Department of Geography and Geoinformation Science
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GGS 590

Deep Learning for Geosciences

1. General Information

Instructor:	Dr. Olga Gkountouna
Where:	Research Hall 290
When:	Tuesday, 4:30-7:10pm. Jan 22 - May 15, 2019
Course website:	Blackboard
Credits:	3
Prerequisites:	*Required*: **GGS 787** or permission of instructor. *Optional*: GGS 560, GGS 650.
Office Hours:	Tuesday, Wednesday 3:00-4:00pm / or by appointment

2. Course Description

Deep learning is the latest advancement of the machine learning and artificial intelligence community. Its many successful applications in speech recognition, computer vision, automatic game playing, self-driving vehicles, natural language processing, and others, have brought deep learning in the center of attention of various disciplines. This course captures the involvement of the geosciences in this new paradigm shift. Each lecture of this course is divided in two parts. The *first part* explores the fundamental theory behind machine learning and its applications in geosciences. The topics that will be covered include the maximum likelihood (MLE) as well as the maximum a posteriori (MAP) estimation, Naïve Bayes, Gaussian Mixture Model, BayesNet, to help students get a comprehensive overview of machine learning. The course also covers the Logistic Regression, Loss Function, MLP, CNN, and RNN. The scope of this class is not a general introduction, but rather a deeper understanding of how deep learning algorithms work with respect to SGD, Momentum, and Regularization. The course will help the students gain the abilities to develop Deep Learning models. The *second part* of each class is application-oriented, focusing on large-scale geospatial problems, such as satellite image recognition, location-based services, etc. Coding assignments will be held during class and as homework. By the end of the course, the students will deliver a large programming project applying deep learning on real data. By working on this area, the students will develop the skills to (i) read and understand the latest state-of-the-art advances of Deep Learning; and (ii) implement deep learning models for geospatial problems using the appropriate libraries and explore the latest software advancements in the field.

3. Learning Outcomes

By the end of the course each student will

- have a broad knowledge on fundamentals, theory and techniques of machine learning and particularly deep learning algorithms,
- be able to articulate and effectively communicate concepts and ideas related to Deep Learning for Geosciences to experts, non-experts, and other professionals in a work environment,
- have the ability to appropriately apply the knowledge acquired in the course for various hypothetical and real-world machine learning tasks,
- have a solid programming experience with free and open-source machine learning frameworks, in order to apply deep learning solutions to new data sets,
- be able to properly interpret machine learning / deep learning results.

4. Format

The course will be taught as a combination of seminars, tutorials, and programming labs.

5. Textbooks

No required textbook. Course slides and reading material will be provided via Blackboard.
Suggested Readings: *Deep Learning (Adaptive Computation and Machine Learning series)*, *Pattern Recognition and Machine Learning (Information Science and Statistics)*, Carnegie Mellon University Online Course, Youtube list.

6. Technology Requirements

Hardware: To be determined. *Software:* This course will be using Python as a programming language and Jupyter Notebooks as the default development environment. Pytorch will be used as the main deep learning package. A basic understanding of computer programming principles, linear algebra, probability theory, and strong coding skills are necessary.

7. Course outline (tentative)

In this course we will cover the following topics (please note that the topics and their order are subjected to change at the discretion of the instructor, any changes will be announced in class):

Week of	Mod. #	Topic	Assignment
01/22	1	Overview of Machine Learning and Deep Learning – Course organization and philosophy – ML Examples	Discussion in class
01/29		Snow day – no classes	
01/05	2	Basic concepts and theory: Probabilities, MLE – MAP, Causal diagrams, Supervised Learning: Naïve Bayes.	Assignment 1: Logistic regression (Due on 02/26, 4:00pm)
02/12	3	Linear algebra, Logistic regression	
02/19	4	Gradient Descent, SGD, Over-fitting, Bias Variance trade-off, Model selection	
02/26	5	Support vector Machines, Tree-based models, Ensembles, Sampling, Bagging, Boosting	
03/05	6	Perceptron, Multi-layer Perceptron, Backpropagation, Unsupervised Learning, Bayes Net	Assignment 2: Multi-layer Perceptron (Due on 04/02, 4:00pm)
03/12	7	Spring Break	
03/22		Backpropagation, Autograd tutorials, Q & A on midterm	
03/26	8	**Midterm Exam** Convolutional Neural Networks	Assignment 3: Paper reading (Due 04/09)
04/02	9	Midterm solution, CNN tutorial, Regularization in deep learning	Assignment 4: Convo-lutional Neural Networks (Due on 04/16, 4:00pm)
04/09	10	Research paper presentations. Discussion Topics: Computer vision, Object recognition, Satellite image processing	
04/16	11	Research paper presentations.	
04/23	12	Discussion Topics: Natural Language Processing, Reinforcement Learning, Simulation, Game Theory, AI	
04/30	13	Project Presentations	
05/07	14	Project Presentations	
05/14	15	--	**Project Submission**

8. Grades

Each assignment, the project and the written exam will be given a numerical grade on a 0-100 scale. Some assignments may include bonus tasks. At the end of the term all the marks will be totaled as a weighted average according to the following weights:

Intermediate Assignments	**40%**
Midterm Exam	**20%**
Final Project	**40%**

Assignments will have the same weight, each accounting for 10% of your final grade. Final grades at the end of the course will be assigned using **absolute achievements only**, independent of the relative standing in the class.

9. Exams

The course includes a mandatory written midterm exam. The material covered in the exam will be announced in class. A student who cannot write a course examination or complete a course assignment because of an incapacitating illness, severe domestic affliction or other compelling reasons can apply for extension of time to complete an assignment.

10. Project

The project will include python implementations of most deep learning tasks discussed in classroom, as well as an experimental evaluation, performed on real datasets. Each student will be provided with a data set and will be assigned to implement a specific set of tasks, by the instructor. The student is required to implement the tasks, test them on the real data, visualize the results, and write a final report describing the methods used, the insights and knowledge extracted from the data. The project requires very good programming skills. The grade of the project will be based on the readability and performance of the python code, the visualization of results, and the written report.

11. Assignments:

The course will include several written assignments on selected topics from the material covered in class and in the assigned reading. Assignments may include tasks such as analysis of data using Python, discussion/analysis of theoretical concepts and test cases of algorithms. All assignments are mandatory. Typically, two weeks will be allocated for every assignment.

Assignments should be done **through the Blackboard course website**.

Please note: Assignments should be submitted only through the Assignment submission section of the Blackboard system - DO NOT email assignments directly to the instructor.

12. Late paper submission:

Papers submitted **after the due date will not be accepted**. Exceptions to this policy may be made given serious circumstances at the discretion of the Instructor.

Please note: Deferral of term work is a privilege and not a right; there is no guarantee that a deferral will be granted. Please make sure you notify the instructor as soon as you know a deferral is required.

13. General guidelines for ASSIGNMENT preparation and submission

a. Grades of assignments will be based on:

- **Academic merit** of your answers.

- **Conciseness** and **completeness** of your answers. Please write to the point and explicitly address the question or task. Avoid using unnecessary graphics (figures, tables, graphs etc.) unless they serve a specific purpose. Make sure to use captions and to refer to the graphics you include in your written answer. Graphics without any reference or accompanying explanation will be disregarded.
- **Organization** and **presentation**. Remember that your assignment report is a reflection of your thinking and learning process. Please organize your report in a logical fashion so that your answers could be easily identified. A general format for your presentation should, as a minimum, include the following components: (1) Question number, (2) Your written answer and/or description and discussion of your results, and (3) Visualization of your results, e.g. images, graphs, tables, as necessary.

b. Please remember that your assignment is a **professional document**, and should therefore be formatted and constructed accordingly. All assignments are to be typed. Hand-written assignments will not be accepted.

c. Submission of a hardcopy will be made in class; submission of a softcopy will be made through Blackboard.

d. The electronic submission of your assignment report has to be in **PDF format**.

e. If more than one file is submitted, you may submit a single **ZIP** file containing all the assignment files.

f. Each assignment submission should include a cover page with the following information: assignment title, assignment number, student name, and submission date.

g. Please make sure you have a backup of all the materials you submit.

14. Course website:

The course has a Blackboard website. This website will provide you a single portal through which you may obtain lecture notes, retrieve assignment data and, review links to additional materials, and receive special announcements. You are required to visit the course website **once per day**. Please notify ITU (and, if necessary, the instructor) if you encounter any problems accessing this website.

15. Electronic communication:

All course related email correspondence, including submission of assignments, should be made through the course Blackboard website. Please DO NOT send emails to the instructors' @gmu.edu address.

16. Student Expectations:

- **Academic Integrity:** Students must be responsible for their own work, and students and faculty must take on the responsibility of dealing explicitly with violations. The tenet must be a foundation of our university culture. [See http://academicintegrity.gmu.edu/distance].
- **Honor Code:** Students must adhere to the guidelines of the George Mason University Honor Code [See http://oai.gmu.edu/the-mason-honor-code/].
- **MasonLive/Email (GMU Email):** Students are responsible for the content of university communications sent to their George Mason University email account and are required to activate their account and check it regularly. All communication from the university, college, school, and program will be sent to students solely through their Mason email account.
  [See https://masonlivelogin.gmu.edu].
- **Patriot Pass:** Once you sign up for your Patriot Pass, your passwords will be synchronized, and you will use your Patriot Pass username and password to log in to the following systems: Blackboard, University Libraries, MasonLive, myMason, Patriot Web, Virtual Computing Lab, and WEMS. [See https://password.gmu.edu/index.jsp].
- **University Policies:** Students must follow the university policies.
  [See http://universitypolicy.gmu.edu].Responsible Use of Computing - Students must follow the university policy for Responsible Use of Computing.
  [See http://universitypolicy.gmu.edu/policies/responsible-use-of-computing].
- **University Calendar:** Details regarding the current Academic Calendar.

[See http://registrar.gmu.edu/calendars/index.html].

- **Students with Disabilities:** Students with disabilities who seek accommodations in a course must be registered with the George Mason University Office of Disability Services (ODS) and inform their instructor, in writing, at the beginning of the semester [See http://ods.gmu.edu].
- Students are expected to follow courteous Internet etiquette at all times; see http://www.albion.com/netiquette/corerules.html for more information regarding these expectations.

2. Student Services:

- **University Libraries:** University Libraries provides resources for distance students. [See http://library.gmu.edu/distance and http://infoguides.gmu.edu/distance_students].
- **Writing Center:** The George Mason University Writing Center staff provides a variety of resources and services (e.g., tutoring, workshops, writing guides, handbooks) intended to support students as they work to construct and share knowledge through writing. [See http://writingcenter.gmu.edu]. You can now sign up for an Online Writing Lab (OWL) session just like you sign up for a face-to-face session in the Writing Center, which means YOU set the date and time of the appointment! Learn more about the Online Writing Lab (OWL).
- Counseling and Psychological Services: The George Mason University Counseling and Psychological Services (CAPS) staff consists of professional counseling and clinical psychologists, social workers, and counselors who offer a wide range of services (e.g., individual and group counseling, workshops and outreach programs) to enhance students' personal experience and academic performance [See http://caps.gmu.edu].
- **Family Educational Rights and Privacy Act (FERPA):** The Family Educational Rights and Privacy Act of 1974 (FERPA), also known as the "Buckley Amendment," is a federal law that gives protection to student educational records and provides students with certain rights. [See http://registrar.gmu.edu/privacy].

Disclaimer: Any typographical errors in this Course Outline are subject to change and will be announced in class. The date of the final examination is set by the Registrar and takes precedence over the final examination date reported by the instructor.

Note: Recording is permitted only with the prior written consent of the professor or if recording is part of an approved accommodation plan.