The%20Event-Related%20Potential)

(mat)

**Topic 5**

Oct 17: Class discussion: The power spectrum

Oct 22,24: Conceptual and computer challenges

Materials

Readings: (pdf) Chapter 3 @ Kramer & Eden, *Case studies in neural data analysis*, 2016.

(pdf) Kramer, SFN Short Course Document.  
 (pdf) Chapter 10 @ M. X. Cohen, *Analyzing neural time series data*,2014.

(pdf) Chapter 11 @ M. X. Cohen, *Analyzing neural time series data*,2014.

(lib) **Advanced**: Chapter 4 @ Percival & Walden, *Spectral Analysis for Physical Applications.*

Tutorial: (pynb) [Analysis of Rhythmic Activity in the Scalp EEG](https://github.com/Mark-Kramer/Case-Studies-Python/tree/master/Analysis%20of%20Rhythmic%20Activity%20in%20the%20Scalp%20EEG)

**MA666: Advanced Modeling and Data Analysis in Neuroscience (Fall 2019)**

**Instructor:** Mark Kramer (mak@math.bu.edu)

**Course Hours:** October 29, 2018 – December 10, 2018 [7 weeks]

Tuesday & Thursday, 12:30-1:45 PM, CAS B25B

**Office Hours:** Math & Stats Room 224 by appointment

**Textbook:** None

**Course Website:**https://github.com/Mark-Kramer/BU-MA665-MA666

**Prerequisites:** Graduate standing or consent of instructor.

**Course goals**

The goal of this course is further study topics in computational neuroscience. The typical format of this course will be lecture on Tuesday, and computer lab on Thursday. We will continue to focus on three broad areas of computational neuroscience: (1) computer programming, (2) data analysis, (3) modeling. You are encouraged to continue working in teams.

**Course requirements**

The main requirement in this course is effort. I expect your full effort during our course meetings, and outside of the course, to meet the course objectives. As part of this course, you may work together in teams of 2-4. You will work with your team to complete assignments related to the topics in computational neuroscience

**Grades**

To earn an “A”, the general requirements are: attend lectures and labs, complete all assigned challenge problems; provide feedback on the GitHub repository.

**Schedule (tentative)**

**Topic 6**

Oct 29: Class discussion: coherence

Oct 31,Nov 5: Conceptual and computer challenges: coherence

Materials

Readings: (pdf) Chapter 5 @ Kramer & Eden, *Case studies in neural data analysis*, 2016.

(pdf) Kramer, SFN Short Course Document.

(pdf) Chapter 25 @ M. X. Cohen, *Analyzing neural time series data*,2014.

(pdf) Chapter 26 @ M. X. Cohen, *Analyzing neural time series data*,2014.

Tutorial: (pynb) [Analysis of Coupled Rhythms](https://github.com/Mark-Kramer/Case-Studies-Python/tree/master/Analysis%20of%20Coupled%20Rhythms)

**Topic 7**

Nov 7: Class discussion: Cross-frequency coupling

Nov 12,14: Conceptual and computer challenges: Cross-frequency coupling

Materials

Readings: (pdf) Chapter 7 @ Kramer & Eden, *Case studies in neural data analysis*, 2016.

(pdf) Tort et al, J Neurophysiol, 2010.

(pdf) Hyafil et al, Trends Neurosci, 2015.

Tutorial: (pynb) [Cross-Frequency-Coupling](https://github.com/Mark-Kramer/Case-Studies-Python/tree/master/Cross-Frequency-Coupling)

**Topic 8**

Nov 19: Class discussion: Spike-field coherence

Nov 21, 26: Conceptual and computer challenges: Spike-field coherence

Materials

Readings: (pdf) Chapter 11 @ Kramer & Eden, *Case studies in neural data analysis*, 2016.

(pdf) [Advanced] Lepage et al, Neural Computation, 2011.

(pdf) Pesaran et al, Nat Neuro, 2018.

Tutorial: (pynb) [Spike-Field Coherence](https://github.com/Mark-Kramer/Case-Studies-Python/tree/master/Spike-Field%20Coherence)

**Topic 9**

Dec 3: Class discussion: ING and PING

Dec 5, 10: Conceptual and computer challenges: ING and PING

Materials

Reading:

Videos:

Tutorials: