

COMPLEX SYSTEMS AND DATA SCIENCE

OVERVIEW

The Vermont Complex Systems Center's MS in CSDS is a two year degree with optional disciplinary tracks. UVM undergraduates may incorporate the degree as part of an Accelerated Master's Program. The program's central 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 MS

FACULTY

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

Bongard, Joshua; Associate Director of Complex Systems Center; Associate Professor, Department of Computer Science; PHD, University of Zurich

Buzas, Jeff; Chair and Professor, Department of Mathematics and Statistics; PHD, North Carolina State University Raleigh

Danforth, Chris; Associate Director of Complex Systems Center; Associate Professor, Department of Mathematics and Statistics; PHD, University of Maryland College Park

Dodds, Peter; Director of Complex Systems Center; Professor, Department of Mathematics and Statistics; PHD, Massachusetts Institute of Technology

Eppstein, Margaret; Chair of Complex Systems Curriculum Committee; Chair and Professor, Department of Computer Science; PHD, University of Vermont

Courses

CSYS 213. Systems & Synthetic Biology. 3 Credits.

Applying engineering tools to the design and analysis of biomolecular processes; gene regulatory networks; nonlinear dynamics in molecular biology; biological circuit design; biological signal processing. Prerequisite: Background required: Differential Equations, Linear Algebra, Programming. Cross-listed with: ME 213, EE 213.

CSYS 221. Deterministic Modls Oper Rsch. 3 Credits.

The linear programming problem. Simplex algorithm, dual problem, sensitivity analysis, goal programming. Dynamic programming and network problems. Prerequisites: MATH 122 or MATH 124; MATH 121 recommended. Cross-listed with: MATH 221.

CSYS 226. Civil Engineering Systems Anyl. 3 Credits.

Linear programming, dynamic programming, network analysis, simulation; applications to scheduling, resource allocation routing, and a variety of civil engineering problems. Pre/co-requisites: Senior/ Graduate standing in CEE or Instructor permission. Cross-listed with: CE 226.

CSYS 245. Intelligent Transportation Sys. 3 Credits.

Introduction to Intelligent Transportation Systems (ITS), ITS user services, ITS applications, the National ITS architecture, ITS evaluation, and ITS standards. Pre/co-requisites: CE 140 or equivalent; Instructor permission. Cross-listed with: CE 245.

CSYS 251. Artificial Intelligence. 3 Credits.

Introduction to methods for realizing intelligent behavior in computers. Knowledge representation, planning, and learning. Selected applications such as natural language understanding and vision. Prerequisites: CS 103 or CS 123; CS 104 or CS 124; STAT 153 or equivalent. Cross-listed with: CS 251.

CSYS 253. Appl Time Series & Forecasting. 3 Credits.

Autoregressive moving average (Box-Jenkins) models, autocorrelation, partial correlation, differencing for nonstationarity, computer modeling. Forecasting, seasonal or cyclic variation, transfer function and intervention analysis, spectral analysis. Prerequisites: CE 211 or CE 225; or CE 141 or CE 143 with Instructor permission. Cross-listed with: STAT 253.

CSYS 256. Neural Computation. 3 Credits.

Introduction to artificial neural networks, their computational capabilities and limitations, and the algorithms used to train them. Statistical capacity, convergence theorems, backpropagation, reinforcement learning, generalization. Prerequisites: MATH 122 or MATH 124 or MATH 271; STAT 143 or STAT 153 or equivalent; CS 110. Cross-listed with: STAT 256, CS 256.

CSYS 266. Chaos,Fractals&Dynamical Syst. 3 Credits.

Discrete and continuous dynamical systems, Julia sets, the Mandelbrot set, period doubling, renormalization, Henon map, phase plane analysis and Lorenz equations. Co-requisite: MATH 271 or MATH 230 or Instructor permission. Cross-listed with: MATH 266.

CSYS 268. Mathematical Biology&Ecology. 3 Credits.

Mathematical modeling in the life sciences. Topics include population modeling, dynamics of infectious diseases, reaction kinetics, wave phenomena in biology, and biological pattern formation. Prerequisites: MATH 122 or MATH 124 or MATH 230 or Instructor permission. Cross-listed with: MATH 268.

CSYS 300. 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 and statistics required; Linear algebra, differential equations, and computer programming recommended but not required. Cross-listed with: MATH 300.

CSYS 302. 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. Pre/co-requisites: Computer programming in any language; calculus. Linear algebra recommended. Cross-listed with: CS 302.

CSYS 303. 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: MATH 301/CSYS 301, calculus, and statistics required. Cross-listed with: MATH 303.

CSYS 312. Adv Bioengineering Systems. 3 Credits.

Advanced bioengineering design and analysis for current biomedical problems spanning molecular, cell, tissue, organ, and whole body systems including their interactions and emergent behaviors. Cross-listed with: ME 312.

CSYS 350. Multiscale Modeling. 3 Credits.

Computational modeling of the physics and dynamical behavior of matter composed of diverse length and time scales. Molecular simulation. Coarse-graining. Coupled atomistic/continuum methods. Cross-listed with: ME 350.

CSYS 352. 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, and statistics. Cross-listed with: BIOL 352, CS 352.

CSYS 355. Statistical Pattern Recognitn. 3 Credits.

Analysis of algorithms used for feature selection, density estimation, and pattern classification, including Bayes classifiers, maximum likelihood, nearest neighbors, kernels, discriminants, neural networks, and clustering. Prerequisite: STAT 241 or STAT 251 or Instructor permission. Cross-listed with: STAT 355, CS 355.

CSYS 359. Appld Artificial Neural Ntwrks. 1-3 Credits.

Introduction to artificial neural networks. A broad range of example algorithms are implemented in MATLAB. Research applications to real data are emphasized. Pre/co-requisites: STAT 223, CS 016/CE 011, or Instructor permission. Cross-listed with: CE 359.

CSYS 369. 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. Pre/co-requisites: STAT 223 or STAT 225; CS 016/CE 011 or Instructor permission. Cross-listed with: STAT 369.

CSYS 395. Special Topics. 1-18 Credits.

See Schedule of Courses for specific titles.