

MA 421G (001), 3 credits — Spring 2020
MWF 11:00-11:50, Room: xxx

Mathematical Introduction to Deep Learning

Instructor: Qiang Ye
Office Address: 735 POT
Office Hours: MWF xx:xx-xx:xx and by appointment
Email: qye3@uky.edu
Office Phone: (859) 257-4653

Course Description (Bulletin): This course introduces deep learning with its mathematical foundation, algorithms, and programming tools. Students will learn the basics of deep learning algorithms and gain related foundational knowledge in linear algebra, optimization, and probability and information theory. The students will also get programming experiences in building deep neural networks for some real-world data problems.

Prerequisites: MA 320/STA 320 (or STA 524), MA 321/CS 321, and MA 322, or consent of instructor. Fluency with the Python programming will be assumed.

Student Learning Outcomes: After completing this course, students will be able to:

- (1) formulate a deep learning approach to solve a variety of real world data problems;
- (2) implement a deep neural network model using a deep learning API (Application Programming Interface) such as Keras;
- (3) use linear algebra, optimization, and probability to solve some applied problems.

Required Materials: There will not be any required text. The materials will be drawn from various sources. The following book will be a valuable reference for students:

- Deep Learning, by Ian Goodfellow, Yoshua Bengio and Aaron Courville, MIT Press, 2016.
A free online version is available at <http://www.deeplearningbook.org/>

Course Activities and Assignments

Homework: There will be 8 homework assignments, including programming type problems. Students are encouraged to work on homework problems together, but solutions must be written in their own words and submitted independently.

Exams: There will be one midterm exam during the regular class time and a final exam of two hour duration to be scheduled by the Registrar's office.

Expectations for graduate students beyond the expectations for undergraduates : Students taking this course for graduate credit will be expected to complete a project. The project will involve applying a deep learning model covered in this class to a real-world data problem. The report of the project must be typed and must, at a minimum, include an introduction, a description of data and problem, discussions of models used, summary and discussions of results; and a references list. The project will be due the last day of classes.

Course Grading: For undergraduate students, the grade will be based on 8 HW sets, a midterm exam and a final exam with the weights given as follows:

Homework	55%
Midterm	15%
Final	30%

The following scale will be used to determine a student's final grade:

A	90%-100%
B	80%-89.9%
C	70%-79.9%
D	60%-69.9%
E	0%-59.9%

For graduate students, the grade will be based on 8 HW sets, a project, a midterm exam and a final exam with the weights given as follows:

Homework	50%
Project	15%
Midterm	10%
Final	25%

The following scale will be used to determine a graduate student's final grade:

A	90%-100%
B	80%-89.9%
C	70%-79.9%
E	0%-69.9%

Mid-term grades will be posted in myUK by the deadline established in the Academic Calendar.

Tentative Course Schedule:

Week	Topic
1	INTRODUCTION TO MACHINE LEARNING.
1-2	LINEAR REGRESSION: vector and matrix norms; linear least squares problems; Cholesky algorithm; Richardson iterations, steepest descent and conjugate gradient methods; condition numbers and convergence; data normalization.
3-4	LINEAR CLASSIFICATION: logistic sigmoid functions; softmax function; maximum likelihood principles; cross-entropy loss; logistic regression;
5	NEURAL NETWORKS: nonlinear activation functions; universal approximation theorem.
6-7	OPTIMIZATION METHODS: multivariate Taylor theorem, local extremum, fixed point iterations, gradient descent method and convergence analysis, nonlinear conjugate gradient method.
8-9	OPTIMIZATION FOR DEEP NEURAL NETWORKS: backpropagation algorithm, mini-batch training; gradient descent and momentum; AdaGrad, RMSProp, and Adam methods; batch normalization.
10	REGULARIZATION: overfitting; validation and cross validation; data enhancements; Tikhonov regularization; L_1 -regularization; dropout regularization.

Week	Topic
11	CONVOLUTIONAL NEURAL NETWORKS: convolution operation and its variations; convolutional layer; pooling layer.
12	RECURRENT NEURAL NETWORKS: state-space model for input-output systems, basic and orthogonal recurrent networks; long short term memory networks; gated recurrent units.
13	INFORMATION THEORY: entropy; Jensen's inequality; KL divergence; Jensen-Shannon divergence.
13-15	UNSUPERVISED LEARNING: singular value decomposition; principal component analysis; autoencoders; variational autoencoders; generative adversarial networks.

Policies

Attendance and excused absences: Attendance is mandatory. Be on time and remain until dismissed. Do not leave in the middle of class. Whenever possible, please notify your instructor of absences prior to class. S.R. 5.2.4.2 defines the following as acceptable reasons for excused absences: (a) serious illness, (b) illness or death of family member, (c) University-related trips, (d) major religious holidays, and (e) other circumstances found to fit as reasonable cause for nonattendance by the professor. You may be asked to verify absences in order for them to be considered excused. Senate Rule 5.2.4.2 states that faculty have the right to request appropriate verification when students claim an excused absence because of illness or death in the family. Appropriate notification of absences due to university-related trips is required prior to the absence. If you anticipate an absence for a major religious holiday please notify your instructor (in writing) of anticipated absences due to your observance of such holidays no later than the last day in the semester to add a class. Two weeks prior to the absence is reasonable, but should not be given any later. Information regarding major religious holidays may be obtained through the Ombud (859) 257-3737,

http://www.uky.edu/Ombud/ForStudents_ExcusedAbsences.php

You are expected to withdraw from the class if more than 20% of the classes scheduled for the semester are missed (excused or unexcused) per university policy.

Classroom behavior: Electronic devices such as mobile phones, laptops and tablets should be put away or used only as part of class activities during lectures. Mobile phones, laptops, and computers may not be used during exams.

Make-up policies: Per Senate Rule 5.2.4.2, if you are missing any graded work due to an excused absence you are responsible for informing the Instructor about your excused absence within one week following the period of the excused absence (except where prior notification is required); and for making up the missed work. The instructor will give you an opportunity to make up the work and/or the exams missed due to an excused absence, and shall do so, if feasible, during the semester in which the absence occurred. In particular, if you have university excused absences or have university-scheduled class conflicts with uniform examinations you may arrange with their instructor to take the exam at an alternate time. Generally these make-up exams will be scheduled on the day of or on the day after the regularly scheduled exam. Work-related conflicts are neither university excused absences nor university-scheduled absences.

Students needing accommodations: If you have a documented disability that requires academic accommodations, please see your instructor as soon as possible. In order to receive accommodations in this course, you must provide your instructor with a Letter of Accommodation from the Disability Resource Center (DRC). The DRC coordinates campus disability services available to students with disabilities. It is located on the corner of Rose Street and Huguelet Drive in the Multidisciplinary Science Building,

Suite 407. You can reach them via phone at (859) 257-2754 and via email at drc@uky.edu. Their web address is

<http://www.uky.edu/StudentAffairs/DisabilityResourceCenter/>

Accommodations for victims of violence: By federal law, any student who is a victim of dating violence, domestic/intimate partner violence, sexual assault, or stalking (whether on or off campus) is entitled to appropriate accommodations for his or her coursework. To get help getting accommodations and other support, students who are assaulted can do any of the following:

- Tell your instructor who can assist you in accessing resources appropriate to your situation;
- Call the UK VIP Center (Violence Intervention and Prevention Center) at 257-3574 or vipcenter@uky.edu or

http://www.uky.edu/StudentAffairs/VIPCenter/about_contact.php

or walk in to the Center in Frazee Hall, lower level, between 8:30 and 5:00;

- Call the University Counseling Center at 257-8701; 2nd floor, Frazee Hall;
- Call Ms. Patty Bender from the UK Institutional Equity and Equal Opportunity at 257-8927 or patty.bender@uky.edu;
- In the case of an emergency, contact the UK Police Department at 911.
- Students may also contact community resources 24-hours a day, including:
 - (a) Bluegrass Rape Crisis Center at 800.656.4673 or <http://bluegrassrapecrisis.org/>
 - (b) Greenhouse17 (formerly Bluegrass Domestic Violence Program) at 800.544.2022 or <http://greenhouse17.org/>

Academic Honesty: Cheating or plagiarism is a serious offense and will not be tolerated. It will be thoroughly investigated, and might lead to failure in the course or even to expulsion from the university. See <http://www.uky.edu/StudentAffairs/Code/part2.html> (Sections 6.3.1 and 6.3.2) for information on cheating, plagiarism, and penalties. A summary of recent changes to rules on cheating can be found at the Academic Ombud website: <http://www.uky.edu/Ombud>