ECE MS Program in Electrical and Computer Engineering

Spring 2022 EC 500 - 700 Course Offerings

ENG EC 500 A1 Special Topics in ECE: Optimization for Machine Learning **Prof Cutkosky**

Efficient algorithms to train large models on large datasets have been critical to the recent successes in machine learning and deep learning. This course will introduce students to both the theoretical principles behind such algorithms as well as practical implementation considerations. Topics include convergence properties of first-order optimization techniques such as stochastic gradient descent, adaptive learning rate schemes, and momentum. Particular focus will be given to the stochastic optimization problems with non-convex loss surfaces typically present in modern deep learning problems. Additional topics may include second-order methods and variance reduction. After completing this course, students should be able to read, understand, and implement cutting-edge optimization algorithms used in machine learning. 4cr.

ENG EC 500 L6 Special Topics in ECE: Plasma Engineering & Technology **Prof Lee**

Electrodynamics is the background knowledge for the "Plasma Engineering and Technologies" course. Hence, Maxwell equations and some related time-varying electromagnetic phenomena in a medium will be reviewed. However, plasma as a quasi-neutral medium with charged particles behaves differently from a magnetic material with a permeability, while it is still appropriate to derive a plasma dielectric constant. These distinctive features will be elaborated in this course at the beginning. 4cr

ENG EC 503 A1 Introduction to Learning from Data **Prof Orabona**

This is an introductory course in statistical learning covering the basic theory, algorithms, and applications. This course will focus on the following major classes of supervised and unsupervised learning problems: classification, regression, density estimation, clustering, and dimensionality reduction. Generative and discriminative data models and associated learning algorithms of parametric and non-parametric varieties will be studied within both frequentist and Bayesian settings in a unified way. A variety of contemporary applications will be explored through homework assignments and a project. 4 cr

ENG EC 504 A1 Advanced Data Structures **Prof Castanon**

Review of basic data structures and Java syntax. Data abstraction and object-oriented design in the context of high-level languages and databases. Design implementation from the perspective of data structure efficiency and distributed control. Tailoring priority queues, balanced search trees, and graph algorithms to real-world problems, such as network routing, database management, and transaction processing. 4 cr

ENG EC 512 A1 Enterprise Client-Server Software Systems Design **Prof Skinner**

Examination of past, current, and emerging technologies. Client side technologies including DHTML, CSS, scripting, ActiveX, RSS, and proprietary applications. Legacy server side technologies including CGI, ISAPL, and active server pages. Current and emerging server technologies including ASP.NET 2, XML/SOAP web services, wireless and handheld access, WAP/WML, SQL databases, streaming media, CMS, and middleware. Design and implementation of solutions involving database connectivity, session state, security requirements, SSL, and authentication of clients. Small-team projects involving design through implementation. 4 cr

ENG EC 513 A1 Computer Architecture **Prof Joshi**

Computer architecture and design. Topics include computer arithmetic and ALU design; performance evaluation; instruction set design; CPU design, including pipelining, branch prediction, and speculative execution; memory hierarchy, including cache basics, cache design for performance, and virtual memory support; I/O, including devices, interfaces, specification, and modeling. Examples from high-end microprocessors and embedded systems. 4 cr

ENG EC 520 A1 Digital Image Processing and Communication **Prof Konrad**

Review of signals and systems in multiple dimensions. Sampling of still images. Quantization of image intensities. Human visual system. Image color spaces. Image models and transformations. Image enhancement and restoration. Image analysis. Image compression fundamentals. Image compression standards (JPEG, JPEG-2000). Homework will include MATLAB assignments. 4 cr

ENG EC 522 A1 Computational Optical Imaging **Prof Tian**

Recent years have seen the growth of computational optical imaging - optical imaging systems that tightly integrate hardware and computation. The results are the emergence of many new imaging capabilities, such as 3D, super resolution, and extended depth of field. Computational optical imaging systems have a wide range of applications in consumer photography, scientific and biomedical imaging, microscopy, defense, security and remote sensing. This course looks at this new design approach as it is applied to modern optical imaging, with a focus on the tools and techniques at the convergence of physical optical modeling, and signal processing. 4 cr

ENG EC 523 A1 Deep Learning **Prof Kulis & Prof Saenko**

Mathematical and machine learning background for deep learning. Feed-forward networks. Backpropagation. Training strategies for deep networks. Convolutional networks. Recurrent neural networks. Deep reinforcement learning. Deep unsupervised learning. Exposure to Tensorflow and other modern programming tools. Other recent topics, time permitting. Same as CAS CS 523 and ENG SE 523. Students may not receive credit for both. 4 cr

ENG EC 526 A1 Parallel Programing for High Performance Computing **Prof Brower**

The explosive advance in High Performance Computing (HPC) and advances in Big Data/Machine Learning and Cloud Computing now provides a fundamental tool in all scientific, engineering, and industrial advances. Software is massively parallel so parallel algorithms and distributed data structures are required. Examples will be drawn from FFTs, Dense and Sparse Linear Algebra, Structured and unstructured grids. Techniques will be drawn from real applications to simple physical systems using Multigrid Solvers, Molecular Dynamics, Monte Carlo Sampling and Finite Elements with a final student project and team presentation to explore one example in more detail. Coding exercises will be in C++ in the UNIX environment with parallelization using MPI message passing, OpenMP threads and QUDA for GPUs. Rapid prototypes and graphics may use scripting in Python or Mathematica. 4 cr

ENG EC 527 A1 High Performance Programming with Multicore and GPUs **Prof Herbordt**

Considers theory and practice of hardware-aware programming. Key theme is obtaining a significant fraction of potential performance through knowledge of the underlying computing platform and how the platform interacts with programs. Studies architecture of, and programming methods for, contemporary high-performance processors. These include complex processor cores, multicore processors, and graphics processors. Laboratory component includes use and evaluation of programming methods on these processors through applications such as matrix operations and the Fast Fourier Transform. 4 cr

ENG EC 530 A1 Software Engineering Principles **Prof Alshaykh**

This class was designed to bring the basic concepts of software engineering together and practice them in real life examples. We will focus on studying different concepts that the students have taken in different classes or were not exposed to that are necessary for their careers. Examples include continuous build and integration, Modular Design, API Design, Rest APIs, Application frameworks, Containers, and Multi-. The class follows a flipped classroom model. Outside of the classroom, the students: study concepts, read assigned papers and tutorials; work on homework, which is equivalent to what other classes consider projects. 4 cr

ENG EC 534 A1 Discrete Stochastic Models **Prof Levitin**

Markov chains, Chapman-Kolmogorov equation. Classification of states, limiting probabilities, Poisson process and its generalization, continuous-time Markov chains, queuing theory, reliability theory. 4 cr

ENG EC 544 A1 Networking the Physical World **Prof Montazam**

Considers the evolution of embedded network sensing systems with the introduction of wireless network connectivity. Key themes are computing optimized for resource constrained (cost, energy, memory and storage space) applications and sensing interfaces to connect to the physical world. Studies current technology for networked embedded network sensors including protocol standards. A laboratory component of the course introduces students to the unique characteristics of distributed sensor motes including programming, reliable communication, sensing modalities, calibration, and application development. Same as ENG ME 544 and ENG SE 544. Students may not receive credits for both. 4 cr

ENG EC 552 A1 Computational Synthetic Biology for Engineers **Prof Densmore**

This course presents the field of computational synthetic biology through the lens of four distinct activities: Specification, Design, Assembly, and Test. Engineering students of all backgrounds are provided an introduction to synthetic biology and then exposed to core challenges and approaches in each of the four areas. Same as ENG BE 552. Students may not receive credit for both. 4 cr

ENG EC 556 A1 Optical Spectroscopic Imaging **Prof Cheng**

This introductory graduate-level course aims to teach students how electromagnetic waves and various forms of molecular spectroscopy can be used to study a complex biological system by pushing the physical limits on engineering system design. The course will cover fundamental concepts of optical spectroscopy and microscopy, followed by specific topics covering fluorescence-based, absorption-based, and scattering-based spectroscopic imaging. In addition, this course will provide in-depth discussions of linear and nonlinear spectroscopic imaging in the aspects of theory, instrumentation, image data analysis and enabling applications. Students will learn how to give a concise and informative presentation of a recent literature to the class. Students will be able to challenge their creativity in designing advanced imaging instrument of data analysis methods as part of their course assignments. The students will learn how to write and present a convincing proposal for the required final project to be designed by interdisciplinary teams formed among the students. Same as ENG BE 556. Students may not receive credit for both. 4 cr

ENG EC 568 A1 Optical Fibers and WaveGuides **Prof Popovic**

Whether it be the FIOS? internet connection at our homes, or fiber lasers powerful enough to cut metals (many automobile chassis are now made using fiber lasers), or the ability to perform endoscopic surgery and imaging, or doing frequency metrology with super-continuum sources (the basis of a few recent Nobel prizes)... the optical fiber has played a central, often dominant, role in many applications that impact the way we live. The main function of an optical fiber is to carry an electromagnetic (in the optical frequency) pulse over distances ranging from meters to greater than ten thousand kilometers without distortions. Fibers can also become smart light-pipes when they are intentionally designed to alter, temporally shape or amplify light pulses. Moreover, new developments in this field such as photonic bandgap fibers, fiber nanowires and higher-order mode fibers, are opening up new directions in science and technology. This course will introduce the optical fiber waveguide and its theory of operation. Specifically, the design and impact of the two most important properties in optical fibers -- dispersion and nonlinearity -- that govern the evolution of light in optical fibers, will be covered in detail. The latter part of the course will describe new fibers and fiber-structures that are active research topics today. One lecture of the course will include a tour of an actual, industrial-scale fiber fabrication facility. 4 cr

ENG EC 570 A1 Lasers and Applications **Prof Sander**

Review of wave optics. Gaussian, Hermite-Gaussian, Laguerre-Gaussian, and Bessel optical beams. Planar- and spherical-mirror resonators; micro resonators. Photons and photon streams. Energy levels; absorption, spontaneous emission, and simulated emission. Thermal and scattered light. Laser amplification and gain saturation. Laser oscillation. Common lasers and introduction to pulsed lasers. Photon interactions in semiconductors. LEDs, laser diodes, quantum-confined lasers, and micro cavity lasers. Introduction to photon detectors. Laboratory experiments: beam optics; longitudinal laser modes; laser-diode output characteristics. 4 cr

ENG EC 575 A1 Semiconductor Devices **Prof Sharifzadeh**

Fundamentals of carrier generation, transport, recombination, and storage in semiconductors. Physical principles of operation of the PN junction, metal-semiconductor contact, bipolar junction transistor, MOS capacitor, MOSFET (Metal Oxide Semiconductor Field Effect Transistor), JFET (Junction Field Effect Transistor), and bipolar junction transistor. Develops physical principles and models that are useful in the analysis and design of integrated circuits. 4 cr

ENG EC 710 A1 Dynamic Programming and Stochastic Control **Prof Caramanis**

Introduction to sequential decision making via dynamic programming. The principle of optimality as a unified approach to optimal control of dynamic systems and Markovian decision problems. Applications from control theory and operation research include linear-quadratic problems, the discrete Kalman Filter, inventory control, network, investment, and resource allocation models. Adaptive control and numerical solutions through successive approximation and policy iteration, suboptimal control, and neural network applications involving functional approximations and learning. Same as ENG ME 710 and ENG SE 710. Students may not receive credits for both. 4 cr

ENG EC 719 A1 Statistical Learning Theory **Prof Saligrama**

Classical and contemporary theories of machine learning. Topics/emphasis may change based on instructor preference in different years. A project involving computer implementation of a learning or inference algorithm accompanied by or in support of theoretical analysis is required. 4 cr

ENG EC 724 A1 Advanced Optimization Theory & Methods **Prof Olshevsky**

Introduces advanced optimization techniques. Emphasis on nonlinear optimization and recent developments in the field. Topics include: unconstrained optimization methods such as gradient, conjugate direction, Newton and quasi-Newton methods; constrained optimization methods such as gradient projection, feasible directions, barrier and interior point methods; duality theory and methods; convex duality; and introduction to other advanced topics such as semi-definite programming, incremental gradient methods and stochastic approximation algorithms. Applications drawn from control, production and capacity planning, resource allocation, communication and neural network problems. Same as ENG ME 724 and ENG SE 724. Students may not receive credits for both. 4 cr

ENG EC 733 A1 Discrete Event & Hybrid Systems **Prof Cassandras**

Review of system theory fundamentals distinguishing between time-driven and event-driven dynamics. Modeling of Discrete Event and Hybrid Systems: Automata, Hybrid Automata, Petri Nets, basic queueing models, and stochastic flow models. Monte Carlo computer simulation: basic structure and output analysis. Analysis, control and optimization techniques based on Markov Decision Process theory with applications to scheduling, resource allocation and games of chance. Perturbation Analysis and Rapid Learning methods with applications to communication networks, manufacturing systems, and command-control. Same as ENG ME 733 and ENG SE 733. Students may not receive credits for both. 4 cr

ENG EC 763 A1 Nonlinear and Ultrafast Optics **Prof Ramachandran**

Tensor theory of linear anisotropic optical media. Second- and third-order nonlinear optics. Three-wave mixing and parametric interaction devices, including second-harmonic generation and parametric amplifiers and oscillators. Four-wave mixing and phase conjugation optics. Electro-optics and photo-refractive optics. Generation, compression, and detection of ultra-short optical pulses. Femtosecond optics. Pulse propagation in dispersive linear media. Optical solitons. 4 cr

ENG EC 774 A1 Semiconductor Quantum Structures and Photonic Devices **Prof Paiella**

Optical properties of semiconductors: interband optical transitions; excitons. Low-dimensional structures: quantum wells, superlattices, quantum wires, quantum dots, and their optical properties; intersubband transitions. Lasers: double-heterojunction, quantum-well, quantum-dot, and quantum-cascade lasers; high-speed laser dynamics. Electro-optical properties of bulk and low-dimensional semiconductors; electroabsorption modulators. Detectors: photoconductors and photodiodes; quantum-well infrared photodetectors. Same as ENG MS 774. Students may not receive credit for both. 4 cr

ENG EC 777 A1 Nanostructure Optics **Prof Dal Negro**

Discussion of the fundamental physical aspects and device applications of optical fields confined and generated in nanoscale environments. Review of classical electrodynamics and angular spectrum representation of optical fields, classical and quantum models for light-matter interaction, light emission from semiconductor quantum dots and wires, surface-plasmon polaritons and sub-wavelength light transport/localization in metal nanostructures, slot waveguide structures, surface-enhanced Raman scattering (SERS) and SERS-based sensors, light scattering in complex photonic structures such as: metal-dielectric photonic crystals, fractal structrures, random lasers. 4 cr