Tentative - subject to change

ENGR 316 Neural Engineering

Instructor: Dr. Harry Blaise
Office: MECC 395
Office Hours: TBD

Lecture: 8:00-9:15
Location: TBD

Course Description: This seminar uses an integrative and cross-disciplinary approach to survey basic principles and modern theories and methods in several important areas of neural engineering. Course topics include: neural prosthetics, neural stimulation, neurophysiology, neural signal detection and analysis and computational neural networks. The practicalities of the emerging technology of brain-computer interface as well as other research topics in neural engineering will be discussed. Students will also have the opportunity to perform hands-on computer simulation and modeling of neural circuits and systems. Class participation, being a highly valued component of learning, will contribute a significant portion of the student's grade.

Reference Text: Bin He, Ed., "Neural Engineering", 2nd edition, Springer, New York, 2013. http://link.springer.com/book/10.1007%2F978-1-4614-5227-0 (The textbook is open-source and is freely available on the Moodle course page)

Course Policy:

- Attendance is mandatory.
- Do the assigned reading and assignment before coming to class.
- Review your notes for completeness and clarity
- A minimum of 9 hours/week of engaged outside of class learning is expected.
- Facial coverings/masks (covering both mouth and nose) must be worn while in the classroom due to the coronavirus disease epidemic (Covid-19) as per College, Connecticut State and CDC guidelines and policies.
- Office hours are posted above and will be held via Zoom (please email the instructor to obtain a zoom link). If you can't make the posted hours, please contact the instructor via email for alternate times and to obtain a zoom link.

Grading Policy:
Homework: 10%
Attendance, In-Class Discussion & Participation: 10%
Quizzes: 60%
Final Exam: 20% (comprehensive of all course topics)

Learning Goals:

- Define the relationship between engineering and neurobiology
- Describe how neurorobotics systems are used to treat neurological disorders
- Identify and use computer models of the brain
- Demonstrate the impact of real-world ethical issues on the development of new neurotechnologies.

Course Topics

1. Introduction to the course
   a. Definition: Neural Engineering
   b. Gross Neuroanatomy
   c. Major Regions of the Brain and their Functions
   d. Neurons and Glia

2. Neurorobotics
   a. Rudimentary prosthetic limbs
   b. Evolution of robotic exoskeletons
   c. Muscle-controlled neurorobotics
   d. Brain-controlled neurorobotics

3. Brain-Computer Interfaces (BCI)
   a. Definition: BCI
   b. Applications and Limitations of BCI technology
   c. Role of feedback and adaptation in BCI
   d. Operating elements of a typical BCI system

4. Sensory Neural Prostheses
   a. Definition: Motor & sensory neural prostheses
   b. Concept of Inductive Coupling
   c. Silicon microelectrode arrays
   d. Cochlear implants
   e. Retinal implants: epidural and subdural
   f. Limitations

5. Neural Tissue Interfacing
   a. Definition: Neural & Bioinstrument microsystems
   b. Neuron-Based biosensors
   c. Interfacing with electrical, magnetic, optical and chemical signals
   d. By-products and waste elimination

6. Electrical Stimulation of the Neuromuscular System
   a. Definition: Functional Electrical Stimulation (FES)
   b. Surface, intramuscular and implanted FES systems
   c. Current propagation in excitable tissue
   d. Passive and active tissue damage
   e. Safety concerns

7. Neural Signal Processing
   a. Definition: Biosignal processing
   b. Stochastic vs. deterministic signals
   c. Neural signal acquisition
   d. Concepts of Analog-to-digital Conversion
   e. Nyquist Frequency and Aliasing
   f. Power spectral analysis

8. Neural Engineering of Systems to Predict/Prevent Epileptic Seizures
   a. Partial vs. Generalized seizures
   b. Resection surgery therapy
   c. Deep brain stimulation (DBS) therapy
   d. Anti-epileptic drug (AED) therapy
   e. Transcranial magnetic stimulation (TMS) therapy
   f. Non-traditional therapies: ketogenic diet, neurofeedback, hyperbaric oxygen.

9. Artificial Neural Networks (ANN)
   a. Definition: Artificial neurons and networks
   b. Supervised vs. Unsupervised Learning
   c. Backpropagation
   d. Perceptron and Learning Rules
   e. Applications and Limitations

10. Computer Models of the Human Brain
    a. Definition: What is a model?
    b. Concepts of Capacitance and Conductance
    c. Activation and de-inactivation of membrane conductance
    d. Cable theory and action potential propagation

11. Neuroethics
    a. Definition: What is neuroethics?
    b. Brain fingerprinting technology
    c. Event-related potentials
    d. Ethics of psychopharmaceutical enhancement and coercion
    e. Neurochemical haves and have-nots.
    f. Safety concerns
    g. What about free will?

Final Exam (scheduled for Finals Week. Inclusive of all course topics)