Title: Machine Intelligence on Embedded Systems (520.440/640)

Instructors:

Andreas G Andreou,

Dan Mendat

Credits: 3

Lecture Hours: 1

Lab Hours: 2

Required or Recommended Text:

Tiny ML by Peter Warden and Daniel Situnayake

Dive into Deep Learning by Zhang et. al.

Preferred Room or Instructional Materials Needed:

N/A

Registration Restrictions:

None

Designation Code (if UG):

Does it require Lab Safety Intro

N/A

Is it writing intensive (if UG): Yes

Will S/U be accepted (if UG): No

How many sections do you need? 1

Enrollment Limit: 20

Preferred Class Time and Day: Tuesday 1.30 to 4.15

Does this class require your approval to enroll? Yes

Final Exam, Yes or No: No

Pre-reqs. or Co-Reqs. (if UG): ECE 520.412/612: Machine Learning for Signal Processing, ECE 520.409/609 Machine Intelligence, CS 601.475/675: Machine Learning

Course Description:

The second wave of AI is about statistical learning of low dimensional structures from high dimensional data. Inference is done using multilayer, data transforming networks using fixed point arithmetic with parameters that have limited precision known as Deep Neural Networks. In this course students will learn about Machine Learning and AI on embedded systems that have limited computational, storage and communication resources. Students are expected to be familiar with linear algebra and Python as well as some familiarity with typical ML frameworks (TensorFlow, Keras etc.). A first course in ML is strongly advised. At the end of the course, students will apply their newly acquired knowledge to complete a final project with real world data for machine perception and cognition.

Course Topics:

* Historical perspective on hardware AI inference and deep Artificial Neural Networks (ANNs) or in short Deep Neural Networks (DNN) and deep learning.
* Classes of embedded devices (GPU based NVIDIA Jetson Nano, TPU based EdgeTPU, Arduino class (ARM Cortex and RISC-V based).
* Computer architectures for machine intelligence (GPU, TPU, hardware accelerators).
* Why machine intelligence on embedded devices; computational, energy, memory, and communication challenges.
* Algorithmic tradeoffs in DNNs (precision of computation, weight quantization, network pruning, learning using finite precision arithmetic).
* Exact and approximate Bayesian inference in embedded architectures, MCMC on embedded systems.
* Machine intelligence using reconfigurable architectures and Field Programmable Gate Arrays and optimization of resource allocation using architecture exploration frameworks.
* Neuromorphic embedded machine intelligence systems architectures (IBM TrueNorth, Intel Loihi).
* Benchmarking applications and devices.
* Applications in speech, health, and autonomous robots and drones.

**This course will address the following ABET Criterion 3 Student Outcomes:**

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

(3) an ability to communicate effectively with a range of audiences

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

(6) an ability to develop and conduct appropriate experimentation, analyze, and interpret data, and use engineering judgment to draw conclusions

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

**Course Expectations & Grading**

* There will be homework problems that will involve reading critically reviewing and reproducing results from published papers (15%).
* Lab work and mini-Projects (40%)
* Working in small groups, students will work towards a final project on ML and AI for perception and cognition. The work and results for the final project will be submitted in a journal paper format (30%)
* 15 minutes final project presentation class (10%)
* Active participation (5%)

**Assignments & Readings**

These will be posted on the MSFT Teams site for this course.

**Ethics**

The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery, and falsification, lying, facilitating academic dishonesty, and unfair competition. Report any violations you witness to the instructor.

You can find more information about university misconduct policies on the web at these sites:

* For undergraduates: <http://e-catalog.jhu.edu/undergrad-students/student-life-policies/>
* For graduate students: <http://e-catalog.jhu.edu/grad-students/graduate-specific-policies/>

**Personal Wellbeing**

* If you are sick, with an illness that may be contagious, notify me by email but do not come to class. Rather, visit the Health and Wellness: 1 East 31Street, 410-516-8270. See also <http://studentaffairs.jhu.edu/student-life/support-and-assistance/absences-from-class/illness-note-policy/>
* All students with disabilities who require accommodations for this course should contact me at their earliest convenience to discuss their specific needs. If you have a documented disability, you must be registered with the JHU Office for Student Disability Services (385 Garland Hall; 410-516-4720; <http://web.jhu.edu/disabilities/>) to receive accommodations.
* If you are struggling with anxiety, stress, depression, or other mental health related concerns, please consider visiting the JHU Counseling Center. If you are concerned about a friend, please encourage that person to seek out our services. The Counseling Center is located at 3003 North Charles Street in Suite S-200 and can be reached at 410-516-8278 and online at <http://studentaffairs.jhu.edu/counselingcenter/>

**Classroom Climate**

I am committed to creating a classroom environment that values the diversity of experiences and perspectives that all students bring. Everyone here has the right to be treated with dignity and respect. I believe fostering an inclusive climate is important because research and my experience show that students who interact with peers who are different from themselves learn new things and experience tangible educational outcomes. Please join me in creating a welcoming and vibrant classroom climate. Note that you should expect to be challenged intellectually by me, the TAs, and your peers, and at times this may feel uncomfortable. Indeed, it can be helpful to be pushed sometimes to learn and grow. But at no time in this learning process should someone be singled out or treated unequally based on any seen or unseen part of their identity.  
  
If you ever have concerns in this course about harassment, discrimination, or any unequal treatment, or if you seek accommodations or resources, I invite you to share directly with me or the TAs. I promise that we will take your communication seriously and to seek mutually acceptable resolutions and accommodations. Reporting will never impact your course grade. You may also share concerns with the ECE department Head, Prof. Pedro Irazoqui ( [pip@jhu.edu](mailto:pip@jhu.edu) ), the Director of Undergraduate Studies Prof. Susanna Thon ([susanna.thon@jhu.edu](mailto:susanna.thon@jhu.edu) ), the Assistant Dean for Diversity and Inclusion (Darlene Saporu, [dsaporu@jhu.edu](mailto:dsaporu@jhu.edu)), or the Office of Institutional Equity ([oie@jhu.edu](mailto:oie@jhu.edu)).  In handling reports, people will protect your privacy as much as possible, but faculty and staff are required to officially report information for some cases (e.g., sexual harassment).