MET CS 767: Advanced Machine Learning and Neural Network

Reza Rawassizadeh

Who is this course for?

1. Are you good at Python, or can write some python script? Are you willing to learn how to code in Keras, TensorFlow and PyTorch on your own?

2. You should seek to be a data scientist, ML/AI engineer, and related jobs or PhD for this course. If you intend to be only a software engineer with some ML knowledge, this is not the right course for you. You can take CS 555, CS 677, CS 688 or CS 699.

3. Are you okay investing a huge amount of your time to learn state-of-the-art ML algorithms?

4. Are you okay with learning algorithms that resolve state-of-the-art problems (such as Kaggle competition), but no other university or online courses teach them in this detail in one semester?

5. Few students in this class get A. If you have concerns about your final grade, think again about this class. The average GPA last semester in this course was 3.1/4

6. If you are first semester without any prior knowledge of ML and data science, definitely this course is not for you. Please do not take it this semester.

Course Policy

- This course is very different from our traditional MET courses, here, we deal with Neural Networks and it is not possible to run the code in the class.

- This course is 80% theory and 20% coding. Nevertheless, in your assignments, you will do the coding, but I do not teach any coding here.

- It takes time to build a neural network model, and then later we could use the model. Therefore, for the neural network parts of the course, we do have lots of theories and very few codings.

- We are using existing models, and in your assignments, you will experiment with coding neural networks because you might need to leave your model to train the system for several hours.

- This course requires some learn-it-yourself for your assignments. If you feel you are not confident in learning something on your own and researching, I doubt if this course is useful or if you enjoy our journey this semester. Perhaps you can take it another semester when you get more senior in programming and solution finding.

- The material we learn here is very large, which is extremely useful for those of you who give job interviews as AI/data scientist or apply for a Ph.D.

- This course is **not for teaching Python programming** at all. You must have experience using python in one of your previous courses.

- If you are MET student and did not pass one of these courses (CS 555, CS 688, CS 677, CS 699), this course is definitely not for you. Passing only CS 544 or CS 521 is not enough to attend this course.

Evaluation 1/4

- You have 6 assignments, few quizzes, and a final exam.

- For the final exam, you can use your slides to prepare for it. Or I might give you some transcripts (https://github.com/rezar/mlbook).

- I would not put you under stress, but you really dedicate time to this important and challenging course and deeply understand your assignments.

- Near the end of the semester, we do not have time to increase your grade by updating your grade for your missing assignments.

- It is unfair to give one student an extra grade and not to all other students. Therefore, I will not do it at all.

Evaluation 2/4

- Your homework grades will be marked based on the following criteria

    1. Do you correctly understand the problem? And do you choose the correct algorithm?

    2. Does it run properly or does it perform all tasks which have been asked in the assignment?

    3. Can you judge the results and prepare a proper report about them?

    4. Are you able to explain your code and answer my or my tutor’s questions about this?

    5. **You need to submit 5-12 minutes presentation of your homework and describe your code, and what you have done. Every time, we will review it in class and discuss it.**

    6. If you use ChatGPT or other LLM tools, that is fine with me, but you need to be able to describe the code and any modifications you have applied to the code. Just copy/pasting from ChatGPT or another AI code-writing tool is considered plagiarism.

Evaluation 3/4 (final exam and quizzes)

- Your final exam grants you 30/100 points on your final grade.

- The final exam is essay writing and it prepares you for a job interview in a data science field.

- Exams might not be practical, but in this course, there are concepts that we can not evaluate your assignments. To be sure you have learned them, we will conduct an exam.

- Quizzes are constructing 20% of your final grade.

Evaluation 4/4 (Class attendance, Scientific Talks)

- Class attendance is not mandatory, but experience shows that students who attend the class get significantly higher grades + if you ask me for a recommendation letter, I should know you in person.

- It is mandatory to attend research talks we hold in the department. If you miss attending each talk 1% of your final grade will be reduced.

https://www.bu.edu/csmet/research/computer-science-research-seminar

- If you can not attend, you should send me/TA an email before the talk and I will send you the video of the talk as soon as it gets online.

Course Modules (1)

- **Session 1,2: Statistics Required for Generative Models.**
    - Data distributions
    - Parameters that define a distribution
    - Maximum Lilkelihood Estimation and Expectation Maximization.
- **Session 3,4: Regression Models**
    - Linear Regression, Multi-Linear Regression, Polynomial Regression, Parameter estimation, Pieceweise Regression, Regression Challenges and Resolutions. Regression Model Evaluation.
    - Logistic Regression, Parameter estimation, Softmax Regression (Classifier), Parameter estimation.
    - Evaluating Regression Models.
    - Overfitting and Underfitting, Bias-variance trade-off.
    - Regularizations
- **Session 5: Machine Learning Optimization**
    - Mathematical concepts
    - Gradient Descent
    - Newton-Raphson

Course Module (2)

- **Session 5: Review Traditional Classification Approaches**
  - Released classifier
  - Naive Bayes
  - SVM
  - kNN

- **Session 5,6: Trees and Gradient Boston Decision Trees**
  - Decision Trees
    - Iterative Dichotomiser 3 (ID3), Chi-square Automatic Interaction Detector (CHAID), C4.5, Classification and Regression Trees (CART)
  - Ensemble Learnings
    - Bootstrap Aggregating (Bagging), Boosting, Stacking.
    - Random Forest
    - Adaptive Boosting
    - Gradient Boosting-Based Algorithms (Gradient Boosting, XGBoost, LightGBM, CATBoost)

Course Modules (3)

- **Session 7,8: Basic concepts of Neural Networks**
- Artificial Neural Network Structure:
    - Perceptron Algorithm,
    - Multi-Layer Perceptron,
    - Activation Functions,
    - Neural Cost Functions
- Neural Network Optimizers:
    - SGD with Momentum,
    - Nesterov with Momentum,
    - Adagrad,
    - RMSProp
- Backpropagation
- Regularization in Neural Network:
    - Vanishing and Exploding Gradient,
    - Batch Normalization,
    - Dropout,
    - Early Stopping
- **Session 8, 9:**
    - **Convolutional Neural Network:**
        - Convolution and Cross Correlation,
        - CNN steps,
        - Different types of Convolutions.
    - **Recurrent Neural Network:**
        - Concepts,
        - LSTM,
        - GRU,
        - Bidirectional RNN,
        - Deep RNN,

Course Modules (4)

- **Session 10, 11: Self-Supervised Neural Network**
  - Concepts of Representation Learning
  - Self Organized Map (SOM)
  - Boltzmann Machine
  - Restricted Boltzmann Machine
  - Deep Belief Network and Deep Boltzmann Machine
  - **Auto Encoders:** Concepts, Types (Sparse, Denoising, Contractive, Stacked), Variational AutoEncoders, UNet
  - **Generative Adversarial Networks:** Concepts, Training GAN, Challenges, GAN Evaluation.
- **Session 12, 13: Transformer**
  - Transformer concepts and architecture.
  - Computer vision classifiers based on Transformer.
- **Session 14: Neural Network Compression**
  - Concepts
  - Quantization
  - Pruning

My goals in this course

1. Improve your qualification for the job market by getting familiar to state-of-the-art tools and techniques in artificial intelligence and machine learning.

2. Teach you how to construct a research question and conduct a scientific experiment, which is helpful for your PhD and industry work.

3. Not put you under the stress.

Communication with me

- If you have more than one question please wrap them inside one email and avoid distributing your questions in different emails.

- Please send your questions about assignments to TA and not me. I can not answer questions about assignments.

- If you have questions about not understanding a topic or require consultation on your study plan, then please feel free to send your question.

- TA: Runqing Yang, rayna921@bu.edu

- *Sending me an email to get an extra grade at the end of the semester does not work. I will treat all students fairly and can not add a few extra grades to a particular student who asked for a grade.*

About Me

- Reza Rawassizadeh
- Email: rezar@bu.edu. Please include the [MET CS767] in the title of your emails.
- Office hours: Please email me before coming to the office
- Office Address: 1010 Commonwealth Ave. Room 320.
- Home page: http://www.bu.edu/csmet/profile/reza-rawsasizadeh/
- Google Scholar: https://scholar.google.com/citations?user=MImVx_UAAAAJ&hl=en&oi=ao

Books I have used to prepare this course

https://github.com/rezar/mlbook