BMEn 5920: Neural Prosthetics
Spring 2011 (2 credits)

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Meeting Time & Place: 10:10 AM – 12:05 PM, Friday, AmundH 162

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Objectives: To provide an overview of the different types of neural interface technologies currently in use in patients as well as coverage of the biophysics, neural coding, and hardware features relating to their implementation in humans. The course will primarily focus on invasive neural implants that electrically interface with the peripheral or central nervous system. Neurophysiological principles and computational modeling of neurons, current flow through tissue, and the tissue-electrode interface will be covered to understand how electrical signals and information are transmitted between the device and neurons. Practical and ethical considerations for implanting these devices into humans are also presented. A final group project will be required for simulating a neural implant system.

Text Books:

Book A (chapters will be scanned and posted on Moodle)
Horch KW, Dhillon GS. **Neuroprosthetics: Theory and Practice**. Series on Bioengineering & Biomedical Engineering (Vol. 2). World Scientific Publishing Co., 2004.

Book B (downloadable for free from UMN libraries catalog or use link below from a UMN network)
Greenbaum E, Zhou D. **Implantable Neural Prostheses 1: Devices and Applications**. Biological and Medical Physics, Biomedical Engineering Series. Springer, 2009.
http://www.springerlink.com/content/978-0-387-77260-8#section=61808&page=1

Book C (downloadable for free from UMN libraries catalog or use link below from a UMN network)
Zhou D, Greenbaum. **Implantable Neural Prostheses 2: Techniques and Engineering Approaches**. Biological and Medical Physics, Biomedical Engineering Series. Springer, 2009.
http://www.springerlink.com/content/978-0-387-98119-2#section=730338&page=1

Website: A Moodle site is created for this course. It will be used for announcements, assignments, solutions and posting other supplementary files. **All scores will be posted on the Moodle site so please check that they are accurate throughout the Spring term and if there are any errors, please email the TA.**
NOTE: *"In this class, our use of technology will sometimes make students' names and U of M Internet IDs visible within the course website, but only to other students in the same class. Since we are using a secure, password-protected course website, this will not increase the risk of identity theft or spamming for anyone in the class. If you have concerns about the visibility of your Internet ID, please contact me for further information. You can also change your name and profiles to limit the available information."*

Course Format: This is a lecture-based course consisting of one 115-minute lecture per week. Students will be assigned reading materials for each week and will be tested on that material with a short quiz at the start of each lecture. Students are encouraged to participate in discussions during each lecture and will receive in-class participation points for asking and/or answering questions.

The lecture will be organized as follows:

10:10-10:20 – Short quiz (2 questions; full credit for at least 1 correct answer)
10:20-11:10 – Lecture on topic listed in Table below
11:10-11:15 – Short break
11:15-12:05 – Interactive discussion on assigned reading

Grading Policy:

Weekly Quizzes: 25% Homeworks: 25% Final Project: 40% In-Class Participation: 10%

Grading will be based on 100-90%=A, 89-80%=B, 79-70%=C, 69-60%=D, <60%=Fail. The threshold for grades may be lowered depending on overall class performance.

Students will be asked questions during lecture that are based on the assigned reading to receive In-Class Participation points. Students can also receive points for asking questions or providing comments during discussions and then will not be asked a question during a given lecture.

Reading materials/papers can be used for the quizzes. However, there will not be sufficient time to find the answers if the materials were not read ahead of time.

All quizzes, homeworks, and final project must be completed and turned in on the designated dates. Only under severe circumstances (e.g., death in family, severe health condition, etc.) will a make-up opportunity be provided. Homeworks and the final project may be turned in at a later agreed upon date. Make-up quizzes will be administered orally by the professor.

The **Final Project** will require a 40-minute presentation followed by 10 minutes of questions by the instructor and fellow students. The Final Project is a major part of the final grade and it is recommended that the students work on this project throughout the semester. The project topic and groups will be determined during Week 1 Lecture. The students will research on the assigned topic, which will focus on one neural prosthesis (NP) system (see end of syllabus for topics). They will need to research, in detail, this NP to understand and present on the following components:

1) Background/Rationale (10% of points)
2) Neurophysiology underlying NP implementation (20%)
3) Implementation including practical, functional, safety considerations/justifications (30%)
4) Demonstrate simulation of NP with Matlab (30%)
5) Current trends and future directions (10%)

The Instructor will base the final project score on the group presentation and responses to the in-class questions as well as a detailed discussion/simulation during a separate 30-minute meeting set up outside of class with each group. Each group will provide reading materials for the class to read before their presentation and will provide 1 quiz question from that reading. Two NP examples (one encoding and one decoding) will be presented in lectures by the Instructor covering all 5 components above. Students should research and present their projects following a similar organization and content as those lectures.

***For students requiring 3 credits**, an additional final research paper (5 concise but thorough pages) will be required. In addition to the group project above, the student will have to explain how the NP can be improved. These improvements MUST be justified and consistent with the ongoing literature for the NP. Thus the student will need to spend a reasonable amount of time researching the literature and understanding the limitations of the current NP to identify how it can actually be improved. It is not necessary to improve all aspects of the NP but just one or two features will be sufficient. For example, improvements in the interface and/or stimulation strategy and/or decoding algorithm and/or implant location, etc. This research paper will require ~3-4 hours/week commitment (i.e., ~45-60 hours total).

Academic integrity is essential to a positive teaching and learning environment. All students enrolled in University courses are expected to complete coursework responsibilities with fairness and honesty. Failure to do so by seeking unfair advantage over others or misrepresenting someone else's work as your own, can result in disciplinary action. The University Student Conduct Code defines scholastic dishonesty as follows:

Scholastic Dishonesty: Scholastic dishonesty means plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering forging, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis.

Within this course, a student responsible for scholastic dishonesty can be assigned a penalty up to and including an "F" or "N" for the course. If you have any questions regarding the expectations for a specific assignment or quiz, please ask.

Students with disabilities

The instructor will make all reasonable accommodations necessary for students with disabilities.

LECTURES:

WEEK	TOPICS	READING	HWs
1 **Part I: Introduction**	Overview of neural prostheses and considerations; Go over syllabus	A_1.2-1.4 (if needed)	
2 **Part II: Basics**	PNS and CNS electrode/interface technologies and safety/functionality considerations for translation; Case study on Auditory Midbrain Implant	Navarro review Konrad review B_117-154	
3 **Part II: Basics**	PNS and CNS stimulation: Electrode-tissue interface, neural tissue damage, safety stimulation limits, charge injection capacity		
4 **Part II: Basics**	PNS and CNS stimulation: Current spread and activation effects		
5 **Part II: Basics**	PNS and CNS recording: Electrode-tissue interface, neural tissue damage, recording properties (local field potentials/spikes)		Set 1 due
6 **Part II: Basics**	PNS and CNS recording: Local field potential and spike analyses		
7 **Part III: Ethical, Safety, Translational**	Device development/safety; FDA; Patient concerns/rehabilitation; Intellectual property; Collaborations/Commercialization		Set 2 due
8 **Part IV: Encoding Neural Prosthesis Ex.**	Cochlear implant: Rationale, Neurophysiology		

9 **Part IV: Encoding Neural Prosthesis Ex.**	Cochlear implant: Implementation, Matlab simulation		
10 **Part IV: Encoding Neural Prosthesis Ex.**	Cochlear implant: Current trends, Future directions		Set 3 due
11 **Part V: Decoding Neural Prosthesis Ex.**	Cortical control of robotic arm: Rationale, Neurophysiology		
12 **Part V: Decoding Neural Prosthesis Ex.**	Cortical control of robotic arm: Implementation, Matlab simulation		
13 **Part V: Decoding Neural Prosthesis Ex.**	Cortical control of robotic arm: Current trends, Future directions		Set 4 due
14 **Part VI: Presenting a Neural Prosthesis**	Encoding prosthesis group projects with Matlab simulation results		
15 **Part VI: Presenting a Neural Prosthesis**	Encoding prosthesis group projects with Matlab simulation results		
Final Exam Day **Part VI: Presenting a Neural Prosthesis**	Decoding prosthesis group projects with Matlab simulation results		

Project Topics:

Only encoding or decoding topics are mainly covered in this class since modulation topics are covered in a separate course taught by Dr. Matt Johnson

During Week 1, the Instructor will assign the groups and project topics by randomly drawing names written on a piece of paper. 6 groups of 2-3 people each.

1. Retinal or Optic Nerve NP (encoding/stimulation)
2. Visual Cortical NP (encoding/stimulation)
3. Vestibular Nerve NP (encoding/stimulation)
4. Incontinence/Bladder Control Spinal Cord NP (encoding/stimulation)
5. Robotic arm/hand control PNS NP (decoding/recording)
6. Speech/Text Cortical NP (decoding/recording; invasive/noninvasive)