Numerical Methods for Deep Learning
CS 584 / MATH 584, Spring 2018

Instructor: Lars Ruthotto

**Times.**

WedFri: 11:30 AM – 12:45 PM in W302
Make-up time slot: Mon 11:30 AM – 12:45 PM in W302

First day of classes: January 17
Last day of classes: April 27
Recess: March 12 – 16 (Spring Break)
Travel-related cancellations (make-ups will be scheduled in the first sessions): March 5 – 9.

**Office hours.**

I am looking forward to discuss on course topics, your projects, or other stuff with you during regular office hours (see my website) or by appointment (lruthotto@emory.edu)

**Intellectual Scope.**

This course provides students with the mathematical background needed to analyze and further develop numerical methods at the heart of deep learning. The course is simultaneously geared towards computer science students, who may be interested/experienced with deep learning and would like to strengthen their theoretical foundation, and mathematics students, who may have a background in numerical analysis and who are curious about the emerging technology of deep learning. The course primarily targets graduate students. However, exceptional advanced undergraduate students may be admitted on a case-by-case basis.

The ultimate goal is for students to implement a simple, mathematically sound deep learning code from scratch using MATLAB. This look under the hood will provide valuable insight into successful and well-tested software packages for deep learning tasks and understand their success (and failure).

Class time will be split between hands-on coding exercises, lectures providing the necessary theoretical background. Classes will provide an overview of state-of-the-art methods for deep learning with a focus on deep residual networks, and also contain crash courses on some of the most important aspects of numerical analysis that are involved in deep learning, such as convex and nonlinear optimization, differential equations, and optimal control.
Prerequisites.
In order to succeed in this class, students need to have a solid background in multivariate calculus and linear algebra and some programming experience in MATLAB, Julia, or Python.

In addition, students are also expected to have experience or skills in either numerical analysis (optimization, partial differential equations) or machine learning (e.g., CS534, CS584, or similar).

Goals.
The course will equip students with new insights into deep learning. After taking the course, all students will better understand the inner workings of state-of-the-art approaches in the field, will be educated users of state-of-the-art software, and will be able to develop new learning algorithms themselves.

A specific learning objective for math students is to provide them with a gentle introduction to deep learning by highlighting its relation to other problems commonly studied in applied mathematics. A specific learning objective for computer science students is to provide them with new insights that is useful for designing architectures and learning algorithms that are effective in practice.

Grading.
By default, students will receive a letter grade comprised of the following

- 60% homework projects (20% per project)
- 40% final project (proposal, final presentation, final report)

Students who would like to audit the course, need to sign up on OPUS to receive a S/U grade. Satisfactory performance requires active participation and completion of the homework projects, which need to be turned in.

Final Project.
You are encouraged to build a group of 2-3 to design and accomplish the term project. Preferably your team members expertise covers both numerical analysis and machine learning. Possible projects include:

1) developing new learning algorithms, analyze its mathematical properties, and show its potential using some example.
2) Applying the techniques learned in class to existing benchmarks, in-depths performance comparison, and clear description of other learning algorithms commonly used for this data set.
The project is a critical part of the course and a significant factor in determining your grade. Teams are required to hand in a one-page project proposal, a 6-page final project report and prepare one 15-minute presentation on their work. By default, all team members will receive the same score for their project. If a team feels that this is unfair perhaps due to HIGHLY imbalanced contributions, then every team member needs to provide feedback on the contribution of each of the other team members via email before submission of the final report. After that, I will need to have a meeting with all the members together to mediate.

**Homework Projects.**

There will be three homework projects that guide students through all steps towards creating a deep neural network code. Part of the coding will be started in class, but the projects are devoted to extending methods from class and more in-depth experimentation.

Students may work by themselves or in teams of up to 3 participants (same rules as above apply). Students need to submit a single ZIP file containing clearly documented and functional MATLAB code and a report of up to 6 pages that is typeset in LaTeX (a template is provided in Canvas).

**Class Attendance.**

Attendance is not required, but strongly encouraged. If you miss a class, then you should get a copy of the notes from one of your classmates.

**Students with Disabilities.**

If you have a disability and would like to request classroom accommodations, please see me after class or during office hours to discuss arrangements.

**Honor Code.**

All students must adhere to the provisions of the Graduate Student Conduct Code. For more information, see page 29 of the [graduate student handbook](#).