

## AUTONOMY AND ROBOTICS

<https://www.uvm.edu/cems/ebe>

### OVERVIEW

Autonomy and robotics are reshaping the modern world. From advanced manufacturing and intelligent transportation systems to robotic surgery, precision agriculture, energy infrastructure, and next-generation defense technologies, these rapidly evolving fields are driving innovation, strengthening economies, and improving quality of life across industries.

Autonomous systems combine tools and concepts from control systems, signal processing, computer programming, and artificial intelligence to enable engineered systems to perceive, decide, and act independently. Robotics integrates mechanical design, actuator and sensor systems, mathematical modeling, and embedded programming to create machines capable of performing complex, real-world tasks. Together, autonomy and robotics form the technological backbone of many of today's most transformative advancements.

The 12 credit Certificate of Graduate Study in Autonomy and Robotics (CGS-AR) provides a rigorous foundation in autonomous systems, robotics, and artificial intelligence. Designed to formally recognize advanced training in these areas, the program equips students with the interdisciplinary knowledge and technical skills required to lead in this rapidly growing field. While particularly well-suited for graduate students in Electrical Engineering, Mechanical Engineering, and Computer Science, the certificate is open to students across related disciplines seeking expertise at the forefront of intelligent systems.

### DEGREES

Autonomy and Robotics CGS

### FACULTY

**Duffaut Espinosa, Luis;** Assistant Professor, Department of Electrical and Biomedical Engineering; PHD, Old Dominion University

**Ossareh, Hamid-Reza;** Associate Professor, Department of Electrical and Biomedical Engineering, PHD; University of Michigan Ann Arbor

**Treers, Laura;** Assistant Professor, Department of Mechanical Engineering; PHD, University of California

### Courses

#### **EE 5310. Power System Analysis. 3 Credits.**

Transmission system modeling, operations and planning and energy policy are discussed to prepare students for the electricity and energy industry and power/energy systems research. Topics include: transmission line models, generator capability curves, transformer modeling and control, per-unit conversion, power flow calculations and software, smart grid. Prerequisite: Graduate Electrical Engineering student or Instructor permission.

#### **EE 5410. Digital VLSI Circuit Design. 0 or 3 Credits.**

Covers the techniques for the design, analysis and layout of digital CMOS circuits and systems. Major topics include MOSFET basics (structure and behavior of a MOSFET, CMOS fabrication, and design rules), detailed analysis of the CMOS circuits and systems (static behavior, ratioed vs. ratioless design), noise margins, computing rise and fall times, delay models, resistance. Prerequisite: Electrical Engineering Graduate student or Instructor permission. Cross-listed with: CMPE 5410.

#### **EE 5430. RF Circuit Design. 3 Credits.**

Design and analysis of radio frequency and microwave circuits. Covers radio frequency and microwave behavior of passive components, various transmission line structures, electromagnetic (EM) wave propagation in dielectric media, reflection coefficient and load impedance, network properties and applications, impedance matching network design, scattering parameters and their usage for RF. Prerequisite: Electrical Engineering Graduate student or Instructor permission.

#### **EE 5440. Gr Semiconductor Materials/Dev. 0 or 4 Credits.**

Covers energy band theory, effective mass, band structure and electronic properties of semiconductors. Transport of electrons and holes in bulk materials and across interfaces. MOSFETs, BJTs, pn junctions, and Schottky barriers. Experimental portion of course will have a laboratory component for electronic measurements of semiconductor devices. Credit not awarded for both EE 5440 and EE 3440. Prerequisite: Graduate student or Instructor permission. Cross-listed with: PHYS 5675.

#### **EE 5460. Microelec. Circuit Fabrication. 0 or 4 Credits.**

Provides a firm knowledge base in modern semiconductor fabrication technology. This technology lies at the heart of all modern computer and communication systems. Analyze and evaluate the unit processes involved in creating semiconductor chips such as photolithography, plasma etch, ion implant and metallization. Explore the current state-of-the-art and demonstrate how these building blocks affect the electrical behavior of semiconductor devices. Prerequisites: Electrical Engineering, Materials Science, Mechanical Engineering, or Physics Graduate student; or Instructor permission. Cross-listed with: PHYS 5165.

**EE 5503. Modern Signal Processing. 3 Credits.**

Covers principles and methods for digital signal processing. The analysis and design of discrete-time systems as signal processing devices is provided in the context of filter design, adaptive processing, compress sensing, and topics on image processing. Topics covered: quantization, reconstruction of signals, z-transform, FIR/IIR, compress sensing, compress sensing processing, intro to images, pixel and region-based classification, and segmentation, among others.

**EE 5540. Real-Time Control Systems. 3 Credits.**

Digital control systems analysis and design. Topics include: difference equations, the Z-transforms, discrete-time transfer functions, state-space models, sampled-data systems, discretization, real-time control, microprocessor implementation, and optimal control. Project-based final. Prerequisite: Electrical Engineering Graduate student or Instructor permission. Cross-listed with: CMPE 5540.

**EE 5550. Autonomy: Control & Planning. 3 Credits.**

Students learn how to make engineered systems autonomous/intelligent. Covers logic and algorithms, real-time estimation and control of dynamical systems, optimization and optimal planning, path planning for robots and autonomous vehicles, basics of artificial intelligence and machine learning, and ethics of automation. Applications include hover flight of quadrotor drones, perception and navigation of robots including robotic arms and self-driving vehicles, and autonomous control of the power grid. Prerequisites: Graduate student or Instructor permission; content knowledge of control systems (such as EE 3515) assumed.

**EE 5560. Autonomy: Robot Perception. 3 Credits.**

Covers principles and methods for perception and localization of autonomous robotic systems within a systematic software framework. The analysis and design of practical methods for the deployment of control, path planning, localization and mapping, and safety of autonomous systems are provided in the context of the Robotic Operative Systems (ROS). Topics covered: introduction to ROS; perception using RGB-D cameras and lidar; Kalman filters for state estimation; SLAM; and path planning of robotic manipulators. Prerequisite: Knowledge of control systems (EE 3515 or similar) is recommended.

**EE 5650. Communication Theory/Practice. 3 Credits.**

Fundamentals of digital communications including PCM, source and channel coding, pulse shaping and modulation; wireless communications, modulation, antennas and link budgets; application of probability; related laboratory experience. Prerequisite: Graduate standing or Instructor permission.

**EE 5810. Digital Computer Design. 3 Credits.**

To gain a solid understanding of digital computer operating mechanisms and reconfigurable computing, and advance into hands-on experiences to design and debug digital computer system and embedded system. Field programmable gate arrays (FPGAs) will be utilized as the development platform. Prerequisite: Electrical Engineering Graduate student, Computer Science Graduate student, or Instructor permission. Cross-listed with: CMPE 5810, CS 5810.

**EE 5915. Advanced Circuit Applications. 3 Credits.**

Analog and digital circuit applications. Topics may include analog to digital converters, operational amplifiers, optical isolators (linear and non-linear), comparators, voltage to frequency converters, analog switches, voltage references, precision dividers, analog multipliers, multiplexers, phase locked loops, power supply monitoring circuits, instrumentation amplifiers and pulse width modulators. Prerequisites: Electrical Engineering Graduate student or Instructor permission; Knowledge of material in EE 3110 Electronics I.

**EE 5990. Special Topics. 0-18 Credits.**

See Schedule of Courses for specific titles.

**EE 5993. Independent Study. 1-18 Credits.**

A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**EE 6110. System Theory. 3 Credits.**

Linear vector spaces. State equations and solution. Diagonalization and Jordan canonical form. Orthogonal and biorthogonal projections. Quadratic forms. Spectral resolution. Principal component analysis, singular value decomposition and Karhunen-Loeve transform. Compressive sensing. Prerequisites: MATH 3230 or MATH 3201; MATH 2544; EE 3150 or ME 2120.

**EE 6120. Stochastic Processes. 3 Credits.**

Probability theory, random variables and stochastic processes. Response of linear systems to random inputs. Applications in engineering. Prerequisites: Graduate student in CEMS or Instructor permission.

**EE 6130. Convex Optimization. 3 Credits.**

Provides advanced mathematical tools to recognize optimization problems from applications, presents rigorous theory of convex optimization with an emphasis on results that are helpful for implementation/computation/modeling, providing student with the experience and understanding necessary to use the tools in their own research work or applications. Prerequisites: Linear Algebra, multi-variable calculus.

**EE 6391. Master's Thesis Research. 1-18 Credits.****EE 6392. Master's Project Research. 1-3 Credits.**

Master's Project.

**EE 6520. Nonlinear System Theory. 3 Credits.**

Basic nonlinear methods including computational and geometrical techniques for analysis of nonlinear systems. Describing function methods and bifurcation and catastrophe theory. Sensitivity and stability considerations. Prerequisite: MATH 3230 or MATH 3201. Pre/Co-requisite: EE 6110 recommended.

**EE 6990. Special Topics. 1-18 Credits.**

Advanced topics of current interest in Electrical Engineering. Prerequisite: Instructor permission.

**EE 6991. Internship. 1-18 Credits.**

On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

**EE 6993. Independent Study. 1-18 Credits.**

A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**EE 6994. Graduate Teaching Practicum. 3 Credits.**

Student service as a teaching assistant, usually in an introductory-level course in the discipline, for which credit is awarded. Offered at department discretion. Students will develop and deliver instructional materials and perform evaluation under the mentorship of a course instructor. Prerequisites: Instructor permission, completion of PhD comprehensive exam.

**EE 6995. Graduate Independent Research. 1-18 Credits.**

Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**EE 7491. Doctoral Dissertation Research. 1-18 Credits.**

Research for the Doctoral Dissertation.

**EE 7990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles.

**EE 7991. Internship. 1-18 Credits.**

On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

**EE 7995. Graduate Independent Research. 1-18 Credits.**

Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.