Engineering Faculty Document No. 43-19
June 20, 2019

TO: The Faculty of the College of Engineering

FROM: The Faculty of the Weldon School of Biomedical Engineering

RE: New Graduate Course, BME 51100, Biomedical Signal Processing

The faculty of the Weldon School of Biomedical Engineering have approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

BME 51100 Biomedical Signal Processing
Term Offered: Fall or Spring, Lecture 3, Cr. 3
Prerequisite: None

Description: An introduction to the application of digital signal processing to practical problems involving biomedical signals and systems. Topics include: overview of biomedical signals, filtering to remove artifacts, event detection, analysis of wave shape and waveform complexity, frequency domain characterization, modeling biomedical signal-generating systems, analysis of non-stationary signals, pattern classification, and diagnostic decisions. MATLAB is used throughout to apply the theory and techniques discussed to biomedical signals.

Reason: This course provides an advanced signal-processing course that is specifically focused on biomedical signals and systems of interest to a number of BME students, as well as students from other Schools/departments. Theory is covered as needed, but to make this course significant to BME students the major focus is on implementation of fundamental signal-processing techniques to real-world biomedical signals. This course will have students understanding the following concepts for biomedical signal processing: problems faced with objective analysis, relevant underlying physiological and anatomical factors, theoretical background and biomedical applications, practical benefits and limitations of different approaches, and implementation of appropriate algorithms. It has been taught as BME 59500 for five terms in 2010, 2012, 2014, 2015, 2017, and 2018 with 10, 13, 14, 11, 14, and 17 students respectively.

George R. Wodicka

George R. Wodicka,
Dane A. Miller Head and Professor
Weldon School of Biomedical Engineering

PURDUE UNIVERSITY

WELDON SCHOOL OF
BIOMEDICAL ENGINEERING

BIOMEDICAL SIGNAL PROCESSING
BME 595

	Biomedical Signal Processing – 12890 - BME 59500 – MJ4	
Time:	Tuesday/Thursday 9:00-10:15	
Room:	LYLE 1150	
Credits:	3	

Professor: Michael G. Heinz, Ph.D.
Professor of Biomedical Engineering
Professor of Speech, Language, and Hearing Sciences
Office: 3064, Lyles-Porter Hall (LYLE)
Phone: 496-6627
Email: mheinz@purdue.edu
Office Hours: *Tuesdays 1030-1130am*, in LYLE 3064

Course Description: An introduction to the application of digital signal processing to practical problems involving biomedical signals and systems. Topics include: overview of biomedical signals; filtering to remove artifacts; event detection; analysis of waveshape and waveform complexity; frequency domain characterization; modeling biomedical signal-generating systems; analysis of non-stationary signals; pattern classification and diagnostic decisions. MATLAB is used throughout to apply the theory and techniques discussed to biomedical signals.

Course Outcomes:
1. Understand practical problems faced in objective analyses of biomedical signals.
2. Understand the underlying physiological and anatomical factors that are relevant for numerous types of biomedical signals.
3. Understand the theoretical background underlying the use of digital signal processing for biomedical applications.
4. Understand the practical benefits and limitations of various digital signal processing approaches and identify the best solution for specific problems.
5. Implement appropriate signal processing algorithms for practical problems involving biomedical signals and systems.
6. Propose, carry out, orally present, and write up in a conference proceedings format a biomedical-research mini project using signal-processing algorithms.

Learning Strategies: In-class lectures and discussions; Hand-solved and computer-programmed problem sets; Research oriented MATLAB project; Self-designed final research project.

Required Text: Rangayyan , R.M., <u>Biomedical Signal Analysis: A Case-Study Approach</u>, Wiley-IEEE Press, 2001. (ISBN: 0471208116) **[*available online: Purdue libraries*]**

Required Software: MATLAB (see below for options for accessing MATLAB)
MS Office (Word and PowerPoint)

Supplemental References:

1) Bruce, E., Biomedical Signal Processing and Signal Modeling, Wiley-Interscience, 2000. (ISBN: 0471345407).
2) Oppenheim, A.V., Schafer, R.W., and Buck, J.R., Discrete-Time Signal Processing, 2nd Edition, Prentice Hall, 1999. (ISBN: 0137549202).
3) Papoulis, A. and Pillai, S.U., Probability, Random Variables and Stochastic Processes, 4th edition, McGraw-Hill Science, 2001. (ISBN: 0072817259).
4) Chassaing, R. and Reay, D. Digital Signal Processing and Applications with the TMS320C6713 and TMS320C6416 DSK, 2nd edition, Wiley-IEEE Press, 2008 (ISBN: 0470138661).

Blackboard: Materials and grades for the course will be posted on the Blackboard page. Announcements will be made via regular email.

One component of Blackboard that has been useful in other signal-processing courses I've taught is the Online Discussion Board. I would encourage students to use this resource for sharing general and specific MATLAB knowledge across the class (however, please note: no sharing of code, but sharing of command names or HOWTO sorts of things, etc … see note on collaboration below). There are going to be plenty of places to get stuck with MATLAB. Office hours are limited, so I encourage you to use the Online Discussions to ask HOWTO questions when you get stuck, and to share your knowledge with the class when you know the answer to someone's posted question.

Assessment Items and Final Grading Distribution: (Plus/minus grading will be used**)**

Problem Sets (~7)	45%
Midterm group MATLAB Project	20%
Final Project	
- Content	15%
- Oral presentation	10%
- Written presentation	10%

Problem Sets and Project Submissions: Submitted work will consist of both written and electronic files. All assignments are due by the beginning of class on the due date. No late assignments will be accepted (except in extenuating circumstances, discussed with Dr. Heinz prior to the due date). Written material will consist of derived solutions and/or MS Word (*.docx) text with inserted MATLAB figures (TIFFs recommended). No code in Word file (refer to the Mfile in you ZIP). Written work should be handed in at the beginning of class. Electronic material will consist of your *.docx file, and any scripts or functions you have written, and any *.wav files you have generated. The *.docx file must have a list of every electronic file submitted with the assignment, with a brief description. Every figure in your *.docx file should be generated by the code you submit, i.e., we should be able to run your code and see your figures appear with no effort (include data files to make it run!). All electronic files should be submitted as a ZIP file, which should be emailed to me and the TA prior to start of class.

Access to MATLAB: This course will require access to MATLAB and MS Office in order to complete the problem sets and projects. It is each student's responsibility to find a reliable environment in which to do the work for this course. This should be worked out within the first week of class. MATLAB should be available on all ITAP machines on campus, as well as via the remote Citrix server [††]. A number of MATLAB tutorials are posted on Blackboard for reference. Also, office hours and the Online Discussions are available to supplement your existing familiarity with MATLAB. *PLEASE take advantage of these resources – it is very easy to get stuck as you are learning to use MATLAB, and asking questions can often get you unstuck very quickly (e.g., if you don't know the right command or syntax). NOTE: the best way to avoid getting stuck at the end is to start assignments well in advance of the due date!!*

[††] https://goremote.itap.purdue.edu/Citrix/XenApp/auth/login.aspx

MATLAB Project: (~2.5 weeks). This research-oriented project will be done in groups of two or three students, with individual project reports due from each student.

Simulation of Cochlear Implant Processing: Filter-bank simulations of cochlear-implant processing will be implemented to estimate how many frequency channels are needed to understand speech (Shannon et al, 1995). The filter-bank analysis will then be extended to create chimaeric sounds using the envelope from one sound (speech or music) and the fine-time structure from another sound. This processing will be used to determine the salient types of information (envelope or fine-time structure) required for the perception of speech and/or music as a function of the number of channels used (Smith et al., 2002).

Shannon, R.V., Zeng, F.G., Kamath, V., Wygonski, J., and Ekelid, M. "Speech recognition with primarily temporal cues," *Science*, 270, 303–304, 1995.

Smith Z.M., Delgutte B., Oxenham A.J. "Chimaeric sounds reveal dichotomies in auditory perception," *Nature*, 416, 87-90. 2002.

Final Project: (final ~5 weeks). An independent project will apply signal processing to a research question of interest to each student. This project can either be related to ongoing research in a lab or can replicate a published study. It can involve MATLAB or real-time DSP boards (which can be made available to the student (although an XP machine is required to run them), along with tutorial material from previous BME-595 labs), or both (*please discuss with Dr. Heinz early if you are thinking about using the DSP boards*). The final projects are intended to be quite extensive as they will hopefully be in an area of direct interest and familiarity to each student. Projects will be presented to the class during the final two weeks of the semester (modeled after a ~12 minute conference talk) and will be written up in a final report (modeled after a conference proceedings paper, ~6-10 pages). Grading is based on content, oral presentation, and written presentation. Note: content is judged based on what you accomplish by submission of your written report (Thursday of exam week), i.e., you are welcome to keep working after your oral presentation and include a more complete version in your written report.

Statement on Academic Dishonesty & Collaboration: *"Purdue University values intellectual integrity and the highest standards of academic conduct. To be prepared to meet societal needs as leaders and role models, students must be educated in an ethical learning environment that promotes a high standard of honor in scholastic work. Academic dishonesty undermines institutional integrity and threatens the academic fabric of Purdue University. Dishonesty is not an acceptable avenue to success. It diminishes the quality of a Purdue education, which is valued because of Purdue's high academic standards.*

"Fostering an appreciation for academic standards and values is a shared responsibility among students, faculty, and staff. The information [on this website] is directed to students to define academic dishonesty and how to avoid it." See: https://www.purdue.edu/odos/academic-integrity/ .

The skills to be learned in this class rely on each student doing and understanding the assignments themselves. However, collaboration is encouraged in ways that help to avoid students getting stuck with MATLAB and thus not being able to complete an assignment (e.g., not knowing the name of a specific command, etc …). However, in no case should solutions, code, or text be copied from another student. Each student is expected to write their own code, solutions, and text. Violations of this expectation will receive 0 credit and may be referred to the BME dept. and/or Dean of Students for disciplinary action.

By Friday August 24th, all students must email Prof. Heinz the following statement: "I have read, understand, and will comply with the Statement on Academic Dishonesty & Collaboration in the syllabus, as well as the website "Academic Integrity: A Guide for Students" listed in the syllabus."

Students with Disabilities. Students with disabilities must be registered with Adaptive Programs in the Office of the Dean of Students before classroom accommodations can be provided. If you have a disability requiring academic adjustments, please see me to discuss your needs as soon as possible.

Course Flexibility in the Case of Unexpected Emergencies. In the event of a major campus emergency (e.g., a pandemic), course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar. Here are ways to get information about changes in this course. Blackboard web page, my email address: mheinz@purdue.edu, and my office phone: 496-6627. Additional suggestions for best practices in the case of a campus emergency are available at: http://www.purdue.edu/ehps/emergency_preparedness/ (e.g., sign-up for emergency text messages).

BME 595 Fall 2018 Lecture Schedule_V1 (*Tentative – subject to change*)

Week	Date	Lecture Topic	Reading	Assignments
1	8/21 (T)	Introduction; MATLAB; Review Signals/ Systems		PS 1 OUT
	8/23 (TH)	Review; Intro Biomedical Signals & Systems	Chapters 1, 2	
2	8/28 (T)	Review: Z-plane, DFT, Filtering		
	8/30 (TH)	Filtering for Artifact Removal	Ch 3	PS 2 OUT; **PS 1 DUE**
3	9/4 (T)	Filtering for Artifact Removal		
	9/6 (TH)	Filtering for Artifact Removal		PS3: OUT; **PS 2 DUE**
4	9/11 (T)	Filtering for Artifact Removal		
	9/13 (TH)	Event Detection	Ch 4	
5	9/18 (T)	Event Detection		PS4: OUT; **PS 3 DUE**
	9/20 (TH)	Event Detection		
6	9/25 (T)	Waveshape and waveform complexity	Ch 5	
	9/27 (TH)	Waveshape and waveform complexity		**PS 4 DUE**
7	10/2 (T)	MATLAB PROJECT intro: Cochlear Implants (intro to spectrograms)	Shannon et al 1995; Smith et al 2002	PRJ: OUT;
	10/4 (TH)	MATLAB PROJECT intro: Cochlear Implants		
8	10/9 (T)	**OCTOBER BREAK**		
	10/11 (TH)	Waveshape and waveform complexity		
9	10/16 (T)	Real-time DSP		
	10/18 (TH)	Frequency domain characterization	Ch 6	PS5: OUT **MATLAB PRJ DUE**
10	10/23 (T)	Frequency domain characterization		
	10/25 (TH)	Frequency domain characterization		**FINAL PROJECT PROPOSAL DUE**
11	10/30 (T)	Frequency domain characterization		PS6: OUT **PS 5 DUE**
	11/1 (TH)	Modeling biomedical signals and systems	Ch 7	
12	11/6 (T)	Modeling biomedical signals and systems		
	11/8 (TH)	Analysis of nonstationary signals	Ch 8	**PS 6 DUE**
13	11/13 (T)	Pattern Classification, diagnostic decisions	Ch 9	
	11/15 (TH)	Pattern Classification, diagnostic decisions		
14	11/20 (T)	Pattern Classification, diagnostic decisions		
	11/22 (TH)	**THANKSGIVING**		
15	11/27 (T)	Pattern Classification, diagnostic decisions		PS 7: OUT
	11/29 (TH)	Pattern Classification, diagnostic decisions		**PS 7 (brief assessment)**
16	12/4 (T)	**Final Project Presentations**		
	12/6 (TH)	**Final Project Presentations**		
17	12/10	**EXAM WEEK (No exam)** **Final Project Presentations**		
	12/13		**FINAL PAPER DUE: Thursday Dec 13th, by 5pm**	