# Computer and Information Science

## Faculty and Fields of Interest

Students who major in computer science are given a strong background in computer hardware and software, as well as a substantial amount of "hands-on" experience. They are prepared to work both in computer industry and business as well as pursue graduate studies in the discipline. Both major and minor programs are offered.

The undergraduate program is accredited by the Accreditation Board for Engineering and Technology (ABET), Computing Accreditation Commission, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012.

Qualified computer science majors can benefit from the Cooperative Education program offered in cooperation with the local computer industry.

The CIS department also offers a Master of Science Degree in Computer Science with a broad range of required and elective courses in theoretical computer science, computer systems, software engineering, parallel and distributed computing, and computer networks. See the *Graduate Catalogue* for information.

**Emad H Aboelela** quality of service in computer networks, network design optimization, mobile networks, fuzzy systems

**Ramprasad Balasubramanian** computer vision, motion analysis, image processing

**Jan Bergandy** distributed systems, software engineering, theoretical computer science

**Paul Bergstein** object-oriented programming, databases

**Eugene Eberbach** evolutionary computing, concurrent systems, artificial intelligence

**Robert Green (interim vice chancellor for library services, information resources, and technology)** software engineering, parallel architectures

**Boleslaw Mikolajczak (chairperson)** algorithms and complexity, parallel and distributed processing, computer architecture, theoretical computer science

**Li Shen** computer vision, shape analysis, medical imaging

**Richard Upchurch** social implications, software engineering, human-computer interaction

**Iren Valova** artificial intelligence, neural networks, image processing

**Vinod Vokkarane** computer networks, high performance networks, wireless and optical networks

**Haiping Xu** software engineering, distributed computing, multi-agent systems, formal methods

**Gaoyan Xie** component-based software development and engineering, software verification and validation, model checking and software testing

**Xiaoqin Zhang** multi-agent systems, intelligent agents, e-commerce

**Department Mission**

- To offer the strongest Bachelor of Science in Computer Science and ABET accredited program in Massachusetts
- To offer graduate programs in Computer Science of intellectual rigor
- To maintain Computer Science research programs appropriate to the University
- To meet regional and state needs through education and industrial and community outreach
- To build a satisfying and career enhancing environment at UMD
- To help build an interdisciplinary intellectual environment at UMD
- To maintain curricula to meet the computer fluency needs of all UMD students

**Program Goals**

- Graduates who succeed as practicing computer scientists
- Graduates who succeed in advanced study in computer science
- Graduates who adapt and evolve in complex technological environments such as those found in the workplace
- Graduates who influence the development of professional, ethical and legal aspects of computing

**Program Outcomes**

Through its major in computer science, to produce graduates who:

- are able to individually solve problems in algorithmic manner with given computer resources and constraints;
- apply their knowledge of mathematics, science and computer science to solve technical problems;
- apply analytic and empirical techniques to evaluate technical problems and their solutions;
- design system, component, or process to meet specified requirements;
- participate as a member of a problem solving team;
- identify, formulate, and solve problems encountered when constructing solutions involving information technology;
- articulate the social, professional, ethical and legal aspects of a computing milieu;
- evaluate the impact of computing and information technology at the global/societal level;
- analyze contemporary issues related to the evolving computer science discipline;
- communicate effectively both orally and in writing, and including choosing and using the appropriate representations and/or media);
- apply modern skills, techniques, and tools during professional practice.

## Computer Science Major
BS degree

**Alternative Paths Program Requirements**
Depending on the results of placement testing, new freshman students may be placed into one of the following first-year curricula in lieu of the standard curriculum.

| | | | Credits |
|---|---|---|---|
| First Year Courses for Precalculus-Ready Freshmen | | | |
| ENL 101 | Critical Writing and Reading I | | 3 |
| ENL 102 | Critical Writing and Reading II | | 3 |
| MTH 111 | Analytical Geometry & Calculus I | | 4 |
| MTH 131 | Precalculus | | 3 |
| CIS 180 | Object-Oriented Programming | | 4 |
| CIS 181 | Programming Paradigms | | 4 |
| | General Education Electives | | 6 |
| | | **Total:** | **27** |
| First-Year Courses for Algebra-Ready Freshmen | | | |
| ENL 101 | Critical Writing and Reading I | | 3 |
| ENL 102 | Critical Writing and Reading II | | 3 |
| MTH 100 | Basic Algebra | | 3***** |
| MTH 131 | Precalculus | | 3 |
| CIS 120 | Web Page Development | | 3 |
| CIS 180 | Object-Oriented Programming | | 4 |
| | General Education Electives | | 12 |
| | | **Total:** | **31** |

***** Students receive 3 administrative credits for Math 100. Administrative credits do not count towards the total credits required for graduation.

A wide selection of courses offers experience in software engineering, computer languages, artificial intelligence, compilers, computer networks, operating systems, computer architecture, computer graphics, parallel computing, human computer interaction and data bases, as well as theoretical aspects. The undergraduate computer science curriculum is object-oriented, lab intensive, and directed toward software development. The courses are supported by a network of state-of-the-art workstations and various specialized laboratories.

The Computer Science bachelor's degree program is accredited by the Computing Accreditation Commission of the Accreditation Board of Engineering and Technology (CAC/ABET, www.abet.org).

Computer Science majors must fulfill the requirements shown in the chart to the right. In addition, all Computer Science majors must complete the CIS Department Exit Survey in their final semester.

**General Education Departmental Requirements**

Students majoring in Computer Science will meet their departmentally-determined General Education requirements as follows:

Area E: Satisfied by CIS 381
Area I, Tier 2: Satisfied by any CIS course above CIS 110
Area W, Tier 2: Satisfied by ENL 266
Area O: Satisfied by CIS Technical Electives, CIS 362 and 480

**Calculation of GPA in the Computer Science Major**

Students must have a 2.000 cumulative grade point average (GPA) for all courses taken at the University in order to graduate. Students must also have a 2.000 cumulative GPA in the major. For purposes of this computation:
**1** All required courses with a CIS prefix count in calculating the GPA for the Computer Science major. These include all the CIS core courses plus CIS 362 and CIS 381.
**2** All courses on the approved list of CIS technical electives count in calculating the GPA for the Computer Science major, whether or not they are used to satisfy the technical elective requirement.
**3** All other courses are excluded from the calculation of the major cumulative GPA, even if they have a CIS prefix.
**4** Only the most recently earned grade for each course (whether higher or lower than previous grades) shall enter in the calculation of the major cumulative GPA.

## Requirements

## Computer Science BS/MS Option

| | | Credits |
|---|---|---|
| **1** *Complete the following CIS core courses, each with a grade of "C" or better.* | | |
| CIS 180 | Object-Oriented Programming | 4 |
| CIS 181 | Programming Paradigms | 4 |
| CIS 190 | Introduction to Procedural Programming | 4 |
| CIS 272 | Introduction to Computing Systems | 4 |
| CIS 273 | Computer Organization and Design | 4 |
| CIS 280 | Software Specification and Design | 4 |
| CIS 360 | Algorithms and Data Structures | 3 |
| CIS 361 | Models of Computation | 3 |
| CIS 370 | Design of Operating Systems | 4 |
| CIS 480 | Software Engineering | 4 |
| CIS 481 | Parallel & Distrib. Software Systems | 3 |
| **2** *Complete four additional courses from the following CIS technical electives, each with a grade of 'C' or better:* | | |
| CIS 314 | Computer Architecture | 4 |
| CIS 410 | Programming Language Design | 3 |
| CIS 412 | Found. Artificial Intelligence | 3 |
| CIS 421 | Intro. Theory of Computing | 3 |
| CIS 422 | Design of Parallel Algorithms | 4 |
| CIS 430 | Data Mining and Knowledge Discovery | 3 |
| CIS 431 | Human-Computer Interaction | 4 |
| CIS 452 | Database Systems | 3 |
| CIS 454 | Computer Graphics | 3 |
| CIS 465 | Topics in Computer Vision | 3 |
| CIS 467 | Image Analysis and Processing | 3 |
| CIS 471 | Compiler Design | 3 |
| CIS 475 | Computer Networks | 3 |
| CIS 476 | Network Programing | 3 |
| CIS 490 | Machine Learning | 3 |
| **3** *Complete the following Mathematics Requirements:* | | |
| MTH 111,112 | Analytical Geometry & Calculus I, II | 8 |
| MTH 181,182 | Discrete Structures I, II | 6 |
| MTH 331 | Probability | 3 |
| **4** *Complete the following Science/Quantitative courses:* | | |
| PHY 113, 114 | Classical Physics I, II (4, 4) | 8-11 |
| | **or** | |
| CHM 151,152 | Principles of Modern Chemistry I, II (3, 3) | |
| CHM 161,162 | Introduction to Applied Chemistry I, II (1, 1) | |
| | **or** | |
| BIO 121,122 | Biology of Organisms I, II (3, 3) | |
| BIO 131,132 | Biology of Organisms Laboratory I, II (1, 1) | |
| | *and* | |
| CIS 362 | Empirical Methods for Computer Science | |
| | Science/Quantitative course | 3 |
| **5** *Complete the General Education requirements and free electives:* | | |
| *Writing, Tier 1 and Tier 2; Information, Tier 1* | | |
| ENL 101, 102 | Critical Writing and Reading I, II | 6 |
| ENL 266 | Technical Communications | 3 |
| *Ethics and Cultural Responsibility* | | |
| CIS 381 | Social and Ethical Aspects of Computing | 3 |
| *Cultural and Artistic Literacy* | | 9 |
| *Global Awareness* | | 3 |
| *Diversity* | | 3 |
| *Free electives* | | 9 |
| **Program Total** | | **at least 120** |

This fast-track program enables well-qualified BS degree students in Computer Science to complete both the BS and the MS in nine fewer total credits. Students will take three graduate courses as their CIS BS-degree technical electives. Students electing the BS/MS option are required to complete a master's thesis.

**Eligibility**

Current undergraduate Computer Science students (including transfer students) who are in progress towards completing their first bachelor's degree are eligible to apply if they

- have completed 60 credits towards the BS degree;
- have not taken and are not currently enrolled in any senior-level (400-level) or graduate (500-level) course;
- have completed courses CIS 180, 181, 190, 272, 273, 280 (or equivalents for transfer students);
- have a GPA of at least 3.000 in all CIS courses taken at the time of application;
- have completed MTH 181, 182 and 111, 112 (or equivalents for transfer students) with a GPA of at least 2.800.

Those interested may consult the Computer Science Graduate Program Director about their eligibility. Students apply for admission to the BS/MS option through the Office of Graduate Studies, submitting the regular graduate application but without GRE or TOEFL scores, or recommendation letters. Application decisions are reviewed by the CIS Graduate Committee.

**Progression to MS Study**

The student will earn the BS degree at the point of meeting all BS degree requirements, counting the completed three graduate courses as senior electives. At this time, the approved BS/MS student's status changes to graduate level. However, BS/MS students may change to graduate status earlier once they have completed at least 111 credits toward the BS, have completed all junior (300-level) CIS and MTH courses, and have a GPA in all CIS courses at or above 3.000. Students selecting the BS/MS option will pay undergraduate rates until changed to graduate status; in graduate status they may be considered for graduate assistantships.

**Maintaining MS Status**

The department has determined a specific policy to monitor BS/MS students' performance and progression towards their BS and then MS degrees. Any student accepted to the BS/MS option but later dismissed from the MS level will be transferred back to the BS level program.

## Computer Science Minors

Students interested in a minor should contact the CIS department for an application and admission requirements. The department offers three different minors, each with the emphasis indicated. Each requires credits as specified below.

**Admission to one of the minors**

Students must meet the university's admission requirements for a minor, which include having completed 54 credits. For computer science, prospective minors are encouraged to inquire and plan their minor program prior to earning 54 credits, because the structure of requirements could necessitate the use of more than four semesters. Courses completed prior to formal declaration will count toward the minor program.

Admission to the minor is accomplished through an application form available in the office of the chairperson of the department accompanied by current transcript(s). Upon acceptance the student is assigned an advisor, who works with the student to design an individual minor program that meets the stated requirements. Study plans are to be approved by the department chairperson.

### Computer Science

**Objectives**

**1** To develop in the student an understanding of computer science as a discipline, its structure, methodologies, and trends.
**2** To use the computer as a tool to solve problems.
**3** To give the student a sufficient background in computer science to continue his/her study of the discipline independently.
**4** To give students a sufficient knowledge in computer science to gain an advantage when entering the current job market.

**Requirements**

Complete the following courses with a grade of C or better:

| | | credits |
|---|---|---|
| CIS 180 | Object-Oriented Programming | 4 |
| CIS 181 | Programming Paradigms | 4 |
| CIS 280 | Software Specif. & Design | 4 |
| CIS 360 | Algorithms & Data Structures | 3 |
| CIS 361 | Models of Computation | 3 |
| CIS | One additional 300/400 course | 3 |
| | Total | 21 |

Students with prior experience in programming can substitute CIS 183 Object Paradigm for the sequence of courses CIS 180/181. Students can substitute the sequence CIS 115 Computer Programming in C / CIS 215 Program Design and Data Structures for the sequence CIS 180/181.

### Software Engineering

**Objectives**

**1** To develop in the student the ability to use software development methodologies and software processes to participate in the design and implementation of software systems.
**2** To teach the student how to design and implement software.
**3** To give the student a sufficient background in software engineering to continue his/her study of the discipline independently.
**4** To give students a sufficient knowledge in software engineering to gain an advantage when entering the current job market.

**Requirements**

Complete the following courses with a grade of C or better:

| | | credits |
|---|---|---|
| CIS 180 | Object-Oriented Programming | 4 |
| CIS 181 | Programming Paradigms | 4 |
| CIS 280 | Software Specif. & Design | 4 |
| CIS 480 | Software Engineering | 4 |
| CIS 481 | Parallel & Distr. Softw. Systems | 3 |
| CIS | One additional 300/400 course | 3 |
| | Total | 22 |

CIS 480 has as a prerequisite CIS 362 Empirical Methods. Students without a knowledge of empirical methods equivalent to CIS 362 must take that prerequisite course.

Students with prior experience in programming can substitute CIS 183 Object Paradigm for the sequence of courses CIS 180/181.

### System Software

**Objectives**

**1** To develop in the student the ability to use computer systems and system software and participate in the design and implementation of operating systems and computer networks.
**2** To give the student a sufficient background in systems software to continue his/her study of the discipline independently.
**3** To give students a sufficient knowledge in operating software and computer networks to gain an advantage when entering the current job market.

**Requirements**

Complete the following courses with a grade of C or better:

| | | credits |
|---|---|---|
| CIS 115 | Computer Programming with C | 3 |
| CIS 215 | Program Design/Data Str. w/ C | 3 |
| CIS 272 | Intro. to Computing Systems | 4 |
| CIS 273 | Computer Organization and design | 4 |
| CIS 370 | Design of Operating Systems | 4 |
| CIS 475 | Computer Networks | 3 |
| CIS | One additional 300/400 course | 3 |
| | Total | 24 |

**Gen Ed note:** Computer Science courses satisfy the Natural Science and Technology requirement.

## Computer and Information Science Courses

**CIS 110** three credits
**Computer Literacy**
An introduction to computers, evolution of computer systems and the impact of computers on the society. In this hands-on laboratory course, students will use Macintosh computers to learn about components of computer systems and study various applications including word processing, spreadsheet, database, presentation and internet browsing software. With the HyperCard, students will learn how to design and program in the multimedia environment. Each student will then use this knowledge to develop an individual final project for the course.

**CIS 115** three credits **I**
**Computer Programming with C**
Algorithm development, syntax and semantics of a high level programming language, debugging and verification of programs. Concepts of structured programming. Arrays, subroutines. Elementary system concepts (compilation, time-sharing).

**CIS 161** three credits
**Computer Programming BASIC**
An elementary programming course in the BASIC programming language, designed for the student with no prior experience in data processing.

**CIS 120** three credits
**Web Page Development**
An introduction to the theory and application of creating web pages using HTML and JavaScript. HTML is the underlying structure used by the World Wide Web and will be used in this course along with JavaScript to assist students in building a foundation to become proficient in designing web pages. The primary theme of the course is learning how to create web pages that are attractive, meaningful, and well designed. Assessment of achieving these goals also will be addressed. As time allows, DHTML (Dynamic HTML), XML and Java applets may be used.

**CIS 180** four credits
**Object-Oriented Programming I**
3 hours lecture; 2 hours laboratory
Basic concepts in programming, and introduction to the object paradigm. The course introduces the concept of the object paradigm and teaches how to design and implement simple programs in an object-oriented language. The course also covers the basics of how to use a computer and basic software tools, including libraries of components, in the process of developing programs.

**CIS 181** four credits
**Object-Oriented Programming II**
3 hours lecture; 2 hours laboratory
Prerequisite: CIS 180
Software development using advanced object paradigm concepts. This course introduces threads, networking, and exception handling and covers in depth the advanced topics of object paradigm such as inheritance and polymorphism. These concepts are introduced in the context of developing software using software tools including the libraries of components.

**CIS 183** four credits
**Object-Oriented Paradigm**
3 hours lecture; 2 hours laboratory
Introduction to the object paradigm. Software development using advanced object paradigm concepts of inheritance and polymorphism. Introduction to concurrency, and faulty tolerance. Developing software using software tools including the libraries of components. Comparison of procedural and object paradigms. Introduction to programming with multiple processes and with exception handling.

**CIS 190** four credits
**Introduction to Procedural Programming**
3 hours lecture; 2 hours laboratory
Prerequisite: CIS major
Procedural Programming (C/C++) under Unix. Data types, variable declarations, arithmetic expressions, conditional statements, macros, function prototypes, standard libraries, file processing, pointers, structures, unions, and dynamic memory management are discussed. Unix file system, shell scripts, input/output redirection, piping, programming with standard I/O, and unix system calls are covered.

**CIS 210** three credits
**Understanding E-Commerce Technologies**
An introduction to the technology issues in e-commerce. This course covers major types of e-commerce, the technology infrastructure of e-commerce, e-commerce web sites, security and encryption in e-commerce, payment systems, and B2B e-commerce technologies. Case studies on current e-commerce companies are used to gain insight on related issues. This course is intended to provide students from different majors with an overview and also necessary details of e-commerce technologies. No technical background is assumed.

**CIS 261** three credits
**Computer Programming, FORTRAN**
An intensive course in the FORTRAN programming language.

**CIS 265** three credits
**Program Design and Data Structures with C**
Prerequisite: Any Programming Course
An intensive course in the "C" programming language with introduction to UNIX for students who are already proficient in another high-level programming language such as BASIC, FORTRAN, or PASCAL.

**CIS 266** three credits
**Object-Oriented Programming in C++**
Prerequisite: Any programming course
Fundamental conceptual tools and their implementation of object-oriented design and programming such as: object, type, class, implementation hiding, inheritance, parametric typing, function overloading, polymorphism, source code reusability, and object code reusability. Object-Oriented Analysis/Design for problem solving. Implementation of Object-Oriented Programming paradigm is illustrated by program development in C++.

**CIS 272** four credits
**Introduction to Computing Systems**
3 hours lecture; 2 hours laboratory
Prerequisite: CIS 190
Corequisite: MTH 181
Introduction to major components of computer system software. The course introduces fundamental concepts of computing systems, such as binary arithmetic and data representation, the Von Neumann model for processing computer programs, the operation of memory, instruction set, and machine and assembly language programming. It systematically presents the levels of transformations from machine language to assembly language to high level language. The role of such systems software components as assemblers, compilers, linkers, loaders, and operating systems is studied. The course has a strong project component.

**CIS 273** four credits
**Computer Organization and Design**
3 hours lecture; 2 hours laboratory
Prerequisite: CIS 190, 272
Corequisite: MTH 181
Laws of computer organization and design for RISC architectures. Interfaces between hardware and software are studied. Influence of instruction set on performance is presented. Design of a processor with pipelining is analyzed. Computer arithmetic is studied. Memory hierarchy and their

influence on performance is documented. Elements of interfacing and I/O organization are included. The course has a design, implementation, and analytical components. (Formerly offered as CIS 270)

**CIS 280** four credits
**Software Specification and Design**
3 hours lecture; 2 hours laboratory
Prerequisite: CIS 181
Object-oriented analysis and design: methodologies and tools. The course focuses on methodologies of specification and design of software systems. It addresses the issues of user interface design and software prototyping. The course also presents the state of the art in the tool and environments supporting the front end of the software development cycle.

**CIS 298** one to six credits
**Experiential Learning**
Prerequisites: At least sophomore standing; permission of the instructor, department chairperson, and college dean
Work experience at an elective level supervised for academic credit by a faculty member in an appropriate academic field. Conditions and hours to be arranged. Graded CR/NC. For specific procedures and regulations, see section of catalogue on Other Learning Experiences.

**CIS 314** four credits
**Computer Architecture**
Prerequisite: CIS 273, 360
General organization of a computer system. Memory hierarchy. Emphasis on memory organization and management implementation. Local and long distance communication, bus, input-output organization and control. Programmed I/O and I/O processors. Interrupt handling. Processor organization; instruction set; arithmetic-logic unit; parallel and stack processors. Programmed and hardwired, central and distributed control.

**CIS 360** three credits
**Algorithms and Data Structures**
Prerequisite: CIS 181
Comprehensive coverage of all major groups of algorithms, including divide-and-conquer, dynamic programming, greedy, backtracking, branch-and-bound, and parallel algorithms. Discussion of the design and implementation of complex, dynamic data structures. The course also covers an introduction to the functional paradigm.

**CIS 361** three credits
**Models of Computation**
Prerequisites: CIS 181, MTH 182
Models of sequential, parallel, and distributed computations. The Chomsky hierarchy of formal languages and their accepting machines are studied in detail. The relationship of these languages and machines to computer programs is presented. Influence of a Turing machine and related formalisms on modern computing are studied. Decidability of decision problems is explained. Several models of parallel and distributed computations are introduced and compared.

**CIS 362** three credits
**Empirical Methods for Computer Science**
Prerequisite: MTH 331
Topics and methods supporting an experimental approach to the study of issues in computer science and software engineering. Course covers the basic principles of experimental design and case study construction. Emphasis in the course is on the use of empirical methods for decision making and the evaluation of research in computer science and software engineering that employ empirical methods.

**CIS 370** four credits
**Design of Operating Systems**
3 hours lecture; 2 hours laboratory
Prerequisite: CIS 273
Principles of modern operating systems and their design. Scientific principles and engineering rules of operating systems are explored. Process and storage management subsystems are analyzed in detail. Protection and security are taken into account in design. An introduction to distributed operating systems is also presented. This is a design and project based course with a laboratory component.

**CIS 381** three credits **V**
**Social and Ethical Aspects of Computing**
Prerequisite: Junior standing
Introduction to the social, legal, and ethical issues of computing. Topics include how computer use affects social and work relationships and the uses of computers in society. These will be reviewed in the context of risks, privacy and intrusion, computer crime, intellectual property, and professional decision-making. Students analyze scenarios that allow them to view ethical decision-making as a crucial part of understanding the world of computing.

**CIS 410** three credits
**Programming Language Design**
Prerequisite: CIS 360
Fundamental concepts and general principles underlying current programming languages and models. Topics include control and data abstractions, language processing and binding, the relationship between language design and language implementation. A variety of computational paradigms are discussed: functional programming, logic programming, object-oriented programming, and procedural programming.

**CIS 411** three credits
**Seminar**
Prerequisite: Senior CIS standing
Advanced topics in Computer Science.

**CIS 412** three credits
**Artificial Intelligence**
Prerequisite: CIS 360 or permission of instructor
Artificial intelligence problem-solving paradigms. The course covers heuristic versus algorithmic methods, rational and heuristic approaches, and description of cognitive processes; and objectives of work in artificial intelligence, the mid-brain problem and nature of intelligence, simulation of cognitive behavior, and self-organizing systems. Examples are given of representative applications.

**CIS 421** three credits
**Introduction to the Theory of Computing**
3 hours lecture
Prerequisite: CIS 361
Several of the most significant models of computation will be reviewed, i.e., Turing machines, 1-calculus, predicate calculus. The traditional undecidibility results will be covered, along with the attempts to overcome the resulting limitations in restricted situations. Mechanical theorem provers will be considered. The resolution and unification predicate calculus methods will be discussed along with appropriate PROLOG programming assignments. The Boyer-Moore approach will be discussed, along with LISP programming assignments.

**CIS 422** four credits
**Design of Parallel Algorithms**
3 hours lecture, 2 hours laboratory
Prerequisite: CIS 360 or permission of instructor
Design and analysis of algorithms for parallel computers with two modes of operation: shared memory, and message passing. Synchronous and asynchronous parallel algorithms for the following problems will be designed and implemented: selection, merging, sorting, searching, generating permutations and

combinations, and matrix operations. Parallel computational complexity of these algorithms will be analyzed.

**CIS 430** three credits
**Data Mining and Knowledge Discovery**
Prerequisite: CIS 360
Designed to provide students with a solid background in data mining and knowledge discovery concepts, tools, and methodology, as well as their applicability to real world problems. A variety of data mining techniques will be explored including memory-based reasoning, cluster detection, classification, neural networks, and finding understandable knowledge in large sets of real world examples. Some related topics such as web and multimedia mining will be discussed. Students will gain hands-on experience in data mining techniques using various data mining software packages and tools.

**CIS 431** four credits
**Human-Computer Interaction**
3 hours lecture; 3 hours laboratory
Prerequisite: CIS 362 or permission of instructor
Theory and principles for constructing usable software systems. Cognitive and effective aspects of users. The impact of user characteristics on design decisions. The construction and evaluation of the user interface. Sensory and perceptual aspects of interfaces, task structure, input modalities, screen layout, and user documentation. Individual concerns for systems such as personal productivity tools, real-time control systems, instructional software, and games.

**CIS 452** three credits
**Database Systems**
Prerequisite: CIS 280
Use of DBMS software in the development of an information system. Overview of the ANSI/SPARC Study Group on Database Management Systems model. Relational database model techniques. Emphasis on user views necessary to support data management and retrieval.

**CIS 454** three credits
**Computer Graphics**
Prerequisite: At least junior CIS standing
Graphics devices. Two dimensional and three dimensional image representations and transformations. Graphics systems software architecture; graphics standards; packages.

**CIS 455** three credits
**Bioinformatics**
Prerequisites: CIS 360 and CIS 362; or permission of the instructor
Introduction to the field of bio-informatics. This course addresses the analysis of information present in biological systems. This course presents an overview of the applications of computing technologies such as analysis of protein sequence, pattern matching, bio-modeling and simulation, and biological data visualization. It also provides algorithms and methods on a selection of computational problems as well as hands-on experience with tools and data.

**CIS 464** three credits
**Computer Game Design**
Prerequisites: CIS 280, CIS 360, and MTH 112
Science, technology, and art involved in the creation of computer games. A variety of software technologies relevant to games including programming languages, scripting languages, networks, simulation engines, and multimedia design systems are discussed along with underlying scientific concepts from computer science and related fields including simulation and modeling, graphics, artificial intelligence, real-time processing, and game theory. The art and design principles for developing usable and engaging games including software engineering, human computer interaction, thematic structure, graphic design, choreography, music and sound effects, and game aesthetics are introduced and compared.

**CIS 465** three credits
**Topics in Computer Vision**
Prerequisite: CIS 360 or permission of the instructor
Foundations of computer vision. Image formats, projection models, regions, filters, edge detection, segmentation, shape description and representation, object recognition and understanding, and stereo-vision are discussed.

**CIS 467** three credits
**Image Analysis and Processing**
Prerequisite: CIS 360 or permission of the instructor
Fundamentals in image analysis and processing. Topics in image processing such as display and filtering, image restoration, segmentation, compression of image information, warping, morphological processing of images, wavelets, multi-resolution imaging and unitary transforms are discussed.

**CIS 471** three credits
**Compiler Design**
Prerequisite: CIS 361
Organization of a compiler including lexical and syntax analysis, symbol tables, object code generation, error detection and recovery, code optimization techniques, and overall design. Compilation techniques and run-time structures in block-structured language.

**CIS 475** three credits
**Computer Networks**
Prerequisites: CIS 370
Topology of computer networks. Physical transmission. Error handling. Protocols. Satellite, packet radio, and local networks. Network interconnection. Security. Applications of computer networks.

**CIS 476** three credits
**Network Programming**
Prerequisite: CIS 370
Introduction to computer networks, and methods for programming network services and applications. The course covers the Internet protocol suite (e.g. IP, TCP, UDP), socket programming, and client-server design (e.g. connectionless, connection oriented, multiprotocol). The course discusses the implementation of real-time applications (e.g. streaming audio and video), and application -level gateways and tunneling. In addition, the course addresses protocol implementation using routing sockets and raw sockets. Programming projects represent a significant component of the course.

**CIS 477** three credits
**Computer and Information System Security**
Prerequisites: CIS 360 and CIS 370; or permission of the instructor
Introduction to computer and information system security. This course introduces the threats and vulnerabilities in computer and information systems. This course covers elementary cryptography, program security, security in operating systems, database security, network security, web and e-commerce security. It also covers the administration, legal, ethical, and privacy issues in computer security.

**CIS 480** four credits
**Software Engineering**
3 hours lecture; 2 hours laboratory
Prerequisite: CIS 280, 362
Software engineering models and processes; total quality management. The course will address the technical, logistical, and social issues associated with the software

**Note:** Some graduate courses may be open to undergraduates. Please consult your department chairperson. See the *Graduate Catalogue* for graduate general and program requirements.

development process. It will cover the issues of total quality management at the team and enterprise levels.

**CIS 481** three credits
**Parallel and Distributed Software Systems**
Prerequisite: CIS 280, 370
Parallelism and distribution of processing; software bus concept; patterns in software design. The course provides an in-depth discussion of the software systems wit multiple processes and of the relationship between concurrency and distribution of processes. The concept of the software bus, the existing standards, and the issues associated with their implementation are covered.

**CIS 490** three credits
**Machine Learning**
Prerequisite: CIS 360
Constructing computer programs that automatically improve with experience is the main task of machine learning. The key algorithms in the area are presented. Learning concepts as decision trees, artificial neural networks and Bayesian approach are discussed. The standard iterative dichotomizer (ID3) is presented, the issues of overfitting, attribute selection and handling missing data are discussed. Neural nets are discussed in detail, examples of supervised and unsupervised learning are presented. Instance-based learning, i.e. k-nearest neighbor learning, case-based reasoning are introduced. Genetic algorithms are discussed on introductory level.

**CIS 491, 492** three credits each
**Honors Project I, II**
Prerequisites: Junior standing, eligible for department honors program
The project courses required for completion of the departmental honors program. A significant experience in developing a computer system (typically), but equivalent alternatives are allowed. This system should require an extensive design effort prior to implementation and a serious effort for this implementation. It should have scholarly and/or practical value and might well profit by being interdisciplinary in nature.

**CIS 495** variable credit
**Independent Study**
Prerequisites: Upper-division standing; permission of instructor, department chairperson, and college dean
Study under the supervision of a faculty member in an area not otherwise part of the discipline's course offerings. Conditions and hours to be arranged.

**CIS 196, 296, 396, 496** three credits
**Directed Study**
Prerequisites: Permission of the instructor, department chairperson, and college dean
Study under the supervision of a faculty member in an area covered in a regular course not currently being offered. Conditions and hours to be arranged.

## Graduate Courses in Computer Science

**CIS 521** three credits
**Computability Theory**
Prerequisite: CIS 361 or equivalent, or permission of instructor
Computability of sets and functions in terms of various computation models, Church-Turing thesis. Systems of recursion equations and Post canonical systems are studied. Properties of the classes of recursive functions, recursive sets, and recursively enumerable sets are also covered.

**CIS 522** three credits
**Algorithms and Complexity**
Prerequisite: CIS 360 or equivalent, or permission of instructor
Evaluation of algorithms concerning their time and space complexity. Complexity hierarchies, axiomatic approach to computational complexity, NP complete problems, approxi-mation algorithms for these problems.

**CIS 525** three credits
**Parallel and Distributed Software Development**
Prerequisite: CIS 361 or equivalent, or permission of instructor
Design and development of parallel and distributed systems. This course provides state-of-the art presentation of software development for parallel and distributed systems. A systematic model-based approach has been applied across stages of software development. Various versions of Petri nets are used to model , specify, validate, and verify correctness of parallel and distributed systems. Performance is also assessed based on stochastic Petri nets. Rapid prototyping of parallel and distributed systems with automatic code generation is an ultimate goal of his course. Comparison with other approaches is also provided.

**CIS 526** three credits
**Functional Programming and Type Theory**
Prerequisite: CIS 360 or equivalent, or permission of instructor
Introduction to logic, type theory, and the lambda calculus. The course examines LISP as a first application of these ideas, consistency proofs using cut elimination and type theory, and constructive type of theory in functional programming languages in attempts to achieve program verification and automatic code generation.

**CIS 531** three credits
**Software System Specification**
Prerequisite: CIS 480 or equivalent
Formal foundation of the theory and practice of software specification; production of correct, consistent, and reliable software systems by expressing the requirements of the system in formal ways. Formal and informal requirements analysis and specification techniques, the relation of analysis and specification to concerns of validation and verification, maintenance, and reusability.

**CIS 532** three credits
**Software Systems Design**
Prerequisite: CIS 480 or equivalent
Principles and techniques for obtaining an architectural design from a system specification. Where appropriate, automated software design tools are used to demonstrate particular methodology. The relation of various design methods to the production of quality software that meets its specification, and the relation of design method to other life-cycle aspects. Design methods, design tools, the design process, and particular application domains for design techniques.

**CIS 543** three credits
**Software Systems Design with ADA**
Prerequisite: CIS 443 or equivalent, or permission of instructor
Software engineering principles and methodologies. Also considered are issues related to the life cycle of large systems developed in ADA, software engineering of real-time, fault-tolerant and distributed systems, and software reuse.

**CIS 545** three credits
**Programming Languages**
Prerequisite: Permission of instructor
Techniques of formal definition of programming languages, semantics of programming languages, programming styles, and language effects on software production. Introduces current trends in programming such as language features of problem-oriented and object-oriented programming,

and analysis and design of user-oriented application languages.

**CIS 552** three credits
**Database Design**
Prerequisite: CIS 452 or equivalent, or permission of instructor
The relational, hierarchical, and network approaches to database systems, including relational algebra and calculus, data dependencies, normal forms, data semantics, query optimization, and concurrency control on distributed database systems.

**CIS 554** three credits
**Advanced Computer Graphics**
Prerequisite: CIS 454 or equivalent, or permission of instructor
Three-dimensional graphics including: color, shading, shadowing and texture, hidden surface algorithms. An extensive project will be assigned, including documentation and presentation.

**CIS 560** three credits
**Theoretical Computer Science**
Prerequisites: CIS 360, 361, or equivalents
Theoretical basis of the development of computer science. The course details particular formalisms used in the design of hardware and software systems. Intrinsic limitations of computation are described. Advanced topics of automata theory and analysis of algorithms are included. The course also covers Turing machines, the halting problem, models of computation, intractable computations, polynomial reductions, P vs. NP, parallel algorithms, various formal descriptions and specifications of programs and computations, and proofs of program correctness and interactive proof systems.

**CIS 561** three credits
**Artificial Intelligence**
Expert system architectures: forward-production, logic programming, deductive retrieval, and semantic network systems. The course also treats natural language systems, illustrative working systems, and AI programming.

**CIS 563** three credits
**MultiAgent Systems**
Introduction to multiagent systems and distributed artificial intelligence. The course examines the issues that arise when groups or societies of autonomous agents interact to solve interrelated problems. Topics include defining multiagent systems and their characteristics, reasoning about agents' knowledge and beliefs, distributed problem solving and planning, coordination and negotiation, the organization and control of complex, distributed multiagent systems, learning in multiagent systems, and applications in the following domains: internet information gathering, electronic commerce, virtual markets, workflow management, distributed sensing network, distributed planning and resource allocation.

**CIS 564** three credits
**Mobile Robotics**
Prerequisite: Graduate standing
The theory, software and hardware for autonomous mobile robots. Reactive behavior-based, deliberative goal-based, and utility-based robotic architectures will be presented. Control and planning under bounded resources will be covered. Interaction with environment using sensors and actuators, robot kinematics and dynamics, reinforcement and evolutionary learning techniques for intelligent robots, interaction of competing and cooperating multi-robot systems will be presented. Various applications of mobile robots will be explored.

**CIS 565** three credits
**Evolutionary Computation**
Prerequisite: Graduate standing
Presentation of evolutionary algorithms and comparison to traditional solving techniques. This course deals with a powerful new technique for solution of hard, intractable real-world problems, based on principles of natural evolution. Four main areas of evolutionary computation will be explored: genetic algorithms, genetic programming, evolution strategies, and evolutionary programming. Applications of evolutionary computation to related areas of computer science will be discussed.

**CIS 566** three credits
**Theory of Linear and Integer Programming and Computer Applications**
Prerequisite: CIS 360 or equivalent, or permission of instructor
Basics of the simplex algorithm, tableaux, artificial variables, the two-phase method, the dual problem and its economic interpretation, primal-dual relationships and method. Also studied are applications to transportation problems and network flows, the polynomial methods of Khachiyan and Karmarkar, and integer programming. Computer methods and exercises will be employed throughout.

**CIS 570** three credits
**Advanced Computer Systems**
Prerequisite: CIS 314 or equivalent
In depth treatment of current computer systems, with performance issues at the center of an analytical approach. The course explores operating system software and the interrelation between architecture and system software. Advanced topics of compiling, assembly, linking and loading of high-level language software are included. The course treats mechanisms of IO and the memory hierarchy, various features of traditional machines, advanced features of modern machines such as RISC and multi-processor machines, and file systems and networked and distributed systems such as inter- and intra-nets. Throughout, performance issues are at the center of an analytical approach.

**CIS 571** three credits
**Compiler Construction**
Prerequisite: CIS 471 or equivalent, or permission of instructor
Different techniques for lexical analysis, syntax analysis, and object code generation. Emphasis on code optimization techniques and compiler-construction tools. The course will include a significant project.

**CIS 572** three credits
**Real Time Systems**
Prerequisite: CIS 481 or equivalent, or permission of instructor
Design and implementation of real-time systems. Implementation of real-time system in ADA, scheduling, fault tolerance, and distributed real-time systems are also studied.

**CIS 573** three credits
**Operating Systems**
Prerequisite: CIS 370 or equivalent, or permission of instructor
The methodologies of operating systems design and implementation. Concurrency, synchronization, process communication, switching control, deadlocks, implementation of dynamic structures, design of operating systems modules and interfaces, system security and integrity, and system updating and documentation are also studied.

**CIS 574** three credits
**Advanced Computer Architectures**
Prerequisite: CIS 314 or equivalent, or permission of instructor
Study of recent advances in computer organization. Parallel processors, pipelined processors, modular and network architectures data-flow machines, fault-tolerant systems, language-directed, object-based,

capability-based, and message-based processor organizations.

**CIS 575** three credits
**Parallel Algorithms and Parallel Architectures**
Prerequisites: CIS 314, 360 or equivalents; or permission of instructor
Parallel algorithms and their implementations in parallel architectures. In the first part of the course parallel algorithms are analyzed for problems in graph theory, algebra, FFT, and artificial intelligence. The second part presents implementations of these algorithms in various parallel architectures.

**CIS 577** three credits
**Computer Networks**
Prerequisite: CIS 475 or equivalent, or permission of instructor
Analysis and modeling of centralized and distributed computer networks. Queuing network analysis, principles of network design, software considerations, and design of computer networks are also studied.

**CIS 578** three credits
**Evaluation of Computer Systems Performance**
Prerequisite: MTH 331, CIS 314 or equivalents; or permission of instructor.
Techniques of analysis and simulation for evaluation of computer systems performance. Queuing systems, Poisson processes, scheduling, service distribution, conservation laws, queuing networks, and discrete simulations are also studied.

**CIS 579** three credits
**Multimedia Networking**
Prerequisite: CIS 475 or 476 or equivalents
Current techniques in multimedia communications and networking. The course presents the communication requirements of the different types of multimedia applications, the operation of the different underlying communication networks as multimedia carriers, and the communication protocols associated with these networks and gives an overview of the various quality-of-service models, real-time transmission issues, and compression techniques.

**CIS 580** three credits
**Paradigmatic Software Development**
Prerequisite: CIS 311 or equivalent
Software development in the context of various paradigms. The strategies and methods of the procedural, object-oriented, and functional paradigms are studied and practiced. The modeling of software processes will be considered from both the process and product views, as will the appropriateness and measures of effectiveness of these processes in the design of software systems. Students will apply these measures to the course exercises, determining and reviewing the impact of these methods on individual design.

**CIS 581** three credits
**Design and Verification of Information Systems**
Prerequisite: CIS 580 or equivalent, or permission of instructor
Sound design methodologies and technologies in development and maintenance of information systems/business systems with special emphasis on workflow management systems. An applied course that emphasizes the formal approach, this course also addresses issues of adaptability and flexibility of information systems and their evaluation. The course supports concurrent execution of information systems during the design stage and adopts and applies various forms of Petri nets.

**CIS 582** three credits
**Advanced Software Engineering**
Prerequisite: CIS 489 or equivalent, or permission of instructor
Advanced topics in software engineering that examine technical aspects of software development life cycle. This course introduces software process models including object-oriented process model, formal specification and design, distributed programing, software testing, and agent-oriented software engineering. The concepts are introduced in the context of developing large, critical and distributed software systems.

**CIS 583** three credits
**Software Architectures**
Prerequisite: CIS 580 or equivalent
Architectures of software systems. The course presents a systematic overview and analysis of architectural styles such as pipes and filters, distributed systems, layered systems, event-driven systems, control-based systems, implicit invocation, blackboard systems, etc. Formalization of software architectures with Z and Petri nets is presented. Influence of software architectures on business cycle, software quality, and design reusability are explored.

**CIS 585** three credits
**Image Processing and Machine Vision**
Prerequisite: Graduate standing and permission of the instructor
Foundations of image processing and machine vision. Students apply and evaluate topics such as edge detection, segmentation, shape representation, and object recognition. Stereo vision and motion analysis will be covered in detail including calibration, range images, change detection, motion correspondence, and 2-D and 3-D tracking. Important research papers will be discussed in class.

**CIS 588** three credits
**Neural Computing**
Prerequisite: Any course in programming languages and data structures
Fundamentals of artificial neural networks including application needs for neural networks, discussing the various architectures, learning algorithms and examples of applications. The standard neural networks are discussed in greater details, which allows for branching of architectures and combining of strategies for growing and/or constructing neural networks.

**CIS 590** three credits
**Optical Networks**
Prerequisite: CIS 475 or equivalent
Analysis and design of optical network paradigms and architectures. Introduction to optical components, wavelength division multiplexing, evolution of optical networks, design and analysis of wavelength-routed networks, and optical packet-/burst-switched networks are addressed. Principles of network design, linear programming, protocol and algorithm design, discrete event simulation techniques, and queuing theory are also studied.

**CIS 595** three credits
**Independent Study**
Prerequisites: Upper-division standing; permission of instructor, graduate director, and college dean
Study under the supervision of a faculty member in an area not otherwise part of the discipline's course offerings. Conditions and hours to be arranged.

**CIS 596** three credits
**Directed Study**
Prerequisites: Permission of the instructor, graduate director, and college dean
Study under the supervision of a faculty member in an area covered in a regular course not currently being offered. Conditions and hours to be arranged.

**CIS 600** three credits
**Master's Project**
Prerequisites: CIS 560, 570, and 580

Provides an experience in the development of a detailed, significant project in computer science under the close supervision of a faculty member, perhaps as one member of a student team. This project may be a software implementation, a design effort, or a theoretical or practical written analysis. Public presentation of the master's project and evaluation by two faculty other than the project supervisor are required.

**CIS 601, 602, 603** three credits each
**Special Topics**
Offered as needed to present advanced material to graduate students.

**CIS 690** three credits
**Master's Thesis**
Prerequisite: Permission of the Graduate Program Committee, based on performance in CIS 600, approval of proposed topic, and support of a faculty advisor and two faculty readers.
Research leading to submission of a formal thesis. This course provides an optional thesis experience, which may be based on the student's Project in a more intense form or be a sequel effort of a different character. In exceptional circumstances, the student may earn up to six thesis credits, if approved by the Graduate Program Committee. Graded A-F.