Master Course Description for EE-460

Title: Introduction to Neural Engineering

Credits: 3

E E 460 Neural Engineering (3) *Azadeh Yazdan-Shahmorad, Chet Moritz*

Introduces the field of Neural Engineering: overview of neurobiology, recording and stimulating the nervous system, signal processing, machine learning, powering and communicating with neural devices, invasive and non-invasive brain-machine interfaces, spinal interfaces, smart prostheses, deep-brain stimulators, cochlear implants and neuroethics. Heavy emphasis on primary literature.

Prerequisite: either BIOL 130, BIOL 162, or BIOL 220; and one of the following: MATH 308, AMATH 301, or AMATH 352. Offered: jointly with BIOEN 460;

Coordinator: Chet Moritz, Associate Professor, Electrical and Computer Engineering

Goals: The broad goals are to introduce the student to various concepts within the field of neural engineering and its applications. As neural interface development accelerates, and begins to transition from medical to consumer applications, it is important for students to understand both the potential and limitations in the following sub areas of the field: (1) neuroscience and physiology of interfacing with the central and peripheral nervous system including recording and stimulation, (2) challenges in low power wireless implants for neural interfaces, (3) viable medical treatments and future potential, (4) emerging consumer devices, and (5) ethical implications of direct brain interfaces. A final project allows students to gain first-hand knowledge of a specific neural engineering topic in their area of interest.

Learning Objectives: At the end of this course, students will be able to:

1. Identify the sub-fields of neural engineering
2. Understand the basic organization of the human nervous system
3. Understand the basic engineering concepts involved in brain-computer interface design
4. Identify and trouble-shoot ethical issues in neural engineering
5. Read primary neural engineering literature for understanding
6. Master a neural engineering topic through literature review, and present findings in video and written form

Textbook: No book, only online PDF files and slides.

Prerequisites by Topic:

1. Exposure to Neuroscience and Biology concepts (BIOL 130, BIOL 162, or BIOL 220)

2. Linear models, neural networks & data processing: MATH 308, AMATH 301, or AMATH 352

Topics:

1. Introduction to Neural Engineering
2. Features of the nervous system for neural engineers
3. Stimulating the brain and spinal cord
4. Optogenetics
5. Signal processing I: spike sorting, frequency domain analysis, wavelets (
6. Signal processing II: Time domain analysis, Time-frequency analysis
7. Cochlear implants, auditory cortex and plasticity
8. Retinal prosthesis
9. Machine Learning in neural interfaces
10. Deep brain stimulation
11. Integration of implanted electrodes with the neural tissue
12. Low power, wireless implanted hardware/electronics
13. Next generation neural interfaces
14. Closed-loop brain computer interfaces to control muscle stimulation
15. Neural modeling and decoding
16. Brain-machine interfaces to decode hand and finger movement
17. Brain stimulation for artificial sensory feedback
18. Brain Computer Interfaces to treat stroke
19. Neuroethics

Course Structure: The class meets for two 80-minute interactive lectures a week. Each class session features active learning using small and large group discussions. Homework and programming assignments are given approximately weekly. Quizzes occur during most class sessions to reinforce material and promote attendance. The course includes one group project.

Computer Resources: Programming assignments require a modern PC or Mac capable of running Python or MatLab.

Grading: Approximate distribution: Homework: 50%, Participation and in-class quizzes: 25%, Final Project: 25%

ABET Student Outcome Coverage: This course addresses the following outcomes:

H = high relevance, M = medium relevance, L = low relevance to course.

(1) *An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.* **(M)** Students identify and solve complex problems in neural engineering via homework assignments and the final project.

(3) *an ability to communicate effectively with a range of audiences.* **(L)** Students discuss challenging topics in this interdisciplnary class of electrical, computer and bio-engineers, as well as neuroscientists. They also present their final project to this diverse group.

(4) *an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.* **(M)** Students engage in a 'neuroethical' evaluation of the final project, following an interactive class session by a founding expert in the field of neuroethics.

(5) *An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.* **(L)** In-class discussions and final project require work in diverse groups across disciplines, as well as leadership and collaboration to meet the course objectives.

(6) *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions* **(L)** Programming homework assignments require analysis and interpretation of pre-recorded neural data, and promote an understanding of real-world experiments in the field.

(7) *An ability to acquire and apply new knowledge as needed, using appropriate learning strategies* **(M)** Students must access the literature and web resources to complete the final project, as well as integrate and apply the knowledge gained in course sessions to a new problem of their choice.

Prepared By: Chet Moritz and Azadeh Yazdan-Shahmorad

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