NS6003: A MATHEMATICAL INTRODUCTION TO NEURAL NETWORKS

Effective Term

Semester A 2025/26

Part I Course Overview

Course Title

A Mathematical Introduction to Neural Networks

Subject Code

NS - Neuroscience

Course Number

6003

Academic Unit

Neuroscience (NS)

College/School

College of Biomedicine (BD)

Course Duration

One Semester

Credit Units

3

Level

P5, P6 - Postgraduate Degree

Medium of Instruction

English

Medium of Assessment

English

Prerequisites

Nil

Precursors

Nil

Equivalent Courses

Nil

Exclusive Courses

Nil

Part II Course Details

Abstract

This advanced course explores the principles and applications of neural networks and numerical methods, with a focus on their relevance to neuroscience and biological systems. Students will delve into various neural network architectures, training algorithms, and their biological inspirations, while also learning essential numerical methods for solving complex problems in neuroscience. The course covers advanced concepts of machine learning, deep learning, and their applications in analyzing neurological data, modeling neural systems, and solving biological problems. Emphasis will be placed on understanding the parallels between artificial neural networks and biological neural systems, as well as the numerical techniques used to simulate and analyze these systems.

Course Intended Learning Outcomes (CILOs)

	CILOs	**Weighting (if app.)**	**DEC-A1**	**DEC-A2**	**DEC-A3**
1	Demonstrate advanced understanding of neural network concepts and their relationship to biological neural systems	20	x	x	
2	Apply sophisticated machine learning, deep learning, and numerical methods to analyze neurological data and model complex neural systems	30	x	x	x
3	Implement and optimize advanced neural network models using programming tools and numerical techniques	25	x	x	x
4	Critically evaluate and compare the potential and limitations of neural networks and numerical methods in neuroscience research and applications	15	x	x	
5	Design and conduct original research projects applying neural networks and numerical methods to solve cutting-edge neuroscience problems	10	x	x	x

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Learning and Teaching Activities (LTAs)

	LTAs	**Brief Description**	**CILO No.**	**Hours/week (if applicable)**
1	Lecture	Advanced presentation of neural network concepts, architectures, numerical methods, and their biological inspirations	1, 2, 4	

2	Laboratory Sessions	Hands-on experience with implementing and optimizing neural networks using Python, relevant libraries, and numerical algorithms	2, 3, 5	
3	Case Studies	In-depth analysis of state-of-the-art applications of neural networks and numerical methods in neuroscience research	2, 4	
4	Research Projects	Individual and group work on applying neural networks and numerical methods to solve complex neuroscience-related problems	1, 2, 3, 4, 5	

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Midterm Exam	1, 2	25	-	No
2	Advanced Programming Assignments	2, 3, 5	25	Allowed to assist programming mathematical models	Yes
3	Research Project	2, 4, 5	25	Allowed to assist programming mathematical models	Yes

Continuous Assessment (%)

75

Examination (%)

25

Examination Duration (Hours)

3

Assessment Rubrics (AR)

Assessment Task

1. Advanced Programming Assignments (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Able to show the origination of the knowledge and concept involved in the computational project.

Excellent

(A+, A, A-) The student is able to implement neural network models without assistance.

Good

(B+, B, B-) The student is able to implement neural network models with minimal assistance.

Fair

(C+, C, C-) The student is able to implement basic neural network models with some assistance.

Marginal

(D) The student is able to implement only parts of the neural network models.

Failure

(F) The student fails to implement functioning neural network models

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Assessment Task

2. Research Project (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Based on the submitted programming codes and reports to evaluate whether the students can apply neural network concepts and implement models to address neuroscience-related problems.

Excellent

(A+, A, A-) The student is able to implement neural network models without assistance, demonstrating a deep understanding of the concepts and their applications in neuroscience. The code is well-documented and efficient, and the accompanying report is clear and insightful.

Good

(B+, B, B-) The student is able to implement neural network models with minimal assistance, showing a good understanding of the concepts and their applications. The code is functional and mostly well-documented, with a clear accompanying report.

Fair

(C+, C, C-) The student is able to implement basic neural network models with some assistance, demonstrating an adequate understanding of the concepts. The code functions with minor issues, and the report covers the main points.

Marginal

(D) The student is able to implement only parts of the neural network models and submits a basic report with some gaps in understanding.

Failure

(F) The student fails to implement functioning neural network models and is unable to produce a coherent report.

Assessment Task

3. Midterm and Final Examinations (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Able to show the understanding of concepts and applications of numerical methods and models.

Excellent

(A+, A, A-) Students achieve an 86% or greater on the examination

Good

(B+, B, B-) Students achieve a 65% or greater on the examination

Fair

(C+, C, C-) Students achieve a 50% or greater on the examination

Marginal

(D) Students achieve between 40% to 50% on the examination

Failure

(F) Students achieve less than 40% on the examination

Part III Other Information

Keyword Syllabus

Advanced artificial neural networks, Deep learning architectures (CNNs, RNNs, Transformers), Biological neural systems and computational neuroscience, Supervised, unsupervised, and reinforcement learning, Numerical methods for differential equations, Optimization algorithms for neural networks, High-performance computing for neuroscience, Neurological data analysis and visualization, Ethical considerations in AI and neuroscience

Reading List

Compulsory Readings

	Title
1	Nil

Additional Readings

	Title
1	Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.
2	Dayan, P., & Abbott, L. F. (2001). Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems. MIT Press.
3	Aggarwal, C. C. (2018). Neural Networks and Deep Learning: A Textbook. Springer.
4	Ramsundar, B., Eastman, P., Walters, P., & Pande, V. (2019). Deep Learning for the Life Sciences: Applying Deep Learning to Genomics, Microscopy, Drug Discovery, and More. O'Reilly Media.
5	Izhikevich, E. M. (2007). Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting. MIT Press.
6	Sejnowski, T. J. (2018). The Deep Learning Revolution. MIT Press.
7	Recent research papers from top journals in computational neuroscience and machine learning.