COMPUTER SCIENCE AND ENGINEERING

Chair: Gita Alaghband
Program Manager: Christina Ridd
Administrative Assistant: Megan Rogers
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Overview

Mission Statement

With the advances in technology and the rapid and prevalent growth of the information-based economy, computer science has become an enabling science for nearly all disciplines that impact engineering, science, business, health and government. The future of the discipline promises even more innovative advances. The Department of Computer Science and Engineering at the University of Colorado Denver is committed to providing outstanding education and research training to our diverse undergraduate and graduate students for productive careers in industry, academia and government in the Denver metropolitan area, state and beyond. Our faculty strives for excellence in teaching, research and service by covering a broad spectrum of the discipline’s core fundamentals, as well as applied aspects including those of interdisciplinary nature. We actively engage our students in classroom and out-of-classroom research and help them develop the skills needed to solve complex real-world technological problems of modern society.

The Department of Computer Science and Engineering offers MS and PhD degrees:

- The MS degree (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/computer-science-ms/) is awarded in computer science (CS) to those students who wish to pursue graduate studies to further develop their education. The MS in CS graduate program covers the core knowledge of key concepts of computer science as well as offers flexibility to pursue specializing in various fields of interests.
- A track in Data Science in Biomedicine is offered as a MS thesis option. Students who choose this track will adopt biomedical applications of data science to learn data science methodologies and technologies.
- The graduate certificate in software engineering is designed for working professionals, or computer science students beginning their careers, who are in the field of software engineering and/or software development.
- The graduate certificate in cybersecurity & defense is designed for working professionals in the field of computer science, network and/or security operations. The certificate program in Cyber Security and Defense will prepare Computer Science professionals to identify, analyze, and mitigate technical cybersecurity related vulnerabilities, exploits and attacks against network and critical cyber infrastructure.
- The Computer Science and Information Systems PhD (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/computer-science-information-systems-phd/) is awarded from the College of Engineering, Design and Computing.

Most up-to-date information on all programs offered through the Computer Science and Engineering Department can be obtained from the department’s website at: engineering.ucdenver.edu/cse (http://engineering.ucdenver.edu/cse/).

Graduate Programs

The Department of Computer Science and Engineering (CSE) offers a master of science in computer science (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/computer-science-ms/). The CSE department also offers a doctoral degree in computer science and information systems (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/computer-science-information-systems-phd/). In addition, the engineering and applied science doctor of philosophy degree (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/engineering-applied-science-phd/) is available through the CSE department.

Expertise expand several areas of research including algorithms, artificial intelligence, big data management & mining, cloud computing, computer architectures, computer graphics, computer networks, computer security, cyber-physical systems, cyber security & defense, data science, database systems, distributed computing, graph theory, high-performance computing, Internet, machine learning, mobile computing, operating systems, parallel and distributed systems, software engineering and virtual reality.

Computer Science and Information Systems (CSIS) PhD

The Computer Science and Information Systems PhD is awarded from the College of Engineering, Design and Computing. The CSIS PhD supports interdisciplinary research between computer science and many fields of interest.

Our students work with research centers and researchers from a variety of disciplines, including the CU School of Medicine, chemistry, mathematics, biology, all engineering disciplines, economics, health, and education, in addition to industry and businesses. This distinctive infrastructure supports basic research in both computer science and information systems as well as the demand of computing and IT integration with all other scientific and business fields.

Advisor

Upon entering the program, each chooses an advisor to provide mentoring and guidance throughout the program and work with the student to prepare a program of study. Requests to change advisors must be approved by the program director, and this happens in very rare circumstances.

Program Requirements and Milestones

For details about program requirements in the computer science track, see the CSIS PhD Handbook.
Engineering, Design and Computing PhD

The multidisciplinary Engineering and Applied Science Doctor of Philosophy degree program is offered by the College of Engineering, Design and Computing and consists of a primary and secondary concentration. Applicants apply and enter the program through one of four departments, called the host department, which is chosen based on the applicant’s intended primary concentration of study. The four departments that serve as host departments are:

- Civil Engineering
- Computer Science and Engineering
- Electrical Engineering
- Mechanical Engineering

Each host department offers several concentrations. A list of concentrations can be found on each department’s website. Go to engineering.ucdenver.edu (http://engineering.ucdenver.edu) to learn more.

The required secondary concentration can be chosen from any remaining department within the college, including the Department of Bioengineering. The secondary concentration may also be chosen from another CU Denver school or college. A student chooses his/her secondary concentration with the help of a faculty advisor after entering the program.

Degree Requirements

The minimum degree requirements consist of 30 semester hours of course work in the primary and secondary areas of concentration, as well as 30 semester hours of research/dissertation credit. Each candidate for the degree is expected to take a preliminary examination by the end of the second year. After successful completion of this exam, the student is required to take the comprehensive examination and the doctoral dissertation defense examination. Additional requirements are outlined in the Rules and Regulations document that each student signs after being admitted to the program. Each student must also satisfy the degree requirements of the CU Denver Graduate School.

Program Requirements and Milestones

For details about program requirements in the computer science track, see the CSIS PhD Handbook.

Admissions to Computer Science and Engineering Graduate Programs

Requests for applications for graduate study in computer science and engineering should be addressed to:

Graduate School
Campus Box 163
P.O. Box 173364
Denver, CO 80217-3364

Courier Address (UPS, FEDEX, etc.):
Graduate School
1380 Lawrence Street, Suite 1251
Denver, CO 80204

Contact Email: graduateschool@ucdenver.edu
Phone: 303-315-2179

All applicants for admission must submit complete credentials as outlined in the instructions that accompany the application materials.

Master of Science (MS) in Computer Science

Admission Requirements

Applicants should hold a bachelor’s degree from an institution comparable to the University of Colorado. They need to have sufficient programming experience and mathematical maturity to understand advanced courses. Qualified applicants holding a degree outside computer science or equivalent fields may need to take additional foundational undergraduate courses before starting the graduate program.

Admission decisions are based on prior academic performance, letters of recommendation, English proficiency, if applicable, as well as the applicant’s written statement of purpose.

Additional requirements include:

1. 10 credit hours, on the semester basis, of university-level calculus
2. at least one math course beyond calculus, such as advanced calculus, differential equations, linear algebra, probability, statistics or combinatorial analysis.

Students lacking some of these requirements, whose background is otherwise satisfactory, may be admitted with the understanding that the certain undergraduate courses have to be completed after admission. Additional information regarding the admissions process may be found at engineering.ucdenver.edu/cse (http://engineering.ucdenver.edu/cse/).

Required GPA

Regular admission: Applicants should have an undergraduate GPA of at least 3.0.

Transfer Credit

A maximum of 9 semester hours of graduate course work may be transferred into the program based on department approval. In principle, core courses must be taken from the CSE department at CU Denver.

Note: Candidates applying for MS study will be individually evaluated by the department’s graduate committee. A letter with a decision will be sent to the applicant by the graduate committee chair.

Computer Science and Information Systems (CSIS) PhD

Admission

Admission criteria include GPA (undergraduate and graduate), letters of recommendation, prior achievements in academia and industry and an application portfolio essay describing an applicant’s motivation and an initial plan for doctoral study. The application portfolio is important to gauge an applicant’s motivation for research training.

Exceptionally motivated students with BS degrees in computer science, information systems, or closely related fields may apply to the CSIS PhD program directly. Students without a master’s degree must complete at least 30 hours of CSIS PhD required course work in addition to the 30 hours of dissertation.
Engineering and Applied Science PhD
Graduate School Policies and Procedures (http://catalog.ucdenver.edu/cu-denver/graduate/graduate-school-policies-procedures/) apply to this program

Requirements for Admission
Requirements for admission to the Engineering and Applied Science PhD program can be found under the Degree Programs link on each host department's website.

• Civil Engineering (engineering.ucdenver.edu/civil)
• Computer Science and Engineering (engineering.ucdenver.edu/cse)
• Electrical Engineering (engineering.ucdenver.edu/electrical)
• Mechanical Engineering (engineering.ucdenver.edu/mechanical)
• Computer Science and Information Systems, PhD (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/computer-science-information-systems-phd/)
• Computer Science, MS (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/computer-science-ms/)
• Cybersecurity and Defense Graduate Certificate (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/cyber-security-defense-graduate-certificate/)
• Engineering and Applied Science, PhD (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/engineering-applied-science-engineering/engineering-applied-science-phd/)
• Software Engineering Graduate Certificate (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-engineering-design-computing/computer-science-engineering/software-engineering-graduate-certificate/)

Faculty

Professors
Gita Alaghband, PhD, University of Colorado
Research areas: parallel and distributed systems, parallel algorithms, applications and languages, high-performance computing

Tom Altman, PhD, University of Pittsburgh
Research areas: algorithms, optimization, theory

Min-Hyung Choi, PhD, University of Iowa
Research areas: computer graphics, animation, virtual reality, human computer interface

Dave Ogle, PhD, Ohio State University
Research areas: networks

Douglas Sicker, PhD, University of Pittsburgh
Research areas: cybersecurity and wireless systems

Associate Professors
Ellen Gethner, PhD, University of British Columbia; PhD, Ohio State University
Research areas: graph theory, number theory, combinatorics, discrete geometry, computational geometry, visualization, algorithms

Ilkyeun Ra, PhD, Syracuse University
Research areas: computer networks, cloud computing, high-performance computing, distributed computing systems

Assistant Professors
Mazen Al Borno, PhD, University of Toronto
Research areas: computational motor control and mobile health

Farnoush Banai-Kashani, PhD, University of Southern California
Research areas: big data, data science, data management and mining, database systems, applied machine learning, computational biomedicine and biology

Ashis Biswas, PhD, University of Texas at Arlington
Research areas: machine learning, data mining, big data analysis, bioinformatics

Farnoush Banaei-Kashani, PhD, University of Southern California
Research areas: computer networks, cloud computing, high-performance computing, distributed computing systems

Madhuri Debnath, PhD, University of Texas at Arlington, Clinical Teaching Track
Research areas: data mining, spatio-temporal data analysis, data science, machine learning

Liang He, PhD, Nankai University
Research areas: cyber-physical systems, cognitive battery management, IoTs, mobile computing

Haadi Jafarian, PhD, University of North Carolina Charlotte
Research areas: proactive security for cyber threats, big data analytics for cyber threat intelligence, security for cyber-physical systems & critical infrastructures, security for IoTs, security analytics & automation, science of security

Salim Lakhani, PhD, Purdue University
Research areas: cloud computing and security, distributed computing & database systems

Zhengxiong Li, PhD, SUNY Buffalo
Research areas: Internet of Things, cybersecurity, emerging technologies and applications

Senior Instructor
Diane Yoha, MS, University of Colorado Denver, Clinical Teaching Track
Research areas: artificial intelligence, linguistic geometry, natural language processing

Professor Emeriti
Boris Stilman, PhD, National Research Institute for Electrical Engineering, Moscow, Russia
## Computer Science (CSCI)

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<thead>
<tr>
<th>Course Code</th>
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<tr>
<td>CSCI 5010</td>
<td>Software Architecture</td>
<td>3</td>
<td>This course will focus on two major areas. The first part of the course will cover Software Requirements Analysis and Development as well as Software Architecture and the Soft Skills needed by high level Software Architects. The second part of the course will cover how Persistent Data fits into different types of Software Systems. The primary focus of the second part of the course will be on incorporating larger scale Enterprise Data Systems into Software Systems and will be an application of the first part of the course material. Restriction: Restricted to students with graduate standing. Max hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
</tr>
<tr>
<td>CSCI 5011</td>
<td>Software Project Management Support</td>
<td>3</td>
<td>Large Software Systems must be Planned, Scheduled, and Staffed. To accomplish these tasks Software Engineers must understand the Software Architecture, the Software System Dependencies, Effort Estimation and the various Project Development Models that might be used. This course will look at different Project Models, Project Management Needs, and various Effort Estimation tools and techniques. Restriction: Restricted to students with graduate standing. Max hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
</tr>
<tr>
<td>CSCI 5098</td>
<td>Computer Science for Bioscientists</td>
<td>3</td>
<td>Provides a broad but detailed overview of the computer science field to graduate students in the biosciences, with emphasis on web technologies, programming languages, algorithms and database systems. No credit for CS graduate students. Prereq: Working knowledge of programming language (e.g., Java). Max Hours: 3 Credits. Grading Basis: Letter Grade Repeatable. Max Credits: 3.</td>
</tr>
<tr>
<td>CSCI 5110</td>
<td>Applied Number Theory</td>
<td>3</td>
<td>Every year, Topics include divisibility, prime numbers, congruences, number theoretic functions, quadratic reciprocity, special diophantine equations, cryptography, computer security, and engineering applications. Cross-listed with CSCI 4110. Restriction: Restricted to students with graduate standing. Max hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5172</td>
<td>Complexity and Problem Solving</td>
<td>3</td>
<td>Theoretical and practical aspects of solving complex problems, in particular, but not limited to, NP-complete and PSPACE-complete problems. Various heuristic and approximation algorithms, including greedy, ant, and Genetic Algorithms will be studied. This course is by instructor's permission only. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5407</td>
<td>Security &amp; Cryptography</td>
<td>3</td>
<td>A broad overview of cryptography and its relation to computer security. Topics include basic standard cryptographic techniques, a history of codes and ciphers, RSA, DES, AES, Elliptic Curve Cryptography, ElGamal, and applications to current and future technologies. Restriction: Restricted to Graduate Standing. Cross-listed with CSCI 7407. Max hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5408</td>
<td>Applied Graph Theory</td>
<td>3</td>
<td>Introduces discrete structures applications of graph theory to computer science, engineering and operations research. Topics include connectivitiy, coloring, trees, Euler and Hamiltonian paths and circuits. Matching and covering problems, shortest route and network flows. Restriction: Restricted to students with graduate standing. Note: Expected knowledge of abstract mathematics including discrete structures. Cross-listed with MATH 4408. Max hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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</table>
CSCI 5409 - Graph Theory and Graph Algorithms (3 Credits)
Studies geometric graphs and other geometric objects, both analysis and algorithmic construction, leads to interesting connections among VLSI design, graph theory and graph algorithms. Studies a subset of the recent literature, with special emphasis on visibility graphs, thickness of graphs, graph coloring and the surprising and elegant connections among them all. Other topics are introduced as time permits. Prereq: CSCI 5408. Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 5411 - Computational Geometry (3 Credits)
Many practical and aesthetic algorithmic problems have their roots in geometry. Applications abound in the areas of computer graphics, robotics, computer-aided design, and geographic information systems, for example. A selection of topics from convex hull, art gallery problems, ray tracing, point location, motion planning, segment intersection, Voronoi diagrams, visibility and algorithmic folding will be covered. Cross-listed with CSCI 4411. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 5446 - Theory of Automata (3 Credits)
Studies the relationships between classes of formal languages (regular, context-free, context-sensitive, phrase-structure) and classes of automata (finite-state, pushdown, Turing machines). Additional topics include decidability and computability issues. Restriction: Restricted to students with graduate standing. Note: Expected knowledge of algorithms equivalent to CSCI 3412. Cross-listed with MATH 5446. Max hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 5451 - Algorithms (3 Credits)
Advanced design and analysis techniques: dynamic programming, greedy algorithms, amortized analysis. Advanced data structures: Fibonacci heaps, union-find data structures. Study of variety of special topics, which may include: graph algorithms, optimization problems, Fast Fourier Transform, string matching, geometric algorithms, NP-completeness and approximation algorithms. Restriction: Restricted to students with graduate standing. Note: Expected knowledge of algorithms equivalent to CSCI 3412. Max hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 5455 - Data Mining (3 Credits)
Introduces concepts, techniques and methodologies to discover patterns in data. Topics include (but are not limited to) data preprocessing and cleansing, data warehousing, pattern mining, classification, prediction, cluster analysis, outlier detection, and online data analytics. Restriction: Graduate Standing. Cross-listed with CSCI 4455. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 5511 - Parallel and Distributed Systems (3 Credits)
Examines a range of topics involving parallel and distributed systems to improve computational performance. Topics include parallel and distributed programming languages, architectures, networks, algorithms and applications. Prereq: Graduate standing. Cross-listed with CSCI 7551. Max hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 5522 - Advanced Topics in Parallel Processing (3 Credits)
Examines the advances of sequential computers for gaining speed and application of these techniques to high-speed supercomputers of today. Programming methodologies of distributed and shared memory multiprocessors, vector processors and systolic arrays are compared. Performance analysis methods for architectures and programs are described. Cross-listed with CSCI 7552. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 5551 - Parallel and Distributed Systems (3 Credits)
Examines a range of topics involving parallel and distributed systems to improve computational performance. Topics include parallel and distributed programming languages, architectures, networks, algorithms and applications. Prereq: Graduate standing. Cross-listed with CSCI 7551. Max hours: 3 Credits.
Grading Basis: Letter Grade
CSCI 5574 - Advanced Topics in Operating Systems (3 Credits)
Covers the advanced topics in operating systems by examining functionality and performance issues in CPU scheduling, communications, distributed file systems, distributed operating systems, shared-memory multiprocessors and real-time operating systems. In addition to studying papers, reviews and presentations, students carry out a semester long term project within the scope of one of the above topics. Cross-listed with CSCI 7574. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5595 - Computer Animation (3 Credits)
This course introduces the state of the art techniques for modern computer animation focused on a practical, example driven approach to learning the unique art of 3D animation. Topics include modeling, kinematics, rigging, textures, physically based dynamics, and rendering. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5597 - Universal Compiler: Theory and Construction (3 Credits)
Theoretical foundations and step-by-step hands-on experience in the development of a compiler, which can tune itself to a new programming language. This is a must-take course for future software developers as well as those interested in applications of the theory of Computer Science. Cross-listed with CSCI 7640. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5598 - Algorithms for Communication Networks (3 Credits)
Algorithmic and mathematical underpinnings of communication networks. A taxonomy of data-packet networks depending on modes of communication: fixed-interconnection networks, radio networks and multiple-access channel. Algorithms to implement packet routing and broadcasting. Cross-listed with CSCI 7654. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
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<tr>
<td>CSCI 5660</td>
<td>Numerical Analysis I</td>
<td>3 Credits</td>
<td>Techniques used to resolve continuous mathematical problems on the computer. Solution of linear and nonlinear equations, interpolation and integration. Prereq: MATH 2411, MATH 3191 or MATH 3195, and programming experience. Cross-listed with CSCI 4650, MATH 4650, and MATH 5660. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5661</td>
<td>Numerical Analysis II</td>
<td>3 Credits</td>
<td>Includes queuing theory and stochastic processes. Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5667</td>
<td>Introduction to Approximation Theory</td>
<td>3 Credits</td>
<td>Tchebychev approximation by polynomials and other related families. Least squares approximation and splines. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5682</td>
<td>Expert Systems</td>
<td>3 Credits</td>
<td>Reviews and analyzes many expert systems documented in the literature, such as Mycin, Macsyma, and Xcon. Emphasis is given to the design of rule-based systems, the use of uncertain and incomplete information and system shells. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
</tr>
<tr>
<td>CSCI 5690</td>
<td>Knowledge Representation for Intelligent Systems</td>
<td>3 Credits</td>
<td>An in-depth study of different types of knowledge representation in artificial intelligence for the efficient control of complex real-world systems like autonomous robots, space vehicles, and military units. Major emphasis is on search algorithms and heuristics, logical representation with applications to planning, formal linguistic representation. At the conclusion, all the theories studied are combined in the form of introduction to the state-of-the-art linguistic geometrical representation of complex control systems. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5702</td>
<td>Big Data Mining</td>
<td>3 Credits</td>
<td>Introduces techniques to discover patterns in Big Data. Selected topics: time-series analysis at scale, big graph mining, big scientific data mining, and spatiotemporal data mining, with applications in precision medicine, social network analysis, transportation, scientific data analysis, and geospatial analytics. Cross-listed with CSCI 7702. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5704</td>
<td>Introduction to Distributed Systems</td>
<td>3 Credits</td>
<td>Studies design, implementation and management of distributed systems, including communication issues, security reliability, resource sharing, and remote execution. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5728</td>
<td>Software Engineering</td>
<td>3 Credits</td>
<td>Groups of students plan, analyze and design large software projects. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5741</td>
<td>Principles of Cybersecurity</td>
<td>3 Credits</td>
<td>Focuses on the most common threats to cybersecurity as well as ways to prevent security breaches or information loss. Topics will include: understanding and thwarting hacker methods, authentication, cryptography, programming security, malware analysis, web, database and file server security, network and enterprise security methods. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5742</td>
<td>Cybersecurity Programming and Analysis</td>
<td>3 Credits</td>
<td>Focuses on cybersecurity related programming and analysis skills. Topics include: network and security application development, intrusion detection, automating security hardening. Students will design and develop security applications in multiple programming languages. Undergraduate algorithms and programming knowledge expected. Cross-listed with CSCI 4742. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
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<tr>
<td>CSCI 5743</td>
<td>Cyber and Infrastructure Defense</td>
<td>3 Credits</td>
<td>Presents analytical study of state-of-the-art attack and defense paradigms in cyber systems and infrastructures. Analysis will focus on: theoretical foundations of cybersecurity, practical development of novel technical defense techniques and analysis of alternatives. Knowledge of undergraduate-level networking. Restriction: Restricted to students with graduate standing. Cross-listed with CSCI 4743. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
</tr>
<tr>
<td>CSCI 5765</td>
<td>Computer Networks</td>
<td>3 Credits</td>
<td>An in-depth study of active research topics in computer networks. Topics include: Internet protocols, TCP/UDP, congestion and flow control, IP routings, mobile IP, P2P overlay networks, network security, performance, and other current research topics. Prereq: Graduate standing. Cross-listed with CSCI 7765. Max Hours: 3 Credits. Grading Basis: Letter Grade Restriction: Restricted to students with graduate standing.</td>
</tr>
</tbody>
</table>
CSCI 5771 - Introduction to Mobile Computing (3 Credits)
Provides the fundamentals of mobile computing. Studies existing and proposed solutions for ubiquitous computing. This course focuses on systems and networking issues involved with supporting mobility. Cross-listed with CSCI 4771. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5772 - Mobile and IoT Security (3 Credits)
This course concentrates on the computing of emerging mobile and IoT systems security in the Computer Science domain. The seminar will discuss recent research on computing for mobile user authentication, vulnerability risk detection of mobile/IoT systems, and software based defense mechanism. Restriction: Restricted to graduate school standing.
Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5770 - Theory of Distributed Computing (3 Credits)
Elements of the theory of distributed computing through fundamental algorithmic ideas, lower bound techniques, and impossibility results. Timing assumptions (asynchrony and synchrony), simulations between models (message passing and shared memory), failure types (crash and Byzantine). Restriction: Restricted to students with graduate standing.
Note: Expected knowledge of algorithms equivalent to CSCI 3412. Max hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5799 - Cloud Computing (3 Credits)
This course studies fundamental designs and key technologies in Cloud Computing by reading technical articles, and conducting a semester group project. Topics include cloud computing design and architectures, service models, virtualization, advanced computer networks, programming, often software, and security. Note: Operating System, Computer Networks, and programming experience are recommended for success in this course. Prereq: Graduate standing.
Cross-listed with CSCI 7799. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 3.

CSCI 5800 - Special Topics (3 Credits)
These special topics courses cover recent developments in an aspect of computer science. Restriction: Restricted to students with graduate standing. Repeatable. Max hours: 9 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 9.
Restriction: Restricted to students with graduate standing.

CSCI 5840 - Independent Study (1-3 Credits)
For graduate computer science students. Repeatable. Max Hours: 8 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 8.

CSCI 5866 - Advanced Mobile and Ubiquitous Systems (3 Credits)
This course covers various aspects of mobile and ubiquitous systems to provide an in-depth understanding of principles, state-of-the-art solutions and challenges in design and implementation of such systems. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5951 - Big Data Systems (3 Credits)
Provides a foundation on big data and technologies for storing and processing large data sets. Topics include architectures and technologies for supporting big data, data storage, data processing, and security. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5920 - Computer Game Design and Programming (3 Credits)
Computer Game Design and Programming introduces practical and example driven approaches to modern 3D game development. Topics include 3D modeling, character animation, UI design, level design, scripting, texture mapping, and sound effect. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5930 - Machine Learning (3 Credits)
Provides theoretical and computational foundations in machine learning to design and develop intelligent applications to perform object recognition, personalized recommendations, improve cybersecurity, fact-checking, forecasting and finding communities based on three classes of algorithms: supervised, unsupervised, semi-supervised and reinforcement learning. Restriction: Graduate Standing. Cross-listed with CSCI 4930.
Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 5939 - Internship (1-3 Credits)
Faculty or employer-supervised employment in industry. Enrollment is limited to students who fully complete a contract for cooperative education credit by the last day of the drop or add period. Students who want to enroll this course should submit an official job description that must clearly show the level of work requires a bachelor’s degree in the computer science field or equivalent work experience. This course will not be counted towards either MSCS or PhD in CSIS or EAS. Prereq: Complete at least two of category A courses (for MS) or complete Preliminary exam (for PhD) and 3.0 or better GPA. Restricted to students with a minimum of 1 full academic year of study at the graduate level. Repeatable. Max Hours: 3 Credits.
Grading Basis: Pass/Fail Only
Repeatable. Max Credits: 3.

CSCI 5941 - Directed Study: Programming Project (3 Credits)
Software development project supervised by a faculty member approved by the Center for Computational Biology. Used towards a certificate in Computational Biology. Count as an independent study. Prereq: CSCI 5451 and CSCI 5610. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 5951 - Big Data Systems (3 Credits)
Provides a practical while in-depth review of the principles of a series of modern data processing systems (e.g., Hadoop, Spark, TensorFlow) designed to address the Big Data challenges. In combination, these systems enable the data to knowledge (Big) data lifecycle. Restriction: Restricted to Graduate standing. Cross-listed with CSCI 5951. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.
CSCI 5952 - Big Data Science (3 Credits)
Introduces methodologies that enable Big Data lifecycle. Selected topics: topic modeling, causality analysis, structure learning, learning with less supervision, and massive-scale data analytics, with applications in social media analysis, computational biology, climate modeling, health care, and traffic monitoring. Restriction: Graduate standing. Cross-listed with CSCI 7952. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 6010 - Principles of Programming (3 Credits)
This course introduces students to fundamental principles and techniques in the design and implementation of modern programming such as C++, Java. Students learn how to write programs in an object oriented high level programming language. Weekly laboratory assignments will provide hands-on experience in this course. (non-CS majors) Prereq: meet MAPS requirements and familiarity with computer use. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 6020 - Data Structures and Algorithms (3 Credits)
This course introduces students to fundamental skills in computer science such as data structures and computer algorithms. Students will learn how to design efficient algorithms and analyze them. (non-CS majors) Max Hours: 3 Credits.
Grading Basis: Letter Grade
D-EN-Pre: CSCI 6010

CSCI 6030 - Computer Systems & Application (3 Credits)
This course surveys essential technologies such operating systems, database systems, and the Internet. Students study the basic of operating systems, database systems, and the Internet. Weekly laboratory experiments will provide hands-on experience. (non-CS majors)
Max Hours: 3 Credits.
Grading Basis: Letter Grade
D-EN-Pre: CSCI 6010

CSCI 6040 - Teaching Practice of Computer Science (3 Credits)
This course provides students the opportunity for practicing and developing courses for adolescents using previously acquired knowledge. Students will design and develop a computer science class of their interest and appropriate to their area of expertise which they will offer at their school. (non-CS majors) Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: CSCI 6020 and 6030

CSCI 6050 - Computational Methods in Nonlinear Programming (3 Credits)
Introduces fundamental algorithms and theory for nonlinear optimization problems. Topics include Newton, quasi-Newton and conjugate direction methods; line search and trust-region methods; active set, penalty and barrier methods for constrained optimization; convergence analysis and duality theory. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 6664 - Numerical Linear Algebra (3 Credits)
Offered every other year. Solution of linear equations, eigenvector and eigenvalue calculation, matrix error analysis, orthogonal transformation, iterative methods. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 6670 - Computational Methods in Optimization (3 Credits)
Covers a variety of optimization techniques. Topics include numerical methods for solving systems of linear equations, unconstrained optimization, constrained optimization, convex optimization, and stochastic optimization. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 6950 - Master's Thesis (1-9 Credits)
Repeatable. Max hours: 12 Credits.
Grading Basis: Letter Grade with IP
Repeatable. Max Credits: 12.
Additional Information: Report as Full Time.

CSCI 6960 - Master's Report (3 Credits)
Students seeking a Master of Science in computer science, who do not choose to do a thesis, must complete an individual project of an investigative and creative nature under supervision of a full-time CS graduate faculty. Student must present their results to a faculty committee. Max hours: 3 Credits.
Grading Basis: Letter Grade with IP
Additional Information: Report as Full Time.

CSCI 6970 - MS Research Report (0 Credits)
This course is for students who select the Plan III (Course Only) option to complete their MS degree requirements. Graduating students must register for this course their final semester and submit a final written research paper on a subject specified by a CSE faculty committee.
Grading Basis: Pass/Fail Only

CSCI 7002 - Computer Security (3 Credits)
A broad overview of computer security roughly divided into three unequal components: a) the history of codes and ciphers; b) basic cryptographic techniques, for example, symmetric cryptography, authentication techniques, and asymmetric crypto systems, and; c) applications to current and future computer-related technologies, for example, network security, wireless communication, quantum cryptography, and more.
Prereq: CSCI 5451. Cross-listed with ISMG 7002. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7173 - Computational Complexity and Algorithms (3 Credits)
A solid, in-depth theoretical foundations in computing, computational complexity, and algorithmics. Various algorithms, including both discrete and non-discrete problem domains. NP-complete and other complete classes of problems/languages. Restriction: Restricted to students with graduate standing. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: CSCI 5446

CSCI 7200 - Advances in Management Information Systems (3 Credits)
Provides a broad coverage of research on the management of information technology. The course covers the systems-oriented research, organizational-oriented research, and information systems economics research. Prereq: PhD standing. Cross-listed with ISMG 7200. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7210 - Topics in Analytical Research in Management Information Systems (3 Credits)
Covers a variety of analytical research topics of interest to the IS research community including the evaluation of data mining algorithm performance, cost sensitive learning and outlier detection. Prereq: Admission to the CSIS PhD program. Cross-listed with ISMG 7210. Max Hours: 3 Credits.
Grading Basis: Letter Grade
CSCI 7211 - Topics in Behavioral-Organizational Research in Management Information Systems (3 Credits)
Provides in-depth exposure to some key behavioral, management and organizational theories and models used in Information Systems research. Covers topics in socio-technical, trust, computer self-efficacy, organizational transformation, organizational learning, resource-based and coordination theories. Prereq: Admission to the CSIS PhD program. Cross-listed with ISMG 7211. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7407 - Security & Cryptography (3 Credits)
A broad overview of cryptography and its relation to computer security. Topics include basic standard cryptographic techniques, a history of codes and ciphers, RSA, DES, AES, Elliptic Curve Cryptography, ElGamal, and applications to current and future technologies. Restriction: Restricted to Graduate Standing. Cross-listed with CSCI 5407. Max hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7502 - Research Methods (3 Credits)
Promotes research skills. Involves presenting a research topic and discussions of its merits, reviewing journal articles, writing a paper and/or a proposal in the NIH/NSF format in the student's area of research. Prereq: PhD student standing or permission of instructor for MS students who are writing a thesis. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7551 - Parallel and Distributed Systems (3 Credits)
Examines a range of topics involving parallel and distributed systems to improve computational performance. Topics include parallel and distributed programming languages, architectures, networks, algorithms and applications. Prereq: Graduate standing. Cross-listed with CSCI 5551. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7552 - Advanced Topics in Parallel Processing (3 Credits)
Examines the advances of sequential computers for gaining speed and application of these techniques to high-speed supercomputers of today. Programming methodologies of distributed and shared memory multiprocessors, vector processors and systolic arrays are compared. Performance analysis methods for architectures and programs are described. Cross-listed with CSCI 5552. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7574 - Advanced Topics in Operating Systems (3 Credits)
Covers the advanced topics in operating systems by examining functionality and performance issues in CPU Scheduling, communications, distributed file systems, distributed operating systems, shared-memory multiprocessors and real-time operating systems. In addition to studying papers, reviews and presentations, students carry out a semester long team project within the scope of one of the above topics. Cross-listed with CSCI 5574. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7582 - Artificial Intelligence (3 Credits)
Approaches to design of systems for solving problems usually solved by humans, especially those related to intelligent decision making. Emphasis on various types of knowledge representation. Cross-listed with CSCI 5582. Restriction: Restricted to students with graduate standing. Max hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7595 - Computer Animation (3 Credits)
This course introduces the state of the art techniques for modern computer animation focused on a practical, example driven approach to learning the unique art of 3D animation. Topics include modeling, kinematics, rigging, textures, physically based dynamics, and rendering. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7654 - Algorithms for Communication Networks (3 Credits)
Algorithmic and mathematical underpinnings of communication networks. A taxonomy of data-packet networks depending on modes of communication: fixed-interconnection networks, radio networks and multiple-access channel. Algorithms to implement packet routing and broadcasting. Cross-listed with CSCI 5654. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7702 - Big Data Mining (3 Credits)
Introduces techniques to discover patterns in Big Data. Selected topics: time-series analysis at scale, big graph mining, big scientific data mining, and spatiotemporal data mining, with applications in precision medicine, social network analysis, transportation, scientific data analysis, and geospatial analytics. Cross-listed with CSCI 5702. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7711 - Bioinformatics I (4 Credits)
(BIOL 7711-Offered on a semester basis from H.S.C.) What is Bioinformatics and why study it? How is large-scale molecular biology data generated, where and how can researchers gain access to it, what computational analyses are possible and computational techniques for solving inference problems in molecular biology? Prereq: Permission of instructor. Max Hours: 4 Credits.
Grading Basis: Letter Grade
Typically Offered: Fall.

CSCI 7712 - Bioinformatics II (4 Credits)
(BIOL 7712-offered on a semester basis from H.S.C.) Inference problems and computational techniques for molecular biology, with emphasis on machine learning approaches. Use of computational induction techniques focused on information extraction from biomedical literature, inference of biochemical networks from high-throughput data and prediction of protein function. Estimation, clustering, discrimination and regression. Prereq: CSCI 7711. Max Hours: 4 Credits.
Grading Basis: Letter Grade
Typically Offered: Spring.

CSCI 7765 - Computer Networks (3 Credits)
An in-depth study of active research topics in computer networks. Topics include: Internet protocols, TCP/UDP, congestion and flow control, IP routings, mobile IP, P2P overlay networks, network security, performance, and other current research topics. Prereq: Graduate standing. Cross-listed with CSCI 5765. Max Hours: 3 Credits.
Grading Basis: Letter Grade
CSCI 7799 - Cloud Computing (3 Credits)
This course studies fundamental designs and key technologies in Cloud Computing by reading technical articles, and conducting a semester group project. Topics include cloud computing design and architectures, service models, virtualization, advanced computer networks, programming, often software, and security. Note: Operating System, Computer Networks, and programming experience are recommended for success in this course. Prereq: Graduate standing. Cross-listed with CSCI 5799. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 3.

CSCI 7800 - Special Topics (3 Credits)
These special topics courses cover recent developments in an aspect of computer science. Prereq: As determined by instructor. Max Hours: 3 Credits.
Grading Basis: Letter Grade

CSCI 7840 - Independent Study (1-6 Credits)
Offers doctoral students opportunity for independent, creative work under supervision of a CSE full-time graduate faculty. Repeatable. Max Hours: 6 Credits.
Grading Basis: Letter Grade

CSCI 7866 - Advanced Mobile and Ubiquitous Systems (3 Credits)
This course covers various aspects of mobile and ubiquitous systems to provide an in-depth understanding of principles, state-of-the-art solutions and challenges in design and implementation of such systems. Restriction: Restricted to students with graduate standing. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 7952 - Big Data Science (3 Credits)
Introduces methodologies that enable Big Data lifecycle. Selected topics: topic modeling, causality analysis, structure learning, learning with less supervision, and massive-scale data analytics, with applications in social media analysis, computational biology, climate modeling, health care, and traffic monitoring. Restriction: Graduate standing. Cross-listed with CSCI 5952. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to students with graduate standing.

CSCI 8990 - Doctoral Dissertation (1-9 Credits)
Repeatable. Max hours: 9 Credits.
Grading Basis: Letter Grade with IP
Repeatable. Max Credits: 9.
Additional Information: Report as Full Time.

Engineering (ENGR)

ENGR 5150 - Seminar: Special Topics in Engineering (1 Credit)
A flexible seminar format dealing with topics of special interest in engineering on a graduate level. Topics vary from semester to semester. Prereq: Graduate standing. Cross-listed with ENGR 4150 and 7150. Max Hours: 1 Credit.
Grading Basis: Pass/Fail Only
Restriction: Restricted to graduate students
Typically Offered: Fall, Spring.

ENGR 5208 - Special Topics (1-3 Credits)
Repeatable. Max Hours: 9 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 9.

ENGR 5301 - Systems Engineering: Principles and Practice (3 Credits)
Max Hours: 3 Credits.
Grading Basis: Letter Grade

ENGR 5302 - Systems Engineering: Planning and Management (3 Credits)
Max Hours: 3 Credits.
Grading Basis: Letter Grade

ENGR 5303 - Special Topics: Systems Engineering (3 Credits)
Repeatable. Max Hours: 6 Credits.
Grading Basis: Letter Grade

ENGR 5800 - Long Range Infrastructure Planning and Design: Colorado 2050 (3 Credits)
The goal of this course is to equip students to address the problems of long term future resource limitation and its influence on urban infrastructure in Colorado. Repeatable. Max Hours: 6 Credits.
Grading Basis: Letter Grade

ENGR 7150 - Seminar: Special Topics in Engineering (0.5 Credits)
A flexible seminar format dealing with topics of special interest in engineering on an advanced graduate level. Topics vary from semester to semester. Prereq: Graduate standing. Cross-listed with ENGR 4150 and 5150. Repeatable. Max Hours: 1 Credit.
Grading Basis: Pass/Fail Only
Repeatable. Max Credits: 1.
Restriction: Restricted to graduate students
Typically Offered: Fall, Spring.