Robotics

Degrees Offered

• Graduate Certificate in Robotics
• Master of Science in Robotics (Non-Thesis)
• Master of Science in Robotics (Thesis)
• Doctor of Philosophy in Robotics

Program Director
Kevin Moore

Professors
Qi Han
Tyrone Vincent

Associate Professors
Kathryn Johnson
Hao Zhang
Xiaoli Zhang

Assistant Professors
Neil Dantam
Andrew Petruska
Thomas Williams
Qin Zhu

Admissions and Program Policies

Mines' Combined Undergraduate / Graduate Degree Program

Current Mines undergraduate students are encouraged to apply for the combined program once they have taken five or more technical classes at Mines (classes transferred from other universities will not be considered). This requirement may be met by any 200-level or above course with a CSCI, MEGN, or EENG prefix, excluding field session and senior design courses.

Students enrolled in Mines’ Combined Undergraduate/Graduate Program may double count up to six hours of credits which were used in fulfilling the requirements of their undergraduate degree at Mines, towards their graduate program. Any courses that count towards the graduate degree requirements as either "Required Coursework" or "Elective Coursework", as defined below, may be used for the purposes of double counting at the discretion of the advisor (MS Non-Thesis) or thesis committee (MS Thesis or PhD). These courses must have been passed with a "B-" or better and meet all other University, Department, Division, and Program requirements for graduate credit.

MS and PhD

The minimum requirements for admission to the MS and PhD degrees in Robotics 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 prior to matriculating into the Robotics degree program.

• Students are expected to have completed the following coursework: (1) two semesters of calculus, (2) differential equations, and (3) data structures. The Robotics graduate admissions committee may require that students who do not meet this expectation demonstrate competency or take remedial coursework. Such coursework may not count toward the graduate degree. The committee will decide whether to recommend regular or provisional admission.

• Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with a computer science, engineering, or math degree from Mines within the past five years are not required to submit GRE scores.

• Applicants who are not US citizens or permanent residents and whose native language is not English, must prove English proficiency as part of the application process. Refer to the Graduate Admissions website for more details.

• For the PhD program, prior research experience is desired but not required.

Transfer Credit

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 home department head, as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the MS degree, no more than nine credits may transfer. For the PhD degree, up to 24 credit hours of courses may be transferred. In lieu of transfer credit for individual courses, students who enter the PhD 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 MS and PhD requirements, a maximum of nine (9.0) semester hours of department approved 400-level course work.

Advisor and Thesis Committees

Students must have an Advisor from the Robotics 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 Robotics faculty by rank is available in the faculty tab of the catalog.

The department of the Advisor is the student’s home department.

Master of Science (Thesis option) students in Robotics must have at least three members on their Thesis Committee. In addition to the institutional requirements, at least one Committee member who is not the advisor must be Robotics faculty.

Robotics PhD Thesis Committees must have at least four members. In addition to the institutional requirements, at least one Committee member who is not the advisor must be Robotics faculty.

Program Requirements

Graduate Certificate

The Graduate Certificate will require 12 credit hours of coursework. The table below summarizes the requirements for the Graduate Certificate. Please note: only 3 of the 12 credit hours can be at the 400-level to achieve the Graduate Certificate.

<table>
<thead>
<tr>
<th>Course Type</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics Core</td>
<td>Four courses, one from each focus area's core course list</td>
</tr>
<tr>
<td>Total Semester Hrs</td>
<td>12.0</td>
</tr>
</tbody>
</table>

MS Degrees

The MS degrees will require 30 credit hours, with thesis research options substituting for electives.

MS Non-Thesis (MS-NT)

Students must take 30 credit hours of coursework to complete the degree. The table below summarizes the requirements for the MS-NT degree.

<table>
<thead>
<tr>
<th>Course Type</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics Core (Breadth)</td>
<td>Four courses, one from each focus area's core course list</td>
</tr>
<tr>
<td>Robotics Electives (Depth)</td>
<td>Two courses from robotics course list</td>
</tr>
<tr>
<td>Technical Electives</td>
<td>Four courses in any participating robotics department (CSCI, EDNS, EENG, MEGN)</td>
</tr>
<tr>
<td>Total Semester Hrs</td>
<td>30.0</td>
</tr>
</tbody>
</table>

MS Thesis

Students must take 21 credit hours of coursework and 9 credit hours of MS thesis research to complete the degree. The table below summarizes the requirements for the MS Thesis degree.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Robotics Core (Breadth)</td>
<td>Four courses, one from each focus area's core course list</td>
</tr>
<tr>
<td>Robotics Electives (Depth)</td>
<td>Two courses from robotics course list</td>
</tr>
<tr>
<td>Technical Electives</td>
<td>One course in any participating robotics department (CSCI, EDNS, EENG, MEGN)</td>
</tr>
<tr>
<td>Total Semester Hrs</td>
<td>30.0</td>
</tr>
</tbody>
</table>

PhD Degree

The Robotics PhD requires 36 credit hours of coursework, plus 36 research credit hours. The table below summarizes the coursework requirements. PhD students must additionally complete a qualifying examination, a thesis proposal, and a thesis defense.

<table>
<thead>
<tr>
<th>Course Type</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics Core (Breadth)</td>
<td>Four courses, one from each focus area's core course list</td>
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<tr>
<td>Robotics Electives (Depth)</td>
<td>Four Courses from robotics course list</td>
</tr>
<tr>
<td>Technical Electives</td>
<td>Four courses in any participating robotics department (CSCI, EDNS, EENG, MEGN)</td>
</tr>
<tr>
<td>MEGN707</td>
<td>GRADUATE THESIS / DISSERTATION RESEARCH CREDIT</td>
</tr>
<tr>
<td>Total Semester Hrs</td>
<td>72.0</td>
</tr>
</tbody>
</table>

Robotics PhD Qualifying Examination

The Robotics PhD Qualifying Examination will test a student’s ability to conduct research in their chosen area. The qualifier will have two components: a coursework component and a research component.

Coursework Qualifier: To satisfy the coursework component of the qualifier, the student must complete their four selected Robotics Core courses with a minimum grade of “B” in each class.

Research Qualifier: The research qualifier consists of a research project. Robotics PhD students must take the qualifying examination by the end of their fourth semester (typically by the end of their second year). The examination will be evaluated by a committee consisting of at least the student’s advisor, a Robotics-affiliated faculty member, and one additional faculty member.

For the qualifier, the student will conduct a literature review of 30-40 papers and perform a research project approaching the level necessary for a conference publication. The research project must be approved by the advisor and committee and will likely be some combination of the following:

- Design, analyze and/or simulate a novel robot system;
- Design and evaluate new algorithms or systems for an important research problem;
- Develop a new research software system;
- Solve a set of theoretical problems.

The deliverables will be a literature review (3-4 pages, IEEE style [4]), a research report (4-5 pages, IEEE style), and a research presentation (30 minutes to present, plus questions) delivered to the committee.

At the conclusion of the qualifier presentation, each committee member will vote their evaluation as one of “Strong Support”, “Weak Support”, or “Do not support.” The student must receive at least two “Strong Support” votes to pass. In the case the student does not pass, the committee may decide to offer a “conditional pass” based on extra conditions, such as revisions to the report or additional
experiments, the student must perform to pass the qualifier. The committee will set an explicit deadline for student to complete the extra conditions. If the student does not meet the extra conditions as determined by the committee by the deadline, the “conditional pass” becomes a “fail.” If the student does not pass the qualifier on their first attempt (inclusive of a conditional pass), they may make one additional attempt to pass; the same conditional pass procedure may also be applied to the second attempt. A student who fails the qualifier on the second attempt may not continue in the program.

Robotics PhD Proposal and Defense

After passing the qualifying examination, the student must prepare a written thesis proposal and present it formally to the student’s Thesis Committee and other interested faculty. Typically, the proposal will take place within 24 months of the student completing the qualifier.

The committee for the thesis proposal and defense will follow institutional requirements. Additionally, at least one committee member who is not the advisor must be robotics-affiliated faculty.

At the conclusion of the student’s PhD program, the student must make a formal presentation and defense of their thesis research. A student must “pass” this defense to earn a PhD degree. Typically, the defense will take place within 24 months of the student completing the thesis proposal.

Robotics Course List

The Robotics courses are divided into four focus areas. Each focus area is comprised of core courses and electives, as detailed below. Beyond the courses in these four focus areas, there is also a list of additional Robotics electives.

For the Graduate Certificate only 3 credit hours may be from a 400 level course. For the MS and PhD degrees, only 9 credit hours may be from 400 level courses.

Perception

Core Courses

CSCI507  INTRODUCTION TO COMPUTER VISION  3.0
CSCI573  HUMAN-CENTERED ROBOTICS  3.0
EENG519  ESTIMATION THEORY AND KALMAN FILTERING  3.0

Elective Courses

CSCI508  ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION  3.0

Cognition

Core Courses

CSCI404  ARTIFICIAL INTELLIGENCE  3.0
CSCI575  ADVANCED MACHINE LEARNING  3.0
CSCI534  ROBOT PLANNING AND MANIPULATION  3.0

Elective Courses - None.

Action

Core Courses

MEGN540  MECHATRONICS  3.0
MEGN544  ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL  3.0
MEGN545  ADVANCED ROBOT CONTROL  3.0
EENG517  THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS  3.0

Elective Courses

EENG417  MODERN CONTROL DESIGN  3.0
EENG515  MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS  3.0

Interaction & Society

Core Courses

CSCI5XX  HUMAN-ROBOT INTERACTION  3.0
CSCI532  ROBOT ETHICS  3.0

Elective Courses

CSCI5XX  LINGUISTIC HUMAN-ROBOT INTERACTION  3.0

Additional Robotics Electives

CSCI406  ALGORITHMS  3.0
CSCI561  THEORY OF COMPUTATION  3.0
CSCI562  APPLIED ALGORITHMS AND DATA STRUCTURES  3.0
CSCI565  DISTRIBUTED SYSTEMS  3.0
CSCI572  COMPUTER NETWORKS II  3.0
EENG411  DIGITAL SIGNAL PROCESSING  3.0
EENG511  CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS  3.0
EENG521  NUMERICAL OPTIMIZATION  3.0
MEGN586  LINEAR OPTIMIZATION  3.0
MEGN587  NONLINEAR OPTIMIZATION  3.0
MEGN588  INTEGER OPTIMIZATION  3.0
MEGN686  ADVANCED LINEAR OPTIMIZATION  3.0
MEGN688  ADVANCED INTEGER OPTIMIZATION  3.0