CMSC - COMPUTER SCIENCE

CMSC100 Bits and Bytes of Computer and Information Sciences (1 Credit)
Students are introduced to the fields (and disciplines) of computer science and information science within a small classroom setting. They will learn to make a successful transition from high school to the university, while exploring study skills, student success plans and research opportunities.
Cross-listed with: INST101.
Restriction: For first time freshmen and first time transfer students; or permission of CMNS-Computer Science department.
Credit Only Granted for: CMSC100 or INST101.

CMSC106 Introduction to C Programming (4 Credits)
Design and analysis of programs in C. An introduction to computing using structured programming concepts. Intended for students with no or minimal programming experience.
Prerequisite: MATH115.
Restriction: Must not be in Computer Science program; and must not have completed any courses from CMSC131-499 course range.
Credit Only Granted for: CMSC106 or CMSC122.

CMSC115 Gender, Race and Computing (3 Credits)
Race and gender have shaped computing from its earliest histories to contemporary debates over bias in search algorithms, surveillance, and AI. As computational processes shape ever more dimensions of everyday life from the personal to the global scale, understanding how they operate and how power operates within them grows ever more important. Combating racism and sexism is not as simple as ensuring the pool of programmers and engineers is more diverse; structures of power are embedded in digital technologies as they are in all aspects of our society, and we must learn to perceive their operation if we hope to transform them. We will examine how racism and sexism operate in the field of computer science and in everyday uses of digital technologies, while studying how feminist and racial justice movements have created alternative approaches. This class is for anyone who wishes to better understand the relationships between digital technology, structural power, and social justice.
Cross-listed with: WGSS115.
Restriction: Must not have taken CMSC216 or higher.
Credit Only Granted for: WGSS115 or CMSC115.

CMSC122 Introduction to Computer Programming via the Web (3 Credits)
Introduction to computer programming in the context of developing full featured dynamic web sites. Uses a problem solving approach to teach basics of program design and implementation using JavaScript; relates these skills to creation of dynamic web sites; then explores both the potential and limits of web-based information sources for use in research. Intended to help relate a student's major to these emerging technologies.
Restriction: Must not have completed any courses from CMSC131-499 course range; and must not be concurrently enrolled in CMSC131.
Credit Only Granted for: CMSC106, or CMSC122.

CMSC125 Introduction to Computing (3 Credits)
Introduces you to the computing field as a whole. You will gain skills used across the spectrum of computing majors and learn about the great variety of routes into the various areas of study and employment in technological fields.
Prerequisite: Must have completed or be concurrently enrolled in MATH115 or higher.
Restriction: Must not be in the Computer Science program; and must not have completed any courses from CMSC131-499; and must not have completed BMGT302, IMDM127 or INST126.
Credit Only Granted for: IMDM127 or CMSC125.

CMSC131 Object-Oriented Programming I (4 Credits)
Introduction to programming and computer science. Emphasizes understanding and implementation of applications using object-oriented techniques. Develops skills such as program design and testing as well as implementation of programs using a graphical IDE. Programming done in Java.
Corequisite: MATH140.
Credit Only Granted for: CMSC131, CMSC133 or CMSC141.

CMSC132 Object-Oriented Programming II (4 Credits)
Introduction to use of computers to solve problems using software engineering principles. Design, build, test, and debug medium -size software systems and learn to use relevant tools. Use object-oriented methods to create effective and efficient problem solutions. Use and implement application programming interfaces (APIs). Programming done in Java.
Prerequisite: Minimum grade of C- in CMSC131; or must have earned a score of 5 on the A Java AP exam; or must have earned a satisfactory score on the departmental placement exam; and minimum grade of C- in MATH140.
Credit Only Granted for: CMSC132 or CMSC142.

CMSC133 Object Oriented Programming I Beyond Fundamentals (2 Credits)
An introduction to computer science and object-oriented programming for students with prior Java programming knowledge (conditionals, loops, methods). Program design, implementation, and testing using object-oriented techniques. All programming will be done in Java using a graphical IDE.
Prerequisite: Must have completed or be concurrently enrolled in MATH140.
Restriction: Permission of CMNS-Computer Science department; and student must have earned a 4 on the AP Computer Science A exam or a satisfactory score on the CMSC131 department placement exam.
Credit Only Granted for: CMSC131 or CMSC133.

CMSC198 Special Topics in Computer Science for Non-Majors (1-4 Credits)
A course designed to allow non-computer science majors and non-computer engineering majors to pursue a specialized topic or project.
Restriction: Must not be in Computer Science program.
Repeatable to: 6 credits if content differs.

CMSC216 Introduction to Computer Systems (4 Credits)
Introduction to the interaction between user programs and the operating system/hardware. Major topics include C programming, introductory systems programming, and assembly language. Other concepts covered include UNIX, machine data representation, thread management, optimization, and virtual memory. Programming is done in the Linux Environment.
Prerequisite: Minimum grade of C- in CMSC132; and minimum grade of C- in MATH141.
Restriction: Must be in a major within the CMNS-Computer Science department; or must be in Engineering: Computer program; or must be in the Computer Science Minor program; and Permission of CMSC - Computer Science department.

CMSC250 Discrete Structures (4 Credits)
Fundamental mathematical concepts related to computer science, including finite and infinite sets, relations, functions, and propositional logic. Introduction to other techniques, modeling and solving problems in computer science. Introduction to permutations, combinations, graphs, and trees with selected applications.
Prerequisite: Minimum grade of C- in CMSC131; and minimum grade of C- in MATH141.
Restriction: Must be in a major within the CMNS-Computer Science department; or must be in Engineering: Computer program; or must be in the Computer Science Minor program; and Permissions of CMSC - Computer Science department.

CMSC298 Special Topics in Computer Science (1-4 Credits)
A course designed to allow a lower level student to pursue a specialized topic or project.
Restriction: Permission of CMNS-Computer Science department.
Repeatable to: 6 credits if content differs.

CMSC298Q Quantum Steampunk Science-Fiction Workshop (3 Credits)
Steampunk is a science-fiction genre in which futuristic technologies populate Victorian-era settings. Recently, steampunk has come to life in the scientific field of quantum thermodynamics. Thermodynamics, the study of energy, grew out of the Industrial Revolution. Two centuries later, quantum physics is transforming computing and cryptography. Quantum science is now revolutionizing 19th-century thermodynamics in quantum thermodynamics, which features quantum engines, automata, and more. Quantum thermodynamics inspired the growing subgenre of quantum steampunk. In this course, you will read science fiction, write quantum steampunk short stories, receive feedback, and critique classmates' writing. In parallel, you will learn about quantum physics, technologies, and thermodynamics.
Cross-listed with: ARHU270, CHEM298Q, ENME299Q, PHYS299Q.
Credit Only Granted for: ARHU270, ARHU298Q, CHEM298Q, CMSC298Q, ENME299Q or PHYS299Q.

CMSC320 Introduction to Data Science (3 Credits)
An introduction to the data science pipeline, i.e., the end-to-end process of going from unstructured, messy data to knowledge and actionable insights. Provides a broad overview of several topics including statistical data analysis, basic data mining and machine learning algorithms, large-scale data management, cloud computing, and information visualization.
Prerequisite: Minimum grade of C- in CMSC216 and CMSC250.
Restriction: Permission of CMNS-Computer Science department.
Credit Only Granted for: CMSC320, DATA320 or STAT426.

CMSC330 Organization of Programming Languages (3 Credits)
A study of programming languages, including their syntax, semantics, and implementation. Several different models of languages are discussed, including dynamic, scripting (e.g., Ruby, Python) functional (e.g., OCaml, Haskell, Scheme), and memory safe systems programming (e.g., Rust). Explores language features such as formal syntax, scoping and binding of variables, higher-order programming, typing, and type polymorphism. Introduces finite automata, context free grammar, parsing, lambda calculus, and basics of security attacks and software security.
Prerequisite: Minimum grade of C- in CMSC250 and CMSC216.
Restriction: Must be in a major within the CMNS-Computer Science department; or must be in the Computer Science Minor program; or must be in Engineering: Computer program; and Permission of CMSC - Computer Science department.

CMSC335 Web Application Development with JavaScript (3 Credits)
Provides an introduction to modern ways of developing Web Applications/Services using JavaScript for both front-end and back-end. The course covers topics on fundamental JavaScript language constructs, server-side JavaScript, back-end data persistence, and client-side JavaScript to build Web Applications that interact with Web services and back-end databases.
Prerequisite: Minimum grade of C- in CMSC216 and CMSC250.
Restriction: Permission of CMNS-Computer Science Department.
Credit Only Granted for: CMSC389N or CMSC335.
Formerly: CMSC389N.

CMSC351 Algorithms (3 Credits)
A systematic study of the complexity of some elementary algorithms related to sorting, graphs and trees, and combinatorics. Algorithms are analyzed using mathematical techniques to solve recurrences and summations.
Prerequisite: Minimum grade of C- in CMSC250 and CMSC216.
Restriction: Must be in a major within the CMNS-Computer Science department; or must be in Engineering: Computer program; or must be in the Computer Science Minor program; and Permission from the CMSC - Computer Science department.

CMSC388 Special Topics in Computer Science (1-3 Credits)
Seminar courses that allow students to pursue new and emerging areas of Computer Science.
Restriction: Permission of CMNS-Computer Science department.
Repeatable to: 6 credits if content differs.

CMSC389 Special Topics in Computer Science (1-3 Credits)
Seminar courses that allow students to pursue new and emerging areas of Computer Science; course may be used as electives for the undergraduate degree and minor.
Repeatable to: 6 credits if content differs.

CMSC395 Teaching Techniques for Computer Science (1 Credit)
This course will assure that teaching assistants become better skilled at applying effective teaching practices that improve the classroom environment while learning methods to implement mechanisms to improve diversity and inclusion. Legal and ethical aspects of the role will also be considered. Students in the class will be currently working as a teaching assistant and, therefore, be able to apply what they are learning immediately in their own context.
Restriction: Students must be hired as a teaching assistant in the Computer Science Department for the semester they are registered for the course; and permission of the Computer Science Department.

CMSC396 Computer Science Honors Seminar (1 Credit)
Overview of computer science research activities, techniques, and tools. Diverse research areas will be covered, including systems, networks, artificial intelligence, human-computer interaction, software engineering, graphics, vision, and theory.
Prerequisite: Must have admission into Computer Science Departmental Honors Program.
Restriction: Permission of CMNS-Computer Science department.

CMSC398 Special Topics in Computer Science (1-3 Credits)
Seminar courses that allow students to pursue new and emerging areas of Computer Science.
Restriction: Permission of CMNS-Computer Science Department.
Repeatable to: 6 credits if content differs.

CMSC401 Algorithms for Geospatial Computing (3 Credits)
An introduction to fundamental geospatial objects and geometric algorithms for spatio-temporal data processing and analysis. Point data representation and analysis: spatial data models and data structures, algorithms for spatial queries, point clustering algorithms. Surface and scalar field modeling, such as terrains: raster and triangle-based models (TINs), algorithms for building and querying TINs. Algorithms for natural and urban terrain analysis: morphology computation and visibility analysis. Applications to processing and analysis of LiDAR (Light Detection And Ranging) data in the context of terrain reconstruction, urban modeling, forest management and bathymetry reconstruction for coastal data management. Road network computation and analysis: algorithms for route computation in road networks, and for road network reconstruction from GPS and satellite data.
Prerequisite: GEOG276; or a minimum grade of C- in CMSC330 and CMSC351; or permission of instructor.
Cross-listed with: GEOG470.
Jointly offered with: GEOG770.
Credit Only Granted for: CMSC498Q, CMSC401, CMSC788I, GEOG470, GEOG498I, GEOG770, or GEOG788I.
Formerly: GEOG498I.

CMSC411 Computer Systems Architecture (3 Credits)
Input/output processors and techniques. Intra-system communication, buses, caches. Addressing and memory hierarchies. Microprogramming, parallelism, and pipelining.
Prerequisite: Minimum grade of C- in CMSC330; or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.
Restriction: Permission of CMNS-Computer Science department.
Credit Only Granted for: ENEE446 or CMSC411.

CMSC412 Operating Systems (4 Credits)
A hands-on introduction to operating systems, including topics in: multiprogramming, communication and synchronization, memory management, IO subsystems, and resource scheduling polices. The laboratory component consists of constructing a small kernel, including functions for device IO, multi-tasking, and memory management.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; and 1 course with a minimum grade of C- from (CMSC414, CMSC417, CMSC420, CMSC430, CMSC433, CMSC435, ENEE440, ENEE457).
Restriction: Permission of CMNS-Computer Science department; or must be in one of the following programs (Computer Science (Master's); Computer Science (Doctoral)).
Credit Only Granted for: CMSC412 or ENEE447.

CMSC414 Computer and Network Security (3 Credits)
An introduction to the topic of security in the context of computer systems and networks. Identify, analyze, and solve network-related security problems in computer systems. Fundamentals of number theory, authentication, and encryption technologies, as well as the practical problems that have to be solved in order to make those technologies workable in a networked environment, particularly in the wide-area Internet environment.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.
Restriction: Permission of CMNS-Computer Science department.
Credit Only Granted for: CMSC414 or ENEE457.

CMSC416 Introduction to Parallel Computing (3 Credits)
Introduction to parallel computing. Topics include programming for shared memory and distributed memory parallel architectures, and fundamental issues in design, development, and performance analysis of parallel programs.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; or permission of instructor.
Jointly offered with: CMSC616.
Restriction: Permission of CMNS-Computer Science department.
Credit Only Granted for: CMSC416, CMSC498X, CMSC616, or CMSC818X.
Formerly: CMSC498X.

CMSC417 Computer Networks (3 Credits)
Computer networks and architectures. The OSI model including discussion and examples of various network layers. A general introduction to existing network protocols. Communication protocol specification, analysis, and testing.
Prerequisite: Minimum grade of C- in CMSC351 and CMSC330; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.

CMSC420 Advanced Data Structures (3 Credits)
Description, properties, and storage allocation functions of data structures including balanced binary trees, B-Trees, hash tables, skiplists, tries, KD-Trees and Quadtrees. Algorithms for manipulating structures. Applications from areas such as String Processing, Computer Graphics, Information Retrieval, Computer Networks, Computer Vision, and Operating Systems.
Prerequisite: Minimum grade of C- in CMSC351 and CMSC330; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.

CMSC421 Introduction to Artificial Intelligence (3 Credits)
Introduces a range of ideas and methods in AI, varying semester to semester but chosen largely from: automated heuristic search, planning, games, knowledge representation, logical and statistical inference, learning, natural language processing, vision, robotics, cognitive modeling, and intelligent agents. Programming projects will help students obtain a hands-on feel for various topics.
Prerequisite: Minimum grade of C- in CMSC351 and CMSC330; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.

CMSC422 Introduction to Machine Learning (3 Credits)
Machine Learning studies representations and algorithms that allow machines to improve their performance on a task from experience. This is a broad overview of existing methods for machine learning and an introduction to adaptive systems in general. Emphasis is given to practical aspects of machine learning and data mining.
Prerequisite: Minimum grade of C- in CMSC320, CMSC330, and CMSC351; and 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461, ENEE290); and permission of CMNS-Computer Science department.

CMSC423 Computational Genomics (3 Credits)
Computers have revolutionized modern biological research by enabling the management and analysis of the large amounts of data generated through high-throughput experiments. This course provides insight into some of the biological problems that can be addressed using computational methods and introduces the main data structures and algorithms used to solve problems related to biological sequences such as DNA, RNA, and proteins. Many of the techniques taught in this course are applicable beyond the bioinformatics domain, as they are relevant to and commonly used in other areas of computer science. No knowledge of biology is required for this course.
Prerequisite: Minimum grade of C- in CMSC351 and CMSC330; and permission of CMNS-Computer Science department.

CMSC424 Database Design (3 Credits)
Students are introduced to database systems and motivates the database approach as a mechanism for modeling the real world. An in-depth coverage of the relational model, logical database design, query languages, and other database concepts including query optimization, concurrency control; transaction management, and log based crash recovery. Distributed and Web database architectures are also discussed.
Prerequisite: Minimum grade of C- in CMSC351 and CMSC330; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.

CMSC425 Game Programming (3 Credits)
An introduction to the principles and practice of computer game programming and design. This includes an introduction to game hardware and systems, the principles of game design, object and terrain modeling, game physics, artificial intelligence for games, networking for games, rendering and animation, and aural rendering. Course topics are reinforced through the design and implementation of a working computer game.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351.
Restriction: Permission of CMNS-Computer Science department.

CMSC426 Computer Vision (3 Credits)
An introduction to basic concepts and techniques in computervision. This includes low-level operations such as image filtering and edge detection, 3D reconstruction of scenes using stereo and structure from motion, and object detection, recognition and classification.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351 and 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461, ENEE290); or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program; or permission of the instructor.
Restriction: Permission of CMNS-Computer Science department.

CMSC427 Computer Graphics (3 Credits)
An introduction to 3D computer graphics, focusing on the underlying building blocks and algorithms for applications such as 3D computer games, and augmented and virtual reality (AR/VR). Covers the basics of 3D image generation and 3D modeling, with an emphasis on interactive applications. Discusses the representation of 3D geometry, 3D transformations, projections, rasterization, basics of color spaces, texturing and lighting models, as well as programming of modern Graphics Processing Units (GPUs). Includes programming projects where students build their own 3D rendering engine step-by-step.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461, ENEE290).
Restriction: Permission of CMNS-Computer Science department.

CMSC430 Introduction to Compilers (3 Credits)
Topics include lexical analysis, parsing, intermediate representations, program analysis, optimization, and code generation.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.

CMSC431 Privacy Engineering (3 Credits)
Explores the intersection of technology and privacy, including technical mechanisms for data privacy, legal and regulatory privacy regimes, and mediation of interpersonal privacy through technology.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; and permission of CMNS-Computer Science Department.
Credit Only Granted for: CMSC431 or CMSC498G.
Formerly: CMSC498G.

CMSC433 Programming Language Technologies and Paradigms (3 Credits)
Programming language technologies (e.g., object-oriented programming), their implementations and use in software design and implementation.
Prerequisite: Minimum grade of C- in CMSC330; or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.
Restriction: Permission of CMNS-Computer Science department.

CMSC434 Introduction to Human-Computer Interaction (3 Credits)
Assess usability by quantitative and qualitative methods. Conduct task analyses, usability tests, expert reviews, and continuing assessments of working products by interviews, surveys, and logging. Apply design processes and guidelines to develop professional quality user interfaces. Build low-fidelity paper mockups, and a high-fidelity prototype using contemporary tools such as graphic editors and a graphical programming environment (eg: Visual Basic, Java).
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.

CMSC435 Software Engineering (3 Credits)
State-of-the-art techniques in software design and development. Laboratory experience in applying the techniques covered. Structured design, structured programming, top-down design and development, segmentation and modularization techniques, iterative enhancement, design and code inspection techniques, correctness, and chief-programmer teams. The development of a large software project.
Prerequisite: 1 course with a minimum grade of C- from (CMSC412, CMSC417, CMSC420, CMSC430, CMSC433, ENEE447); and permission of CMNS-Computer Science department.

CMSC436 Programming Handheld Systems (3 Credits)
Fundamental principles and concepts that underlie the programming of handheld systems, such as mobile phones, personal digital assistants, and tablet computers. Particular emphasis will be placed on concepts such as limited display size, power, memory and CPU speed; and new input modalities, where handheld systems differ substantially from non-handheld systems, and thus require special programming tools and approaches. Students will apply these concepts and principles in the context of an existing handset programming platform.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.
Restriction: Permission of CMNS-Computer Science department.

CMSC437 Introduction to Quantum Software Laboratory (3 Credits)
Introductory Programming/Software laboratory for quantum computing. Understand the existing programming tools for quantum computers and the characteristics of quantum hardware. Develop quantum application prototypes and tools to characterize and mitigate the limitations of quantum hardware.
Prerequisite: Minimum grade of C- in CMSC457 or PHYS467; and familiarity with basic programming, languages (e.g., Python).
Restriction: Permission of CMNS-Computer Science department.

CMSC451 Design and Analysis of Computer Algorithms (3 Credits)
Fundamental techniques for designing efficient computer algorithms, proving their correctness, and analyzing their complexity. General topics include graph algorithms, basic algorithm design paradigms (such as greedy algorithms, divide-and-conquer, and dynamic programming), network flows, NP-completeness, and other selected topics in algorithms.
Prerequisite: Minimum grade of C- in CMSC351; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.

CMSC452 Elementary Theory of Computation (3 Credits)
Techniques are developed to determine the difficulty of a problem relative to a model of computation. Topics include Finite Automata, P, NP, decidability, undecidability, and communication complexity.
Prerequisite: Minimum grade of C- in CMSC351; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.

CMSC454 Algorithms for Data Science (3 Credits)
Fundamental methods for processing a high volume of data. Methods include stream processing, locally sensitive hashing, web search methods, page rank computation, network and link analysis, dynamic graph algorithms as well as methods to handle high dimensional data/dimensionality reduction.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351.
Restriction: Permission of CMSC-Computer Science department.

CMSC456 Cryptography (3 Credits)
The theory, application, and implementation of mathematical techniques used to secure modern communications. Topics include symmetric and public-key encryption, message integrity, hash functions, block-cipher design and analysis, number theory, and digital signatures.
Prerequisite: (CMSC106, CMSC131, or ENEE150; or equivalent programming experience); and (2 courses from (CMSC330, CMSC351, ENEE324, or ENEE382); or any one of these courses and a 400-level MATH course, or two 400-level MATH courses); and Permission of CMNS-Mathematics department or permission of instructor.
Cross-listed with: MATH456, ENEE456.
Credit Only Granted for: MATH456, CMSC456 or ENEE456.

CMSC457 Introduction to Quantum Computing (3 Credits)
An introduction to the concept of a quantum computer, including algorithms that outperform classical computation and methods for performing quantum computation reliably in the presence of noise. As this is a multidisciplinary subject, the course will cover basic concepts in theoretical computer science and physics in addition to introducing core quantum computing topics. No previous background in quantum mechanics is required.
Prerequisite: 1 course with a minimum grade of C- from (ENEE290, MATH240, MATH341, MATH461, MATH243); and 1 course with a minimum grade of C- from (CMSC351, PHYS313).
Cross-listed with: PHYS457.
Credit Only Granted for: CMSC457 or PHYS457.
Additional Information: Only Physics students may use MATH243 to satisfy the Linear Algebra prerequisite for CMSC/PHYS457.

CMSC460 Computational Methods (3 Credits)
Basic computational methods for interpolation, least squares, approximation, numerical quadrature, numerical solution of polynomial and transcendental equations, systems of linear equations and initial value problems for ordinary differential equations. Emphasis on methods and their computational properties rather than their analytic aspects. Intended primarily for students in the physical and engineering sciences.
Prerequisite: 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461, ENEE290, MATH243); and 1 course with a minimum grade of C- from (MATH241, MATH340); and 1 course with a minimum grade of C- from (CMSC106, CMSC131); and 1 course with a minimum grade of C- from (MATH246, MATH341, ENEE290, MATH243).
Cross-listed with: AMSC460.
Credit Only Granted for: AMSC460, AMSC466, CMSC460, or CMSC466.

CMSC466 Introduction to Numerical Analysis I (3 Credits)
Floating point computations, direct methods for linear systems, interpolation, solution of nonlinear equations.
Prerequisite: 1 course with a minimum grade of C- from (CMSC106, CMSC131); and minimum grade of C- in MATH410.
Cross-listed with: AMSC466.
Credit Only Granted for: AMSC460, CMSC460, AMSC466, or CMSC466.

CMSC470 Introduction to Natural Language Processing (3 Credits)
Introduction to fundamental techniques for automatically processing and generating natural language with computers. Machine learning techniques, models, and algorithms that enable computers to deal with the ambiguity and implicit structure of natural language. Application of these techniques in a series of assignments designed to address a core application such as question answering or machine translation.
Prerequisite: Minimum grade of C- in CMSC320, CMSC330, and CMSC351; and 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461, ENEE290).
Restriction: Permission of CMNS-Computer Science department.

CMSC471 Introduction to Data Visualization (3 Credits)
Datasets are becoming increasingly large and complex, requiring intuitive ways to explore and interpret them quickly and efficiently. In this case, a picture is worth a thousand words: visualizations enable us to transform data into images that are easier to understand and reason about, compared to raw numbers and raw text. Visualizations are critical tools in externalizing and organizing our knowledge and insights, whether to explore collected datasets to improve our understanding of the physical world, to assess and debug analysis/experimental workflows, or to present new and interesting results to diverse audiences. In this course we will study techniques and algorithms for creating effective visualizations based on principles from graphic design, perceptual psychology, and cognitive science. Students will learn how to design and build interactive visualizations for the web, using the D3.js (Data-Driven Documents) framework.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; and permission of CMNS-Computer Science Department.
Restriction: Permission of the CMNS-Computer Science Department.
Credit Only Granted for: CMSC471 or CMSC498O.
Formerly: CMSC498O.

CMSC472 Introduction to Deep Learning (3 Credits)
An introduction to deep learning, a machine learning technique, as well as its applications to a variety of domains. Provides a broad overview of deep learning concepts including neural networks, convolutional neural networks, recurrent neural networks, generative models, and deep reinforcement learning, and an intuitive introduction to basics of machine learning such as simple models, learning paradigms, optimization, overfitting, importance of data, and training caveats.
Prerequisite: Minimum grade of C- or higher in CMSC330 and CMSC351; and 1 course with a minimum grade of C- or higher from (MATH240, MATH341, MATH461, ENEE290).
Restriction: Permission of the CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's) program.

CMSC473 Capstone in Machine Learning (3 Credits)
Semester-long project course in which each student will identify and carry out a project related to machine learning, with the goal of publishing a research paper or software tool.
Prerequisite: Minimum grade of C- or higher in CMSC421 or CMSC422.
Recommended: Background or exposure to machine learning topics is strongly encouraged.
Restriction: Permission of instructor and Permission of CMSC - Computer Science department.
Credit Only Granted for: CMSC498P or CMSC473.
Formerly: CMSC498P.
Additional Information: Students will be paired with project advisors from the UMD faculty or alternatively, an industry advisor. Students are encouraged to plan for projects results that can be published at academic conferences or will impact academic research.

CMSC474 Introduction to Computational Game Theory (3 Credits)
Game theory deals with interactions among agents (either human or computerized) whose objectives and preferences may differ from the objectives and preferences of the other agents. It will also provide a comprehensive introduction to game theory, concentrating on its computational aspects.
Prerequisite: Minimum grade of C- in CMSC351 and CMSC330; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.
Credit Only Granted for: CMSC474, ECON414, GVPT390 or GVPT399A.

CMSC475 Combinatorics and Graph Theory (3 Credits)
General enumeration methods, difference equations, generating functions. Elements of graph theory, matrix representations of graphs, applications of graph theory to transport networks, matching theory and graphical algorithms.
Prerequisite: 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461, ENEE290, MATH243); and 1 course with a minimum grade of C- from (MATH241, MATH340); and 1 course with a minimum grade of C- from (MATH310, CMSC250).
Cross-listed with: MATH475.
Credit Only Granted for: MATH475 or CMSC475.

CMSC477 Robotics Perception and Planning (3 Credits)
A hands-on introduction to perception and planning for robotics, including rigid body transformations and rotations, dynamics and control of mobile robots/drones, graph based and sampling based planning algorithms, Bayseian and Kalman filtering, camera models and calibration, projective geometry, visual features, optical flow, pose estimation, RANSAC and Hough transform, structure from motion, visual odometry, machine learning basics, visual recognition and learning.
Prerequisite: 1 course from (MATH240, MATH341, MATH461, ENEE290); and (ENEE467 or CMSC420).
Restriction: Must be in the Robotics and Autonomous Systems minor; and permission of Computer Science department.
Additional Information: Students in the Robotics and Autonomous Systems minor should take ENEE467 as a prerequisite; Computer Science students not in the minor should take CMSC420.

CMSC488 Special Topics in Computer Science (1-3 Credits)
Seminar courses that allow students to pursue new and emerging areas of Computer Science.
Restriction: Permission of CMNS-Computer Science department.
Repeatable to: 6 credits if content differs.
Additional Information: Course may be used as electives for the undergraduate degree and minor.

CMSC498 Selected Topics in Computer Science (1-3 Credits)
An individualized course designed to allow a student or students to pursue a selected topic not taught as a part of the regular course offerings under the supervision of a Computer Science faculty member. In addition, courses dealing with topics of special interest and/or new emerging areas of computer science will be offered with this number. Selected topics courses will be structured very much like a regular course with homework, project and exams. Credit according to work completed
Restriction: Permission of CMNS-Computer Science department.

CMSC499 Independent Undergraduate Research (1-3 Credits)
Students are provided with an opportunity to participate in a computer science research project under the guidance of a faculty advisor. Format varies. Students and supervising faculty member will agree to a research plan which must be approved by the department. As part of each research plan, students should produce a final paper delineating their contribution to the field.
Restriction: Must be in one of the following programs (Computer Science; Engineering: Computer) ; and permission of CMNS-Computer Science department.