Complex Networks (CNET)

CNET 1990. Elective. (4 Hours)
Offers elective credit for courses taken at other academic institutions.

CNET 2990. Elective. (4 Hours)
Offers elective credit for courses taken at other academic institutions.

CNET 3990. Elective. (4 Hours)
Offers elective credit for courses taken at other academic institutions.

CNET 4990. Elective. (4 Hours)
Offers elective credit for courses taken at other academic institutions.

CNET 5050. Fundamentals of Complex Networks. (4 Hours)
Presents an interdisciplinary introduction to the science of complex networks and the starting point for students looking to develop an expertise in network science. Explores the mathematical foundation of networks (graph theory) and examines common tools for describing and analyzing networks. Discovers the origin of complex networks throughout our world, examining properties such as the degree distribution, centrality measures, path lengths, clustering, homophily, and robustness. Investigates evolving networks, growing networks, and network null models. Introduces common applications of network science in a variety of domains including biology, medicine, sociology, technology, and finance. Requires students to conduct their own analysis of a real network dataset of their choosing as part of the final project.

CNET 5051. Analyzing Complex Network Data. (4 Hours)
Presents an overview of the core data scientific skills required to analyze complex networks.Through hands-on lectures, labs, and projects, exercises actionable skills about network analysis techniques using Python (in particular, the NetworkX library). Covers the basics of network analysis including data input/output, network statistics, and visualization.Explores instruction in random graph models and algorithms for computing network properties such as path lengths, clustering, degree distributions, and community structure. Offers students an opportunity to develop web scraping skills and introduces the vast landscape of software tools for analyzing complex networks. Concludes with a large-scale final project to demonstrate proficiency in network analysis.

CNET 5052. Advanced Tools for Complex Network Analysis. (4 Hours)
Delves into more advanced techniques for analyzing large, complex networks such as filtering, backboning, and embedding. Demonstrates how the presence of extra network features, such as a temporal dimension, requires more advanced and computationally demanding techniques. Presents a more formal treatment of network generative models, such as the stochastic block model; exponential random graphs with particular focus on sampling from such models; and the basics of network reconstruction involving appropriate statistical/inference methods.

Prerequisite(s): CNET 5051 with a minimum grade of C

CNET 5126. Spreading on Networks: From Epidemics to Memes. (4 Hours)
Explores fundamentals of contagion on networks, starting with simple disease dynamics in mean field systems and building to spreading processes on complex networks. Examines a variety of contagion modeling techniques, which include state-of-the-art techniques for using networks to forecast the trajectory of an infectious disease, the emergence of a best-seller, predicting elections, or even modeling cascading failures in infrastructure networks. Introduces a diverse range of datasets and case studies, which students may draw from for their final modeling/analysis project. From biological pathogens like SARS-CoV-2, Ebola, and influenza to social contagions like fake news, memes, and influencers, complex network analysis gives us powerful tools to understand contagion processes in our modern world.

Prerequisite(s): CNET 5050 with a minimum grade of C ; CNET 5051 with a minimum grade of C

CNET 5311. Physical and Digital Human Traces. (3 Hours)
Examines how to use physical and digital human traces to understand how people interact with each other and their environment to gain fresh insights into human behavior. These traces can be captured from data sources such as mobile phones, social media posts, smart sensors, and transportation networks. The unprecedented availability of these data traces enables us to delve into theoretical and practical aspects of spatiotemporal data analysis techniques to characterize human behaviors. Studies technical proficiency required for investigating human dynamics to identify factors that determine how humans interact in physical spaces. Examines data science and statistical methods commonly employed in urban analytics to offer students an opportunity to obtain a robust comprehension of the methodologies, models, and data pertinent to study human dynamics.

Prerequisite(s): CNET 5050 with a minimum grade of C ; INSH 5301 with a minimum grade of C

CNET 5314. Complexity in Social Systems. (3 Hours)
Offers an in-depth exploration of complex systems and networks. Emphasizes the modeling of social phenomena using physical models. Focuses on quantitative phenomenology to understand and describe emergent features observed in large-scale social phenomena. Aims to identify general behavioral classes, not based on microscopic definitions but on universal, large-scale characteristics. This approach is used to uncover mechanisms behind various social dynamics such as opinion consensus, cultural dissemination, collective motion, and social hierarchies. Examines a range of contagion phenomena, from biological disease spread to social and technological contagions, highlighting the impact of complexity inherent in social, biological, and cultural aspects on these propagation processes.

Prerequisite(s): CNET 5050 with a minimum grade of C

CNET 5360. Research Design for Social Networks. (4 Hours)
Presents an in-depth exploration of experimental design in the context of social network analysis and a guide to the craft of research. Explores the knowledge and skills necessary to design and implement experiments that investigate social phenomena through the lens of network structures and dynamics. Every study is the result of a myriad of choices: What are the compelling questions and what data are needed to answer them? What exactly should you measure and how do you collect that data? What are the best ways to analyze these data? Considers digital trace, survey, qualitative data, and ethical considerations for each choice. Offers students an opportunity to develop a solid foundation in both social network analysis principles and experimental research methodologies.

Prerequisite(s): INSH 5301 with a minimum grade of C

CNET 5411. Financial and Economic Networks. (3 Hours)
Identifies the complex web of financial and economic interactions that shape our global economy. Examines a wide range of relevant and emerging topics of today's interconnected world and approaches to studying these networks. Investigates the integration of techniques, applications, and the impact of network theory in these fields. Explores in-depth three main topics: trade, financial, and socioeconomic networks. Delves into network models of trade, leveraging input-output data to understand production, as well as firm-level supply chain analysis. Considers topics of finance, including banking and online systems, as well as financial transactions. Draws insights into microeconomic topics of knowledge creation, the labor market, and income inequality.

Prerequisite(s): CNET 5050 with a minimum grade of C

CNET 5515. Complex Network Analysis for Biological Systems. (4 Hours)
Covers the properties of diverse biological networks and foundational computational methods for analyzing, visualizing, and performing statistical investigations of networked data. Investigates how physicists have uncovered remarkable regularities in networked systems by applying approaches from scaling theory to biological networks. Explores the diversity of biological networks and provides the foundational tools needed to study networks derived from real-world data, including tools from machine learning. Focusing on a series of case studies, studies how to elucidate the structure and function of biological networks using empirical data.

Prerequisite(s): CNET 5050 with a minimum grade of C ; CNET 5051 with a minimum grade of C

CNET 5901. Visualizing Complex Networks. (2 Hours)
Studies the knowledge and skills necessary to effectively visualize complex network data. Covers foundational principles of network data visualization and effective strategies to present core network properties to a range of different audiences. Offers students an opportunity to obtain experience using various network visualization tools such as Networkx and matplotlib, Gephi, and other web-based tools. Examines case studies to explore diverse network visualization approaches to effectively convey scientific insights, advance policy, and inform the public, including examples from such diverse fields as brain science, supply chains, epidemiology, and urban analytics. Students give and receive feedback, collectively building competency in how to create and interpret visualizations of complex data. Final projects are designed to prepare students for working with clients and collaborators from industry, nonprofits, government agencies, and research.

Prerequisite(s): CNET 5050 with a minimum grade of C ; CNET 5051 with a minimum grade of C

CNET 5902. Communicating Network Data. (2 Hours)
Examines critical aspects of conveying complex network data effectively and ethically. Explores not only how to simplify and articulate complex network concepts to various audiences but also grapples with the ethical implications of the work, ensuring that communication is not just effective but also responsible and legally compliant. This is done through a combination of lectures and reading, as well as through guest lecturers and case studies. Requires a final project presentation that is based on a previous project selected by the student and that offers new presentations of the material designed for two (imagined) audiences: a general audience and a technically trained audience. Designed to help students bridge the gap between technical network analysis and effective, ethical communication.

Prerequisite(s): CNET 5051 with a minimum grade of C

CNET 6000. Professional Development for Co-op. (1 Hour)
Introduces the cooperative education program. Offers students an opportunity to develop job-search and career-management skills; to assess their workplace skills, interests, and values and to discuss how they impact personal career choices; to prepare a professional resumé; and to learn proper interviewing techniques. Explores career paths, choices, professional behaviors, work culture, and career decision making.

CNET 6061. Analyzing Higher-Order Networks. (2 Hours)
Delves into specialized network structures including temporal networks, higher-order networks (such as simplicial complexes and hypergraphs), and multilayer networks. Explores the dynamic aspects of temporal networks, the rich representation of relationships in higher-order networks, and the interconnected systems modeled by multilayer networks. By mastering the analysis and modeling of these advanced network structures, aims to equip students to address complex real-world challenges across various domains, ranging from epidemiology and social sciences to transportation planning and resilience analysis.

Prerequisite(s): CNET 5050 with a minimum grade of C ; CNET 5051 with a minimum grade of C

CNET 6063. Probabilistic Mathematics of Networks. (2 Hours)
Introduces advanced probabilistic tools and statistical methodologies within the realm of network science. Offers students an opportunity to obtain the skills needed to navigate and analyze the complexities and inherent uncertainties of networked systems. Introduces basic probabilistic computing with probability generating functions, the development of message-passing algorithms, and their various applications in the field of network science. Focuses primarily on modeling complex dynamical systems and tackling statistical inference problems using real-world network data, demonstrating the depth and versatility of these techniques.

Prerequisite(s): CNET 5050 with a minimum grade of C ; INSH 5301 with a minimum grade of C

CNET 6099. Special Topics in Complex Networks. (2 Hours)
Delves into advanced and specialized topics within the interdisciplinary field of network science. Network science explores the structure, behavior, and dynamics of complex systems represented as networks, encompassing social, technological, biological, and physical systems. Examines in-depth cutting-edge research, theoretical frameworks, and practical applications to offer students an opportunity to obtain a deeper understanding of the current trends and challenges in network science.

Prerequisite(s): CNET 5050 with a minimum grade of C ; CNET 5052 with a minimum grade of C

CNET 6107. Complex Network Analysis Research Rotation. (2 Hours)
Offers students up to three lab rotations and self-directed exploration of how network science can model social, technical, physical, and epidemiological systems and solve applied societal problems.Diverse topics could include disease spreading, effects of public policies and health interventions, drug efficacy, improvement of health and security of human populations, science of success, shaping of social behavior, formulation of political beliefs, group decision making, geometry of networks, topological data analysis on graphs, anomaly detection, algorithmically infused societies, and unifying the physics of networks with the mining of graphs. After research rotations, students independently explore areas to apply their skill set and utilize research community to engage in outreach for workforce opportunities. May be repeated once.

Prerequisite(s): CNET 5050 with a minimum grade of C ; CNET 5051 with a minimum grade of C ; CNET 5052 with a minimum grade of C

CNET 6108. Complex Network Analysis Capstone. (2 Hours)
Offers students an opportunity to apply network analytic tools and network science concepts to a project that further develops skills and expands understanding of how to approach problems using network analytics and principles. Students may propose a topic or choose projects presented by a sponsoring organization or agency. Topics must be approved by the instructor, and students are expected to provide regular updates and present their final project. May be repeated once.

Prerequisite(s): CNET 5050 with a minimum grade of C ; CNET 5051 with a minimum grade of C ; CNET 5052 with a minimum grade of C

CNET 6962. Elective. (4 Hours)
Offers elective credit for courses taken at other academic institutions.

CNET 6964. Co-op Work Experience. (0 Hours)
Provides eligible students with an opportunity for work experience. May be repeated up to seven times.

CNET 6990. Thesis. (2 Hours)
Offers analytical, research, and/or experimental work conducted under the auspices of the department. May be repeated once.

Prerequisite(s): CNET 5050 with a minimum grade of B- ; CNET 5051 with a minimum grade of B- ; CNET 5052 with a minimum grade of B-