Our high performance computing research focuses on using compiler and runtime techniques to optimize Big Data and machine learning applications on heterogeneous systems.

MACHINE LEARNING
Includes research in developing mathematical foundations and algorithm design needed for computers to learn. Focus areas include fundamental research in machine learning and numerical methods, as well as developing novel algorithms for bioinformatics, data mining, computer vision, biomedical image analysis, parallel computing, natural language processing, and data privacy.

NETWORKED SYSTEMS
Research aims to enable emerging wireless applications via networks and systems support, ranging from hardware design to algorithms development and software integration, from credible simulations to actual system deployment and testing.

PROGRAM DETAILS
The CS Department offers the degrees Master of Science and Doctor of Philosophy in Computer Science. The master's program is designed to prepare candidates for careers in industry or government or for further study at the Ph.D. level; both thesis and non-thesis options are available. The Ph.D. degree program is sufficiently flexible to prepare candidates for careers in industry, government, or academia. See the information that follows for full details on these two degrees.

Combined Program: The CS Department also offers combined BS/MS degree programs. These programs offer an expedited graduate school application process and allow students to begin graduate coursework while still finishing their undergraduate degree requirements. Details on this program can be found in the Mines Undergraduate Catalog.

PREREQUISITES
Requirements for Admission to CS: The minimum requirements for admission to the M.S. and Ph.D degrees in Computer Science are:

- Applicants must have a Bachelor's degree, or equivalent, from an accredited institution with a grade-point average of 3.0 or better on a 4.0 scale.
- Students are expected to have completed two semesters of calculus, along with courses in object-oriented programming and data structures, and upper level courses in at least three of the following areas: software engineering, numerical analysis, computer architecture, principles of programming languages, analysis of algorithms, and operating systems.
- Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with an engineering degree from CSM within the past five years are not required to submit GRE scores.
- TOEFL score of 79 or higher (or 550 for the paper-based test or 213 for the computer-based test) for applicants whose native language is not English. In lieu of a TOEFL score, an IELTS score of 6.5 or higher will be accepted.
- For the Ph.D. program, prior research experience is desired but not required.

Admitted Students: The CS Department Graduate Committee may require that an admitted student take undergraduate remedial coursework
to overcome technical deficiencies. The committee will decide whether to recommend regular or provisional admission.

Transfer Courses: Graduate level courses taken at other universities for which a grade equivalent to a "B" or better was received will be considered for transfer credit with approval of the Advisor and/or Thesis Committee, and CS Department Head, as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the M.S. degree, no more than nine credits may transfer. For the Ph.D. degree, up to 24 credit hours may be transferred. In lieu of transfer credit for individual courses, students who enter the Ph.D. program with a thesis-based master’s degree from another institution may transfer up to 36 hours in recognition of the course work and research completed for that degree.

400-level Courses: As stipulated by the Mines Graduate School, students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work.

Advisor and Thesis Committee: Students must have an Advisor from the CS faculty to direct and monitor their academic plan, research, and independent studies. Advisors must be full-time permanent members of the faculty. In this context, full-time permanent members of the faculty are those that hold the rank of professor, associate professor, assistant professor, research professor, associate research professor or assistant research professor. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors. A list of CS faculty by rank is available in the faculty tab of the catalog.

Master of Science (thesis option) students in CS must have at least three members on their Thesis Committee; the Advisor and one other member must be permanent faculty in the CS Department. CS Ph.D. Thesis Committees must have at least four members; the Advisor/co-advisor and two additional members must be permanent faculty in the CS Department, and one member must be outside the departmental faculty and serving as chair of the committee. Students who choose to have a minor program must select a representative from the minor area of study to serve on the Thesis Committee.

Degree Audit and Admission to Candidacy: Master students must complete the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadline. Ph.D. students need to submit the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadline and need to submit the Admission to Candidacy form (https://inside.mines.edu/GS-Candidacy-Addendum) two weeks prior to census day of the semester in which they want to be considered eligible for reduced registration.

Time Limit: As stipulated by the Mines Graduate School, a candidate for a Masters degree must complete all requirements for the degree within five years of the date of admission into the degree program. A candidate for a doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program.

PROGRAM REQUIREMENTS

Master of Science - Computer Science
The M.S. degree in Computer Science (Thesis or Non-Thesis option) requires 30 credit hours. Requirements for the thesis M.S. are 21 hours of coursework plus 9 hours of thesis credit leading to an acceptable Master’s thesis; thesis students are encouraged to find a thesis advisor and form a Thesis Committee by the end of the first year. The non-thesis option consists of two tracks: a Project Track and a Coursework Track.

Requirements for the Project Track are 24 hours of coursework plus 6 hours of project credit; requirements for the Coursework Track are 30 hours of coursework. The following four core courses are required of all students. Students may choose elective courses from any CSCI graduate course offered by the Department. In addition, up to six credits of elective courses may be taken outside of CSCI. Lastly, a maximum of six Independent Study course units can be used to fulfill degree requirements.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CSCI406</td>
<td>ALGORITHMS</td>
<td>3.0</td>
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<tr>
<td>CSCI442</td>
<td>OPERATING SYSTEMS</td>
<td>3.0</td>
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<tr>
<td>CSCI561</td>
<td>THEORY OF COMPUTATION</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI564</td>
<td>ADVANCED COMPUTER ARCHITECTURE</td>
<td>3.0</td>
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M.S. Project Track: Students are required to take six credits of CSCI700 to fulfill the MS project requirement. (It is recommended that the six credits consist of two consecutive semesters of three credits each.) At most six credits of CSCI700 will be counted toward the Masters non-thesis degree. Deliverables include a report and a presentation to a committee of two CS faculty including the Advisor. Deliverables must be successfully completed in the last semester in which the student registers for CSCI700. A student must receive two “pass” votes (i.e., a unanimous vote) to satisfy the project option.

M.S. Thesis Defense: At the conclusion of the M.S. (Thesis Option), the student will be required to make a formal presentation and defense of her/his thesis research. A student must “pass” this defense to earn an M.S. degree.

CS Minor: A CS Minor at the Master’s level requires a minimum of 9 semester hours of CSCI course work, of which, at least 6 semester hours of course work must be at the 500-level or above excluding independent studies and graduate seminars. Pursuant to Graduate School rules all minors must be approved by the student’s advisor, home department head, and a faculty representative of the minor area of study. A minor may not be taken in the student’s major area of study.

Doctor of Philosophy - Computer Science
The Ph.D. degree in Computer Science requires 72 credit hours of course work and research credits. Required course work provides a strong background in computer science. A course of study leading to the Ph.D. degree can be designed either for the student who has completed the master’s degree or for the student who has completed the bachelor’s degree. The following five courses are required of all students. Students who have taken equivalent courses at another institution may satisfy these requirements by transfer.

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<td>ADVANCED COMPUTER ARCHITECTURE</td>
<td>3.0</td>
</tr>
<tr>
<td>SYGN502</td>
<td>INTRODUCTION TO RESEARCH ETHICS</td>
<td>1.0</td>
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Ph.D. Qualifying Examination: Students desiring to take the Ph.D. Qualifying Exam must have:

- (if required by your advisor) taken SYGN 501 The Art of Science (previously or concurrently),
- taken at least four CSCI 500-level courses at CSM (only one CSCI599 is allowed), and
• maintained a GPA of 3.5 or higher in all CSCI 500-level courses taken.

The Ph.D. Qualifying Exam must be taken no later than the fourth semester of study. Exception must be formally requested via email to the Qualifying Exam Committee Chair and approved by the Graduate Committee. The Ph.D. Qualifying Exam is offered once a semester. Each Ph.D. Qualifying Exam comprises of two research areas, chosen by the student. The exam consists of the following steps:

Step 1. A student indicates intention to take the CS Ph.D. Qualifying Exam by choosing two research interest areas from the following list: algorithms, education, high-performance computing, human-centered robotics, image processing, machine learning, and networks. This list is subject to change, depending on the current faculty research profile. Students must inform the CS Graduate Committee Chair of their intention to take the exam no later than the first class day of the semester.

Step 2. The Graduate Committee Chair creates an exam committee of (at least) four appropriate faculty. The exam committee assigns the student deliverables for both research areas chosen. The deliverables will be some combination from the following list:

• read a set of technical papers, make a presentation, and answer questions;
• complete a hands-on activity (e.g., develop research software) and write a report;
• complete a set of take-home problems;
• write a literature survey (i.e., track down references, separate relevant from irrelevant papers); and
• read a set of papers on research skills (e.g., ethics, reviewing) and answer questions.

Step 3. The student must complete all deliverables no later than the Monday of Dead Week.

Step 4. Each member of the exam committee makes a recommendation on the deliverables from the following list: strongly support, support, and do not support. To pass the Ph.D. Qualifying Exam, the student must have at least two “strongly supports” and no more than one “do not support”. The student is informed of the decision no later than the Monday after finals week. A student can only fail the exam one time. If a second failure occurs, the student has unsatisfactory academic performance that results in an immediate, mandatory dismissal of the graduate student from the Ph.D. program.

Ph.D. Thesis Proposal: After passing the Qualifying Examination, the Ph.D. student is allowed up to 18 months to prepare a written Thesis Proposal and present it formally to the student’s Thesis Committee and other interested faculty.

Admission to Candidacy: In addition to the Graduate School requirements, full-time Ph.D. students must complete the following requirements within two calendar years of enrolling in the Ph.D. program.

• Have a Thesis Committee appointment form on file in the Graduate Office:
• Have passed the Ph.D. Qualifying Exam demonstrating adequate preparation for, and satisfactory ability to conduct doctoral research.

Ph.D. Thesis Defense: At the conclusion of the student’s Ph.D. program, the student will be required to make a formal presentation and defense of her/his thesis research. A student must “pass” this defense to earn a Ph.D. degree.

CS Minor: A CS Minor at the PhD level requires a minimum of 12 semester hours of CSCI course work, of which, 9 semester hours of course work must be at the 500-level or above excluding independent studies and graduate seminars. Pursuant to Graduate School rules all minors must be approved by the student’s advisor, home department head, and a faculty representative of the minor area of study. A minor may not be taken in the student’s major area of study.

Professor and Department Head
Tracy Camp

Professor
Dinesh Mehta

Associate professors
Qi Han
William Hoff

Assistant professors
Neil Dantam
Hua Wang
Thomas Williams
Bo Wu
Dejun Yang
Chuan Yue
Hao Zhang

Teaching Associate Professors
Wendy Fisher
Christopher Painter-Wakefield
Jeffrey Paone, Assistant Department Head

Emeritus Teaching Professor
Cyndi Rader

Professor of Practice
Mark Baldwin
Courses

CSCI507. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI437, CSCI512, EENG507, EENG512, EGGN512.
(I) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. Prerequisites: Undergraduate level knowledge of linear algebra, statistics, and a programming language. 3 hours lecture; 3 semester hours.

CSCI508. ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with EENG508.
(II) This course covers advanced topics in perception and computer vision, emphasizing research advances in the field. The course focuses on structure and motion estimation, general object detection and recognition, and tracking. Projects will be emphasized, using popular software tools. Prerequisites: EENG507 or CSCI507. 3 hours lecture; 3 semester hours.

CSCI522. INTRODUCTION TO USABILITY RESEARCH. 3.0 Semester Hrs.
(I) An introduction to the field of Human-Computer Interaction (HCI). Students will review current literature from prominent researchers in HCI and will discuss how the researchers' results may be applied to the students' own software design efforts. Topics include usability testing, ubiquitous computing user experience design, cognitive walkthrough and talk-aloud testing methodologies. Students will work in small teams to develop and evaluate an innovative product or to conduct an extensive usability analysis of an existing product. Project results will be reported in a paper formatted for submission to an appropriate conference (UbiComp, SIGCSE, CHI, etc.). Prerequisite: CSCI 261 or equivalent. 3 hours lecture, 3 semester hours.

CSCI542. SIMULATION. 3.0 Semester Hrs.
Equivalent with MACS542.
(I) Advanced study of computational and mathematical techniques for modeling, simulating, and analyzing the performance of various systems. Simulation permits the evaluation of performance prior to the implementation of a system; it permits the comparison of various operational alternatives without perturbing the real system. Topics to be covered include simulation techniques, random number generation, Monte Carlo simulations, discrete and continuous stochastic models, and point/interval estimation. Offered every other year. Prerequisite: CSCI 262 (or equivalent) and MATH 323 (or MATH 530 or equivalent). 3 hours lecture; 3 semester hours.

CSCI544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with MATH544.
This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.
CSCI563. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.
(I) Students are taught how to use parallel computing to solve complex scientific problems. They learn how to develop parallel programs, how to analyze their performance, and how to optimize program performance. The course covers the classification of parallel computers, shared memory versus distributed memory machines, software issues, and hardware issues in parallel computing. Students write programs for state of the art high performance supercomputers, which are accessed over the network. Prerequisite: Programming experience in C. 3 hours lecture; 3 semester hours.

CSCI564. ADVANCED COMPUTER ARCHITECTURE. 3.0 Semester Hrs.
The objective of this class is to gain a detailed understanding about the options available to a computer architect when designing a computer system along with quantitative justifications for the options. All aspects of modern computer architectures including instruction sets, processor design, memory system design, storage system design, multiprocessors, and software approaches will be discussed. Prerequisite: CSCI442 or equivalent. 3 hours lecture; 3 semester hours.

CSCI565. DISTRIBUTED COMPUTING SYSTEMS. 3.0 Semester Hrs.
(II) This course discusses concepts, techniques, and issues in developing distributed systems in large scale networked environment. Topics include theory and systems level issues in the design and implementation of distributed systems. Prerequisites: CSCI 442 or equivalent. 3 hours of lecture; 3 semester hours.

CSCI568. DATA MINING. 3.0 Semester Hrs.
Equivalent with MACS568.
(II) This course is an introductory course in data mining. It covers fundamentals of data mining theories and techniques. We will discuss association rule mining and its applications, overview of classification and clustering, data preprocessing, and several applicationspecific data mining tasks. We will also discuss practical data mining using a data mining software. Project assignments include implementation of existing data mining algorithms, data mining with or without data mining software, and study of data mining related research issues. Prerequisite: CSCI 262. 3 hours lecture; 3 semester hours.

CSCI571. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.
(I) Artificial Intelligence (AI) is the subfield of computer science that studies how to automate tasks for which people currently exhibit superior performance over computers. Historically, AI has studied problems such as machine learning, language understanding, game playing, planning, robotics, and machine vision. AI techniques include those for uncertainty management, automated theorem proving, heuristic search, neural networks, and simulation of expert performance in specialized domains like medical diagnosis. This course provides an overview of the field of Artificial Intelligence. Particular attention will be paid to learning the LISP language for AI programming. Prerequisite: CSCI 262. 3 hours lecture; 3 semester hours.

CSCI572. COMPUTER NETWORKS II. 3.0 Semester Hrs.
Equivalent with MACS572.
(II) This course covers the network layer, data link layer, and physical layer of communication protocols in depth. Detailed topics include routing (unicast, multicast, and broadcast), one hop error detection and correction, and physical topologies. Other topics include state-of-the-art communications protocols for emerging networks (e.g., ad hoc networks and sensor networks). Prerequisite: CSCI 471 or equivalent. 3 hours lecture; 3 semester hours.

CSCI573. HUMAN-CENTERED ROBOTICS. 3.0 Semester Hrs.
Equivalent with CSCI473.
(II) Human-centered robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making. Students in CSCI 473 will be able to model and analyze human behaviors geared toward human-robot interaction applications. They will also be able to implement a working system using algorithms learnt to solve a given problem in human-centered robotics application. Students in CSCI 573 will get a more in-depth study into the theory of the algorithms. They will be able to compare the different algorithms to select the most appropriate one that can solve a specific problem. Prerequisites: CSCI 262 and MATH 201. 3 hours lecture; 3 semester hours.

CSCI574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with MATH574.
Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Prerequisites: CSCI 262 plus undergraduate-level knowledge of statistics and discrete mathematics. 3 hours lecture, 3 semester hours.

CSCI575. MACHINE LEARNING. 3.0 Semester Hrs.
Equivalent with MACS575.
(II) The goal of machine learning research is to build computer systems that learn from experience and that adapt to their environments. Machine learning systems do not have to be programmed by humans to solve a problem; instead, they essentially program themselves based on examples of how they should behave, or based on trial and error experience trying to solve the problem. This course will focus on the methods that have proven valuable and successful in practical applications. The course will also contrast the various methods, with the aim of explaining the situations in which each is most appropriate. Prerequisites: CSCI 262 and MATH 201. 3 hours lecture; 3 semester hours.
CSCI576. WIRELESS SENSOR SYSTEMS. 3.0 Semester Hrs.
With the advances in computational, communication, and sensing capabilities, large scale sensor-based distributed environments are becoming a reality. Sensor enriched communication and information infrastructures have the potential to revolutionize almost every aspect of human life benefiting application domains such as transportation, medicine, surveillance, security, defense, science and engineering. Such a distributed infrastructure must integrate networking, embedded systems, distributed computing and data management technologies to ensure seamless access to data dispersed across a hierarchy of storage, communication, and processing units, from sensor devices where data originates to large databases where the data generated is stored and/or analyzed. Prerequisite: CSCI406, CSCI446, CSCI471. 3 hours lecture; 3 semester hours.

CSCI580. ADVANCED HIGH PERFORMANCE COMPUTING. 3.0 Semester Hrs.
This course provides students with knowledge of the fundamental concepts of high performance computing as well as hands-on experience with the core technology in the field. The objective of this class is to understand how to achieve high performance on a wide range of computational platforms. Topics will include sequential computers including memory hierarchies, shared memory computers and multicore, distributed memory computers, graphical processing units (GPUs), cloud and grid computing, threads, OpenMP, message passing (MPI), CUDA (for GPUs), parallel file systems, and scientific applications. 3 hours lecture; 3 semester hours.

CSCI585. INFORMATION SECURITY PRIVACY. 3.0 Semester Hrs.
(I) This course provides an introduction to the principles and best practices in information security and privacy. Lectures will include basic concepts of information security and privacy, fundamental security design principles, major topics in security and privacy, essential knowledge and skills, risk assessment and mitigation, policy development, and so on. In the classroom, students will also present and discuss a list of recent or classic research papers corresponding to the major topics in security and privacy. Outside of the classroom, students will work on homework assignments, security lab exercises, quizzes, research paper summaries, and a course project. Prerequisites: CSCI262, CSCI341. 3 hours lecture; 3 semester hours.

CSCI598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI700. MASTERS PROJECT CREDITS. 1-6 Semester Hr.
(I, II, S) Project credit hours required for completion of the non-thesis Master of Science degree in Computer Science (Project Option). Project under the direct supervision of a faculty advisor. Credit is not transferable to any 400, 500, or 600 level courses. Repeatable for credit.

CSCI707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.