FLORIDA ATLANTIC UNIVERSITY

NEW COURSE PROPOSAL
Graduate Programs

Department Computer and Electrical Eng. and Comp. Science

College Engineering and Computer Science

(*To obtain a course number, contact* ***erudolph@fau.edu***)

UGPC Approval ____________
UFS Approval ____________
SCNS Submittal ____________
Confirmed ____________
Banner ____________
Catalog ____________

Prefix BME **Number** 6718	(*L = Lab Course; C = Combined Lecture/Lab; add if appropriate*) **Lab Code**	**Type of Course** Lecture	**Course Title** Computational Modeling of Biological Neural Networks
Credits (*Review Provost Memorandum*) 3 **Effective Date** (*TERM & YEAR*) Fall 2021	**Grading** (*Select One Option*) **Regular** X **Sat/UnSat**	**Course Description** (*Syllabus must be attached; see Guidelines*) The course covers main concepts of neuroscience and uses tools from science and mathematics to explain how information is processed in the brain. The course starts at modeling single brain cells and expands to computational models of neural coding and architecture of biological neural networks.	

Prerequisites None ***Prerequisites, Corequisites and Registration Controls are enforced for all sections of course.***	**Academic Service Learning (ASL) course** Academic Service Learning statement must be indicated in syllabus and approval attached to this form. **Corequisites** NA	**Registration Controls** (*For example, Major, College, Level*)
Minimum qualifications needed to teach course: Member of the FAU graduate faculty and has a terminal degree in the subject area (or a closely related field.)	**List textbook information in syllabus or here** Please see the syllabus.	
Faculty Contact/Email/Phone Hanqi Zhuang, zhuang@fau.edu; 5612973413	**List/Attach comments from departments affected by new course** College of Science, College of Medicine, Brain Institute	

Approved by		***Date***
Department Chair	Hanqi Zhuang	1/20/2021
College Curriculum Chair	Francisco Presuel-Moreno Digitally signed by Francisco Presuel-Moreno DN: cn=Francisco Presuel-Moreno, o, ou, email=fpresuel@fau.edu, c=US Date: 2021.01.22 10:05:53 -05'00'	1/22/2021
College Dean	MCardei Digitally signed by Mihaela Cardei DN: cn=Mihaela Cardei, o=Florida Atlantic University, ou, email=mcardei@fau.edu, c=US Date: 2021.01.22 12:17:26 -05'00'	1/22/2021
UGPC Chair		
UGC Chair		
Graduate College Dean		
UFS President		
Provost		

Email this form and syllabus to UGPC@fau.edu 10 days before the UGPC meeting.

Department of Computer & Electrical Engineering
and Computer Science
Florida Atlantic University
Course Syllabus

1. Course title/number, number of credit hours	
BME 6718 Computational Modeling of Biological Neural Networks	# of credit hour 3

2. Course prerequisites, corequisites, and where the course fits in the program of study

Prerequisites: None

3. Course logistics

Term: Fall 2021
Class location and time: TBD

4. Instructor contact information

Instructor's name	Ramin Pashaie
Office address	EE 317
Office Hours	TBA
Contact telephone number	561-297-1041
Email address	rpashaie@fau.edu

5. TA contact information

TA's name	NA
Office address	
Office Hours	
Contact telephone number	
Email address	

6. Course description

The course covers main concepts of neuroscience and uses tools from science and mathematics to explain how information is processed in the brain. The course starts at modeling single brain cells and expands to computational models of neural coding and architecture of biological neural networks.

7. Course objectives/student learning outcomes/program outcomes

Course objectives	In terms of parallel data processing and energy efficiency, human brain is occasionally considered the most fascinating system in the universe. This biological tissue generates functions, such a perception, cognition, intelligence, or consciousness which are quite complex capabilities for any system. Brain is an assembly of billions of coupled nerve cells where each cell functions as a nonlinear processing element. Subpopulations of neurons build up self-organizing networks or topographic maps that develop over time and adapt for parallel data processing. Engineers who study the brain and its dynamics can use this information at least in three different areas: **1.** Discovery of new treatments for psychiatric and neurological disorders, **2.** Engineering neuroprosthetic devices that compensate or bypass dysfunctional brain circuits,

	3. Complementing the architecture of conventional computers by adding capabilities to perform brain-like operations including perception, cognition, and intelligent acts. In the course, we look at the biology and physics of data processing in nervous systems. We study electrochemical processes which form the basis of computation in biological systems. We will build up the theory of computation from single cells to networks. We study how nerve cells encode information and communicate in such networks. We also look at the process of learning, including supervised, unsupervised and reinforcement learning and memory consolidation in the nervous system. All these topics will be covered from the view point of mathematics, physics, and computational models. The main objective of this course is to teach some of the main concepts of neuroscience to students who have background in engineering and physics. We intend to use the language of engineers and tools of physics and mathematics to explain how information is processed in the brain, how computation takes place in this tissue and how memory is consolidated. We will start from models that capture the dynamics of a single cell. Then we expand to networks of cells and the autonomous models that emulate such dynamics. We explain how cells encode information and which approaches are tested to decipher neural codes. We will use calculus, probability theory, and stochastic process to explain how brain circuits process information to generate perception. Our knowledge of the brain tissue is still limited. However, in order to improve our understanding of this complex system, we need to develop new brain interface/imaging platforms. To achieve this goal, we need to train a new generation of engineers who have solid understanding of neuroscience. My goal in this course is to introduce these topics to students with computational mindsets.
Student learning outcomes & relationship to ABET 1-7 outcomes	

8. Course evaluation method

• We will have 8 mini-projects in the form of computer programming. The task for each project will be assigned by the instructor and students will have one week to finish the project and return reports. • We will have one final project in which students will choose the topic from recently published literature, they will get the confirmation from the instructor, and they will have up to one-month time frame to return their reports. Based on the load of the project, students can work individually or as a member of a team.	• Mini projects are the best way for the students to learn the topics covered in lectures. These projects are based on research publications. Students will receive one or two papers for each project. They need to carefully study assigned papers, understand the material of the paper and implement a computer model to test the theory or hypothesis in a biological neural assembly. *Example:* once we finish the topic of spiking neural networks and plasticity, students will be asked to implement a network of neurons that forms an artificial eye. They implement the network and test its capability in generating sparse codes,

8 mini- projects (10% each) 80% Final project 20%	pattern recognition and feature extraction. Later, they will add an associative memory to this artificial eye to complete the loop for pattern recognition all based on emulating biological neural networks. • The main idea for the final project is to give students the opportunity to review the literature and learn more about the applications of what they have learned not only in the field of computational neuroscience but also in their own field of interest or research. For example, a student can get the idea from brain computation and use it in a control theory problem or efficient energy harvesting application which are example from past experiences.

9. Course grading scale

80% of the final score comes from 8 mini projects (10% for each project) and 20% from a research based final project.

For each project, student will ask to return a report. In the report, they will summarize their approach, analysis of the network or process they have studied, computer codes generated for modeling, and results obtained.

90 and above: "A", 87-89: "A-", 83-86: "B+", 80-82: "B", 77-79 : "B-", 73-76: "C+", 70-72: "C", 67-69: "C-", 63-66: "D+", 60-62: "D", 51-59: "D-", 50 and below: "F."

10. Policy on makeup tests, late work, and incompletes

No project report can be delivered after the assigned deadline unless the student provides justifications which are acceptable based on the university code of conduct including sickness with valid approval from doctor's office or proven family emergency etc.

11. Special course requirements

NA

12. Classroom etiquette policy

13. Attendance policy statement

Students are expected to attend all of their scheduled University classes and to satisfy all academic objectives as outlined by the instructor. The effect of absences upon grades is determined by the instructor, and the University reserves the right to deal at any time with individual cases of non-attendance.

Students are responsible for arranging to make up work missed because of legitimate class absence, such as illness, family emergencies, military obligation, court-imposed legal obligations or participation in University-approved activities. Examples of University-approved reasons for absences include participating on an athletic or scholastic team, musical and theatrical performances and debate activities. It is the student's responsibility to give the instructor notice prior to any anticipated absences and within a reasonable amount of time after an unanticipated absence, ordinarily by the next scheduled class meeting. Instructors must allow each student who is absent for a University-approved reason the opportunity to make up work missed without any reduction in the student's final course grade as a direct result of such absence.

14. Disability policy statement

In compliance with the Americans with Disabilities Act Amendments Act (ADAAA), students who require reasonable accommodations due to a disability to properly execute coursework must register with Student Accessibility Services (SAS) and follow all SAS procedures. SAS has offices across three of FAU's campuses – Boca Raton, Davie and Jupiter – however disability services are available for students on all campuses. For more information, please visit the SAS website at www.fau.edu/sas/.

15. Counseling and Psychological Services (CAPS) Center

Life as a university student can be challenging physically, mentally and emotionally. Students who find stress negatively affecting their ability to achieve academic or personal goals may wish to consider utilizing FAU's Counseling and Psychological Services (CAPS) Center. CAPS provides FAU students a range of services – individual counseling, support meetings, and psychiatric services, to name a few – offered to help improve and maintain emotional well-being. For more information, go to http://www.fau.edu/counseling/

16. Code of Academic Integrity policy statement

Students at Florida Atlantic University are expected to maintain the highest ethical standards. Academic dishonesty is considered a serious breach of these ethical standards, because it interferes with the university mission to provide a high quality education in which no student enjoys an unfair advantage over any other. Academic dishonesty is also destructive of the university community, which is grounded in a system of mutual trust and places high value on personal integrity and individual responsibility. Harsh penalties are associated with academic dishonesty. For more information, see University Regulation 4.001. If your college has particular policies relating to cheating and plagiarism, state so here or provide a link to the full policy—but be sure the college policy does not conflict with the University Regulation.

17. Required texts/reading

To reduce costs for our students, we strongly encourage you to explore the adoption of open educational resources (OER), textbooks and other materials that are freely accessible. We also encourage you to clearly state in the syllabus if course materials are available on reserve in the Library.

"Mathematics for Neuroscientists," Fabrizio Gabbiani, Steven Cox, 2nd Ed., Academic Press, ISBN-13: 978-0128018958.

18. Supplementary/recommended readings

"Principals of Computational Modelling in Neuroscience," David Sterratt, Bruce Graham, Andrew Gillies, David Willshaw, 1st Ed., Cambridge University Press.

This book is available online in the form of downloadable PDF files for the webpage of the Cambridge University Press.

This is a research-based course and it is essential that students read multiple papers for each topic. Papers which will be uploaded on the course webpage.

19. Course topical outline, including dates for exams/quizzes, papers, completion of reading

Week - 1 Basics of neural signal processing, Nernst and Goldman Equations-derivation and the physics behind it, Electrochemical balance of the cell in the resting state.

We explain how nerve cells maintain their essential chemical balance to develop a stable electric potential across their membrane. We will use the principals of thermodynamics and chemistry to develop a theory which explains the process and provides a mechanism for modeling and computation.

Week - 2 Ion channels, Biochemical structure and function, and mathematical models, Zoo of ion channels.

Ion channels are the most important elements in the kinetics of neural membrane. We will look at the chemical structure of these proteins, similarities and differences between these structures particularly between sodium and potassium channels and we follow the path which was taken by Nobel prize winners, Hodgkin and Huxley, to build a model for the dynamics of these proteins. We will also look into non Hodgkin-Huxley ion channels and more complex kinetics that lead to firing adaptation, inhibitory rebound, burst firing, etc. Light sensitive ion channels, used in optogenetic stimulation, will be studied as well.

Week - 3 Hodgkin-Huxley Model

Hodgkin-Huxley model is still the most advance model we have in computational biology. We develop this model and analyze its performance.

Week - 4 Compartmental Models and Signal Propagation

We look at the physics of signal propagation along dendrites and axon both in passive and active scenarios. We will develop formulations to model signal propagation along cellular membrane. Rall's models will be discussed.

Week - 5 Kinetics of Ion Pumps

Ion pumps are also another essential element in neural signal processing. We will mathematically model ion pumps and show details of their dynamics in maintaining ionic balance across the membrane and even volumetric fluctuations in cells as a result of ion pump functions.

Week - 6 Introduction to NEURON, software package to model complex neural dynamics

NEURON is known as the most reliable software package in modeling single cells or biological neural networks. Fortunately, this is a free code, developed by funding from the NIH mostly at Yale university. NEURON is a highly valuable tool in computational neuroscience. We will go over this software and we will use the package in our course projects.

Week - 7 Physics of Extracellular Recording

Electrophysiology, in all different forms, is perhaps the most reliable tool we have in recording from cells or cell populations. Recording from single cells, including patch clamp, is what we study in early weeks of this course. Extracellular recording is a more advanced topic that we cover in Week 7 of the course. We will use electromagnetic theory to show how different electrode configurations, such as EEG or ECOG arrays, can record from cell populations and how the geometry of the design or distance from cells can affect acquired recordings.

Week - 8 Calcium Dynamics

Calcium has major effect in learning. We will look at the dynamics of calcium in neurons.

Week - 10 Two Dimensional Neuron Models

Hodgkin-Huxley models (HH Model) are too complicated to be used in many applications. Here, we use the theory of nonlinear dynamics to reduce the HH model to couple of well-known two-dimensional dynamical models and we show how we can use these models to explain many salient features of neural responses.

Week - 11 Theory of Plasticity and Learning

We will study the dynamics and chemical processes of synaptic plasticity which leads to long term and short term potentiation.

Week - 12 Neural Noise

Firing patterns in neurons are complicated and we always see certain level of uncertainty in firing patterns. We look at statistical models that show the main sources of such fluctuations.

Week - 13 Population Coding

Population codes are neural representations at the level of groups of cells. From single cell coding theory, we expand to population coding and we study how neurons response to complex stimulations or sensory inputs.

Week - 14 Information theory and Neural Codes

Information theory quantifies how much information a neural response carries about the stimulus. We study neural codes from the information theory point of

	view to quantitatively measure how much information is embedded in a collection of given firing patterns.
Week - 15	Neuro-vascular Coupling Neural networks use significant amount of energy to process stimulations. This energy and metabolic substances are delivered by the vascular network to the cells based on their temporal demands. As a result, neural circuits and adjacent vascular networks are tightly coupled and this coupling is used in many advanced brain functional imaging modalities (such as fMRI) to monitor brain activity. We look at some details of this coupling and related mathematical models.

From: William Kalies <WKALIES@fau.edu>
Sent: Tuesday, February 2, 2021 1:07 AM
To: Mihaela Cardei <mcardei@fau.edu>
Subject: Re: Neuroengineering concentrations and related courses

Hello Mihaela

The Neuroengineering concentration and new course proposals were sent to the departments of Biological Sciences, Psychology, and Physics, as well as the Center for Complex Systems and Brain Sciences, as the those in the College of Science that would potentially be affected by the proposals. After the withdrawal of EEE 6266, these departments support the proposal for the new concentration and the new courses BME 6390 and BME 6718.

Bill

—
Bill Kalies
Associate Dean for Graduate Studies
Charles E. Schmidt College of Science
Professor of Mathematical Sciences

Florida Atlantic University
777 Glades Rd, SE-43, Room 242
Boca Raton, FL 33431
tel: 561-297-1107
—

On Jan 8, 2021, at 9:49 AM, Mihaela Cardei <mcardei@fau.edu> wrote:

Hello Bill,

Happy New Year!

Our College has prepared proposals for adding the Neuroengineering concentration to the PhD in Electrical Engineering and to the PhD in Mechanical Engineering programs, as well as three new course proposals:
EEE 6266 Medical Imaging
BME 6390 Neural Engineering
BME 6718 Computational Modeling of Biological Neural Networks

Please find attached all these proposals. Please let us know whether the College of Science has any objections for the proposed curriculum items.

Thank you,
Mihaela

From: Marc Kantorow <MKANTORO@health.fau.edu>
Sent: Tuesday, January 19, 2021 4:09 PM
To: Mihaela Cardei <mcardei@fau.edu>
Cc: Janet Robishaw <jrobishaw@health.fau.edu>; Massimo Caputi <MCAPUTI@health.fau.edu>; Bridget Smith <BSTATLER@health.fau.edu>
Subject:FW: Neuroengineering concentrations and related courses

Hi Mihaela,
Hope all is well. Our committee raised no objectives to the proposal and new courses.
Let us know if we can be of further assistance.
All the best,
Marc

Marc Kantorow PhD, FARVO
Associate Dean for Graduate Programs
Professor of Biomedical Science
Charles E. Schmidt College of Medicine
Florida Atlantic University
Boca Raton, FL USA 33431
mkantoro@health.fau.edu
561-297-2910

From: Mihaela Cardei <mcardei@fau.edu>
Date: Friday, January 8, 2021 at 9:51 AM
To: Marc Kantorow <MKANTORO@health.fau.edu>
Cc: Hanqi Zhuang <zhuang@fau.edu>, Manhar Dhanak <dhanak@fau.edu>
Subject: Neuroengineering concentrations and related courses

Hello Marc,

Happy New Year!

Our College has prepared proposals for adding the Neuroengineering concentration to the PhD in Electrical Engineering and to the PhD in Mechanical Engineering programs, as well as three new course proposals:
EEE 6266 Medical Imaging
BME 6390 Neural Engineering
BME 6718 Computational Modeling of Biological Neural Networks

Please find attached all these proposals. Please let us know whether the College of Medicine has any objections for the proposed curriculum items.

Thank you,
Mihaela

From: Mihaela Cardei <mcardei@fau.edu>
Sent: Wednesday, January 13, 2021 8:15 AM
To: Randy Blakely <rblakely@health.fau.edu>
Cc: William Kalies <WKALIES@fau.edu>; Hanqi Zhuang <zhuang@fau.edu>; Manhar Dhanak <dhanak@fau.edu>
Subject: Re: COECS – Neuroengineering concentrations

Great, thank you for your feedback Randy.

Best regards,
Mihaela

From: Randy Blakely <rblakely@health.fau.edu>
Sent: Tuesday, January 12, 2021 8:26 PM
To: Mihaela Cardei <mcardei@fau.edu>
Cc: William Kalies <WKALIES@fau.edu>; Hanqi Zhuang <zhuang@fau.edu>; Manhar Dhanak <dhanak@fau.edu>
Subject: Re: COECS – Neuroengineering concentrations

Hi Mihaela
Thanks for the follow up. Yes, those course title change requests went in some time ago, surprised it hasn't been accomplished yet. My suspicion for the two courses being different was just as Ramin explained. I am not sure a student would get the difference from reading the text which as I noted was significantly duplicated. I like what he wrote in his email and would suggest that he work that into his text. Regardless, it's great to see them going on the books
Randy

Randy D. Blakely, Ph.D.
Executive Director, FAU Brain Institute
Professor of Biomedical Science
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Room 109, MC-17
5353 Parkside Dr.
Jupiter, FL 33458
Tel: 561-799-8100
email: rblakely@health.fau.edu
http://www.blakelylab.org

From: Mihaela Cardei <mcardei@fau.edu>
Date: Monday, January 11, 2021 at 10:10 AM
To: Randy Blakely <rblakely@health.fau.edu>
Cc: William Kalies <WKALIES@fau.edu>, Hanqi Zhuang <zhuang@fau.edu>, Manhar

Dhanak <dhanak@fau.edu>
Subject: Re: COECS – Neuroengineering concentrations

Hello Randy,

Thank you for your reply and for taking time to review the items. We have approved them in the college and are ready to submit for approvals to the university level.

Thank you for letting me know about the upcoming course title changes. "Cellular and Molecular Neuroscience" and "Systems and Integrative Neuroscience" are not in the catalog as of now. Therefore, we will have to keep Neuroscience 1 & 2 in the proposal and change them as soon as the catalog is updated.

The Neuroengineering Concentration for the ME Major document doesn't list the extent of elective courses as with the one in EE. It has a note "Additional courses may be approved by the dissertation advisor" that gives flexibility to the advisor and student to derive a plan of study including courses from other departments and colleges as electives.

BME 6390 and BME 6718 are being proposed by Dr. Ramin Pashaie. He changed the title of the special topics course "Brain Modeling" to "Computational Modeling of Biological Neural Networks". He confirmed that the two courses are different, please see below his explanation email*.

Regarding the PhD in Neuroscience program, master's "along the way" (MALW) is a great idea (https://fau.edu/graduate/docs/Masters_Along_the_Way_Instructions.pdf). MS in Bioengineering is the closest, and we could also consider MS ME and MS EE. We will have to check and confirm with the Graduate College since the document indicates that "The MALW must be in the same field as the doctoral program". The master programs in our college are 30 credits. Non-thesis (10 courses) may be an easier path. For thesis, we cannot use the same research for the MS and PhD. Even if the area is the same, the research problem that they address must be different.

Thank you,
Mihaela
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
* Here is the email from Dr. Pashaie:

Hi Mihaela and Hanqi,

Neural engineering and Computational Modeling for Biological Neural Networks are completely different topics.

Neural engineering concentrated on development of devices (such as electrodes or prosthetic platforms) that can record from brain or stimulate brain circuits. For example, we see people who have lost an arm and the arm is replaced by a robotic system which reads signals from neurons and transform those to commands for the artificial limb. This is about implementation of brain machine interface (BMI) platforms.
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Computational modeling concentrates on building mathematical and computational models for the dynamics of a cell or network of cells. for example, a mathematical model for how an ion channel functions under different membrane voltages or how an electric signal propagates along the body of a nerve cell. We study with mathematical tool how neurons get connected to each other and how learning takes place in biology again by using engineering and mathematics.

These two courses can be offered with minimum or zero overlap. The syllabus that I provided for neural engineering has a little overlap with computational modeling. The reason is that I first prepared the syllabus for computational modeling and at the time I didn't know that we will go for neural engineering any time soon. Therefore, I included just some minimum neural engineering related topics that I thought are very beneficial for students who don't have a chance to take a neural engineering course. It is possible to modify the syllabus of computational modeling and remove any form of overlap with neural engineering.

Hope this is helpful. Please let me know if you need more information.

Sincerely Yours,
Ramin

From: Randy Blakely <rblakely@health.fau.edu>
Sent: Sunday, January 10, 2021 2:50 PM
To: Mihaela Cardei <mcardei@fau.edu>
Cc: William Kalies <WKALIES@fau.edu>; Hanqi Zhuang <zhuang@fau.edu>; Manhar Dhanak <dhanak@fau.edu>
Subject: Re: COECS – Neuroengineering concentrations

Hi Mihaela
Thanks for sending these items along. Nice to see the effort progressing. Just a few notes

- Neuroscience 1 is being renamed Cellular and Molecular Neuroscience, with the same course code.
- Neuroscience 2 is being renamed Systems and Integrative Neuroscience, with the same course code.
- The Neuroengineering Concentration for the ME Major document doesn't list the extent of elective courses as with the one in EE (many would be the same). Is this is due to heavier core coursework?
- 6390 and 6718 look identical and have duplicated text for Course Evaluation Method. At least on paper, the two courses don't appear well enough differentiated. Are these courses listed as distinct courses due to having different kinds of students? Have both already been approved?

I wonder if you have considered the pathway by which Neuroscience PhD students, training with Engineering faculty, could obtain a Masters degree in Engineering? After they do their Core courses, it is conceivable that the three electives they take prior to being examined for their PhD thesis proposal could be ones acceptable for a Masters, with a couple courses taken after qualification leading to the

Masters? Can you see a curricular path that might work for this? Could a defense of their PhD thesis proposal, written as a thesis document, satisfy the thesis requirement for the Engineering Masters?

Randy

Randy D. Blakely, Ph.D.
Executive Director, FAU Brain Institute
Professor of Biomedical Science
Charles E. Schmidt College of Medicine
Florida Atlantic University
Room 109, MC-17
5353 Parkside Dr.
Jupiter, FL 33458
Tel: 561-799-8100
email: rblakely@health.fau.edu
http://www.blakelylab.org

From: Mihaela Cardei <mcardei@fau.edu>
Date: Friday, January 8, 2021 at 9:48 AM
To: Randy Blakely <rblakely@health.fau.edu>
Cc: William Kalies <WKALIES@fau.edu>, Hanqi Zhuang <zhuang@fau.edu>, Manhar Dhanak <dhanak@fau.edu>
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Please find attached all these proposals. Please let us know if you have any feedback.

Thank you,
Mihaela