Artificial Intelligence Course

School of Electrical and Computer Engineering- University of Tehran

Spring 2024

Course Syllabus

Instructor

Professor Mohammad Khoshnevisan
Affiliated Research Professor
Northeastern University, MA, USA
Email1: m.khoshnevisan@northeastern.edu
E-mail 2: m.khoshnevisan@ieee.org
Office hours: By appointment

https://www.maplesoft.com/books/details.aspx?id=638

https://qspace.qu.edu.qa/handle/10576/38644

https://ainyilai.com/

Day and Time: Sunday-Tuesday [7:30 am- 9:00 am(Tehran)]

Research Interests: Applications of Deep Neural Networks in Gastroenterology and Hepatology, Neurosurgery, Neurology, Endodontics, Oral and Maxillofacial Radiology, Quantum Computing and Quantum Machine Learning, Computational Mathematics in Engineering.

Programming Languages: Python and Maple
Framework: TensorFlow

Artificial Intelligence Basic Components

1. Computer Science and Software Engineering
2. Applied Mathematics
3. Applied Probability and Statistics
4. Domain Expertise (example: gastroenterology, nephrology, oncology, cardiology, endodontics, mechanical engineering, electrical engineering, and quantum physics)
5. Cloud Computing and GPU

Active Research Teams

1.AI in Gastroenterology and Hepatology with Professor Mohammad Reza Zali (Fellowship in Gastroenterology, Tulane University, USA and Distinguished Professor of Gastroenterology and Hepatology), Professor Behzad Moshiri, Professor of Control

Systems Engineering at the University of Tehran and an Adjunct Professor in ECE at the University of Waterloo, Canada, and Professor Kosrow Dehnad (PhD Mathematics, University of California Berkeley and PhD Applied Statistics, Stanford University), Columbia University, USA.

2. AI in Neurosurgery with Dr Jaber Hatam, Assistant Professor of Neurosurgery- Iran University of Medical Sciences, Dr Maryam Kachooyie, Assistant Professor of Pediatric Neurology (Iran University of Medical Sciences), Professor Behzad Moshiri, Professor of Control Systems Engineering at the University of Tehran and an Adjunct Professor in ECE at the University of Waterloo, Canada, and Professor Kosrow Dehnad (PhD Mathematics, University of California Berkeley and PhD Applied Statistics, Stanford University), Columbia University, USA.

Main Teaching Assistant

Mr Amir Abbas Yahyaeian
Master of Engineering- Purdue University, USA
Ph.D student in Automotive Engineering, Clemson University, USA
E-mail: amiryah@clemson.edu

Short biography

Mr Amir Abbas Yahyaeian was my student. He also worked as a TA for my Advanced Engineering Mathematics and Artificial Intelligence courses. He is currently a Ph.D student in Automotive Engineering at Clemson University, USA.

Auxiliary Teaching Assistant

Mr Behzad Mohasel Afshari
B.Sc- University of Tehran
M.Sc -Sharif University of Technology

Short biography

Mr Behzad Mohasel Afshari has been my research assistant for four years. He co-authors the book "Vibrational Mechanics by Maple Practical Applications." [https://www.maplesoft.com/books/details.aspx?id=638], which we published last year with Professor Mansour Nikkhah Bahrami at Tehran University. Behzad works with Professor Kosrow Dehand(Columbia University, USA) and me on various AI applications in medicine.

Guest Speakers

Most likely, we will have the following guest speakers during the semester. They will address applications of AI in the industry.

1.Professor Kosrow Dehnad(PhD Mathematics, University of California Berkeley and PhD Applied Statistics, Stanford University), Columbia University, USA. He will explain the Application of AI/machine learning in trading. [One session].

2. Dr Jaber Hatam-MD is an Assistant Professor of Neurosurgery at Iran University of Medical Sciences. He will explain the applications of AI in detecting brain tumors such as Glioblastoma, Lymphoma, and Meningioma using deep neural networks. He will also elucidate the importance of early detection of lumbar spinal stenosis using AI.[One session].

3. Dr Maryam Kachooyie-MD is an Assistant Professor of Pediatric Neurology at Iran University of Medical Sciences. She will explain the use of AI in detecting the dysfunctionality of the Vagus nerve (Cranial nerve X) in patients suffering from Irritable Bowel Syndrome (IBS). [One session]

Note 1: We have an active project in Gastroenterology and Hepatology- (Nonalcoholic Fatty Liver Disease, Nonalcoholic Steatohepatitis, Cirrhosis, and Hepatocellular Carcinoma) at the Institute of Gastroenterology and Hepatology with Professor Mohammad Reza Zali (Fellowship in Gastroenterology, Tulane University, USA and Distinguished Professor of Gastroenterology and Hepatology). If time permits and he is available, I can ask him to provide a presentation regarding the AI application for detecting various stages of Nonalcoholic Fatty Liver Disease.

Course Topics

Part I- Lectures

1. Overview of Neuroanatomy and Physiology-Theory
2. Introduction to Artificial Intelligence-Theory
3. Artificial Neural Networks and Optimization -Theory and Application
4. Deep Neural Networks (Supervised [Regression and Classification] & Unsupervised Learning)-Theory and Application
5. Convolutional Neural Networks (Computer Vision)-Theory and Application [LeNet, AlexNet, VGG 16/19, and ResNet50]- Theory and Application

Part II-Lectures

1. Introduction to Machine Learning-Theory
2. Support Vector Machine (SVM)-Theory and Application
3. Decision Tree-Theory and Application
4. Random Forest -Theory and Application
5. Gradient Boosting and Extreme Gradient Boosting-Application
6.LightGBM-Application

Part III-Lectures

1. Markov Decision Processes-Theory and Application
2. Artificial Agents-Theory

3. Reinforcement Learning (RL)-Theory and Application
4. Stochastic Processes and Games-Theory

Part IV-Lectures

1. Natural Language Processing (NLP)-Theory and Application
2. Recurrent Neural Networks (RNN)-Theory and Application
3. Long-Short Term Memory (LSTM)-Theory and Application

Part V-Lecture

1. Probability-Theory and Application
2. Naïve Bayes-Theory
3. Bayes Net-Theory
4. Bayes Net Inference-Theory
5. Genetic Algorithms and Limitations-Theory and Application

Part VI-Lectures

1. Informed Search -Theory
2. Uninformed Search-Theory
3. Constraint Satisfaction Problems-Theory
4. Adversarial Search- Theory
5. Propositional Logic and First Order Logic

Part VII-Lectures

1. Mathematics of Quantum Computing (Qubits, Probability Amplitude, Superposition, Entanglement, and Paul Dirac Mathematical Notations)-Theory
2. Quantum Computing (Quantum Gates and Quantum Circuits)-Application
3. Quantum Neural Networks (Variational Circuit)-Theory and Application
4. Challenges

Part VIII- AI Applications in Medicine and Dentistry- Research

1. Neurosurgery-Classifying the Severity of Lumbar Spinal Stenosis.
2. Gastroenterology and Hepatology- Nonalcoholic Fatty Liver Disease, Nonalcoholic Steatohepatitis, Cirrhosis, and Hepatocellular Carcinoma.
3. Gastroenterology and Hepatology- Gallbladder dysfunctions and pathologies.
A. Cholelithiasis- formation of stone in the gallbladder- Cholecystectomy may be warranted.
B. Cholecystitis- Obstruction and inflammation of the cystic duct and a gallstone block bile from exiting the organ. Cholecystectomy is warranted in most cases.
C. Choledocholithiasis- Obstruction of the common bile duct. Gallstones are in the common bile duct. Endoscopic Sphincterotomy is warranted in many cases.
4. Neurogastroenterology - Evaluating the functionality of the Vagus nerve (Cranial nerve X) via ultrasonography to understand Irritable Bowel Syndrome (IBS). There could be some changes in the dimension of the Vagus nerve.

5. Dentistry- Detection and diagnosis of dental caries using a deep learning convolutional neural network.
6. Dentistry- Deep neural networks to differentiate Stafne's bone cavity from pathological radiolucent lesions of the mandible in panoramic radiography.
7. Dentistry- Using Convolutional Neural Networks to differentiate between the fractures /cracks and the existing filling materials by Cone Beam Computed Tomography (CBCT-3D).

Part IX-Course Grading Policy

I. Mini Projects

A. Project in Deep Neural Networks and Convolutional Neural Networks-(Two Models-Code Submission + Recorded Video Presentation-25 minutes). [Theory and Application].
Weight=20%.
B. Project in Machine Learning-(Two Models-Code Submission + Recorded Video Presentation-20 minutes). [Theory and Application].
Weight=15%
C. Project in Reinforcement Learning (One Model-Code Submission + Recorded Video Presentation -25 minutes). [Theory and Application].
Weight=20%.
D. Project in Quantum Machine Learning and Quantum Neural Networks (Two Models-Code Submission + Recorded Video Presentation -25 minutes). [Theory and Application].
Weight=20%.

Note 2: Your notebook must be clearly elucidated. You must explain the codes before each code block in the text cell. Notebooks with mathematical and coding errors will not be accepted. I will run your codes and make sure they are correct. Also, your notebook should not have any spelling or grammatical mistakes. Your notebook must be flawless. You must show your face during recording. You should save your file as [First Name- Last Name- First Project]. This format applies to all assessment items. When you complete your notebook and video, you should send the link to Mr Amir Abbas Yahyaeian, who is the TA for the course. You must ensure your notebook and video work before sending your link to the TA. Your link must be open and should not have a lock. Please do not send your link to me.

II. Assignments

A. Genetic Algorithms and Bayes Network-(Code Submission + Recorded Video Presentation-15 minutes). [Theory and Application].
Weight=5%.
B. Informed Search and Uninformed Search-(Code Submission + Recorded Video Presentation-15 minutes). [Theory and Application].
Weight=5%

III. Tutorial Participation and Presentation

You must attend the tutorials. I randomly select students during the tutorials and ask them questions about the previous lecture. Therefore, you should be prepared before each tutorial session.
Weight=5%.

IV. Review Paper and Oral Presentation

You must choose from the topics listed in the course outline and write a review paper. Your review paper should not be more than 12 pages and less than ten pages. Your review paper should have an introduction, body, summary, and conclusion. There are various sources available online that will help you to format your paper correctly. This part of your assessment can be done individually or in a group of four students. No more than four students are allowed in the group. The contribution of each member must be stated in the paper. You should submit your paper to the course TA with your recorded video (no more than 15 minutes) and 7-10 PowerPoint slides. You should clearly explain the review paper. You can consult the website below.
https://websites.uwlax.edu/biology/ReviewPapers.html.
You can also study Engineering Research Methodology by Dipankar Deb, Rajeeb Dey, and Valentina E. Balas
Weight=10%.

Part X- How Do I Evaluate Your Work?

I use the following metric system to assess your work.

1. Concept explanation. Your elucidation must be straightforward and to the point. Please do not philosophize your explanation. For instance, If I ask you to explain the difference between Principal component analysis and Isomap Embedding, you only need to explain the difference between the two algorithms. There is no need to discuss the fast algorithm for Independent Component Analysis (FastICA).
2. Clear explanation of the mathematics and logic behind the algorithms.
3. Your coding skills in Python and explanation of the codes.
4. Your presentation skills.
5. Your scientific writing skills.
6. Your class participation.

Note 3: The language of computational mathematics and computer science is precise. I guess we are a bit fortunate. Therefore, I will not accept vague explanations in your work. Please learn the algorithms, build and deploy AI models, and put them into production. I believe memorizing some theories and algorithms without applying them is not helpful for engineering students. Thus, you do not need to memorize the materials in this course. I will not test your memory in this course. All in all, your understanding of the logic behind the algorithms and building practical models are the core objectives of this course.

Note 4: We have limited time this semester. I encourage you to learn the following. They are not required for the course. I am happy to send you my notebooks. My TA has the following notebooks. You can contact him, and he will send them to you.

1. Transfer Learning
2. YOLO Object Detection Algorithm
3. Deep Reinforcement Learning
4. Catboost

Note 5: I have formed three AI groups with Professor Behzad Moshiri(School of Electrical and Computer Engineering-University of Tehran) and Professor Kosrow Dehand(Columbia University, USA) in Gastroenterology and Hepatology, Neurosurgery and Dentistry. If you want to join one of the AI groups, please get in touch with me at the end of the semester.

Part XI

Recommended Readings

[1].S. Ganguly, Quantum Machine Learning: An Applied Approach: The Theory and Application of Quantum Machine Learning in Science and Industry. Apress, 2021.

[2].S. Pattanayak, Quantum Machine Learning with Python: Using Cirq from Google Research and IBM Qiskit. Apress, 2021.

[3].N. M. P. D, Quantum Computing. Pragmatic Bookshelf, 2020.

[4].F. M. Ham and I. Kostanic, Principles of Neurocomputing for Science and Engineering. McGraw Hill, 2000.

[5].M. Sewak, M. R. Karim, and P. Pujari, Practical Convolutional Neural Networks: Implement advanced deep learning models using Python. Packt Publishing, 2018.

[6].A. Géron, Neural Networks, and Deep Learning. O'Reilly, 2018.

[7].K. Kar, Mastering Computer Vision with TensorFlow 2. x: Build advanced computer vision applications using machine learning and deep learning techniques. Packt Publishing, 2020.

[8].S. C. Kaiser and C. Grenade, Learn Quantum Computing with Python and Q#: A hands-on approach. Manning, 2021.

[9].R. Loredo, Learn Quantum Computing with Python and IBM Quantum Experience: A hands-on introduction to quantum computing and writing your own quantum programs with Python. Packt Publishing, 2020.

[10].A. Grama, Introduction to Parallel Computing. Addison-Wesley, 2003.

[11].A. Géron, Hands-On Machine Learning with Scikit-Learn and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems. O'Reilly Media, 2017.

[12].E. Wirsansky, Hands-On Genetic Algorithms with Python: Applying genetic algorithms to solve real-world deep learning and artificial intelligence problems. Packt Publishing, 2020.

[13].R. A. Bohm, The Fundamentals of Search Algorithms. Nova Science Publishers, 2021.

[14].M. Grinberg, Flask Web Development: Developing Web Applications with Python. O'Reilly, 2018.

[15].H. Nelson, Essential Math for AI. O'Reilly Media, 2023.

[16].P. Singh, Deploy Machine Learning Models to Production: With Flask, Streamlit, Docker, and Kubernetes on Google Cloud Platform. Apress, 2020.

[17].N. J. Nilsson, Artificial Intelligence: A New Synthesis. Morgan Kaufmann Publishers, 1998.

[18].S. J. Russell, P. Norvig, and J. F. Canny, Artificial Intelligence: A Modern Approach. Prentice Hall/Pearson Education, 2003.

[19].I. Vasilev, Advanced Deep Learning with Python: Design and implement advanced next-generation AI solutions using TensorFlow and PyTorch. Packt Publishing, 2019.

[20].IBM. https://research.ibm.com/topics/quantum-machine-learning