Computer Science

Department Website: http://cs.uchicago.edu

Program of Study

The computer science program prepares students for careers in computer science by offering a BA and a BS degree, as well as combined BA/MS and BS/MS degrees. Students who earn the BA are prepared either for graduate study in computer science or a career in industry. Students who earn the BS degree build strength in an additional field by following an approved course of study in a related area. The department also offers a minor. Furthermore, a computer science major or minor serves as an excellent foundation for work in other areas, including but not limited to mathematics, the natural sciences, social sciences, public administration, and the arts.

Program Requirements

Both the BA and BS in computer science require fulfillment of the mathematical sciences requirement in general education by completing an approved two-quarter calculus sequence. The physical sciences requirement in general education must be satisfied by completing an approved two-quarter sequence in either chemistry or physics. Both BA and BS students take at least fourteen computer science courses chosen from an approved program. BS students also take three courses in an approved related field outside computer science.

Advanced Placement

Computer science majors may use AP credit for chemistry or physics to meet their physical sciences requirement in general education or physical science components of the major. However, no credit designated simply as "physical science" (from either AP or the College's physical sciences examinations) may be used to meet general education requirements or requirements in the computer science majors. No course credit is awarded for AP Computer Science.

Approved Programs

The computer science department counselor is responsible for approval of specific courses and sequences, and responds as needed to changing course offerings in our program and other programs. Students should consult the department counselor for details on specific courses they are considering taking to meet the requirements.

Approved Computer Science Program

There is one approved general program for both the BA and BS degrees, comprised of introductory courses, a sequence in Theory, and a sequence in Programming Languages and Systems, followed by advanced electives. Students may substitute upper-level or graduate courses in similar topics for those on the list that follows with the approval of the department counselor. Students who matriculated prior to Autumn 2016 may choose to follow these requirements; otherwise they should consult the archived catalog from their
year of matriculation for the degree requirements in computer science. All students who matriculated in Autumn 2016 or later should follow this program.

For up-to-date information on course offerings and instructors in particular quarters, visit http://course-info.cs.uchicago.edu .

Students considering a computer science major are strongly advised to register for an introductory sequence, starting either with CMSC 15100 or CMSC 16100, in their first year. Incoming students should note that while CMSC 12100 can be used as the first course in the major, it is not open to first-year students, and it is not intended as an entry point for students who already know they want to major in computer science. Students who decide to pursue a computer science major or minor after completing CMSC 12100 may continue with either CMSC 15200-15400 or CMSC 12200-12300-15400. Note that CMSC 12200 does not meet the prerequisites for CMSC 15400.

1. **Introductory Sequence (three courses required):**

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<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Quarter</th>
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<tbody>
<tr>
<td>CMSC 15100</td>
<td>Introduction to Computer Science I</td>
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<tr>
<td>or CMSC 16100</td>
<td>Honors Introduction to Computer Science I</td>
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<tr>
<td>or CMSC 12100</td>
<td>Computer Science with Applications I</td>
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<tr>
<td>CMSC 15200</td>
<td>Introduction to Computer Science II</td>
<td>100</td>
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<tr>
<td>or CMSC 16200</td>
<td>Honors Introduction to Computer Science II</td>
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<tr>
<td>CMSC 15400</td>
<td>Introduction to Computer Systems</td>
<td>100</td>
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</tbody>
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Students may only receive credit for one introductory programming sequence: CMSC 10500-10600 Fundamentals of Computer Programming I-II, CMSC 12100-12200 Computer Science with Applications I-II, CMSC 15100-15200 Introduction to Computer Science I-II, or CMSC 16100-16200 Honors Introduction to Computer Science I-II. Exceptions must be approved by the department counselor prior to taking the second sequence.

2. **Programming Languages and Systems Sequence (three courses required):**

Three of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>CMSC 22001</td>
<td>Software Construction</td>
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<tr>
<td>CMSC 22100</td>
<td>Programming Languages</td>
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<td>CMSC 22200</td>
<td>Computer Architecture</td>
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<td>CMSC 22300</td>
<td>Functional Programming</td>
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<td>CMSC 22600</td>
<td>Compilers for Computer Languages</td>
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<tr>
<td>CMSC 23000</td>
<td>Operating Systems</td>
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<tr>
<td>CMSC 23010</td>
<td>Parallel Computing</td>
</tr>
<tr>
<td>CMSC 23200</td>
<td>Introduction to Computer Security</td>
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</tbody>
</table>
CMSC 23300  Networks and Distributed Systems  
CMSC 23310  Advanced Distributed Systems  
CMSC 23400  Mobile Computing  
CMSC 23500  Introduction to Database Systems  
CMSC 23700  Introduction to Computer Graphics  
CMSC 23710  Scientific Visualization  
CMSC 23800  Game Construction  

3. Theory Sequence (three courses required):  

Three of the following:  
CMSC 27100  Discrete Mathematics  
CMSC 27200  Theory of Algorithms  
CMSC 28000  Introduction to Formal Languages  
or CMSC 28100  Introduction to Complexity Theory  

We strongly encourage all majors to complete their Theory courses by the end of their third year.  

4. Electives (five courses required):  

The major requires five additional elective Computer Science courses numbered 20000 or above.  

Summary of Requirements**  
GENERAL EDUCATION  
One of the following sequences:  
CHEM 10100  & CHEM 10200  Introductory General Chemistry I  
and Introductory General Chemistry II (or higher or equivalent)  

PHYS 12100-12200  General Physics I-II (or higher)  

MATH 13100-13200  Elementary Functions and Calculus I-II (or higher)  

Total Units  
400  

*  Credit may be granted by examination.  

MAJOR  
Introductory Sequence:  
300
CMSC 15100 Introduction to Computer Science I
  or CMSC 16100 Honors Introduction to Computer Science I
  or CMSC 12100 Computer Science with Applications I

CMSC 15200 Introduction to Computer Science II
  or CMSC 16200 Honors Introduction to Computer Science II

CMSC 15400 Introduction to Computer Systems

Programming Languages and Systems Sequence (three courses from the list above) 300
Theory Sequence (three courses from the list above) 300
Five electives numbered CMSC 20000 or above 500
Plus the following requirements: 0-300

BA (no other courses required)

BS (three courses in an approved program in a related field)

Total Units 1400-1700

** Students who matriculated prior to Autumn 2016 may choose to follow these requirements; otherwise they should consult the archived catalog from their year of matriculation for the degree requirements in computer science. All students who matriculated in Autumn 2016 or later should follow this program.

Grading

Computer science majors must take courses in the major for quality grades. A grade of C- or higher must be received in each course in the major. Any 20000-level computer science course taken as an elective beyond requirements for the major may, with consent of instructor, be taken for P/F grading.

Non-majors may take courses either for quality grades or, subject to College regulations and with consent of instructor, for P/F grading. A Pass grade is given only for work of C-quality or higher. Courses fulfilling general education requirements must be taken for quality grades.

Incompletes are typically given in the Department of Computer Science only to students who have done at least 60 percent of the course’s work of a passing quality and who are unable to complete all course work by the end of the quarter. Other restrictions on Incompletes are the province of individual instructors, many of whom do not permit Incompletes. To receive an Incomplete, students must make arrangements in advance with the instructor; a consent form to be signed by the instructor is available from the College adviser.

Honors

Students can earn a BA or BS degree with honors by attaining a grade of B or higher in all courses in the major and a grade of B or higher in three approved graduate computer science
courses (30000-level and above). These courses may be courses taken for the major or as electives.

Students may also earn a BA or BS degree with honors by attaining the same minimum B grade in all courses in the major and by writing a successful bachelor's thesis as part of CMSC 29900 Bachelor's Thesis. This thesis must be based on an approved research project that is directed by a faculty member and approved by the department counselor.

Recommended Introductory Sequences in Computer Science

The Department of Computer Science offers different introductory pathways into the program. In consultation with their College adviser and the Computer Science Department advisers, students should choose their introductory courses carefully. Some guidelines follow.

- Students interested in a technical introduction to computer science, without assuming prior experience or unusually strong preparation in mathematics, are encouraged to take CMSC 15100-15200 Introduction to Computer Science I-II.
- Students with programming experience and strong preparation in mathematics should consider CMSC 16100-16200 Honors Introduction to Computer Science I-II.
- Students majoring in quantitative fields other than computer science, including other sciences, mathematics, and economics, should consider CMSC 12100-12200 Computer Science with Applications I-II, possibly followed by CMSC 12300 Computer Science with Applications III.
- Students in the humanities and social sciences may consider CMSC 11000 Multimedia Programming as an Interdisciplinary Art I.
- Students interested in only one or two quarters of study should consider CMSC 12100-12200 Computer Science with Applications I-II. For students intending to pursue advanced study, we recommend CMSC 15100 Introduction to Computer Science I or CMSC 16100 Honors Introduction to Computer Science I as the first course.
- Students who are interested in web design should take CMSC 10100 Introduction to Programming for the World Wide Web I.
- Students may only receive credit for one introductory programming sequence: CMSC 12100-12200 Computer Science with Applications I-II, CMSC 15100-15200 Introduction to Computer Science I-II, or CMSC 16100-16200 Honors Introduction to Computer Science I-II. Exceptions must be approved by the department counselor prior to taking the second sequence.
- Students who have credit for any of the following courses (or equivalent) may not take CMSC 10200 Introduction to Programming for the World Wide Web II for credit: CMSC 10600 Fundamentals of Computer Programming II, CMSC 12100 Computer Science with Applications I, CMSC 15200 Introduction to Computer Science II, or CMSC 16200 Honors Introduction to Computer Science II.
Please be aware that course information is volatile, and the catalog does not necessarily reflect the latest changes. Students should consult http://course-info.cs.uchicago.edu for up-to-date information.

Minor Program in Computer Science

The minor in computer science requires seven courses. The introductory sequence of three courses is followed by four approved upper-level courses. Courses in the minor must be taken for quality grades, with a grade of C- or higher in each course. Students may not use AP credit for computer science to meet requirements for the minor.

No courses in the minor can be double counted with the student's major(s) or with other minors; nor can they be counted toward general education requirements. More than half of the requirements for the minor must be met by registering for courses bearing University of Chicago course numbers. The minor advisor must approve the student's minor consent form and the student must submit that form to their College adviser by the end of Spring Quarter of their third year.

Introductory Courses

Students must choose three courses from the following (one course each from Areas A, B, and C). Please note that not all possible pathways through these courses are valid: for example, CMSC 15200 is not a prerequisite for CMSC 12300. Please consult the prerequisite information below and/or talk to the minor advisor to discuss viable plans.

<table>
<thead>
<tr>
<th>Area A:</th>
<th>100</th>
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<tbody>
<tr>
<td>CMSC 12100</td>
<td>Computer Science with Applications I</td>
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<tr>
<td>CMSC 15100</td>
<td>Introduction to Computer Science I</td>
</tr>
<tr>
<td>CMSC 16100</td>
<td>Honors Introduction to Computer Science I</td>
</tr>
<tr>
<td>Area B:</td>
<td>100</td>
</tr>
<tr>
<td>CMSC 12200</td>
<td>Computer Science with Applications II</td>
</tr>
<tr>
<td>CMSC 15200</td>
<td>Introduction to Computer Science II</td>
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<tr>
<td>CMSC 16200</td>
<td>Honors Introduction to Computer Science II</td>
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<tr>
<td>Area C:</td>
<td>100</td>
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<tr>
<td>CMSC 12300</td>
<td>Computer Science with Applications III</td>
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<tr>
<td>CMSC 15400</td>
<td>Introduction to Computer Systems</td>
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Upper-Level Courses

The computer science minor must include four courses chosen from among all 20000-level CMSC courses and above. CMSC 12300 may be used as an elective if a student has used CMSC 15400 as the Area C introductory course. A 20000-level course must replace each 10000-level course in the list above that was used to meet general education requirements.
Joint BA/MS or BS/MS Program

Outstanding computer science majors may apply to complete an MS in computer science along with a BA or BS during their four years at the College. Students must be admitted to the joint MS program.

Prior to applying to either joint program, interested students must meet with the department counselor and Pete Segall, the College BA/MS or BS/MS adviser. (For an appointment with Mr. Segall, please contact him at psegall@uchicago.edu.) Students must submit applications for the joint program in the Winter Quarter of their third year.

Participants in the joint BA/MS or BS/MS program must meet the requirements for the BA or BS plus nine courses for the MS and a master's project. Three of the nine courses for the MS may also be used to meet the requirements of the BA or BS, resulting in a total of 20 courses in computer science. For details visit http://cs.uchicago.edu/info/BxMS.

Graduate Courses

Graduate courses and seminars offered by the Department of Computer Science are open to College students with consent of instructor and department counselor. For more information, consult the department counselor.

Computer Science Courses

CMSC 10100. Introduction to Programming for the World Wide Web I. 100 Units.
This course teaches the basics of constructing and maintaining a site on the World Wide Web. We discuss Internet terminology and how the Internet and its associated technologies work. Topics include programming websites, hypertext markup language (HTML5), Cascading Style Sheets (CSS3), and Common Gateway Interface (CGI) scripts (using PHP). The primary programming emphasis will be on using JavaScript to add client-side functionality.
Instructor(s): W. Sterner Terms Offered: Winter
Note(s): This course does not meet the general education requirement in the mathematical sciences.

CMSC 10200. Introduction to Programming for the World Wide Web II. 100 Units.
This course introduces computer programming in Java with a focus on designing and implementing software for the World Wide Web. We first introduce the fundamentals of programming, giving particular attention to basic object-oriented techniques. We employ Java Server Pages to develop programs that interact with users through web browsers. Finally, we study relational databases and, integrating that study with general-purpose Java programming, build database-backed web applications.
Terms Offered: Not offered in 2016-17
Prerequisite(s): Placement into MATH 13100 or equivalent, and knowledge of HTML.
Note(s): This course meets the general education requirement in the mathematical sciences. May not be taken for credit by students who have credit for CMSC 12100, 15200, or 16200.
CMSC 11000-11100. Multimedia Programming as an Interdisciplinary Art I-II.
Either course in this sequence meets the general education requirement in the mathematical sciences. Like other classic Chicago general education courses, this sequence provides students with both practical programming skills and core ideas in computer science in interdisciplinary applications. Students learn how to perform in a multi-platform (Mac/Linux/Windows) environment using a high-level prototyping language (revTalk) that allows for the quick creation of useful multimedia applications. As a classic Core course in the Chicago tradition, the course presents introductory techniques of problem solving, algorithm construction, program coding, and debugging as interdisciplinary arts adaptable to a wide range of disciplines with their specialized problems.

CMSC 11000. Multimedia Programming as an Interdisciplinary Art I. 100 Units.
The first course moves through a sequence from step-by-step introductory labs, to labs that require independent analysis and solution, to a student-designed final project. Instructor(s): W. Sterner Terms Offered: Spring
Prerequisite(s): Placement into MATH 13100 or higher, or by consent.
Note(s): This course meets the general education requirement in the mathematical sciences.

CMSC 11100. Multimedia Programming as an Interdisciplinary Art II. 100 Units.
The second course consists of several scientific and humanistic projects such as Turing Machines, biological modeling, and language manipulation with another final project. Terms Offered: Not offered in 2016-17
Prerequisite(s): Placement into MATH 13100 or higher, or by consent.
Note(s): This course meets the general education requirement in the mathematical sciences.

CMSC 11710. Networks. 100 Units.
Networks help explain phenomena in such technological, social, and biological domains as the spread of opinions, knowledge, and infectious diseases. Networks also help us understand properties of financial markets, food webs, and web technologies. At the same time, the structure and evolution of networks is determined by the set of interactions in the domain. Our study of networks will employ formalisms such as graph theory, game theory, information networks, and network dynamics, with the goal of building formal models and translating their observed properties into qualitative explanations. Instructor(s): J. Simon Terms Offered: Spring
Prerequisite(s): Completion of the general education requirement in the mathematical sciences, and familiarity with basic concepts of probability at the high school level.
Note(s): Necessary mathematical concepts will be presented in class.

CMSC 12100-12200-12300. Computer Science with Applications I-II-III.
This three-quarter sequence teaches computational thinking and skills to students who are majoring in the sciences, mathematics, and economics, etc. Lectures cover topics in (1) programming, such as recursion, abstract data types, and processing data; (2) computer science, such as clustering methods, event-driven simulation, and theory of computation; and to a lesser extent (3) numerical computation, such as approximating functions and their derivatives and integrals, solving systems of linear equations, and simple Monte Carlo techniques.
CMSC 12100. Computer Science with Applications I. 100 Units.
This course is the first in a three-quarter sequence that teaches computational thinking and skills to students in the sciences, mathematics, economics, etc. The course will cover abstraction and decomposition, simple modeling, basic algorithms, and programming in Python. Applications from a wide variety of fields serve both as examples in lectures and as the basis for programming assignments. In recent offerings, students have written programs to simulate a model of housing segregation, determine the number of machines needed at a polling place, and analyze tweets from presidential debates.
Instructor(s): A. Rogers, B. Sotomayor Terms Offered: Autumn
Prerequisite(s): Placement into MATH 15200 or higher, or by consent.
Note(s): This course meets the general education requirement in the mathematical sciences.

CMSC 12200. Computer Science with Applications II. 100 Units.
This course is the second in a three-quarter sequence that teaches computational thinking and skills to students in the sciences, mathematics, economics, etc. Lectures cover topics in (1) data representation, (2) basics of relational databases, (3) shell scripting, (4) data analysis algorithms, such as clustering and decision trees, and (5) data structures, such as hash tables and heaps. Applications and datasets from a wide variety of fields serve both as examples in lectures and as the basis for programming assignments. In recent offerings, students have written a course search engine and a system to do speaker identification. Students will program in Python and do a quarter-long programming project.
Instructor(s): A. Rogers, M. Wachs Terms Offered: Winter
Prerequisite(s): CMSC 12100.
Note(s): This course meets the general education requirement in the mathematical sciences.

CMSC 12300. Computer Science with Applications III. 100 Units.
The course revolves around core ideas behind the management and computation of large volumes of data ("Big Data"). Topics include (1) Statistical methods for large data analysis, (2) Parallelism and concurrency, including models of parallelism and synchronization primitives, and (3) Distributed computing, including distributed architectures and the algorithms and techniques that enable these architectures to be fault-tolerant, reliable, and scalable. Students will continue to use Python, and will also learn C and distributed computing tools and platforms, including Amazon AWS and Hadoop. This course includes a project where students will have to formulate hypotheses about a large dataset, develop statistical models to test those hypotheses, implement a prototype that performs an initial exploration of the data, and a final system to process the entire dataset.
Instructor(s): M. Wachs Terms Offered: Spring
Prerequisite(s): CMSC 12200.
CMSC 15100-15200. Introduction to Computer Science I-II.
This sequence, which is recommended for all students planning to take more advanced courses in computer science, introduces computer science mostly through the study of programming in functional (Scheme) and imperative (C) programming languages. Topics include program design, control and data abstraction, recursion and induction, higher-order programming, types and polymorphism, time and space analysis, memory management, and data structures including lists, trees, and graphs. NOTE: Non-majors may use either course in this sequence to meet the general education requirement in the mathematical sciences; students who are majoring in Computer Science must use either CMSC 15100-15200 or 16100-16200 to meet requirements for the major.

CMSC 15100. Introduction to Computer Science I. 100 Units.
No description available.
Instructor(s): A. Shaw (Aut), M. Wachs (Aut), J. Reppy (Win) Terms Offered: Summer,Autumn,Winter
Prerequisite(s): Placement into MATH 15100 or completion of MATH 13100.
Note(s): This course meets the general education requirement in the mathematical sciences. Non-majors may use either course in this sequence to meet the general education requirement in the mathematical sciences; students who are majoring in Computer Science must use either CMSC 15100-15200 or 16100-16200 to meet requirements for the major.

CMSC 15200. Introduction to Computer Science II. 100 Units.
No description available.
Instructor(s): A. Shaw (Winter), M. Wachs (Winter) Terms Offered: Summer,Winter,Spring
Prerequisite(s): CMSC 15100, CMSC 16100, CMSC 12100, or CMSC 10500.
Note(s): This course meets the general education requirement in the mathematical sciences. Non-majors may use either course in this sequence to meet the general education requirement in the mathematical sciences; students who are majoring in Computer Science must use either CMSC 15100-15200 or 16100-16200 to meet requirements for the major.

CMSC 15400. Introduction to Computer Systems. 100 Units.
This course covers the basics of computer systems from a programmer's perspective. Topics include data representation, machine language programming, exceptions, code optimization, performance measurement, memory systems, and system-level I/O. Extensive programming required.
Instructor(s): H. Gunawi, H. Hoffmann, M. Wachs Terms Offered: Autumn,Spring
Prerequisite(s): CMSC 15200, 16200, or 12300.
Note(s): Required of students who are majoring in Computer Science.

CMSC 16100-16200. Honors Introduction to Computer Science I-II.
Both courses in this sequence meet the general education requirement in the mathematical sciences; students who are majoring in Computer Science must use either CMSC 15200 or 16200 to meet requirements for the major.
CMSC 16100. Honors Introduction to Computer Science I. 100 Units.
Programming in a functional language (currently Haskell), including higher-order functions, type definition, algebraic data types, modules, parsing, I/O, and monads. Basic data structures, including lists, binary search trees, and tree balancing. Basic mathematics for reasoning about programs, including induction, inductive definition, propositional logic, and proofs. Search in graphs, including depth-first and breadth-first search. Search in metric graphs, including greedy and A* search, with applications.
Instructor(s): R. Chugh, S. Kurtz Terms Offered: Autumn
Prerequisite(s): Placement into MATH 16100 or equivalent and programming experience, or by consent.
Note(s): This course meets the general education requirement in the mathematical sciences.

CMSC 16200. Honors Introduction to Computer Science II. 100 Units.
This course emphasizes the C Programming Language, but not in isolation. Instead, C is developed as a part of a larger programming toolkit that includes the shell (specifically ksh), shell programming, and standard Unix utilities (including awk). Nonshell scripting languages, in particular perl and python, are introduced, as well as interpreter (#!) files that use the command-line version of DrScheme. We cover various standard data structures, both abstractly, and in terms of concrete implementations—primarily in C, but also from time to time in other contexts like scheme and ksh. The course uses a team programming approach. There is a mixture of individual programming assignments that focus on current lecture material, together with team programming assignments that can be tackled using any Unix technology. Team projects are assessed based on correctness, elegance, and quality of documentation. We teach the "Unix way" of breaking a complex computational problem into smaller pieces, most or all of which can be solved using pre-existing, well-debugged, and documented components, and then composed in a variety of ways.
Instructor(s): F. Chong Terms Offered: Winter
Prerequisite(s): CMSC 16100, or CMSC 15100 and by consent.
Note(s): Students who have taken CMSC 15100 may take 16200 with consent of instructor. This course meets the general education requirement in the mathematical sciences.

CMSC 22001. Software Construction. 100 Units.
Large software systems are difficult to build. The course discusses both the empirical aspects of software engineering and the underlying theory. Topics will include, among others, software specifications, software design, software architecture, software testing, software reliability, and software maintenance. Students will be expected to actively participate in team projects in this course.
Instructor(s): S. Lu Terms Offered: Spring
Prerequisite(s): CMSC 15400.
CMSC 22010. Digital Fabrication. 100 Units.
Digital fabrication involves translation of a digital design into a physical object. While digital fabrication has been around for decades, only now has it become possible for individuals to take advantage of this technology through low cost 3D printers and open source tools for 3D design and modeling. In this course we will cover the foundations of 3D object design including computational geometry, the type of models that can and can’t be fabricated, the uses and applications of digital fabrication, the algorithms, methods and tools for conversion of 3D models to representations that can be directly manufactured using computer controlled machines, the concepts and technology used in additive manufacturing (aka 3D printing) and the research and practical challenges of developing self-replicating machines. We will have several 3D printers available for use during the class and students will design and fabricate several parts during the course.
Instructor(s): R. Stevens Terms Offered: Spring
Prerequisite(s): CMSC 15400 and some experience with 3D modeling concepts.

CMSC 22100. Programming Languages. 100 Units.
Programming language design aims at the closest possible correspondence between the structures of a program and the task it performs. This course is an introduction to scientific programming language design, whereby design choices are made according to rigorous and well-founded lines of reasoning. The curriculum emphasizes the lambda calculus, type systems, formal semantics, logic and proof, and includes a light introduction to machine assisted formal reasoning. While this course is not a survey of different programming languages, we examine the design decisions embodied by various popular languages when viewed as formal systems.
Instructor(s): Shaw Terms Offered: Spring
Prerequisite(s): CMSC 15400.

CMSC 22200. Computer Architecture. 100 Units.
This course is a survey of contemporary computer organization covering CPU design, instruction sets, control, processors, busses, ALU, memory, pipelined computers, multiprocessors, networking, and case studies. We focus on the techniques of quantitative analysis and evaluation of modern computing systems, such as the selection of appropriate benchmarks to reveal and compare the performance of alternative design choices in system design. We emphasize major component subsystems of high-performance computers: pipelining, instruction-level parallelism, memory hierarchies, input/output, and network-oriented interconnections.
Instructor(s): M. Wachs Terms Offered: Autumn
Prerequisite(s): CMSC 15400.

CMSC 22300. Functional Programming. 100 Units.
We will explore various aspects of advanced functional programming in this course. Topics will vary from quarter to quarter and may include: untyped and typed programming; pure and impure programming; eager and lazy semantics; "object-functional programming"; functional reactive programming; and concurrent functional programming.
Instructor(s): R. Chugh Terms Offered: Winter
Prerequisite(s): CMSC 15400 required, CMSC 15100 or CMSC 16100 recommended.
CMSC 22311. Functional Systems in Haskell. 100 Units.
Advanced and systems programming in Haskell, including testing, meta-programming, exceptions, concurrency, web, IO, and network programming.
Instructor(s): S. Kurtz Terms Offered: Not offered in 2016-17
Prerequisite(s): CMSC 16100 and CMSC 15400, or by consent.

CMSC 22600. Compilers for Computer Languages. 100 Units.
This course covers principles of modern compiler design and implementation. Topics include lexical analysis, parsing, type checking, optimization, and code generation. This is a project oriented course in which students will construct a fully working compiler, using Standard ML as the implementation language.
Instructor(s): J. Reppy Terms Offered: Autumn. This course is offered in alternate years.
Prerequisite(s): CMSC 15400 required; CMSC 22100 recommended. (Note: Prior experience with ML programming not required.)
Note(s): This course is offered in alternate years.

CMSC 22630. Advanced Implementation of Computer Languages. 100 Units.
This course explores advanced topics in the implementation of high-level programming languages that vary each year (e.g., control-flow analysis algorithms, abstract interpretation, partial evaluation, advanced optimizations, runtime system representations, garbage collection algorithms, foreign-function interfaces). Students are expected to develop both a foundational and applied understanding of these topics.
Instructor(s): J. Reppy Terms Offered: Not offered in 2016-17
Prerequisite(s): CMSC 22100, and CMSC 22600 or CMSC 22610.

CMSC 23000. Operating Systems. 100 Units.
This course provides an introduction to basic Operating System principles and concepts that form as fundamental building blocks for many modern systems from personal devices to Internet-scale services. Basic topics include processes, threads, concurrency, synchronization, memory management, virtual memory, segmentation, paging, caching, process and I/O scheduling, file systems, storage devices. The course will also cover special topics such as journaling/transactions, SSD, RAID, virtual machines, and data-center operating systems. The course project will revolve around the implementation of a mini x86 operating system kernel.
Instructor(s): H. Gunawi Terms Offered: Autumn
Prerequisite(s): CMSC 15400 and one of CMSC 22200, CMSC 22600, CMSC 22610, CMSC 23300, CMSC 23400, CMSC 23500, CMSC 23700, CMSC 27310, or CMSC 23800 strongly recommended.

CMSC 23010. Parallel Computing. 100 Units.
This course provides an introduction to the concepts of parallel programming, with an emphasis on programming multicore processors. Topics include: Processes and threads, shared memory, message passing, direct-memory access (DMA), hardware mechanisms for parallel computing, synchronization and communication, patterns of parallel programming. The course will involve a substantial programming project implementing a parallel computations.
Instructor(s): H. Hoffmann Terms Offered: Winter
Prerequisite(s): CMSC 15400 and one of the following: CMSC 22200, CMSC 23000, CMSC 23800; or by consent.
CMSC 23200. Introduction to Computer Security. 100 Units.
This course introduces the principles and practice of computer security. It aims to teach how to model threats to computer systems and how to think like a potential attacker. It presents standard cryptographic functions and protocols and gives an overview of threats and defenses for software, host systems, networks, and the Web. It also touches on some of the legal, policy, and ethical issues surrounding computer security in areas such as privacy, surveillance, and the disclosure of security vulnerabilities. The goal of this course is to provide a foundation for further study in computer security and to help better understand how to design, build, and use computer systems more securely.
Instructor(s): A. Feldman Terms Offered: Autumn
Prerequisite(s): CMSC 15400.

CMSC 23300. Networks and Distributed Systems. 100 Units.
This course focuses on the principles and techniques used in the development of networked and distributed software. Topics include programming with sockets; concurrent programming; data link layer (Ethernet, packet switching, etc.); internet and routing protocols (IP, IPv6, ARP, etc.); end-to-end protocols (UDP, TCP); and other commonly used network protocols and techniques. This is a project-oriented course in which students are required to develop software in C on a UNIX environment.
Instructor(s): B. Sotomayor Terms Offered: Winter
Prerequisite(s): CMSC 15400.
Equivalent Course(s): CMSC 33300

CMSC 23310. Advanced Distributed Systems. 100 Units.
In recent years, large distributed systems have taken a prominent role not just in scientific inquiry, but also in our daily lives. When we perform a search on Google, stream content from Netflix, place an order on Amazon, or catch up on the latest comings-and-goings on Facebook, our seemingly minute requests are processed by complex systems that sometimes include hundreds of thousands of computers, connected by both local and wide area networks. Recent papers in the field of Distributed Systems have described several solutions (such as MapReduce, BigTable, Dynamo, Cassandra, etc.) for managing large-scale data and computation. However, building and using these systems pose a number of more fundamental challenges: How do we keep the system operating correctly even when individual machines fail? How do we ensure that all the machines have a consistent view of the system's state? (And how do we ensure this in the presence of failures?) How can we determine the order of events in a system where we can't assume a single global clock? Many of these fundamental problems were identified and solved over the course of several decades, starting in the 1970s. To better appreciate the challenges of recent developments in the field of Distributed Systems, this course will guide students through seminal work in Distributed Systems from the 1970s, '80s, and '90s, leading up to a discussion of recent work in the field.
Instructor(s): B. Sotomayor Terms Offered: Spring
Prerequisite(s): CMSC 23300 with at least a B+, or by consent.
Equivalent Course(s): CMSC 33310
CMSC 23400. Mobile Computing. 100 Units.
Mobile computing is pervasive and changing nearly every aspect of society. Sensing, actuation, and mediation capabilities of mobile devices are transforming all aspects of computing: uses, networking, interface, form, etc. This course explores new technologies driving mobile computing and their implications for systems and society. Current focus areas include new techniques to capture 3d models (depth sensors, stereo vision), drones that enable targeted, adaptive, focused sensing, and new 3d interactive applications (augmented reality, cyberphysical, and virtual reality). Labs expose students to software and hardware capabilities of mobile computing systems, and develop the capability to envision radical new applications for a large-scale course project.
Instructor(s): A. Chien Terms Offered: Winter
Prerequisite(s): CMSC 15400. CMSC 23000 or 23300 recommended. Knowledge of Java required.

CMSC 23500. Introduction to Database Systems. 100 Units.
This course is an introduction to database design and implementation. Topics include DBMS architecture, entity-relationship and relational models, relational algebra, concurrency control, recovery, indexing, physical data organization, and modern database systems. The lab section guides students through the implementation of a relational database management system, allowing students to see topics such as physical data organization and DBMS architecture in practice, and exercise general skills such as software systems development.
Instructor(s): A. Elmore Terms Offered: Winter
Prerequisite(s): CMSC 15400.

CMSC 23700. Introduction to Computer Graphics. 100 Units.
This course introduces the basic concepts and techniques used in three-dimensional computer graphics. The course covers both the foundations of 3D graphics (coordinate systems and transformations, lighting, texture mapping, and basic geometric algorithms and data structures), and the practice of real-time rendering using programmable shaders. Students are required to complete both written assignments and programming projects using OpenGL.
Instructor(s): J. Reppy Terms Offered: Autumn. Generally offered alternate years.
Prerequisite(s): CMSC 15400.
Note(s): This course is offered in alternate years.

CMSC 23710. Scientific Visualization. 100 Units.
Scientific visualization combines computer graphics, numerical methods, and mathematical models of the physical world to create a visual framework for understanding and solving scientific problems. The mathematical and algorithmic foundations of scientific visualization (for example, scalar, vector, and tensor fields) will be explained in the context of real-world data from scientific and biomedical domains. The course is also intended for students outside computer science who are experienced with programming and computing with scientific data. Programming projects will be in C and C++.
Instructor(s): G. Kindlmann Terms Offered: Winter. Generally offered alternate years.
Prerequisite(s): CMSC 15400 and knowledge of linear algebra, or by consent.
CMSC 23800. Game Construction. 100 Units.
Computer games are one of the most exciting applications of computer technology. They also are large software systems that embody cutting-edge graphics, as well as techniques from AI, scientific simulation, networking, and databases. This course introduces the student to the basic algorithms and techniques used in computer-game construction. Students work in teams to design and create games using existing libraries for graphics, physics simulation, and so forth.
Instructor(s): J. Reppy Terms Offered: Spring
Prerequisite(s): CMSC 15400, and at least two of the following courses: CMSC 23700, CMSC 23000, CMSC 23300, CMSC 23500. Strong background in programming and expertise in at least two technical areas underlying computer games (e.g., AI, graphics, scientific computing, networking).
Equivalent Course(s): CSPP 53800

CMSC 23900. Data Visualization. 100 Units.
Data visualizations provide a visual setting in which to explore, understand, and explain datasets. This class describes mathematical and perceptual principles, methods, and applications of "data visualization" (as it is popularly understood to refer primarily to tabulated data). A range of data types and visual encodings will be presented and evaluated. Visualizations will be primarily web-based, using D3.js, and possibly other higher-level languages and libraries.
Instructor(s): G. Kindlmann Terms Offered: Spring
Prerequisite(s): CMSC 12200, CMSC 15200 or CMSC 16200.

CMSC 25020. Computational Linguistics. 100 Units.
This is a course in the Computer Science department, intended for upper-level undergraduates, or graduate students, who have good programming skills. There will be weekly programming assignments in Python. We will look at several current topics in natural language processing, and discuss both the theoretical basis for the work and engaging in hands-on practical experiments with linguistic corpora. In line with most current work, our emphasis will be on systems that draw conclusions from training data rather than relying on the encoding of generalizations obtained by humans studying the data. As a consequence of that, in part, we will make an effort not to focus on English, but to look at a range of human languages in our treatments.
Instructor(s): J. Goldsmith Terms Offered: Not offered 2016-17
Prerequisite(s): CMSC 12200, CMSC 15200 or CMSC 16200, or by consent.
Equivalent Course(s): CMSC 35050, LING 28600, LING 38600
CMSC 25025. Machine Learning and Large-Scale Data Analysis. 100 Units.
This course is an introduction to machine learning and the analysis of large data sets using distributed computation and storage infrastructure. Basic machine learning methodology and relevant statistical theory will be presented in lectures. Homework exercises will give students hands-on experience with the methods on different types of data. Methods include algorithms for clustering, binary classification, and hierarchical Bayesian modeling. Data types include images, archives of scientific articles, online ad clickthrough logs, and public records of the City of Chicago. Programming will be based on Python and R, but previous exposure to these languages is not assumed.
Instructor(s): J. Lafferty Terms Offered: Spring
Prerequisite(s): CMSC 15400 or CMSC 12200 and STAT 22200 or STAT 23400, or by consent.
Note(s): The prerequisites are under review and may change.
Equivalent Course(s): STAT 37601

CMSC 25400. Machine Learning. 100 Units.
This course offers a practical, problem-centered introduction to machine learning. Topics covered include the Perceptron and other online algorithms; boosting; graphical models and message passing; dimensionality reduction and manifold learning; SVMs and other kernel methods; artificial neural networks; and a short introduction to statistical learning theory. Weekly programming assignments give students the opportunity to try out each learning algorithm on real world datasets.
Instructor(s): R. Kondor Terms Offered: Autumn
Prerequisite(s): CMSC 15400 or CMSC 12300. STAT 22000 or STAT 23400 strongly recommended.
Equivalent Course(s): STAT 27725

CMSC 27100. Discrete Mathematics. 100 Units.
This course emphasizes mathematical discovery and rigorous proof, which are illustrated on a refreshing variety of accessible and useful topics. Basic counting is a recurring theme and provides the most important source for sequences, which is another recurring theme. Further topics include proof by induction; recurrences and Fibonacci numbers; graph theory and trees; number theory, congruences, and Fermat's little theorem; counting, factorials, and binomial coefficients; combinatorial probability; random variables, expected value, and variance; and limits of sequences, asymptotic equality, and rates of growth.
Instructor(s): A. Razborov, J. Simon Terms Offered: Autumn, Winter
Prerequisite(s): CMSC 12300 or CMSC 15400, or MATH 16300 or higher, or by consent.
Note(s): This is a directed course in mathematical topics and techniques that is a prerequisite for courses such as CMSC 27200 and 27400.
CMSC 27130. Honors Discrete Mathematics. 100 Units.
We emphasize mathematical discovery and rigorous proof, which are illustrated on a refreshing variety of accessible and useful topics. Basic counting is a recurring theme and provides the most important source for sequences, which is another recurring theme. Further topics include proof by induction; recurrences and Fibonacci numbers; graph theory and trees; number theory, congruences, and Fermat’s little theorem; counting, factorials, and binomial coefficients; combinatorial probability; random variables, expected value, and variance; and limits of sequences, asymptotic equality, and rates of growth. The honors version of Discrete Mathematics covers topics at a deeper level.
Instructor(s): A. Razborov Terms Offered: Autumn
Prerequisite(s): (CMSC 12300 or CMSC 15400), or MATH 16300 or higher, or by consent.

CMSC 27200. Theory of Algorithms. 100 Units.
This course covers design and analysis of efficient algorithms, with emphasis on ideas rather than on implementation. Algorithmic questions include sorting and searching, graph algorithms, elementary algorithmic number theory, combinatorial optimization, randomized algorithms, as well as techniques to deal with intractability, like approximation algorithms. Design techniques include “divide-and-conquer” methods, dynamic programming, greedy algorithms, and graph search, as well as the design of efficient data structures. Methods of algorithm analysis include asymptotic notation, evaluation of recurrent inequalities, amortized analysis, analysis of probabilistic algorithms, the concepts of polynomial-time algorithms, and of NP-completeness.
Instructor(s): A. Drucker, J. Simon Terms Offered: Winter, Spring
Prerequisite(s): CMSC 27100 or CMSC 37110, or by consent.

CMSC 27230. Honors Theory of Algorithms. 100 Units.
This course covers design and analysis of efficient algorithms, with emphasis on ideas rather than on implementation. Algorithmic questions include sorting and searching, discrete optimization, algorithmic graph theory, algorithmic number theory, and cryptography. Design techniques include divide-and-conquer methods, dynamic programming, greedy algorithms, and graph search, as well as the design of efficient data structures. Methods of algorithm analysis include asymptotic notation, evaluation of recurrent inequalities, the concepts of polynomial-time algorithms, and NP-completeness. The honors version of Theory of Algorithms covers topics at a deeper level.
Instructor(s): A. Drucker Terms Offered: Spring
Prerequisite(s): CMSC 27100 or CMSC 37110 or consent of the instructor.
CMSC 27410. Honors Combinatorics. 100 Units.
Methods of enumeration, construction, and proof of existence of discrete structures are discussed in conjunction with the basic concepts of probability theory over a finite sample space. Enumeration techniques are applied to the calculation of probabilities, and, conversely, probabilistic arguments are used in the analysis of combinatorial structures. Other topics include basic counting, linear recurrences, generating functions, Latin squares, finite projective planes, graph theory, Ramsey theory, coloring graphs and set systems, random variables, independence, expected value, standard deviation, and Chebyshev's and Chernoff's inequalities.
Instructor(s): L. Babai Terms Offered: Spring
Prerequisite(s): MATH 15900 or MATH 25400, or CMSC 27100, or by consent. Experience with mathematical proofs.
Note(s): This course is offered in alternate years.

CMSC 27500. Graph Theory. 100 Units.
This course covers the basics of the theory of finite graphs. Topics include shortest paths, spanning trees, counting techniques, matchings, Hamiltonian cycles, chromatic number, extremal graph theory, Turan's theorem, planarity, Menger's theorem, the max-flow/min-cut theorem, Ramsey theory, directed graphs, strongly connected components, directed acyclic graphs, and tournaments. Techniques studied include the probabilistic method.
Instructor(s): K. Mulmuley Terms Offered: Spring
Prerequisite(s): CMSC 27100, or MATH 20400 or higher.

CMSC 27610. Digital Biology. 100 Units.
Explores the digital nature of biology at the molecular scale. Focuses on the role of hydrophobic effect in protein/ligand associations. Utilizes data-mining as a tool both to understand basic biophysics and to explain protein-ligand associations. Shows how such analog interactions can lead to digital devices (e.g., switches). No biochemistry background will be assumed.
Instructor(s): L. R. Scott Terms Offered: Spring
Prerequisite(s): MATH 15200 or higher, and CMSC 12200 or CMSC 15200 or CMSC 16200. High school chemistry helpful.
Note(s): High school chemistry is helpful.

CMSC 27700-27800. Mathematical Logic I-II.
Mathematical Logic I-II

CMSC 27700. Mathematical Logic I. 100 Units.
This course introduces mathematical logic. Topics include propositional and predicate logic and the syntactic notion of proof versus the semantic notion of truth (e.g., soundness, completeness). We also discuss the Gödel completeness theorem, the compactness theorem, and applications of compactness to algebraic problems.
Terms Offered: Autumn
Prerequisite(s): MATH 25400 or MATH 25700 or (CMSC 15400 and (MATH 15910 or MATH 15900 or MATH 19900 or MATH 16300))
Equivalent Course(s): MATH 27700
CMSC 27800. Mathematical Logic II. 100 Units.
Topics include number theory, Peano arithmetic, Turing compatibility, unsolvable problems, Gödel's incompleteness theorem, undecidable theories (e.g., the theory of groups), quantifier elimination, and decidable theories (e.g., the theory of algebraically closed fields).
Terms Offered: Winter
Prerequisite(s): MATH 27700 or CMSC 27700.
Equivalent Course(s): MATH 27800

CMSC 28000. Introduction to Formal Languages. 100 Units.
This course is a basic introduction to computability theory and formal languages. Topics include automata theory, regular languages, context-free languages, and Turing machines.
Instructor(s): S. Kurtz Terms Offered: Autumn
Prerequisite(s): CMSC 12300 or CMSC 15400, or MATH 15900 or MATH 25500.
Equivalent Course(s): MATH 28000

CMSC 28100. Introduction to Complexity Theory. 100 Units.
Computability topics are discussed (e.g., the s-m-n theorem and the recursion theorem, resource-bounded computation). This course introduces complexity theory. Relationships between space and time, determinism and non-determinism, NP-completeness, and the P versus NP question are investigated.
Instructor(s): K. Mulmuley Terms Offered: Spring
Prerequisite(s): CMSC 27100, or MATH 15900 or MATH 25500; experience with mathematical proofs.
Equivalent Course(s): MATH 28100

CMSC 28501. Topics in Scientific Computing. 100 Units.
This course covers current topics in scientific computing.
Terms Offered: Autumn, Winter, Spring
Prerequisite(s): MATH 20500 or MATH 20900, and CMSC 12200 or CMSC 15200 or CMSC 16200.

CMSC 29700. Reading and Research in Computer Science. 100 Units.
Students do reading and research in an area of computer science under the guidance of a faculty member. A written report is typically required.
Terms Offered: Summer, Autumn, Winter, Spring
Prerequisite(s): By consent of instructor and approval of department counselor.
Note(s): Open both to students who are majoring in Computer Science and to nonmajors. Students are required to submit the College Reading and Research Course Form.
CMSC 29900. Bachelor's Thesis. 100 Units.
No description available.
Terms Offered: Summer, Autumn, Winter, Spring
Prerequisite(s): By consent of instructor and approval of department counselor.
Note(s): Open to fourth-year students who are candidates for honors in Computer Science
Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

Times was used instead of Trajan.

Times was used instead of Palatino.

The editor may contact Leepfrog for a draft with the correct fonts in place.