**EEE 405: Machine Learning Basics with Deployment to FPGAs**

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**Course Catalogue Description**

Machine learning has become an important element in many areas of engineering. The goal of this course is to provide a good mathematical background and give experience with using key packages and methods in Machine Learning (ML). FPGAs provide an efficient method to deploy machine leaning models.

**Enrollment Requirements**

Prerequisites: EEE 203, PHY 131, MAT 342/343; co-requisite: EEE 350. Some programming language background, Java, C, C++, Python, or MatLab Verilog/System Verilog background will be helpful but not required; that content will be provided. Students will not be required to purchase an FPGA; units are available.

**Course Overview *(Optional)***Understanding of basic Machine Learning development, mathematics and methodology and code development for these methods including: Perceptron, Logistic Regression, Margin Perceptron/SVM, K-Nearest Neighbors, Decision Tree, Random Forest, Deep Learning, CNN, LGBM, RNN/LSTM. In addition, topics Natural Language Processing, Training on an FPGA, Deployment of Models to an FPGA, CUDA, Encoders, OpenCV, Reinforced Learning are covered. Optimization topics include GD, SD, Newton’s method, Conjugate Gradients, BFGS.

**Course Objectives**Understanding of basic Machine Learning development, mathematics and methodology and code development. Understanding and working knowledge of basic ML methods including: Perceptron, Logistic Regression, Margin Perceptron/SVM, Naïve Bayes, K-Nearest Neighbors, Decision Tree, Random Forest, Deep Learning, CNN, LGBM, RNN/LSTM, and Reinforced Learning. Understanding of unsupervised methods such as clustering using K-Means. In addition, develop a working knowledge of Natural Language Processing, and a general knowledge of the capabilities of CUDA, and OpenCV. Understanding and of methods for training a ML mocel on an FPGA and deployment of ML models to an FPGA including general understanding of how this is done in Verilog. Working understanding of optimization topics including GD, SD, Newton’s method, and a general understanding of Conjugate Gradients, and BFGS. Understanding of the use of Principle Component Analysis.

**Expected Learning Outcomes**Students will understand the basic methods and be able to develop and implement simple Machine learning algorithms from scratch or using algorithms provided in common libraries, understand and be able use deep learning algorithms and libraries such as PyTorch which is one the leading deep learning frameworks. Understand and ability to code and demonstrate basic optimization schemes used in ML. Then these models will be implemented in Verilog on FPGAs.

**Assignments/Exams**

Homeworks (15%) on Least squares, Perceptron, Logistic Regression, Naïve Bayes, Convolutional Neural Networks (CNN), PyTorch, and RNN/LSTM. Each of these has some theory, mathematics, and coding. These are evenly spaced at 2-week intervals. The last assignment is only for graduate students.

Project (25%) where the students work in groups of 4 on a ML project of their choosing. They make a presentation and report at the end of the semester. Report and presentation formats are given instead of dictating length and they are graded in part on clarity and organization. Graded on presentation and report quality, clarity, organization, grammar and spelling as well as difficulty of problem and outcome of the project. The presentations are in the last week of class, the report is due on the last day of class.

Quizzes 4 of evenly distributed throughout semester, (15%) students work through problems like they might see on exams later. The objective of these open book quizzes is to enforce topics as we go along in the course.

MidTerm (8th week) (20%) Material up to that point in the course focusing on mathematical aspects of methods and optimization. The exam also covers understanding of ML methods and concepts.

Final exam (finals week) (25%) Comprehensive exam on mathematical aspects of methods and optimization and ML methods and concepts. Exams measure the general and specific understanding of these topics in course objectives and learning outcomes.

Late assignments are accepted without penalty until a solution is provided. Late work is accepted with a 75% penalty after the solution is provided. There is a hard stop deadline at the beginning of the last week of class after which no late work is accepted so that everything can be graded by the grade reporting deadline.

**Readings, Activities, Special Materials**

**Required: Machine Learning Refined J. Watt (Cambridge University Press 2016) second edition**

**Recommended:** Python Machine Learning (S. Raschka Packt publishing 2017)

**Lecture PDFs**

**Optional software, Anaconda** <https://www.anaconda.com/products/individual>, and Modelsim and Quartus <https://fpgasoftware.intel.com/?edition=lite>

*No lab equipment is required, FPGAs are available in GWC379.*

**Grade Policies**

Your grade will be determined based on the following grading schema. Depending on the class performance and difficulty of the homework, projects and exams, I may curve the grade up, but will never curve down.

Grade Percentage

A+ 100% - 97%

A <97-94%

A- <94-90%

B+ <90-87%

B <87-84%

B- <84-80%

C+ <80-77%

C <77-70%

D <70-60%

E <60%

Grades on each homework assignment are determined by the portion of the assignment completed and attempted and then points are subtracted for errors impacting the outcome. Following directions is important, and points may be taken off. Each homework problem is worth 10 points. Half of the point value is awarded for attempting each problem, the other half are split up evenly among the deliverables for that problem.

**Schedule or Itinerary**

MWF class face to face

Week 1 Introduction, History, Feature Scaling, Least Squares

Week 2 Perceptron and basic of Optimization

Homework 1 Least Squares

Quiz 1

Week 3 In depth lecture on Optimization methods and variants, and intro to Kernels

Week 4 Advanced Optimization methods and Logistic Regression

Homework 2 Perceptron

Quiz 2

Week 5 Margin Perception and Support Vector Machine, Multi Class, OVA

Week 6 ANN, Naïve Bayes, Decision Trees, and Random Forest

Homework 3 (Gradient Descents and Variants)

Week 7 Unsupervised Learning and comparison of ML Methods

Homework 4 (Logistic Regression)

Quiz 3

Week 8 Deep Learning and introduction to PyTorch

Week 9 Convolution Neural Networks and continued PyTorh

Homework 5 Naïve Bayes

MidTerm covering material to this point in the class

Week 10 Introduction the Research Computing Cluster Resource, Description of the Project assignment

Week 11 Natural Language Processing, and as a separate topic LGBM

Week 12 Verilog and deployment of models to FPGAs with examples

Quiz 4

Week 13 Continued from week 12, introduction to RNN and LSTM

Week 14 RNN and LSTM with examples, and intro to Reinforced Learning

Week 15 Review and Project 5-7 min presentations from teams

Final during Finals Week

**Absence Policy**

Follow the appropriate University policies to request an[accommodation for religious practices. Links to an external site. Links to an external site.](http://www.asu.edu/aad/manuals/acd/acd304-04.html) Or to accommodate a missed assignment[due to University-sanctioned activities .Links to an external site.Links to an external site.](http://www.asu.edu/aad/manuals/acd/acd304-02.html)

In case of a University approved/excused absence student can arrange to take a quiz or exam in advance. If this cannot be done work may be exempted. In the event of illness or emergency a makeup can be arranged with proper documentation. Homeworks are only penalized if submitted after the solution has been published, and the penalty is 75%, because the solution has been published. Attendance in class is strongly encouraged.

**Expected Classroom Behavior**

Students are not allowed to use cell phones during class. In accordance with [ACD 304-06 Commercial Note Taking ServicesLinks to an external site.Links to an external site.](http://www.asu.edu/aad/manuals/acd/acd304-06.html), written permission must be secured from the official instructor of the class in order to sell the instructor's oral communication in the form of notes.  Notes must have the notetaker's name as well as the instructor's name, the course number, and the date.

**Policy against threatening behavior, per the Student Services Manual, SSM 104–02**

Students, faculty, staff, and other individuals do not have an unqualified right of access to university grounds, property, or services. Interfering with the peaceful conduct of university-related business or activities or remaining on campus grounds after a request to leave may be considered a crime. All incidents and allegations of violent or threatening conduct by an ASU student (whether on- or off-campus) must be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students.

**Accommodation for Religious Practices**

The university community should, in all its activities, be sensitive to the religious practices of the various religious faiths represented in its student body and employees. Faculty are asked to recognize the obligations of their students who may be participating in the observance of religious holidays. Students should notify faculty at the beginning of the semester about the need to be absent from class due to religious observances. For more information, visit http://www.asu.edu/aad/manuals/acd/acd304-04.html

**Missed Classes Due to University-Sanctioned Activities**

Students who participate in university-sanctioned activities that require classes to be missed, shall be given opportunities to make up examinations and other graded in-class work. Normally, the made-up work will be due on the class day after the immediately after the absence. Absence from class or examinations due to university-sanctioned activities does not relieve students from responsibility for any part of the course work required during the period of the absence. For more information, visit [http://www.asu.edu/aad/manuals/acd/acd304-02.html](about:blank)

**Academic Integrity/Anti-Plagiarism Policy**

Plagiarism of any kind will not be tolerated. Students must take the exams independently without assistance from other students. Students may not submit papers written by persons other than themselves. Students must submit original work for this course and may not submit papers previously submitted to (an)other class(es). The ASU student academic integrity policy lists violations in detail. These violations fall into five broad areas that include but are not limited to: (1) Cheating on an academic evaluation or assignment; (2) Plagiarizing; (3) Academic deceit, such as fabricating data or information; (4) Aiding academic integrity policy violations and inappropriately collaborating; (5) Falsifying academic records. See https://provost.asu.edu/academic-integrity

**Disruptive, Threatening, or Violent Behavior**

In the classroom and out, students are required to conduct themselves in a manner that promotes an environment that is safe and conducive to learning and conducting other university-related business. All incidents and allegations of violent or threatening conduct by an ASU student will be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students. Such incidents will be dealt with in accordance with the policies and procedures described in Section 104-02 of the Student Services Manual, available at [http://www.asu.edu/aad/manuals/ssm/ssm104-02.html](about:blank)

**Disability Accommodations**

If you are a student with a disability and have need of assistance or special accommodations, contact Student Accessibility and Inclusive Learning Services (SAILS) https://eoss.asu.edu/accessibility. Students requesting accommodations for a disability must register with SAILS, and must submit appropriate documentation to the instructor from SAILS. For more information, please review the policy at http://www.asu.edu/aad/manuals/ssm/index.html#700

**Copyright**

Students must refrain from uploading to any course shell, discussion board, or website used by the course instructor or other course forum, material that is not the student's original work, unless the students first comply with all applicable copyright laws; faculty members reserve the right to delete materials on the grounds of suspected copyright infringement. For more information, see the Computer, Internet, & Electronic Communications Policy at http://www.asu.edu/aad/manuals/acd/acd125.html

**Prohibition Against Discrimination, Harassment, and Retaliation**

Title IX is a federal law that provides that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed on the basis of sex can seek support, including counseling and academic support, from the university. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at http://sexualviolenceprevention.asu.edu/faqs

As a mandated reporter, I am obligated to report any information I become aware of regarding alleged acts of sexual discrimination, including sexual violence and dating violence. ASU Counseling Services, https://eoss.asu.edu/counseling, is available if you wish to discuss any concerns confidentially and privately.