

Master of Science in Computer Science

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Program Description

The master of science in computer science program is designed to provide the student with a thorough knowledge of the concepts, theory, and practice of computer science as well as develop the student's ability to analyze critically solutions to problems and to make sound professional decisions. Students will be prepared for positions of responsibility and expertise. Graduates may assume positions involving such diverse activities as the design, implementation, and testing of software products; the development of new hardware technology; and the analysis, construction, and management of large-scale computer systems. Graduates will possess a good foundation for further study in computer science.

Admission

Each student applying for full admission must meet the following requirements (conditional admission status may be granted to students who do not fully meet these requirements):

1. A baccalaureate degree from an accredited institution with a grade point average of at least 3.0 on a 4.0 scale (B average).
2. The following USM courses or their equivalent with an average grade of 3.0.

If pursuing the software development or computer systems track:

COS 280	Discrete Mathematics II
COS 285	Data Structures
COS 350	Systems Programming
COS 360	Programming Languages

Note: Students with little or no computing background may need to take some or all of the following courses that are prerequisites to the courses listed above: MAT 145, COS 160/COS 170, COS 161, COS 250/COS 255.

If pursuing the computer engineering track:

MAT 152D	Calculus A
MAT 153	Calculus B
COS 250	Computer Organization and
COS 255	Computer Organization Laboratory
or	
ELE 172	Digital Logic and
ELE 271	Introduction to Microprocessors
COS 280	Discrete Mathematics II
COS 350	Systems Programming
ELE 314	Linear Signals and Systems
ELE 342	Electronics I

Note: Students with little or no computing or electrical engineering background may need to take some or all of the following courses that are prerequisites to the courses listed above: MAT 145, COS 160/COS 170, COS 161, COS 285, ELE 211, ELE 262.

3. Official scores for the Graduate Record Examination (GRE).

Admission to the master's program is competitive and based on an evaluation of the application materials by the Computer Science Graduate Admissions Committee. Students whose first language is not English are required to submit TOEFL scores. Applicants whose TOEFL scores are less than 550 on the paper-based TOEFL, 79 on the Internet-based TOEFL, or 213 on the computer-based TOEFL must demonstrate the language skills requisite for graduate study before they can be admitted.

Applicants meeting the entrance requirements for a master's in computer science will be granted regular admission status. Applicants not meeting the entrance requirements of the program may be granted conditional admission during which time the student must compensate for any specific academic deficiency. The Computer Science Graduate Admissions Committee will designate specific undergraduate computer science and mathematics courses to remedy admissions deficiencies.

cies. These courses will carry no credit toward the master's degree and must be successfully completed and must precede the completion of 12 hours of graduate credit. Upon successful completion of the designated preparatory coursework the student may be granted regular admission status.

Application Materials

In addition to the materials described in the Admissions section, applicants for this program must submit three letters of recommendation attesting to the candidate's academic and/or professional accomplishments.

Application Deadline

The application deadline is March 1 for fall semester (September) and October 1 for spring semester (January) admission.

Program Policies

In addition to the general policies described in the Academic Policies chapter, specific policies of this program are as follows:

Transfer Credit A maximum of 9 credit hours of transfer credit may be used toward the degree.

Continuous Enrollment Every semester a student must either register for a course or for GRS 601 to maintain continuous enrollment. Students who do not maintain continuous enrollment will be dropped from the program and will have to reapply for admission to continue with the degree. Students who anticipate being unable to take classes may apply in writing for a fixed-term leave of absence.

Time Limit All required courses for the M.S. degree must be completed within six years prior to graduation. Otherwise, additional coursework must be taken to fulfill program requirements.

Program Requirements

All master's candidates must complete a minimum of 30 total credits, which must include 12 credits of graduate-level computer science courses (computer engineering track requirements differ; see below), excluding COS 598. Students must also take either a 6-credit master's thesis, COS 698, or a 3-credit master's project, COS 698, and an additional graduate course in computer science. Approved 400-level computer science courses can be used to fulfill the remaining credit requirements. At most two courses from other departments may be used toward the graduate degree (computer engineering track requirements differ; see below). The Computer Science Department faculty must approve these in advance.

If a student does not have the equivalent of a specific course from the following list in her/his previous studies, she/he must take it and may use it toward fulfillment of the degree requirements. Courses taken previously to meet other degree requirements cannot be used in the service of the graduate degree.

- COS 450 Operating Systems
- COS 485 Design of Computing Algorithms **or**
- COS 480 Theory of Computation

The culminating work in the M.S. program must take one of the following two forms:

1. *Academic thesis*: the student works on research under the supervision of a thesis committee composed of faculty members.
2. *Project*: the student works on an application of computer science. This could be in the form of a piece of software, a report on a problem, design of an application, etc. The project may be the solution of a problem at the student's place of employment. In this case, a representative of the employer may serve as an additional committee member.

The first option requires a committee of at least three members. The second option requires a committee of at least one faculty member. Both options require that a project proposal addressing a topic in the student's chosen track be approved by the committee. They also require a written final summary document describing the results of the project. This document must be approved by the committee and published according to Departmental guidelines. Oral presentation of the completed project is encouraged.

To ensure that the degree candidate's studies are focused and lead to a deeper knowledge in an area, she or he must choose an emphasis in computer systems, software development, computer engineering, or an area designed by the student. For details of student designed emphases, see Departmental guidelines.

Specific course requirements of each are as follows:

1. *Master of science degree in computer science* with emphasis in computer systems. Some of these courses have MAT 281 or MAT 380 among their prerequisites.

Complete four of the following courses:

- COS 450 Operating Systems
- COS 455 Computer Architecture
- COS 460/540 Computer Networks
- COS 465/542 Distributed Systems
- COS 467/567 Performance Analysis of Distributed Systems
- COS 485 Design of Computing Algorithms
- COS 543 Distributed Systems: A Second Course
- COS 545 Wireless Data Communication
- COS 552 Advanced Computer Networks
- COS 555 Advanced Computer Architecture
- COS 562 Performance Analysis
- COS 566 Simulation and Analytical Modeling

2. *Master of science degree in computer science* with emphasis in software development.

Complete four of the following courses:

- COS 420 Object Oriented Design
- COS 430 Software Engineering
- COS 444/544 Software Project Management
- COS 452 Computer Graphics
- COS 457 Database Systems
- COS 469/569 Compiler Construction
- COS 476/576 Advanced Object-Oriented Design
- COS 485 Design of Computing Algorithms
- COS 495/595 Advanced Web Architectures
- COS 558 Database Management
- COS 565 Software Design and Development
- COS 571 Advanced Database Systems
- COS 574 Advanced Computer Graphics
- COS 578 Advanced Java Technology
- COS 579 Object-Oriented Software Technology

3. *Master of science degree in computer science* with emphasis in computer engineering. Candidates in this track must take a minimum of 30 credits, at least 12 credits of which must be graduate-level courses from the lists below. The minimum of 12 credits of graduate courses should include at least 6 credits of computer science courses and at least 6 credits of electrical engineering courses. The balance of courses may be electrical engineering courses from the list below, or approved computer science courses, subject to the following distribution requirements.

- a. Complete two of the following courses:

- COS 450 Operating Systems
- COS 455 Computer Architecture
- COS 460/540 Computer Networks
- COS 465/542 Distributed Systems
- COS 467/567 Performance Analysis of Distributed Systems
- COS 472 Artificial Intelligence
- COS 543 Distributed Systems: A Second Course
- COS 550 Advanced Operating Systems
- COS 552 Advanced Computer Networks
- COS 555 Advanced Computer Architecture
- COS 562 Performance Analysis
- COS 572 Advanced Artificial Intelligence

- b. Complete two of the following courses:

- ELE 417/517 Robot Modeling
- ELE 418 Robot Intelligence
- ELE 442/542 Digital VLSI Circuits and Design
- ELE 444/544 Analog Integrated Circuits and Design
- ELE 445/545 Special Topics in CMOS Integrated Circuit Design
- ELE 464 Microelectronic Fabrication
- ELE 467 Optoelectronics
- ELE 486/586 Digital Signal Processing
- ELE 489/589 Digital Image Processing

Restricted to students with full graduate standing in the Computer Science Department or permission of the instructor.

COS 540 Computer Networks

An introduction to computer networks. Computer network architecture is described. Other topics include digital data communication, local area networks, wide area networks, internetworks, and the Internet. Specific technologies, including Ethernet and ATM, and protocols, including TCP/IP, will be considered in detail. Prerequisite: graduate standing. Cr 3.

COS 542 Distributed Systems

An introduction to the design and operation of distributed systems. Topics include client-server models, interprocess communications, RPC, replication and consistency, online transaction processing, error and fault recovery, encryption, and security. Examples will be taken from extant distributed systems. Students will design and implement a distributed system. Prerequisites: COS 450 and COS 460, or their equivalents, or permission of instructor. Cr 3.

COS 543 Distributed Systems: A Second Course

A continuation of COS 465/542, the course covers advanced topics relating to distributed systems that are not addressed in the first course. Specific topics include shared data, managing file replication, currency control, distributed transactions, fault tolerance and security. Case studies of existing systems and examination of new developments are also addressed. Prerequisites: COS 465 or COS 542. Cr 3.

COS 544 Software Project Management

Students will learn how to lead and participate in significant software projects. The course will cover the project life cycle, including developing the charter, plans, and justification; outsourcing and other procurement decisions, management of scope, time, cost, quality, personnel, and risk, and the critical role of communications inside and outside the project. Experts from industry will present case studies of success and failure. Prerequisite: previous bachelor's degree and COS 420 or COS 430. Cr 3.

COS 545 Wireless Data Communication

A seminar-based course that surveys the rapidly evolving field of wireless data networks. Wireless technologies, systems, and services are investigated with emphasis on existing systems and standards. Topics cover mobile data and wireless LANs. Prerequisite: COS 460, an equivalent course, or substantial experience with computer network architecture. Cr 3.

COS 550 Advanced Operating Systems

Topics include cooperating processes, privacy and protection of system and user processes, hardware aids, basic concepts of networks and distributed processing. System performance analysis may also be covered. Prerequisite: COS 450. Cr 3.

COS 552 Advanced Computer Networks

This second course in computer networks explores

recent developments with particular emphasis on fiber optic high speed networks. A laboratory component involving performance evaluation of network protocols may be included. Prerequisite: MAT 380 and COS 460/540 or permission of instructor. Cr 3.

COS 555 Advanced Computer Architecture

This course presents topics from research areas in computer architecture as well as advanced and emerging technologies. Possible topics are parallel machines, content addressable memories, VLSI systems. Prerequisite: COS 455. Cr 3.

COS 558 Database Management

After an overview of modern database management systems (DBMS) which discusses the significance of the relational model, the course examines selected research topics from the current literature. Topics in the past have included logic and databases, database design methodologies, and object-oriented systems. Prerequisite: COS 457 or graduate standing. Cr 3.

COS 562 Performance Analysis

The course integrates system measurement, analytic modeling, and simulation modeling to develop computer system performance evaluation techniques. The approach will be problem-oriented with emphasis on benchmarking, simulation modeling and queuing models. Subjects covered will include system measurement, operational analysis, simulation modeling, analysis of simulation results, and mean value analysis. Prerequisites: MAT 380 or equivalent and some experience with an operating system. Cr 3.

COS 565 Software Design and Development

A study of techniques and approaches related to the design and development of large scale software products. Consideration of formal methods for specification, analysis, design, implementation, and testing. A "large" group programming project will be the vehicle for much of the learning in this course. Cr 3.

COS 566 Simulation and Analytical Modeling

The theoretical limitations of analytical modeling will be contrasted with the practical limitations of simulation. The BCMP family of analytical models will be presented along with the computational solutions of these models. The use of simulation will be discussed with regard to a high level language (such as SIM-SCRIPT). Such topics as model verification and evaluation of experimental results will be considered. Cr 3.

COS 567 Performance Analysis of Distributed Systems

The objective of the course is to learn techniques to assess the performance of applications running in a distributed manner. Such assessment is important for developers to understand the behavior of the distributed applications they create, and to identify aspects of the applications that are determining performance. The course presents a variety of evaluation tech-

niques, including queueing theory, simulation, and availability and performance modeling. Other techniques will be introduced as needed. Prerequisite: Previous bachelor's degree, COS 450 or COS 460, and MAT 281 or MAT 380. Cr 3.

COS 569 Compiler Construction

Definition of languages via context-free grammars. Organization of a compiler into phases of lexical analysis, parsing, code generation, and optimization. Students will implement a compiler for a Pascal-like language. Prerequisite: graduate standing. Cr 3.

COS 570 Seminar: Advanced Topics in Computer Science

Topics vary from year to year. Will include current research, emerging technologies, case studies. Cr 3.

COS 571 Advanced Database Systems

This course covers object-oriented and XML database technologies, their interfacing and integration. Object-oriented topics include developments from industrial standards such as ODMG and Java Data Objects, query languages such as OQL, Java database technology, object-relational systems and language integrated queries such as LINQ. The XML technology is represented by schema languages such as XML Schema and query languages such as XQuery. Object-oriented interfaces to XML include DOM, LINQ to XML, LINQ to XSD, as well as other industrial developments. The course includes hands-on experience with advanced database management systems. The requirements include an object-oriented software and database development project, addressed by teams, and a term paper. Prerequisite: Permission of the instructor. Cr 3.

COS 572 Advanced Artificial Intelligence

A survey course that explores the key areas of research within the field of artificial intelligence. Topics discussed include knowledge representation, search, computer vision, automated reasoning, planning, learning, and robotics. The nature of the problems underlying each area, relevant theoretical results, and successful systems are discussed. Prerequisite: COS 472 or graduate standing. Cr 3.

COS 574 Advanced Computer Graphics

Advanced computer graphics techniques are described and analyzed. Subjects considered include the projection of 3D objects to 2D, hierarchical object representation, representation of 3D curves and surfaces, illumination and shading, solid modeling, and advanced graphics hardware. Prerequisite: COS 452 or permission of instructor. Cr 3.

COS 576 Advanced Object-Oriented Design

This course considers developing object-oriented, multi-tier, Web-based applications. Topics will include object-oriented design patterns in distributed environments, software components, and software frameworks. The course also has a significant hands-on implementation component, and, after completing this course, students will have practical experi-

ence with several leading-edge distributed object technologies, including AJAX, Web Services, Enterprise JavaBeans, JDBC, and Servlets. The course is structured so that students will work in teams to develop a medium-sized, multi-tier application that incorporates several of the technologies mentioned above. Lectures will provide an introduction to the technologies and discuss principled ways to apply these technologies. Prerequisites: COS 420 or permission of instructor. Cr 3.

COS 578 Advanced Java Technology

The goal of this course is to provide an in-depth study of the most important and the more advanced components of the Java technology. The course covers topics such as concurrent object-oriented programming in Java, Java Core Reflection, the underlying virtual platform (the Java Virtual Machine), genericity (parametric polymorphism), persistence, and assertions. Programming assignments include concurrent programming, programming with parametric collection types, dynamic loading and compilation, usage of the Java reflective capabilities, and usage of persistent capabilities available in Java and in its extensions. The outcome of this course is a high-level of professional expertise in the overall Java technology. Prerequisite: COS 360. Cr 3.

COS 579 Object-Oriented Software Technology

This course combines formal and practical object-oriented software techniques in developing the following main themes of object-oriented software technology: (i) Object-oriented software systems that provide efficiency and reliability based on an advanced type system (ii) Correctness and behavioral compatibility in software reuse based on object-oriented assertion languages and programming by contract methodology. Practical implications and usage of the general notions such genericity, self typing and reflection in complex software systems will be based on type systems of major object oriented languages such as Java, C# and Eiffel. The assertion languages demonstrating the main themes in this course are JML (Java Modeling Language) and Spec# (an assertion language for C#). The programming assignments are based on a pragmatic methodology for object-oriented software construction (programming by contract) along with the associated tools including program verification techniques and systems. Prerequisites: COS 360. Cr 3.

COS 580 Advanced Theory of Computation: Computability and Complexity

Explores the nature of computation from a mathematical point of view, and determines why many fundamentally important computational problems apparently have no efficient solution, or even no solution at all. Topics include models of computation, the Church-Turing thesis, computably enumerable sets, undecidable problems, the Halting Problem, resource-bounded complexity classes, NP-complete and NP-hard problems, the Traveling Salesman and other optimization problems, and

computational reducibility. Connections may also be drawn to the foundations of mathematics and Gödel's Incompleteness Theorem. Prerequisite: COS 480 or permission of instructor. Cr 3.

COS 582 Design and Analysis of Algorithms

This course deals with the analysis of algorithms, and the relevance of such analysis to the design of efficient computer algorithms. Examination of such topics as sorting, tree and graph algorithms, pattern matching, algebraic simplification and transformations, NP-hard problems, and approximation algorithms. A balance is struck between the derivation of results of theoretical significance and the practical endeavor of designing efficient algorithms. Cr 3.

COS 595 Advanced Web Architectures

The focus of communication over the Internet is shifting to "computer-to-computer" interaction. Standards for this interaction (ebXML, SOAP, WSFL) are now in place and maturing, and commercial use is exploding. We will survey these standards and critically evaluate their security, efficiency, and completeness. We will construct several case studies, including Web-based commerce. As a team we will acquire and learn how to use available tooling, and we will put together working Web services and test their ability to interact with each other. Prerequisite: graduate standing. Cr 3.

COS 598 Internship

Students apply their learning to a specific problem in a practical context under faculty and managerial supervision. See Departmental guidelines for more details. Prerequisites: full graduate standing and prior approval of proposal by instructor and Department chair. Cr 1-3.

COS 697 Independent Study

An opportunity for graduate students to pursue areas not currently offered in the graduate curriculum. Cr 3.

COS 698 Master's Thesis/Project

A six-credit thesis or a three-credit project is required of all students. The appropriate member(s) of the computer science faculty must approve the project in advance. Offered only as a pass/fail course. Prerequisites: full graduate standing and faculty approval. Cr 3-6.

ELE 517 Robot Modeling

This course focuses on the concepts of kinematics, statics, and the dynamics of serial manipulators, as well as on the analysis and design of robotic structures. Students will conduct case studies of multiple platforms in the Robotics and Intelligence Systems Laboratory. This course complements ELE 418. Prerequisites: ELE 210, COS 160 or permission of instructor. (Lecture 3 hrs.) Cr 3.

ELE 542 Digital VLSI Circuits and Design

This course will examine the principles of internal circuit and layout design of digital VLSI circuits, with an emphasis on CMOS technology. Topics

include NMOS and CMOS processes, device physics and SPICE models, logic circuits, electrical and physical design of logic gates, dynamic CMOS circuits, memory, chip layout principles, parasitics, and performance estimation. Simulation, layout, and electronic design automation tools are demonstrated and used. Prerequisites: ELE 172, ELE 342. (Lecture 3 hrs; Lab 1 hr.) Cr 3.

ELE 544 Analog Integrated Circuits and Design

This course will examine the principles of internal circuit operation and design of analog integrated circuits, with emphasis on CMOS technology. Topics include analog CMOS processes, devices and device models, bias and reference sources, differential and high gain amplifiers, OTAs and operational amplifiers, frequency response, feedback, stability, and internal compensation with emphasis on the design of CMOS operational amplifiers, power stages, and dc regulators. SPICE simulation, layout, and electronic design automation tools are demonstrated and used in homework assignments and design projects. Prerequisite: ELE 343 or permission. (Lecture 3 hrs; Lab 1 hr.) Cr 3.

ELE 545 Special Topics in CMOS Integrated Circuit Design

This course will cover special topics, such as, high performance operational amplifiers, silicon integrated sensors and sensor interface circuits, switched capacitor circuits, oscillators and integrated waveform generators, phase-locked-loop circuits, and memory, among others. Three chosen topics will be emphasized and students will conduct instructor-guided projects that will culminate with chip level design of these circuits. SPICE simulation verifications, layout, and electronic design automation tools will be used extensively. Prerequisite: ELE 442/542 or ELE 444/544. (Lecture 3 hrs; Lab 1 hr.) Cr 3.

ELE 586 Digital Signal Processing

This course will cover the basic principles of processing digital signals. Other concepts covered will include sampling and quantization; time and frequency domain representation; analysis of discrete-time signals and systems; FIR and IIR systems; digital filter design; review of classic analog filter design (Butterworth, Chebyshev); quantization and finite-precision effects; and DSP hardware. Computers will be used to design and realize various signal processors. Prerequisites: ELE 314 and COS 160 or equivalent. (Lecture 3 hrs.) Cr 3.

ELE 589 Digital Image Processing

This course will focus on the theory and practice of digital processing of images by computer. Students will be introduced to two-dimensional signal processing theory, including sampling, transforms, and filters. Image acquisition and representation; enhancement methods; image coding; image analysis; and image processing hardware also will be covered. Prerequisites: ELE 314 and COS 160 or equivalent. (Lecture 3 hrs; Lab 1 hr.) Cr 3.