ECE 5268 – Theory of Neural Networks

Spring 2014

Course Description

Artificial Neural Networks (ANNs) refer to mathematical models that were invented to imitate the capabilities and qualities of real, biological neurons. For the last 3 decades they have proven themselves as powerful computational models and have found profound application in a variety of domains. 2006 and onwards experienced a (rather unexpected) revival of the topic after the introduction of the so-called “deep learning” architectures. This fact made it even to featured articles in the New York Times.

This introductory course focuses on the theory of ANNs, as well as of related models, primarily, in the context of regression tasks and much less so to classification tasks. It is offered at the graduate level as ECE 5268 by the ECE Dept. at Florida Tech as often as to meet student demand and for the last few times it has been instructed by me. The course is mainly homework- and project-centered.

The goal of this course is to provide a basic introduction to elements of neural computation. After introducing some necessary background in optimization and inference, a variety of popular models, such as Gaussian Processes, Multi-Layer Perceptron and Support Vector Regression are examined in depth in terms of model fitting and utility. A new exciting addition to this course is an introduction to deep learning and a careful look at Sum-Product Networks that appeared as a freshly minted deep architecture in 2012.

Finally, the course is intended for graduate students of engineering or science majors that already have sufficient background in Calculus III, Linear Algebra and Probability & Statistics. Former attendees of the course have been M.S. and doctoral students of engineering (Electrical, Computer and Systems Engineering) and sciences (Computer Sciences, Mathematics and Physics).

Apart from the aforementioned background, competency in using and programming in an integrated computational and visualization platform has become over time a de-facto requirement in order to successfully complete the course’s hands-on project work in a timely fashion. Among all options, students in the past have heavily relied mostly on MATLAB™, few on Mathematica™ and even fewer on Python.
Instructor Information

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Course Meeting Times

Lectures
Tuesdays & Thursdays, 17:00 – 18:15 (1h 15min)
Jan 7th (first lecture) – Apr 22nd (last lecture)
Room 256, Link Building

Office Hours
My office hours will be always be kept current and posted outside my office and on my website. In order to accommodate and serve you best, please make an appointment before meeting with me in my office.

Course Resources

Material will be drawn primarily from the two textbooks shown below. Additional material may be supplied during the course of the lectures in the form of lecture notes.


Additional valuable references are


Performance Assessment & Grading Policy
This course considers the following student performance assessment instruments: 1) homework, 2) three Mini-Projects (MPs), 3) an Individual Course Project (ICP) and 4) a final oral exam. The score weighting of these deliverables and the grading policy are displayed in the tables below.

<table>
<thead>
<tr>
<th>Score weighting</th>
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<tbody>
<tr>
<td>Homework</td>
<td>10%</td>
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<tr>
<td>Mini-Project I</td>
<td>}</td>
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<tr>
<td>Mini-Project II</td>
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<td>Mini-Project III</td>
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<tr>
<td>Mini-Project IV</td>
<td>}</td>
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<tr>
<td>Indiv. Course Project</td>
<td>20%</td>
</tr>
<tr>
<td>Oral Exam</td>
<td>20%</td>
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Regarding the weighting of individual MP scores, the minimum, median and maximum scores will be weighted by 10%, 15% and 25% respectively. The overall course score to letter grade conversion that will be used for this course is the standard one and is depicted in the table below.

<table>
<thead>
<tr>
<th>Score to Letter Grade conversion</th>
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<tbody>
<tr>
<td>90 and above</td>
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<tr>
<td>80-89</td>
</tr>
<tr>
<td>70-79</td>
</tr>
<tr>
<td>60-69</td>
</tr>
<tr>
<td>59 and below</td>
</tr>
</tbody>
</table>

**Course Conduct**

**Lectures**
Lectures will be delivered in a single 1h 15m segment, twice a week according to schedule.

**Homeworks**
6-8 sets of homework will be assigned a week in advance of their turn-in deadline throughout the semester.

**Mini-Projects**
The announcement and due dates for each mini project (MP) are on Tuesdays indicated in the tentative class schedule depicted further below. Course participants will have 9 days to complete their MP work, which they must electronically submit via ANGEL by 23:55 on the due day. Late submissions will be penalized linearly by 1 point every 14.4 minutes, i.e. 100 points in 24 hours; submission of your MP beyond 24 hours will not be possible and, in case of no submission, you will be assigned a score of 0 for that particular MP.

Each MP will consist of several parts, such as implementations of algorithms, performance of experiments and interpretation of results, questions on theory that may require analytical work (mathematical derivations, critical thinking questions, etc.) and, possibly, some literature review.
Overall, the role of the MPs is to motivate you to gain significant intuition and understanding about the new concepts and techniques discussed during lecture. In the process you will also experience some typical instances of PR in scientific and/or engineering problems. The MP work you will submit has to reflect your personal effort and understanding; collaboration with other individuals is not allowed. Therefore, you are strongly encouraged to interact with your instructor before submitting your MP-related work. However, do not ask your instructor to review any code/implementations. Also, you are strongly encouraged to start working on your MP early; do not overestimate your capabilities or underestimate the level of effort you need to invest in the MPs.

**Individual Course Project**

Each student will select an Individual Class Project (ICP) to work over the period of about 8 weeks. The choice will be made among a small set of potential topics previously identified by your instructor. Student-originated suggestions may also be entertained as an exception. For example, doctoral students may be interested in a topic due to their particular research focus. Such suggestions are welcomed, as long as they are reviewed and approved by your instructor before any project work commences. Overall, the role of the ICP is to provide the student the opportunity to independently study material that is beyond the scope of the lectures and apply her/his knowledge/skills learnt in the course to an application domain, potentially, of her/his interest.

Work on ICPs typically will consist of surveying the literature and implementing particular PR-related algorithms, describing a specific application domain, gathering and processing relevant data to be used in modeling, explaining the experimental setting in use, reporting on experimental results and, finally, draw pertinent conclusions. Each ICP will have as deliverables (i) a project report in a predetermined format of a conference paper, (ii) presentation slides and (iii) a small demo. Deadline(s) to submit ICP deliverables will be announced in time and have to be strictly observed; no late submissions will be accepted.

Presentations of projects will be held during the last week of classes. Each student will be presenting for 20 minutes in front of the class. If you would like to invite someone to attend your presentation, please feel free to do so, as long as your guest will not be disruptive to the presentation process. Finally, more specific details on the ICPs, such as topics, expectations and assessment approach, will be provided in due time.

**Oral Exam**

At the end of the term, during the Study Days before the final exam period, we will hold oral examinations. Each student will be examined on an individual basis in my office for 20-25 minutes. The examination is rather informal and will consist of theory questions related to lecture material taught in class, as well as material you have turned in for the MPs or ICPs. At the end of each lecture and upon request of the class, you will be provided with a few questions that would be considered typical of an oral exam on the lecture matter under discussion.

**Online Management of Course**

FIT’s online course management system, ANGEL (http://courses.fit.edu), will be utilized to manage a couple of important course components. First of all, ANGEL will be used as a repository of recourse materials, such as lecture notes. Furthermore, all deliverables connected to MPs and ICPs must be submitted via ANGEL’s designated drop-boxes; submissions via email will not be taken into account. If you are a new FIT student, please ask Tech Support to provide you with login credentials for ANGEL. Finally, do not use ANGEL’s internal email system to communicate with me, as I am not monitoring my ANGEL email.
**Student-Instructor Interaction**
Students are strongly encouraged to interact with their instructor on a one-on-one basis for clarifications, questions, guidance, etc. as well as regarding their work on their deliverables.

**Make-Up Policy**
No opportunity will be granted for make-up MPs and ICPs, unless provable, legitimate reasons are offered. By *legitimate* reasons, we mean circumstances that were clearly beyond the control of the student and that prohibited him/her from completing the particular assignment. By *provable*, it is meant that the student can produce proof/documentation that supports the claimed circumstances. Therefore, it is the student’s responsibility to turn in complete assignments on time.

Moreover, please note that, due to logistical reasons, as well as reasons of fairness, there will be no additional opportunity (like extra credit assignments, etc.) to improve upon the attained total score for the course. In addition, a letter grade of I (“incomplete”) is reserved only for those individuals that qualify under the 2 criteria stated in FIT’s Student Handbook.

**Disclaimer**
Every effort will be made to follow this syllabus as close as possible throughout the course’s duration. However, it is up to the instructor’s discretion to introduce changes, whenever deemed necessary. In this case, you will be provided with notice as early as circumstances allow for.
Tentative Course Schedule

Below you will find a tentative schedule for the course.

Week #1
Course Introduction – Vector/Matrix Calculus
Elements of Unconstrained Optimization

Week #2
Elements of Unconstrained Optimization
Elements of Constrained Optimization

Week #3
Elements of Constrained Optimization
Basic Numerical Optimization Techniques

Week #4
Rudimentary Statistical Inference: Maximum Likelihood & Bayesian Estimation

Week #5
Ridge Regression
Gaussian Processes for Regression

Week #6
Gaussian Processes for Regression
MP-I announced

Week #7
Multi-Layer Perceptrons
MP-I due

Week #8
Multi-Layer Perceptrons
MP-II announced

Week #9
Spring Break (No lectures)
MP-II due

Week #10
Kernels & Reproducing Kernel Hilbert Spaces

Week #11
Kernel Ridge Regression
Week #12
Support Vector Regression & Support Vector Machines
MP-III announced

Week #13
Introduction to Deep Learning
MP-II due

Week #14
Sum-Product Networks

Week #15
Sum-Product Networks

Week #16
ICP Presentations

Other Important Dates
March 14th 2014 – Last day to withdraw w/ a letter grade of W
April 24th & 25th 2014 – Oral Exams
May 3rd 2014 – Grades reported to the Registrar’s Office