TO: The Faculty of the College of Engineering

FROM: The Faculty of the Weldon School of Biomedical Engineering

RE: New Undergraduate Course, BME 45000, Deep Learning for Medical Imaging

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

BME 450000 Deep Learning for Medical Imaging
Terms offered: Fall or Spring, Lecture 3, Cr. 3
Prerequisites: ECE 30100 or CS 38003

Description: Teaches the foundation of neural network (aka "Deep Learning") approaches and applications to medical imaging: or how to create computable models of biological neural systems, in particular large-scale neural networks, for processing medical images and data. Drawing inspiration from neuroscience and statistics, Deep Learning introduces the basic background on neural networks, presents computable neuron models and extends to large networks of neurons. Students study deep learning with both real and artificial neural networks, along with methods of deep learning about the environment by applying back propagation, Boltzmann machines, auto-encoders, convolutional neural networks and recurrent neural networks. Students will explore how Deep Learning is impacting our understanding of intelligence and contributing to the practical design of automatic medical imaging tools that are able to augment expert medical personnel, enhance diagnosis accuracy and speed, and lower health-care costs.

Reason: This course is one of a required set of technical electives designed for the undergraduate program in the Weldon School of Biomedical Engineering (BME) and designated as Quantitative Breadth electives (students must select two from this category). Quantitative Breadth Electives teach advanced math methods. This new elective course will have direct applications in biomedical imaging applications not found in the other electives. The intent of the course is to provide a semi-rigorous mathematical, quantitative, and analytical foundation for understanding neural network applications in biology, healthcare systems and all disciplines. Computer Vision has become ubiquitous in our society, with applications in search, image understanding, apps, mapping, medicine, drones, and self-driving cars. Core to many of these applications are visual recognition tasks such as image classification, localization and detection. Recent developments in neural network, Deep Learning-approaches have greatly advanced the performance of these state-of-the-art visual recognition systems.

This course teaches the foundations of computer vision and deep learning to be applied to medical images and medical data categorization and forecasting. More importantly, this course will provide the students an opportunity of applying the knowledge they accumulate through our BME undergraduate curriculum to real-world complex problem solving, in order to further prepare our students with a quantitative perspective to biology, medicine, and health.

It has been offered previously as a 400-level experimental course. Historically, this course has been selected by almost all BME seniors. For example, in 2018, there were 40 undergraduates from BME in the course. Primarily driven by the large undergraduate enrollment, the material covered and the pace of the course is appropriate for a 400-level course.

George R. Wodicka

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

BME 45000 Deep Learning for Medical Imaging

Learning outcomes: By completing this course students will be able to:

1) understand and simulate a large biological neural network with several million of neurons.
2) design and use a bio-inspired deep-learning network for application in medical imaging.
3) independently write algorithms that learn to segment, track, categorize, and classify objects of interest.

Syllabus

Deep Learning and Medical Imaging
BME 45000, Spring 2018

Professor:
Eugenio Culurciello
Weldon School of Biomedical Engineering
Purdue University
206 S. Martin Jischke Drive, room 2031
West Lafayette, Indiana 47907
Web: http://engineering.purdue.edu/elab/

Meeting time and place:
Tue/Thu 12 noon - 1:15 PM in MJIS 1083

Assistants:
Dawood Sheik, dawood0@purdue.edu
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Course Description and Objectives:
Learning objectives: this course teaches the foundation of Deep Learning and applications to medical imaging: or how to create computable models of biological neural systems, in particular large-scale neural networks for processing medical images and data. This course focuses on the successful field of "Deep Learning". By drawing inspiration from neuroscience and statistics, it introduces the basic background on neural networks, presents computable neuron models and extends to large networks of neurons. It also studies learning in both real and artificial neural networks, and ways of learning about the environment with: back propagation, Boltzmann machines, auto-encoders, convolutional neural networks and recurrent neural networks. The course also illustrates how Deep Learning is impacting our understanding of intelligence and contributing to the practical design of automatic medical imaging tools able to augment expert medical personnel, enhance diagnosis accuracy and speed, and lower health-care costs.
Lectures will include an overview of the state-of-the-art in the field, new opportunities and ideas for innovation and success with such systems.
Nature and purpose of the course: Computer Vision has become ubiquitous in our society, with applications in search, image understanding, apps, mapping, medicine, drones, and self-driving cars. Core to many of these applications are visual recognition tasks such as image classification, localization and detection. Recent developments in neural network (aka "deep learning") approaches have greatly advanced the performance of these state-of-the-art visual recognition systems. In this course we plan to teach the foundations of computer vision and deep learning to be applied to medical images and medical data categorization and forecasting.
Main topics to be covered: The main topics are Deep Learning, computational neuroscience, machine learning, deep-networks, artificial vision and auditory systems, physiology and neuroscience of mammalian perception, multi-sensory integration, real and artificial neural networks. Applications to medical image dataset, unsupervised learning, computer vision, vision sub-blocks and vision areas.
Any special aspects of the format: The course will include a series of lecture by the instructor and will also feature selected presentation by the instructor from technical papers in the field of Deep Learning applied to medical imaging. In addition, the class will feature final practical projects based on practical application of the learned material. The projects will be tailored to real-life medical imaging analysis, both provided by the instructor and/or suggested by the students themselves.

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Course Schedule:

Week 1: Introduction: Deep Learning and applications to medical imaging
Week 2: Basic of neural networks
Week 3: Training neural networks: back-propagation
Week 4: Training neural networks: using state-of-the-art tools
Week 5: Datasets, medical images
Week 6: Deep Learning state-of-the-art models
Week 7: Recurrent neural networks
Week 8: Recurrent neural networks application in medical imaging
Week 9: Project proposals: solving a problem in medical imaging
Week 10: Unsupervised learning: coping with little labeled medical images
Week 11: Image generation, generative models, denoising
Week 12: Medical image segmentation
Week 13: Reinforcement learning and applications
Week 14: Hardware and computing for Deep Learning
Week 15: Final project reports and presentations

Prerequisites:
Basic knowledge of biology, real neurons, some foundation of the human nervous system is useful but not required.
Students should have knowledge of computers use (linux or similar) and one or more programming languages (C, Java, or similar).
No previous experience of knowledge in machine learning or neural networks is required.
You can ask permission of the instructor if you have taken similar courses elsewhere or wish to be advised

Strongly recommended related courses:
This is a list of course that are not required, but help can help in the course:
BME 301: Bioelectricity - or equivalent
ECE 301: Signals and Systems – or similar
BIOL 230: Biology of the Living Cell – or similar, nervous system focus
BIOL 302: Human Design: Anatomy and Physiology – or similar anatomy course, nervous system focus
CS 110: Introduction to Computers – or equivalent
CS 158, 159, ECE 264: C programming – or equivalent; this is an example programming course
CS 471 Introduction to Artificial Intelligence
You can ask permission of the instructor if you have taken similar courses elsewhere or wish to be advised.

Attendance Policy:
No lecture is available in the textbooks or online in its complete form. In-class attendance is required because of the interactive nature of the course. If students miss a class, they will need to make an

appointment with fellow students to review the missed material. Part of the course features some online lectures that can be enjoyed anytime, but class presence is still required for the full course. Participation is tested with quiz and question in class.

Collaboration Policy:
Students are encouraged to talk to classmates about the homework problem sets, assignments, and final project. The write-up and coding work must be the student's own work.

Required Readings:
The class online schedule will provide a weekly list of reading material that complements the lecture and online-modules. Reading material progress is tested with quiz and question in class.

Recommended online course to deepen knowledge:
- https://www.coursera.org/learn/machine-learning
- http://cs231n.stanford.edu/
- https://www.cs.ox.ac.uk/people/nando.defreitas/machinelearning/

Suggested book titles to read during the course to deepen knowledge:
- http://neuralnetworksanddeeplearning.com/chap1.html
- http://www.deeplearningbook.org/

Software for homework and projects:
This course requires the use and basic knowledge of programming languages. We will provide tools for students to improve their coding skills, but students are required to learn the tools quickly in order to take this course for credit.
- **Lua and Torch** - open source software for algorithm prototyping with neural networks
http://www.torch.ch/
Programming work can be performed on a personal machine or any of the university computers. The BME MJIS laboratory can be used for this purpose.

Projects:
The final project will consist on the design of a complete Deep Learning software to analyze medical images. We will use public medical image datasets such as: http://www.via.cornell.edu/databases/. We use project in this course because it is the best way to stimulate class discussions and also problem-solving abilities, and to understand the theoretical concepts. Projects will require the use of a laptop / PC workstation for groups of 2-4 students. The project can be collaborative within a group, but a final report is required for each individual student. The students will run the software specified above to perform the tasks assigned. Note that software installation, syntax learning and compilation problems are typical with beginner students, so start your projects early to avoid problem. Projects are the final component of this course and require significant amount of time (~6 weeks or more) and also reflect in a large portion of the grade (see: Evaluation). We will devote one lecture week to help students chose the projects and feedback choices to the whole class. Also we will have a mid-project review to monitor progress.

Homework:
The weekly homework will be several coding exercises of neural network model in software.
The homework requires basic knowledge of computers, elementary programming skills, use of operating systems.
Please note that no late assignments will be accepted (less extenuating circumstances discussed in advanced with the teaching crew). Note that software installation, syntax learning and compilation

problems are typical with beginner students, so start your homework early to avoid problem. Instructors are not able to help you on those issues.

Evaluation:
Class participation: 30% (in-class quiz, questions to instructors, question to students, insights)
Homework: 30%
Project: 40%, of which:
- 10% problem analysis and initial system design
- 15% software implementation
- 15% simulation results and demonstrations

Students with special needs:
If you have a disability of any kind that could affect your work for the course, please contact me by email or in person as soon as possible, so that we can arrange appropriate accommodations in consultation with Purdue's Disability Resource Center.

Academic Integrity:
This course is designed at an introductory level for senior undergraduates and beginner graduate students. Both are required to show engagement and reading material well above the basic one provided in the course.
It is important to cite carefully ideas and information that you have obtained by any means other than your own engagement with primary reading (i.e. papers/texts/materials) or from class lectures/discussion. I encourage you to share and discuss your work with your peers in the course, but if you receive help from anyone, it's important to provide a detailed acknowledgment of that help when you turn in your assignment.
See http://www.purdue.edu/odos/osrr/integrity.htm for guidelines on academic integrity. If you are caught cheating in any way you will receive an F for the course.

What do letter grades mean in this class?
A 'B' grade means doing just what was asked of you, a 'C' grade means doing very nearly what was asked, and an 'A' grade means doing a really good job and showing creativity. Creativity doesn't mean making an observation that nobody has ever expressed, but it does mean thinking independently and working steadily so as to sustain your independent thought and design, within the context of the course. In your final portfolio, it's important that you show that you have seriously engaged with novel design aspects and with the questions/ideas at stake in the course, and that you have done your best to explain your responses clearly and persuasively to your peers and instructors.

A: You have shown strong command of the course material and skills involved, showing knowledge, understanding, and independent thought. We expect that you will have very little difficulty in extending these skills in other contexts.

B: You have shown satisfactory command of the course material and skills involved. We expect that you will be able to use and extend the knowledge and skills acquired, and we see potential for development if you pursue this subject and/or continue to develop the skills involved.

C: You have shown some command of the course material. We see some potential for development if you wish to increase your command of the material and analytical skills involved in the course, but there is much room for improvement.

D: You have shown a barely adequate command of the material and skills. We fear that you are unlikely to be able to apply this knowledge at any level or continue studies in this direction unless you drastically change your study techniques.

F: You have not shown enough command of the material to be given credit for learning.

+ and – signs adjust grades within this overall pattern (e.g. a B+ often reflects promising and substantial command of the course materials, but without the independent thought needed for an A- or an A; alternatively a B+ can indicate that the student has shown signs of creativity and understanding, but without the solid basis in knowledge that would result in an A- or A; a B- suggests that there is clear promise for development, but that there are significant areas of weakness that need to be addressed in order to show a solid command of the course material/skills.) An A+ doesn't affect GPA, but it will be used to honor exceptional work.

There is no grading curve in this class. Everyone in the class could potentially achieve at least an A-, if everyone works steadily on their reading week by week (achieving good quiz, homework and project grades and participating thoughtfully in class discussion), and if everyone puts detailed thought into their papers, presentations and project final documents.