

## COMPLEX SYSTEMS AND DATA SCIENCE

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

### OVERVIEW

The College of Engineering and Mathematical Sciences provides an educational program in Complex Systems and Data Science (CSDS) that includes education offerings at three levels:

1. A 5-course Graduate Certificate in Complex Systems that may be taken by any graduate student at UVM to augment their degree.
2. An M.S. in CSDS which is a 2-year degree with optional disciplinary tracks, and which UVM undergraduates may initiate through an Accelerated Master's Program.
3. A Ph.D. in CSDS which will allow students to fully develop a deep portfolio of published research, thereby opening the door to high level research positions in, for example, government, industry, or academia.

The educational program naturally complements UVM's undergraduate degree in Data Science but also thematically connects with many fields across the university.

The program's overall goal is to help students become protean data scientists with eminently transferable skills. Students are provided with a broad training in computational and theoretical techniques for (1) describing and understanding complex natural and sociotechnical systems, enabling them to then, as possible, (2) predict, control, manage, and create such systems. Students will be trained in: Industry standard methods of data acquisition, storage, manipulation, and curation; visualization techniques, with a focus on building high quality web-based applications; finding complex patterns and correlations through, for example, machine learning and data mining; powerful ways of hypothesizing, searching for, and extracting explanatory, mechanistic stories underlying complex systems—not just how to use black box techniques; combining the formulation of mechanistic models (e.g., toy physics models) with genetic programming.

### DEGREES

Complex Systems and Data Science AMP

Complex Systems and Data Science CGS

Complex Systems and Data Science M.S.

Complex Systems and Data Science Ph.D.

### FACULTY

**Allgaier, Nicholas;** Assistant Professor, Department of Psychiatry; Ph.D., University of Vermont

**Bagrow, James;** Associate Professor, Department of Mathematics and Statistics; PHD, Clarkson University

**Bongard, Joshua C.;** Professor, Department of Computer Science; PHD, University of Zurich

**Danforth, Chris;** Professor, Department of Mathematics and Statistics; PHD, University of Maryland College Park

**Dodds, Peter Sheridan;** Professor, Department of Computer Science; PHD, Massachusetts Institute of Technology

**Galford, Gillian Laura;** Research Assistant Professor, Rubenstein School of Environment and Natural Resources; PHD, Brown University

**Garavan, Hugh P.;** Professor, Department of Psychiatry; PHD, Bowling Green State University

**Hébert-Dufresne, Laurent;** Assistant Professor, Department of Computer Science; PHD, Université Laval, Québec, Canada

**Mahoney, John Matthew;** Assistant Professor, Department of Neurological Sciences; PHD, Dartmouth College

**Niles, Meredith;** Assistant Professor, Department of Nutrition and Food Sciences; PHD, University of California-Davis

**Pespeni, Melissa H.;** Assistant Professor, Department of Biology; PHD, Stanford University

**Price, Matthew;** Associate Professor, Department of Psychological Science; PHD, Georgia State University

**Ricketts, Taylor H.;** Professor, Rubenstein School of Environment and Natural Resources; PHD, Stanford University

**Young, Jean-Gabriel;** Research Assistant Professor, Department of Computer Science, PHD, Université Laval

### Courses

#### CSYS 5766. Gr Chaos,Fractals&Dynamcal Syst. 3 Credits.

Discrete and continuous dynamical systems, Julia sets, the Mandelbrot set, period doubling, renormalization, Henon map, phase plane analysis, and Lorenz equations. Prerequisite: Graduate student or Instructor permission. Cross-listed with: MATH 5766.

#### CSYS 5870. Data Science I - Experience. 3 Credits.

Data harvesting, cleaning, and summarizing; working with non-traditional, non-numeric data (social network, natural language textual data, etc.); scientific visualization; advanced data pipelines with a practical focus on real datasets and developing good habits for rigorous and reproducible computational science; Project-based. Prerequisites: Graduate student; Instructor permission; knowledge of CS 1210 and either STAT 1410 or STAT 2430 assumed; knowledge of CS 2100 and MATH 2522 or MATH 2544 strongly recommended. Cross-listed with: STAT 5870, CS 5870.

#### CSYS 5990. Special Topics. 1-18 Credits.

See Schedule of Courses for specific titles.

#### CSYS 6020. Modeling Complex Systems. 3 Credits.

Integrative breadth-first introduction to computational methods for modeling complex systems; numerical methods, cellular automata, agent-based computing, game theory, genetic algorithms, artificial neural networks, and complex networks. Semester team-based project. Pre/Co-requisites: Computer programming in any language; calculus, linear algebra recommended. Cross-listed with: CS 6020.

**CSYS 6391. Master's Thesis Research. 1-9 Credits.**

Master's thesis research under the supervision of a graduate faculty member. Prerequisite: Instructor permission.

**CSYS 6392. Master's Project Research. 1-6 Credits.**

Masters project under the supervision of a graduate faculty member. Prerequisite: Instructor permission.

**CSYS 6520. Evolutionary Computation. 3 Credits.**

Theory and practice of biologically-inspired search strategies including genetic algorithms, genetic programming, and evolution strategies. Applications include optimization, parameter estimation, and model identification. Significant project. Students from multiple disciplines encouraged. Pre/co-requisites: Familiarity with programming, probability, statistics. Cross-listed with: CS 6520.

**CSYS 6540. Deep Learning. 3 Credits.**

Introduction to Deep Learning algorithms and applications, including basic neural networks, convolutional neural networks, recurrent neural networks, deep unsupervised learning, generative adversarial networks and deep reinforcement learning. Includes a semester team-based project. Prerequisite: CS 3540. Cross-listed with: CS 6540.

**CSYS 6701. Principles of Complex Systems. 3 Credits.**

Introduction to fundamental concepts of complex systems. Topics include: emergence, scaling phenomena and mechanisms, multi-scale systems, failure, robustness, collective social phenomena, complex networks. Students from all disciplines welcomed. Pre/co-requisites: Calculus, statistics required; linear algebra, differential equations, computer programming recommended. Cross-listed with: MATH 6701.

**CSYS 6713. Complex Networks. 3 Credits.**

Detailed exploration of distribution, transportation, small-world, scale-free, social, biological, organizational networks; generative mechanisms; measurement and statistics of network properties; network dynamics; contagion processes. Students from all disciplines welcomed. Pre/co-requisites: Calculus, statistics required. Cross-listed with: MATH 6713.

**CSYS 6870. Data Science II. 3 Credits.**

Advanced data analysis, collection, and filtering; statistical modeling, monte carlo statistical methods, and in particular Bayesian data analysis, including necessary probabilistic background material; a practical focus on real datasets and developing good habits for rigorous and reproducible computational science. Prerequisite: STAT 3870, CS 3870, CSYS 5870, or Instructor permission. Cross-listed with: CS 6870, STAT 6870.

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

See Schedule of Courses for specific titles.

**CSYS 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.

**CSYS 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.

**CSYS 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.

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

Research for the Doctoral Dissertation.

**CSYS 7980. Applied Geostatistics. 3 Credits.**

Introduction to the theory of regionalized variables, geostatistics (kriging techniques), special topics in multivariate analysis. Applications to real data subject to spatial variation are emphasized. Prerequisites: STAT 5230, CS 1210; or Instructor permission. Cross-listed with: CEE 7980, STAT 7980.

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

See Schedule of Courses for specific titles.

**CSYS 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.