CMSC - COMPUTER SCIENCE

CMSC402 Bioinformatic Algorithms and Methods for Functional Genomics and Proteomics (3 Credits)
An introduction to the fundamental concepts in the computational analysis of biological systems with applications to: functional genomics, population genetics, proteomics and epigenetics. Computational concepts covered: network and graph algorithms, combinatorial modeling and inference, probabilistic graphical models, sparse methods in data analysis, numerical optimization. No prior knowledge of biology required.
Prerequisite: Minimum grade of C- in CMSC330 and CMSC351; and permission of CMNS-Computer Science department.

CMSC411 Computer Systems Architecture (3 Credits)
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: CMSC411.

CMSC412 Operating Systems (4 Credits)
A hands-on introduction to operating systems, including topics in: multiprogramming, communication and synchronization, memory management, I/O subsystems, and resource scheduling policies. The laboratory component consists of constructing a small kernel, including functions for device I/O, 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, ENEE459C, or ENEE457.

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 Data Structures (3 Credits)
Description, properties, and storage allocation of data structures including lists and trees. Algorithms for manipulating structures. Applications from areas such as data processing, information retrieval, symbol manipulation, 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)
Areas and issues in artificial intelligence, including search, inference, knowledge representation, learning, vision, natural languages, expert systems, robotics. Implementation and application of programming languages (e.g. LISP PROLOG, SMALLTALK), programming techniques (e.g. pattern matching, discrimination networks) and control structures (e.g. agendas, data dependencies).
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, MATH461); and permission of CMNS-Computer Science department.

CMSC423 Bioinformatic Algorithms, Databases, and Tools (3 Credits)
An introduction to the main algorithms, databases, and tools used in bioinformatics. Topics may include assembly and analysis of genome sequences, reconstructing evolutionary histories, predicting protein structure, and clustering of biological data. Use of scripting languages to perform analysis tasks on biological data. No prior knowledge of biology is assumed.
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.

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 CMSC420.
CMSC426 Computer Vision (3 Credits)
An introduction to basic concepts and techniques in computer vision. 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; or must be in the (Computer Science (Doctoral), Computer Science (Master’s)) program.
Restriction: Permission of CMNS-Computer Science department.

CMSC427 Computer Graphics (3 Credits)
An introduction to the principles of computer graphics. Includes an introduction to graphics displays and systems. Introduction to the mathematics of affine and projective transformations, perspective, curve and surface modeling, algorithms for hidden-surface removal, color models, methods for modeling illumination, shading, and reflection.
Prerequisite: MATH240; and minimum grade of C- in CMSC420; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master’s)) program.

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.

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 (e.g: 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); and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master’s)) program.

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.

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 sorting, selection, graph algorithms, and basic algorithm design paradigms (such as divide-and-conquer, dynamic programming and greedy algorithms), lower bounds and NP-completeness.
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.

CMSC456 Cryptology (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 ENEE380); or any one of these courses and a 400-level MATH course, or two 400-level MATH courses). Or permission of instructor. Also offered as: 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.
Prerequisite: 1 course with a minimum grade of C- from (MATH240, PHYS274); and 1 course with a minimum grade of C- from (CMSC351, PHYS373).
Restriction: Permission of CMNS-Computer Science department.
Additional Information: No previous background in quantum mechanics is required.
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.
**Prerequisite:** MATH240 and MATH241; and (CMSC106 or CMSC131); and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.
Also offered as: 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:** MATH240 and MATH241; and (CMSC106 or CMSC131); and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.
Also offered as: AMSC466.
**Credit Only Granted for:** AMSC460, AMSC466, CMSC460, or CMSC466.

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:** MATH240 and MATH241; and permission of CMNS-Computer Science department. Or must be in the (Computer Science (Doctoral), Computer Science (Master's)) program.
Also offered as: MATH475.

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.

CMSC630 Foundations of Software Verification (3 Credits)
**Prerequisite:** CMSC330; or students who have taken courses with comparable content may contact the department; or permission of instructor.

CMSC631 Program Analysis and Understanding (3 Credits)
**Prerequisite:** CMSC330; or students who have taken courses with comparable content may contact the department; or permission of instructor.

CMSC634 Empirical Research Methods for Computer Science (3 Credits)
A graduate-level introductory course on empirical research methods for computer scientists. Experimental techniques for evaluating software systems and processes, human performance using interfaces, programming environments, and software engineering methods. Introduction to constructs and methods of measurements, qualitative and quantitative design, quasi-experimental and non-experimental design, baseline design, and statistical analysis.
**Recommended:** An introductory statistics class.
**Restriction:** Must be in Computer Science (Master's) program; or must be in Computer Science (Doctoral) program; or permission of instructor. 
**Credit Only Granted for:** CMSC838G (Fall2005) or CMSC634.

CMSC641 Principles of 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 what data science means and systems and tools commonly used for data science, and illustrates the principles of data science through several case studies.
**Restriction:** Must be in the Data Science Post-Baccalaureate Certificate of Professional Studies program; and permission of CMNS-Computer Science department.

CMSC642 Big Data Systems (3 Credits)
An overview of data management systems for performing data science on large volumes of data, including relational databases, and NoSQL systems. The topics covered include: different types of data management systems, their pros and cons, how and when to use those systems, and best practices for data modeling.
**Restriction:** Must be in the Data Science Post-Baccalaureate Certificate of Professional Studies program; and permission of CMNS-Computer Science department.
CMSC643 Machine Learning and Data Mining (3 Credits)
Provides a broad overview of key machine learning and data mining algorithms, and how to apply those to very large datasets. Topics covered include decision trees, linear models for classification and regression, support vector machines, neural networks and deep learning, online learning, recommendation systems, clustering and dimensionality reduction, and systems for large-scale machine learning.
Restriction: Must be in the Data Science Post-Baccalaureate Certificate of Professional Studies program; and permission of CMNS-Computer Science department.

CMSC644 Algorithms for Data Science (3 Credits)
Provides an in-depth understanding of some of the key data structures and algorithms essential for advanced data science. Topics include random sampling, graph algorithms, network science, data streams, and optimization.
Restriction: Must be in the Data Science Post-Baccalaureate Certificate of Professional Studies program; and permission of CMNS-Computer Science department.

CMSC651 Analysis of Algorithms (3 Credits)
Efficiency of algorithms, orders of magnitude, recurrence relations, lower-bound techniques, time and space resources, NP-complete problems, polynomial hierarchies, and approximation algorithms. Sorting, searching, set manipulation, graph theory, matrix multiplication, fast Fourier transform, pattern matching, and integer and polynomial arithmetic.
Prerequisite: CMSC451.

CMSC652 Complexity Theory (3 Credits)
This course will define what it means for a problem to be hard (or easy) in a variety of ways. The emphasis will be on natural problems. Topics may include NP-completeness, Sparse Sets, Graph Isomorphism (why it is thought to not be NP-complete), Counting problems, and approximation problems.
Prerequisite: CMSC451 or CMSC452; or permission of instructor.
Credit Only Granted for: CMSC652 or CMSC858G.
Formerly: CMSC858G.

CMSC656 Introduction to Cryptography (3 Credits)
Introduction to modern cryptography. Topics include symmetric-key encryption, hash functions, message-authentication codes, block-cipher design, theoretical foundations, number theory, public-key encryption, and digital signatures.
Prerequisite: CMSC451, CMSC452, or CMSC456.
Credit Only Granted for: CMSC656 or CMSC858K.
Formerly: CMSC858K.

CMSC657 Introduction to Quantum Information Processing (3 Credits)
An introduction to the field of quantum information processing. Students will be prepared to pursue further study in quantum computing, quantum information theory, and related areas.
Prerequisite: Familiarity with complex numbers and basic concepts in linear algebra (e.g., eigenvalues, eigenvectors, Hermitian and unitary matrices) is required.
Credit Only Granted for: CMSC657 or CMSC858K.
Formerly: CMSC858K.

CMSC660 Scientific Computing I (3 Credits)
Monte Carlo simulation, numerical linear algebra, nonlinear systems and continuation method, optimization, ordinary differential equations. Fundamental techniques in scientific computation with an introduction to the theory and software for each topic.
Prerequisite: Must have knowledge of C or Fortran. And CMSC466, AMSC466, AMSC460, or CMSC460; or (must have knowledge of basic numerical analysis (linear equations, nonlinear equations, integration, interpolation); and permission of instructor). Also offered as: AMSC660.
Credit Only Granted for: AMSC660 or CMSC660.

CMSC661 Scientific Computing II (3 Credits)
Fourier and wavelet transform methods, numerical methods for elliptic partial differential equations, numerical linear algebra for sparse matrices, Finite element methods, numerical methods for time dependent partial differential equations. Techniques for scientific computation with an introduction to the theory and software for each topic. Course is part of a two course sequence (660 and 661), but can be taken independently.
Prerequisite: Must have knowledge of C or Fortran. And CMSC466, AMSC466, AMSC460, or CMSC460; or (must have knowledge of basic numerical analysis (linear equations, nonlinear equations, integration, interpolation); and permission of instructor). Also offered as: AMSC661.
Credit Only Granted for: AMSC661 or CMSC661.

CMSC662 Computer Organization and Programming for Scientific Computing (3 Credits)
This course presents fundamentals issues of computer hardware, software, parallel computing, and scientific data management for programming for scientific computation.
Prerequisite: Must have Knowledge of C or Fortran. And CMSC466, AMSC466, AMSC460, or CMSC460; or (must have knowledge of basic numerical analysis (linear equations, nonlinear equations, integration, interpolation); and permission of instructor). Also offered as: AMSC662.
Credit Only Granted for: AMSC662 or CMSC662.

CMSC663 Advanced Scientific Computing I (3 Credits)
In the sequence CMSC663, CMSC664 students work on a year-long individual project to develop software for a scientific task in a high performance computing environment. Lectures will be given on available computational environments, code development, implementation of parallel algorithms. Also offered as: AMSC663.
Credit Only Granted for: AMSC663 or CMSC663.

CMSC664 Advanced Scientific Computing II (3 Credits)
In the sequence CMSC663, CMSC664 students work on a year-long individual project to develop software for a scientific task in a high performance computing environment. Lectures will be given on code development and validation, parallel algorithms for partial differential equations, nonlinear systems, optimization.
Prerequisite: CMSC663.
Restriction: Permission of instructor. Also offered as: AMSC664.
Credit Only Granted for: AMSC664, or CMSC664.

CMSC666 Numerical Analysis I (3 Credits)
Interpolation and approximation, numerical integration, solution algorithms for nonlinear systems of equations, numerical optimization.
Prerequisite: CMSC466 or AMSC466; and MATH410. Also offered as: AMSC666.
Credit Only Granted for: AMSC666 or CMSC666.
CMSC667 Numerical Analysis II (3 Credits)
Prerequisite: AMSC666 or CMSC666. Also offered as: AMSC667.
Credit Only Granted for: AMSC667 or CMSC667.

CMSC701 Computational Genomics (3 Credits)
An introduction to the algorithms and heuristics used in the analysis of biological sequences. Includes an introduction to string matching and alignment algorithms, phylogenetic analysis, string reconstruction (genome assembly), and sequence pattern recognition (gene and motif finding). A particular emphasis will be placed on the design of efficient algorithms and on techniques for analyzing the time and space complexity of these algorithms. Computational concepts will be presented in the context of current biological applications. No prior knowledge of biology necessary.

CMSC702 Computational Systems Biology (3 Credits)
An introduction to the fundamental concepts in the computational analysis of biological systems with applications to: functional genomics, population genetics, interaction networks, epigenetics. Computational concepts covered: network and graph algorithms, machine learning, large data/network visualization, statistical modeling and inference, probabilistic graphical models, sparse methods in data analysis, numerical optimization. No prior knowledge of biology required.

CMSC703 Network Analysis and Modeling of Biological Systems (3 Credits)
An introduction to the computational network analysis and modeling of biological systems focusing on transcriptional, protein, signaling and metabolic networks (with primary emphasis on integrating the former within the latter). Computational methods studied for this type of analysis include: network and graph algorithms, network-based machine learning approaches, modeling dynamical systems, numerical optimization (linear, integer and quadratic programming) and a variety of other methods used to solve constraint based problems (primarily in the context of studying metabolic networks). These methods are complementary to those studied in CMSC701 and CMSC702.
Restriction: Must be in one of the following programs (Computer Science (Doctoral); Computer Science (Master's); Applied Mathematics and Scientific Computation (Doctoral); Applied Mathematics and Scientific Computation (Master's)) ; or permission of instructor.

CMSC711 Computer Networks (3 Credits)
Principles, design, and performance evaluation of computer networks.
Network architectures including the ISO model and local area networks (LANs). Communication protocols and network topology.
Prerequisite: CMSC412; or students who have taken courses with comparable content may contact the department.

CMSC712 Distributed Algorithms and Verification (3 Credits)
Study of algorithms from the distributed and concurrent systems literature. Formal approach to specifying, verifying, and deriving such algorithms. Areas selected from mutual exclusion, resource allocation, quiescence detection, election, Byzantine agreements, routing, network protocols, and fault-tolerance. Formal approaches will handle system specification and verification of safety, liveness, and real-time properties.

CMSC722 Artificial Intelligence Planning (3 Credits)
Automated planning of actions to accomplish some desired goals. Basic algorithms, important systems, and new directions in the field of artificial intelligence planning systems.
Prerequisite: CMSC421; or students who have taken courses with comparable content may contact the department; or permission of CMNS-Computer Science department.

CMSC723 Computational Linguistics I (3 Credits)
Fundamental methods in natural language processing. Topics include: finite-state methods, context-free and extended context-free models of syntax; parsing and semantics interpretation; n-gram and Hidden Markov models, part-of-speech tagging; natural language applications such as machine translation, automatic summarization, and question answering.
Prerequisite: CMSC421; or students who have taken courses with comparable content may contact the department; or permission of instructor. Also offered as: LING723, INST735.
Credit Only Granted for: CMSC723, LING723, or INST735.
Additional Information: May only receive PhD Comp. credit for CMSC723 or CMSC823, not both.

CMSC724 Database Management Systems (3 Credits)
Theoretical and implementation issues in advanced database systems. Topics include distributed databases, parallel databases, database client-server architectures, multimedia access methods, advanced query optimization techniques, data semantics and models, object-oriented databases, and deductive and expert database systems.
Restriction: Must be in one of the following programs (Computer Science (Master's); Computer Science (Doctoral)) ; or permission of instructor; or permission of CMNS-Computer Science department.

CMSC725 Geographical Information Systems and Spatial Databases (3 Credits)
Topics in geographic information systems and spatial databases. Integrates related results from databases, cartography, geography, computer graphics, file access methods, computational geometry, image processing, data structures, and programming languages. Topics include: cartographic modeling, principles of cartography, methods from computational geometry, principles of spatial databases, access methods, and spatial data structures. The architecture of some existing spatial databases and geographic information systems will be examined in greater detail.
Prerequisite: CMSC424 and CMSC420; or permission of instructor.

CMSC726 Machine Learning (3 Credits)
An introduction to modern statistical data analysis using machine learning techniques. The course quickly surveys elementary statistical models (decision trees, nearest neighbors and linear regression) and moves on to more complex algorithms such as support vector machines, boosting, neural networks, structured prediction, apprenticeship learning, online learning, bandits, recommender systems and reinforcement learning. Throughout an emphasis is placed on mathematical rigor.
Prerequisite: CMSC421; or students who have taken courses with comparable content may contact the department; or permission of instructor.
CMSC727 Neural Modeling (3 Credits)
Fundamental methods of neural modeling. Surveys historical development and recent research results from both the computational and dynamical systems perspective. Logical neurons, perceptrons, linear adaptive networks, attractor neural networks, competitive activation methods, error back-propagation, self-organizing maps, and related topics. Applications in artificial intelligence, cognitive science, and neuroscience.
Prerequisite: CMSC421; or students who have taken courses with comparable content may contact the department; or permission of instructor.

CMSC733 Computer Processing of Pictorial Information (3 Credits)
Input, output, and storage of pictorial information. Pictures as information sources, efficient encoding, sampling, quantization, approximation. Position-invariant operations on pictures, digital and optical implementations, the pax language, applications to matched and spatial frequency filtering. Picture quality, image enhancement and image restoration. Picture properties and pictorial pattern recognition. Processing of complex pictures; figure extraction, properties of figures. Data structures for pictures description and manipulation; picture languages. Graphics systems for alphanumeric and other symbols, line drawings of two- and three-dimensional objects, cartoons and movies.
Prerequisite: CMSC420.

CMSC734 Information Visualization (3 Credits)
Information visualization defined in relation to graphics, scientific visualization, databases, data mining, and human-computer interaction. Visualizations for dimensional, temporal, hierarchical and network data. Examines design alternatives, algorithms and data structures, coordinated views, and human factors evaluations of efficacy.
Prerequisite: CMSC434; or students who have taken courses with comparable content may contact the department; or permission of instructor.

CMSC737 Fundamentals of Software Testing (3 Credits)
Examine fundamental software testing and related program analysis techniques. In particular, the important phases of testing will be reviewed, emphasizing the significance of each phase when testing different types of software. Concepts include: test generation, oracles, prioritization and coverage, regression and mutation testing, and program analysis.
Prerequisite: CMSC435; or students who have taken courses with comparable content may contact the department; or permission of instructor.
Formerly: CMSC838M.

CMSC740 Advanced Computer Graphics (3 Credits)
An introduction to the principles of computer graphics. Includes an introduction to graphics displays and systems, introduction to the mathematics of affine and projective transformations, perspective, curve and surface modeling, algorithms for hidden-surface removal, color models, methods for modeling illumination, shading, and reflection.
Prerequisite: MATH240 and CMSC420; or permission of instructor.

CMSC751 Parallel Algorithms (3 Credits)
A presentation of the theory of parallel computers and parallel processing. Models of parallel processing and the relationships between these models. Techniques for the design and analysis of efficient parallel algorithms including parallel prefix, searching, sorting, graph problems, and algebraic problems. Theoretical limits of parallelism, inherently sequential problems, and the theory of P-completeness.
Prerequisite: CMSC451; or students who have taken courses with comparable content may contact the department.

CMSC754 Computational Geometry (3 Credits)
Introduction to algorithms and data structures for computational problems in discrete geometry (for points, lines, and polygons) primarily in two and three dimensions. Topics include triangulations and planar subdivisions, geometric search and intersection, convex hulls, Voronoi diagrams, Delaunay triangulations, line arrangements, visibility, and motion planning.
Prerequisite: CMSC451 and CMSC420; or permission of instructor.

CMSC760 Advanced Linear Numerical Analysis (3 Credits)
Advanced topics in numerical linear algebra, such as dense eigenvalue problems, sparse elimination, iterative methods, and other topics.
Prerequisite: AMSC666 or CMSC666; or permission of instructor. Also offered as: AMSC660.
Credit Only Granted for: AMSC660 or CMSC760.

CMSC763 Advanced Linear Numerical Analysis (3 Credits)
Advanced topics in numerical linear algebra, such as dense eigenvalue problems, sparse elimination, iterative methods, and other topics.
Prerequisite: AMSC666 or CMSC666; or permission of instructor. Also offered as: AMSC763.
Credit Only Granted for: AMSC660, CMSC760, AMSC763, or CMSC763.
Formerly: CMSC760.

CMSC764 Advanced Numerical Optimization (3 Credits)
Modern numerical methods for solving unconstrained and constrained nonlinear optimization problems in finite dimensions. Design of computational algorithms and the analysis of their properties.
Prerequisite: MATH410; or permission of instructor. Also offered as: AMSC607.
Credit Only Granted for: AMSC607 or CMSC764.
Formerly: CMSC878O.

CMSC773 Computational Linguistics II (3 Credits)
Natural language processing with a focus on corpus-based statistical techniques. Topics include: stochastic language modeling, smoothing, noisy channel models, probabilistic grammars and parsing; lexical acquisition, similarity-based methods, word sense disambiguation, statistical methods in NLP applications; system evaluation.
Prerequisite: LING723 or CMSC723; or permission of instructor. Also offered as: LING773.
Formerly: CMSC828R.
Additional Information: May only receive PhD Comp. credit for CMSC723 or CMSC823, not both.

CMSC798 Graduate Seminar in Computer Science (1-3 Credits)
CMSC799 Master's Thesis Research (1-6 Credits)

CMSC818 Advanced Topics in Computer Systems (1-3 Credits)
Advanced topics selected by the faculty from the literature of computer systems to suit the interest and background of students.
Restriction: Permission of instructor.
Repeatable to: 99 credits.

CMSC828 Advanced Topics in Information Processing (1-3 Credits)
Advanced topics selected by the faculty from the literature of information processing to suit the interest and background of students.
Restriction: Permission of instructor.
Repeatable to: 99 credits.

CMSC838 Advanced Topics in Programming Languages (1-3 Credits)
Advanced topics selected by faculty from the literature of programming languages to suit the interest and background of students.
Restriction: Permission of instructor.
Repeatable to: 99 credits.
CMSC858 Advanced Topics in Theory of Computing (1-3 Credits)
Advanced topics selected by the faculty from the literature of theory of computing to suit the interest and background of students.
Restriction: Permission of instructor.
Repeatable to: 99 credits.

CMSC878 Advanced Topics in Numerical Methods (1-3 Credits)
Advanced topics selected by the faculty from the literature of numerical methods to suit the interest and background of students.
Restriction: Permission of instructor.
Repeatable to: 99 credits.

CMSC898 Pre-Candidacy Research (1-8 Credits)
Prerequisite: permission of instructor. Advanced topics selected by the faculty from the literature of applications of computer science to suit the interest and background of students. May be repeated for credit.
Restriction: Permission of instructor.

CMSC899 Doctoral Dissertation Research (1-8 Credits)