Neural Networks - A Leading Edge of AI

Fall 2024

COURSE INFORMATION

Course Number: ST 7375
Course Title: Neural Networks – A Leading Edge of AI
Course Prerequisites: Ability to program in Python
Term and Year: Fall 2024
Credit Hours: 4
Class Schedule: Thursdays, 3:00 pm – 6:20 pm
Course Format: In class on the Oakland campus

INSTRUCTOR INFORMATION

Instructor Name: Sergey K. Aityan, DSc, PhD.
Email address: "Sergey Aityan" <s.aityan@northeastern.edu>
Office hours: by appointment

TEACHING ASSISTANT INFORMATION

TA Name: Vikram Sawant
Email address: "Vikram Sawant" <sawant.vik@northeastern.edu>
Office hours: In person or online via Zoom or Teams in scheduled sessions and individually by appointment

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COURSE DESCRIPTION

This is a comprehensive course on artificial neural networks (NNs) as a leading edge of modern artificial intelligence (AI), ranging from the introduction through the advanced principles, architectures, and modern trends. The role of neural networks in the progress of artificial intelligence is discussed. The course covers theoretical foundations, models, and trends; NNs design and development; their applications, trends, challenges, and limitations. Special attention is given to scientific, technological, and philosophical aspects of NNs and their impact on society. Students learn fundamental principles, how to develop NNs from scratch, how to train and tune them, how to apply NNs for a variety of purposes, and explore new approaches and models.

RECOMMENDED MATERIALS AND TEXBOOK

- **Main source:** Sergey Aityan: ST 7375 lecture slides and notes
- **Other sources:** Various sources recommended by the instructor.

COURSE LEARNING OUTCOMES

At the completion of this course, the student should be able to:

- Clearly understand and explain the fundamental principles of artificial neural networks (NNs) and their inspiration in nature.
- Understand the models of neurons and NNs.
- Understand different architectures of NNs.
- Design and develop NNs of different architectures.
- Train, tune, optimize, and apply NNs for practical applications.
- Understand the advantages, trends, and limitations of NNs.
- Understand and explain the role of NNs in the progress of AI and their impact on society.

INSTRUCTIONAL METHODOLOGIES

This course will combine lectures and presentations with multiple hands-on assignments that reinforce the material. Lectures and presentations will focus on concepts and ideas while home tasks and lab assignments will provide practical experience and skills. Students will also have a course project, which allows them to apply their acquired knowledge to design and implementation of an artificial neural network.

EXAMS

- There will be both a midterm exam and a final exam.
- Each exam includes about ten essay-style questions (no multiple choice).
- The answers must be written clearly and easy to read, structurally with a clear and logical presentation of the answers.
- Graphs, charts, tables, and other supporting illustrations are required if needed.
- Simple examples to illustrate the answers are mandatory required.
- The exams are neither “open book” nor “open notes.”
- The final exam is comprehensive, i.e. includes the whole course.
- The exams are taken in class and the students must be physically present in class during the exam.
- Telephones and other communication devices must be turned off during the exam.
- Cheating in exam results in immediate termination of the exam, and grade “F” with ZERO points.
- The instructor reserves the right to change the exam format, replace the written exam with a verbal exam or multiple choice if finds appropriate.

HOMEWORK, QUIZZES, ASSIGNMENTS, AND PROJECTS

- There will be extensive home tasks each week during the course to be submitted by next week’s class. These home tasks will serve to develop practical skills on the learned material.
- A brief quiz may be given in class to check the students’ knowledge learned in the previous class.
- Students should complete lab assignments and submit the results at the due time,
- All students are required to work in teams on a course project. Each team consists of 4-6 members depending on the overall class size. The teams will present their complete project to the class at the end of the semester in a group presentation that consists of three parts: (1) a complete written report, (2) a live project demo, and (3) a PowerPoint presentation with the problem statement, design ideas, major challenges, and results followed by the class discussion on the project. All team members should participate in

the presentation by delivering a certain part of it. The team members absent in class at the time of their presentation will not pass the project assignment.

- All programming assignments should be submitted in the form of files in the GitHub repository:
  - ✓ the source code and compiled files stored in the repository.
  - ✓ a separate file with the actual output and the discussion of the results.

GRADING POLICY

Each answer in assignment including exams labs, homework, and quizzes will be graded by points assigned to the task. The total percentage for each category of activities is calculated as the total collected points divided by the total possible maximum points.

Activity	Percentage weights
Classroom activities and quizzes	15%
Home tasks and labs	20%
Midterm Exam	20%
Final Exam	20%
Course project	25%

The final grade for the course will be given as the total weighted score for all activities according to the percentage wrights shown in the table below.

Grade	A	A-	B+	B	B-	C+	C	C-	F
% points	95-100	90-94	87-89	84-86	80-83	77-79	74-76	70-73	0-69

NO MAKE-UP WORK

Assignments are to be completed on time during the course. Late assignment submissions will result in a reduced grade. Mid-term and final exams and group presentations cannot be made up unless there was a documented emergency.

COURSE SCHEDULE

Class #	Date	Topic	Chapters
1	Sep. 5	• About the course	
		• Human brain, biological neurons, synapses, and neural networks • McCulloch and Pitts neuron model	Ch. 1
		• The Perceptron • History of the Perceptron	Ch. 2
		• Project discussion	
2	Sep.12	• Supervised training • Perceptron for logistic regression • Neural networks for logistic regression and classification • Linear binary classifier • Loss (Cost) function • Gradient descent optimization • Logistic regression • Neural Networks for logistic regression	Ch. 3

		• Perceptron for logistic regression with the sigmoid activation function and a single training sample • Vectors and Matrices • Perceptron for logistic regression with the sigmoid activation function and many training samples	Ch. 4
		• Project discussion	
3	Sep. 19	• Limitations of Perceptron • Neural networks with one hidden layer	Ch. 5
		• Project discussion	
4	Sep. 26	• Deep (Multilayer) neural networks • Forward and backward propagation • Gradient descent optimization • Applications of Neural Networks • Vector Neural Networks	Ch. 6
		• Activation functions • How to choose activation functions	Ch. 7
		• Project discussion	
5	Oct. 3	• Training parameters vs hyperparameters • Parameters initialization • Training, validation, and testing sets • Common pitfalls in the training data split • Cross-validation • Data augmentation	Ch. 8
		• Overfitting and underfitting • Classification bias vs variance trade off • Regularization to reduce overfitting • Dropout to reduce overfitting	Ch. 9
		• Lab 1 and Couse Project discussion	
6	Oct. 10	• Normalization • Vanishing and exploding gradients. • Gradient checking • Batch normalization for training • Batch, mini-batch, stochastic gradient descent • Exponential-weighted average • Gradient descent with momentum • RMSprop • Adam optimization algorithm	Ch.10
		• Learning rate decay • The problem of local optima and plateaus • Hyperparameters • Normalization and mini-batches • Batch norms	Ch.11
		• Softmax classifier	Ch.12
		• Pre-exam Q&A	
7	Oct. 17	• Midterm exam	Chs.1-12
8	Oct. 24	• Review and analysis of the midterm exam	

		• Convolutions • Edge detection • Padding • Strided convolutions • Convolutions on RGB image and multiple filters	Ch.13
		• Convolutional neural networks (CNN) • Pooling layers • Examples of convolutional networks • Residual networks (ResNet)	Ch.14
		• Lab 2 Discussion	
9	Oct.31	• Inception networks • Normal convolutions • Depthwise convolution • Pointwise convolution • Sense of 1x1 convolution • Transfer learning	Ch.15
		• Localization and detection • Landmark detection • Object detection, intersection over union • Convolutional sliding window • Bounding box prediction • Object localization and non-max suppression	Ch.16
		• Project discussion	
10	Nov. 7	• Overlapping objects • Anchor boxes • Transposed convolution • Deep learning for semantic segmentation • U-Net	Ch.17
		• Face verification • Similarity and Siamese network • Triplet loss • Neural style transfer	Ch.18
		• Lab 3 and project discussion	
11	Nov. 14	• The RNN Architecture • Discrete Time RNNs • Types of RNNs • RNN Loss Function • RNN Forward- and Backpropagation • Variants of RNN	Ch.19
		• Language Model • Exploding and Vanishing Gradients • LSTM and GRU	Ch.20
		• Project discussion	
12	Nov. 21	• Bidirectional and deep RNN • Word representation • Sentiment classification	Ch.21

		• Speech recognition • Natural Language Processing (NLP) • Machine translation	
		• Attention model • Trigger word detection • Transformers • LLM – Large Language Model • Generative AI • GPT – Generative pre-trained transformers • ChatGPT, Gemini, etc • Diffusion networks	Ch.22
		• Project discussion	
	Nov. 28	Thanksgiving Break – No Classes	
13	Dec. 5	• Final exam	Chs.1-22
14	Dec. 12	• Project Presentations and final discussion	

CHEATING AND PLAGIARISM

Cheating is the actual or attempted practice of fraudulent or deceptive acts for the purpose of improving one's grade or obtaining course credit. Acts of cheating include, but are not limited to, the following:
(a) plagiarism;
(b) copying or attempting to copy from others during an examination or on an assignment;
(c) communicating test information with another person during an examination;
(d) allowing others to do an assignment or portion of an assignment;
(e) using a commercial term paper service.
Cheating or plagiarism will result in zero points and letter grade F for an assignment, project, or exam and a report of the incident to the Dean of Students, who may place related documentation in a file. Repeated acts of cheating may result in an F in the course and/or disciplinary action.

OTHER COMMENTS

- Please participate. What you put into the class will determine what you get out of it – and what others get out of it.
- Please come on time. Late arrivals disturb everyone else.
- If you miss a class, you are responsible for getting lecture notes/slide printouts on the material covered from a classmate or the instructor.
- Use of cellular phones is prohibited during class or exams. Cellular phones must be turned off or silenced.
- Questions and comments during the class are welcome. Do not hesitate to ask questions – do not leave anything unclear for you.

MODIFICATION OF THE SYLLABUS:

The instructor reserves the right to modify this syllabus at any time during the semester. Announcements of any changes will be made in a classroom.

GENERAL MGEN POLICIES

Attendance Policy

Students registered in MGEN courses (INFO, CSYE, and DAMG) are allowed a maximum of 2 absences per course, with 3 or more absences resulting in an automatic 'F' for that course. Students are expected to inform their instructors of any absences in advance of the class; if a student is sick long-term or experiences a medical issue that prevents class attendance, it is strongly encouraged that they speak with their Academic Advisor (coe-mgen-gradadvising@northeastern.edu) to learn more about the Medical Leave of Absence. Should a student anticipate being unable to attend 3 or more classes, they should discuss their situation with their Academic Advisor to explore other types of leave in accordance with the University's academic and global entry expectations. International students should review the Office of Global Services webpage to understand their visa compliance requirements.
Teaching Assistants (TAs) or Instructional Assistants (IAs) will be present at each class to collect student attendance.

Late Work Policy

Students must submit assignments by the deadline in the time zone noted in the syllabus. Students must communicate with the faculty prior to the deadline if they anticipate work will be submitted late. Work submitted late without prior communication with faculty will not be graded.

End-of-Course Evaluation Surveys

Your feedback regarding your educational experience in this class is particularly important to the College of Engineering. Your comments will make a difference in the future planning and presentation of our curriculum.
At the end of this course, please take the time to complete the evaluation survey at https://neu.evaluationkit.com. Your survey responses are completely anonymous and confidential. For courses 6 weeks in length or shorter, surveys will be open one week prior to the end of the courses; for courses greater than 6 weeks in length, surveys will be open for two weeks. An email will be sent to your Northeastern University Mail account notifying you when surveys are available.

Academic Integrity

A commitment to the principles of academic integrity is essential to the mission of Northeastern University. The promotion of independent and original scholarship ensures that students derive the most from their educational experience and their pursuit of knowledge. Academic dishonesty violates the most fundamental values of an intellectual community and undermines the achievements of the entire University.

As members of the academic community, students must become familiar with their rights and responsibilities. In each course, they are responsible for knowing the requirements and restrictions regarding research and writing, examinations of whatever kind, collaborative work, the use of study aids, the appropriateness of assistance, and other issues. Students are responsible for learning the conventions of documentation and acknowledgment of sources in their fields. Northeastern University expects students to complete all examinations, tests, papers, creative projects, and assignments of any kind according to the highest ethical standards, as set forth either explicitly or implicitly in this Code or by the direction of instructors.

Go to http://www.northeastern.edu/osccr/academic-integrity-policy/ to access the full academic integrity policy.

MGEN Student Feedback

Students who would like to provide the MGEN unit with anonymous feedback on this particular course, Teaching Assistants, Instructional Assistants, professors, or to provide general feedback regarding their program, may do so using this survey: https://neu.co1.qualtrics.com/jfe/form/SV_cTIAbH7ZRaaw0Ki

University Health and Counseling Services

As a student enrolled in this course, you are fully responsible for assignments, work, and course materials as outlined in this syllabus and in the classroom. Over the course of the semester if you experience any health issues, please contact UHCS.

For more information, visit https://www.northeastern.edu/uhcs.

Student Accommodations

Northeastern University and the Disability Resource Center (DRC) are committed to providing disability services that enable students who qualify under Section 504 of the Rehabilitation Act and the Americans with Disabilities Act Amendments Act (ADAAA) to participate fully in the activities of the university. To receive accommodations through the DRC, students must provide appropriate documentation that demonstrates a current substantially limiting disability.

For more information, visit https://drc.sites.northeastern.edu.

Library Services

The Northeastern University Library is at the hub of campus intellectual life. Resources include over 900,000 print volumes, 206,500 e-books, and 70,225 electronic journals.

For more information and for education specific resources, visit
https://library.northeastern.edu
Network Campus Library Services: Northeastern University Library Global Campus Portals

24/7 Canvas Technical Help

For immediate technical support for Canvas, call 617-373-4357 or email help@northeastern.edu
Canvas Student Resources: https://canvas.northeastern.edu/student-resources/
For assistance with my Northeastern e-mail, and basic technical support:
Visit ITS at https://its.northeastern.edu
Email: help@northeastern.edu
ITS Customer Service Desk: 617-373-4357

Diversity and Inclusion

Northeastern University is committed to equal opportunity, affirmative action, diversity, and social justice while building a climate of inclusion on and beyond campus. In the classroom, members of the University community work to cultivate an inclusive environment that denounces discrimination through innovation, collaboration, and an awareness of global perspectives on social justice.
Please visit http://www.northeastern.edu/oidi/ for complete information on Diversity and Inclusion

Title IX

Title IX of the Education Amendments of 1972 protects individuals from sex or gender-based discrimination, including discrimination based on gender-identity, in educational programs and activities that receive federal financial assistance.

Northeastern's Title IX Policy prohibits Prohibited Offenses, which are defined as sexual harassment, sexual assault, relationship or domestic violence, and stalking. The Title IX Policy applies to the entire community, including male, female, transgender students, faculty, and staff.

In case of an emergency, please call 911.

Please visit https://www.northeastern.edu/ouec for a complete list of reporting options and resources both on- and off-campus.