

Neurophysiology and Information

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Part 1: Introduction

Reading: Fiorillo, unpublished manuscript, *Three approaches to information and their relevance to the nervous system*

Additional background reading: Jaynes, Chapters 1-3 of *Probability Theory: The Logic of Science* Available at:

<http://bayes.wustl.edu/etj/prob/book.pdf>

What is this course about?

- The intersection of neurophysiology and information
 - These topics are usually taught separately
 - I will provide a brief overview of the meaning of ‘information’ and a brief overview of the mechanics of the nervous system
 - Most of the course will focus on how the nervous system processes information
- Most people who study the mechanics of the nervous system have never thought about what information is
- Most theoreticians who study neural information processing are confused about what information is
 - This is my opinion. In the course I will present differing approaches to information, but I will not pretend to be neutral
- The course will be devoted entirely to the nervous system, but it should provide insight into how to create artificial intelligence

Reading Material

- There is no textbook
 - The few textbooks that exist in theoretical neuroscience do not exhibit a clear understanding of information
- Most reading will be from original articles
 - Examples:
 - “Natural image statistics and neural representation” Annual Reviews of Neuroscience 2001.
 - “Efficiency and ambiguity in an adaptive neural code” Nature 2001.
 - “Towards a general theory of neural computation based on prediction by single neurons” PLoS ONE 2008.
 - “Theory for the development of neuron selectivity: orientation and binocular specificity in visual cortex” J. Neurosci 1982.
 - “A neural substrate of prediction and reward” Science 1997.

Work and Grading

- 3 exams
 - Each will be 25% of the total grade
- Each student will present one published paper to the class
 - 15% of the total grade
- One Essay
 - 1 page minimum
 - 10% of total grade
- This plan may change

The Relationship between Students and Professors

- Too much deference and respect for your professors can interfere with learning and creativity
 - I have read that in Korea, to ask questions is impolite
 - In the US, it is impolite not to ask questions
- It is not possible to be creative and to generate new ideas if you have too much respect for the ideas of your seniors
 - Your seniors do not have the answers to the unsolved questions
 - These questions should be your focus

My Background

- PhD in neuroscience, 2000
 - electrophysiology in rat brain slices
 - Studied synaptic inputs to dopamine neurons and their modulation by addiction drugs
- Postdoctoral work
 - electrophysiology in behaving primates
 - Studied responses of dopamine neurons to natural reward stimuli
 - Worked with W. Schultz (Switzerland and England)
 - Worked with W.T. Newsome (Stanford, California)
- Started at KAIST in January 2009

My Current Research

- My interests shifted towards theoretical neuroscience
- In 2008, I published a general theory of neural computation
 - This is the only general theory ever published
 - Most people do not yet know about it
 - We will cover the paper in this class, along with other papers
- My current research will test this theory
 - computer simulations
 - in vitro electrophysiology experiments

Why should you take this course?

1. The function of the brain is among the largest unsolved mysteries in science
2. It is easy to argue that it is a more important question than any other, such as how the universe began, or how life began, since it concerns our own minds and everything that we experience
3. This is the only class that will present a hypothesis about how it works

Why have we made so little progress?

- In the 1950s, there was optimism that we would soon understand the nervous system and develop artificial intelligence
 - In less than 10 years:
 - Turing had described the principles of modern computers
 - Shannon had developed information theory
 - Hodgkin and Huxley had described the biophysics of neural communication
 - Watson and Crick had characterized the genetic code
- It was about 50 years later that a computer defeated the best human at chess
 - This was made possible entirely by the increased speed of computers, not increased intelligence
 - Chess is a great game but a terrible analogy to the real world

Essay

- Write a 1+ page essay on “why we have not made significant progress towards artificial intelligence”
 - Or, if you disagree, present an argument that we have made significant progress
- The main purpose of this essay is for me to understand your views on this topic **before** I present my own views
- A second purpose is to promote discussion
- I do not expect you to do research on the topic. Just think about the problem and write down your ideas.
- The essay will contribute only 10% to your final grade
- The essay will be judged on the coherence and rationale of the ideas, not on whether I agree with your views
- I will try not to grade based on English skills
- The essay should be complete by class on Thursday
 - Each student will informally present their ideas to the class on Thursday.