Additional Majors and Minors in SCS

To see information for the additional major and minor in Computer Science, see the main School of Computer Science section.

Computational Biology Minor

Director: Dr. Ziv Bar-Joseph
Advisor: Phillip Compeau
Admin Coordinator: Nicole Stenger

The computational biology minor is open to students in any major of any college at Carnegie Mellon. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in biological sciences that are central to computational biology.

Why Minor in Computational Biology?

Computational Biology is concerned with solving biological and biomedical problems using mathematical and computational methods. It is recognized as an essential element in modern biological and biomedical research. There have been fundamental changes in biology and medicine over the past two decades due to spectacular advances in high throughput data collection for genomics, proteomics and biomedical imaging. The resulting availability of unprecedented amounts of biological data demands the application of advanced computational tools to build integrated models of biological systems, and to use them to devise methods of prevent or treat disease. Computational Biologists inhabit and expand the interface of computation and biology, making them integral to the future of biology and medicine.

A minor in Computational Biology will position students well for entering the job market and graduate school in this exciting and growing field.

Admission

Students must apply for admission no later than November 30 of their senior years; an admission decision will usually be made within one month. Students are encouraged to apply as early as possible in their senior years; an admission decision will usually be made within one month. Students are encouraged to apply as early as possible in their senior years. To apply, send email to Dr. Ziv Bar-Joseph and Dr. Phillip Compeau. Include in your email:

• Full name
• Andrew ID
• Preferred email address (if different)
• Your class and College/School at Carnegie Mellon
• Semester you intend to graduate
• All (currently) declared majors and minors
• Statement of purpose (maximum 1 page) — Describes why you want to take this minor and how it fits into your career goals
• Proposed schedule of courses for the minor (this is your plan, NOT a commitment)

Curriculum

The minor in computational biology requires a total of five courses: 3 core courses, 1 biology elective, and 1 computer science elective, for a total of at least 45 units.

### Prerequisites

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>03-121</td>
<td>Modern Biology</td>
</tr>
<tr>
<td>15-122</td>
<td>Principles of Imperative Computation</td>
</tr>
</tbody>
</table>

### Core Classes

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-250</td>
<td>Introduction to Computational Biology</td>
</tr>
<tr>
<td>02-261</td>
<td>Quantitative Cell and Molecular Biology Laboratory (03-116 Phage Genomics Research or 03-343 Experimental Techniques in Molecular Biology may be substituted for 02-261 with permission of the minor advisor)</td>
</tr>
</tbody>
</table>

plus one of the following courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-510</td>
<td>Computational Genomics</td>
</tr>
<tr>
<td>02-512</td>
<td>Computational Methods for Biological Modeling and Simulation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-530</td>
<td>Cell and Systems Modeling</td>
</tr>
<tr>
<td>03-231</td>
<td>Biochemistry I</td>
</tr>
<tr>
<td>03-320</td>
<td>Cell Biology</td>
</tr>
<tr>
<td>03-327</td>
<td>Phylogenetics</td>
</tr>
<tr>
<td>03-330</td>
<td>Genetics</td>
</tr>
<tr>
<td>03-362</td>
<td>Cellular Neuroscience</td>
</tr>
<tr>
<td>03-363</td>
<td>Systems Neuroscience</td>
</tr>
<tr>
<td>03-364</td>
<td>Developmental Neuroscience</td>
</tr>
<tr>
<td>03-439</td>
<td>Introduction to Biophysics</td>
</tr>
<tr>
<td>03-442</td>
<td>Molecular Biology</td>
</tr>
<tr>
<td>03-534</td>
<td>Biological Imaging and Fluorescence Spectroscopy</td>
</tr>
<tr>
<td>42-202</td>
<td>Physiology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-422</td>
<td>Advanced Algorithms for Computational Structural Biology</td>
</tr>
<tr>
<td>02-450</td>
<td>Automation of Biological Research</td>
</tr>
<tr>
<td>02-500</td>
<td>Undergraduate Research in Computational Biology</td>
</tr>
<tr>
<td>02-510</td>
<td>Computational Genomics</td>
</tr>
<tr>
<td>02-512</td>
<td>Computational Methods for Biological Modeling and Simulation</td>
</tr>
<tr>
<td>02-530</td>
<td>Cell and Systems Modeling</td>
</tr>
<tr>
<td>02-740</td>
<td>Bioimage Informatics</td>
</tr>
<tr>
<td>09-560</td>
<td>Computational Chemistry</td>
</tr>
<tr>
<td>10-601</td>
<td>Introduction to Machine Learning (Masters)</td>
</tr>
<tr>
<td>15-381</td>
<td>Artificial Intelligence: Representation and Problem Solving</td>
</tr>
<tr>
<td>15-386</td>
<td>Neural Computation</td>
</tr>
<tr>
<td>15-415</td>
<td>Database Applications</td>
</tr>
<tr>
<td>16-720</td>
<td>Computer Vision</td>
</tr>
</tbody>
</table>

A number of graduate courses in CS and Robotics may be taken in consultation with the minor advisor.

Note: No more than two courses may be double counted with your major’s core requirements. Courses in the minor may not be counted towards another SCS minor. Consult the advisor for the minor for more information.

Human-Computer Interaction Additional Major

The undergraduate major in HCI is available only as an additional major. If you have questions, please contact the Academic Program Manager at hciibachelors@cs.cmu.edu.

Human-Computer Interaction (HCI) is devoted to the design, implementation, and evaluation of interactive computer-based technology. Examples of HCI products include intelligent computer tutors, wearable computers, and highly interactive web sites. Constructing an HCI product is a cyclic, iterative process that involves at least three stages.

Human-Computer Interaction Minor

The Minor in Human-Computer Interaction will give students core knowledge about techniques for building successful user interfaces, approaches for conceiving, refining, and evaluating interfaces that are useful and useable, and techniques for identifying opportunities for computational technology to improve the quality of people’s lives. The students will be able to effectively collaborate in the design, implementation, and evaluation of easy-to-use, desirable, and thoughtful interactive systems. They will be prepared to contribute to multidisciplinary teams that create new interactive products, services, environments, and systems.

The key concepts, skills and methods that students will learn in the HCI Minor include:

• Fieldwork for understanding people's needs and the influence of context
• Generative approaches to imagining many possible solutions such as sketching and “bodystorming”
• Iterative refinement of designs
• Basic visual design including typography, grids, color, and the use of images
• Implementation of interactive prototypes
• Evaluation techniques including discount and empirical evaluation methods

The HCI minor is targeted at undergraduates who expect to get jobs where they design and/or implement information technology-based systems for end users, and well as students with an interest in learning more about the design of socio-technical systems. It is appropriate for students with majors in Computer Science and Information Systems, as well as students in less software-focused majors, including Design, Architecture, Art, Business Administration, Psychology, Statistics, Decision Science, Mechanical Engineering, Electrical Engineering, English and many others in the university.

Curriculum

The only prerequisite for this Minor is an introductory-level college programming course (such as 15-110, 15-112, 15-121, or 51-257) and to be in good standing with the University.

In addition to the programming prerequisite, the Minor has required two courses—05-391 Designing Human Centered Software (DHCS) and 05-392 Interaction Design Overview (IxDO)—and four electives. The student will be required to get a grade of “C” or better in each course in order for it to count as part of the Minor. There is no final project or research required for the Minor.

Required Courses

• 05-391 Designing Human Centered Software (DHCS)\(^1\): This course provides an overview of the most important methods taught in the Additional Major in HCI, such as Contextual Inquiry, Prototyping and Iterative Design, Heuristic Evaluation, and Think Aloud User Studies. It covers in a more abbreviated form the content of 05-410 User-Centered Research and Evaluation, 05-430 Programming Usable Interfaces, and 05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces.

• 05-392 (IxDO)\(^2\): This is a design course that will combine material from 05-651 and 05-650 for students who do not have any previous experience with design, in a form that will fit appropriately in to a one-semester format.

Electives

The HCI minor requires four electives approved by the undergraduate director.

Double Counting

Students may double count up to two (2) of the required courses or electives with their primary major.

Relationship between the BHCI Major and Minor

Admission

• BHCI Major: Application and admissions required, information on the HCII website (http://www.hcii.cmu.edu/academics/hci-undergraduate/major).

• BHCI Minor: Admissions form available at the HCII website(http://www.hcii.cmu.edu/academics/hci-undergraduate/minor).

Prerequisites

• BHCI Major:  
  • Freshman-level programming (51-257 or 15-110 or 15-112 or 15-121).
  • Statistics (Introductory)
  • Cognitive Psychology
  • Interaction Design Fundamentals or Communication Design Fundamentals

• BHCI Minor:  
  • Freshman-level programming (51-257 or 15-110 or 15-112 or 15-121).

Core Courses

• BHCI Major:  
  • Interaction Design Studio I & II (IxDS)
  • User Centered Research & Evaluation (UCRE)
  • HCI Programming (PUISUI) and Lab

• BHCI Minor:  
  • Interaction Design Overview (IxDO)
  • Designing Human Centered Systems (DHCS)

Electives

• BHCI Major: Four (4) electives

• BHCI Minor: Four (4) electives

Footnotes

\(^1\) Alternatively, a student can take both the BS/HCIC empirical methods course (05-410) and the BS/HCIC core-programming course (either 05-430 Programming Usable Interfaces or 05-431 Software Structures for User Interfaces, along with its associated 05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces). If students take this course sequence, they would get credit for fulfilling this requirement plus one elective.

\(^2\) Alternatively, a student can fulfill the design requirement by taking 05-650 and 05-651. If students take this course sequence, they would get credit for fulfilling this requirement plus one elective.

These alternative ways of fulfilling the requirements for the HCI minor are designed for students who are in the HCI 2nd major who want to “downgrade” to the minor. These students can use some the courses completed for the HCI 2nd major as a way of fulfilling the requirements for the minor.

Students who are in the HCI minor right from the start are strongly encouraged to follow the regular requirements outlined above and are strongly discouraged from trying these alternative ways of fulfilling the requirements. It can be extremely difficult to get into any of the alternative courses. This is true especially for 05-650, but for other courses as well. The fact that a student in the minor has already taken 05-651 will not give priority for getting into Studio.

IDeATe Minors

Advisor: Kelly Delaney
E-mail: kellydel@andrew.cmu.edu
Website: http://ideate.cmu.edu

The Integrative Design, Arts and Technology (IDeATe) network offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students engage in active “learning by doing” in state-of-the-art maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of eight interrelated concentration areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and the arts. Four of these minors are based in the School of Computer Science:

Animation & Special effects minor

Explore the technical and artistic aspects of 3D and 2D animation in an integrated manner and within different application contexts, from film animation and special effects to interactive displays. Students interested in declaring the minor should meet with the IDeATe advisor to discuss curriculum and to make a loose plan of study.

Additional Majors and Minors in SCS

• 05-392 (IxDO)
• 05-391 Designing Human Centered Software (DHCS)
Design effective new media systems for learning using new technologies, learning science principles and media arts knowledge. Produce engaging experiences from games to tangible learning tool kits and remote systems.

Intelligent Environments Minor

Develop spaces and devices that support efficiency and high quality of experience, in contexts like daily activity, built environment, making process (from laying plaster to robot development), and arts performance.

Physics computing minor

Build interfaces and circuitry to embed in physical contexts, such as mobile environments and new creative practice instruments.

Learning Media minor

Design effective new media systems for learning using new technologies, learning science principles and media arts knowledge. Produce engaging and effective experiences from games to tangible learning tool kits and remote systems.
Language Technologies Minor

Chair: Alan W. Black
E-mail: awb@cs.cmu.edu
Website: http://www.lti.cs.cmu.edu/learn

Human language technologies have become an increasingly central component of Computer Science in the last decade. Information retrieval, machine translation and speech technology are used daily by the general public, while text mining, natural language processing, and language-based tutoring are used regularly within more specialized professional or educational environments. The Language Technologies Minor allows students to learn about language technologies and apply them through a directed project.

Prerequisites

<table>
<thead>
<tr>
<th>Core Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-721 Grammars and Lexicons</td>
<td>12</td>
</tr>
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Electives (choose 3)

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-411 Natural Language Processing</td>
<td>12</td>
</tr>
<tr>
<td>11-441 Machine Learning for Text Mining</td>
<td>9</td>
</tr>
<tr>
<td>11-492 Speech Processing</td>
<td>12</td>
</tr>
<tr>
<td>11-711 Algorithms for NLP</td>
<td>12</td>
</tr>
<tr>
<td>11-741 Machine Learning for Text Mining</td>
<td>12</td>
</tr>
<tr>
<td>11-751 Speech Recognition and Understanding</td>
<td>12</td>
</tr>
<tr>
<td>11-752 Speech II: Phonetics, Prosody, Perception and Synthesis</td>
<td>12</td>
</tr>
<tr>
<td>11-761 Language and Statistics</td>
<td>12</td>
</tr>
<tr>
<td>80-180 Nature of Language</td>
<td>9</td>
</tr>
<tr>
<td>80-280 Linguistic Analysis</td>
<td>9</td>
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Additional Majors and Minors in SCS

Mathematical Statistics (Honors)

<table>
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<tr>
<th>Course</th>
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<tbody>
<tr>
<td>9-381 Probability</td>
<td>9</td>
</tr>
<tr>
<td>9-382 Statistical Inference</td>
<td>9</td>
</tr>
<tr>
<td>9-383 Computational Statistics</td>
<td>9</td>
</tr>
<tr>
<td>9-385 Computational Data Analysis</td>
<td>9</td>
</tr>
</tbody>
</table>

Electives

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>86-375 Statistical Graphics and Visualization</td>
<td>9</td>
</tr>
<tr>
<td>36-402 Advanced Methods for Data Analysis</td>
<td>9</td>
</tr>
<tr>
<td>36-462 Special Topics: Data Mining</td>
<td>9</td>
</tr>
<tr>
<td>36-463 Special Topics: Multilevel and Hierarchical Models</td>
<td>9</td>
</tr>
<tr>
<td>36-464 Special Topics: Applied Multivariate Methods</td>
<td>9</td>
</tr>
</tbody>
</table>

The Minor in Neural Computation

Director: Dr. Tai Sing Lee
Administrative Coordinator: Melissa Stupka
Website: http://www.cnbc.cmu.edu/upnc/nc_minor/

The minor in Neural Computation is an inter college minor jointly sponsored by the School of Computer Science, the Mellon College of Science, and the Dietrich College of Humanities and Social Sciences, and is coordinated by the Center for the Neural Basis of Cognition (CNBC) (http://www.cnbc.cmu.edu).

The Neural Computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, Dietrich College and MCS. The primary objective of the minor is to encourage students in biology and psychology to take computer science, engineering and mathematics courses, to encourage students in computer science, engineering, statistics and physics to take courses in neuroscience and psychology, and to bring students from different disciplines together to form a community. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in cognitive science and neuroscience that are central to computational neuroscience.

Curriculum

A. Neural Computation

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-386 Neural Computation</td>
<td>9</td>
</tr>
<tr>
<td>15-387 Computational Perception</td>
<td>9</td>
</tr>
<tr>
<td>15-883 Computational Models of Neural Systems</td>
<td>12</td>
</tr>
<tr>
<td>85-419 Introduction to Parallel Distributed Processing</td>
<td>9</td>
</tr>
<tr>
<td>86-375 Computational Perception</td>
<td>9</td>
</tr>
<tr>
<td>Pitt-Mathematics-1800 Introduction to Mathematical Neuroscience</td>
<td>9</td>
</tr>
</tbody>
</table>
B. Neuroscience

03-362 Cellular Neuroscience  9
03-363 Systems Neuroscience  9
03-365 Neural Correlates of Learning and Memory  9
42-630 Introduction to Neuroscience for Engineers  12
(crosslisted with 18-690)
85-765 Cognitive Neuroscience  Var.
Pitt-Neuroscience 1000 Introduction to Neuroscience  9
Pitt-Neuroscience 1012 Neurophysiology  9

C. Cognitive Psychology

85-211 Cognitive Psychology  9
85-213 Human Information Processing and Artifical Intelligence  9
85-412 Cognitive Modeling  9
85-414 Cognitive Neuropsychology  9
85-419 Introduction to Parallel Distributed Processing  9
85-426 Learning in Humans and Machines  9
85-765 Cognitive Neuroscience  Var.

D. Intelligent System Analysis

10-601 Introduction to Machine Learning (Masters)  12
15-381 Artificial Intelligence: Representation and Problem Solving  9
15-386 Neural Computation  9
15-387 Computational Perception  9
15-494 Cognitive Robotics: The Future of Robot Toys  12
16-299 Introduction to Feedback Control Systems  12
16-311 Introduction to Robotics  12
16-385 Computer Vision  9
18-290 Signals and Systems  12
24-352 Dynamic Systems and Controls  12
36-225 Introduction to Probability Theory  9
36-247 Statistics for Lab Sciences  9
36-401 Modern Regression  9
36-410 Introduction to Probability Modeling  9
42-631 Neural Data Analysis  9
42-632 Neural Signal Processing  12
86-375 Computational Perception  9
86-631 Neural Data Analysis  9

Prerequisites

The required courses in the above four core areas require a number of basic prerequisites: basic programming skills at the level of 15-110 Principles of Computing and basic mathematical skills at the level of 21-122 Integration and Approximation or their equivalents. Some courses in Area D require additional prerequisites. Area B Biology courses require, at minimum, 03-121 Modern Biology. Students might skip the prerequisites if they have the permission of the instructor to take the required courses. Prerequisite courses are typically taken to satisfy the students' major or other requirements. In the event that these basic skill courses are not part of the prerequisite or required courses of a student's major, one of them can potentially count toward the five required courses (e.g. the depth elective), conditional on approval by the director of the minor program.

Research Requirements (Optional)

The minor itself does not require a research project. The student however may replace the depth elective with a year-long research project. In special circumstances, a research project can also be used to replace one of the five courses, as long as (1) the project is not required by the student's major or other minor, (2) the student has taken a course in each of the four core areas (not necessarily for the purpose of satisfying this minor's requirements), and (3) has taken at least three courses in this curriculum not counted toward the student's major or other minors. Students interested in participating in the research project should contact any faculty engaged in computational neuroscience or neural computation research at Carnegie Mellon or in the University of Pittsburgh. A useful webpage that provides listing of faculty in neural computation is http://www.cnbc.cmu.edu/computational-neuroscience. The director of the minor program will be happy to discuss with students about their research interest and direct them to the appropriate faculty.

Fellowship Opportunities

The Program in Neural Computation (PNC) administered by the Center for the Neural Basis of Cognition currently provides 3-4 competitive full-year fellowships ($11,000) to Carnegie Mellon undergraduate students to carry out mentored research in neural computation. The fellowship has course requirements similar to the requirements of the minor. Students do not apply to the fellowship program directly. They have to be nominated by the faculty members who are willing to mentor them. Therefore, students interested in the full-year fellowship program should contact and discuss research opportunities with any CNBC faculty at Carnegie Mellon or University of Pittsburgh working in the area of neural computation or computational neuroscience and ask for their nomination by sending email to Dr. Tai Sing Lee, who also administers the undergraduate fellowship program at Carnegie Mellon. See http://www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/ for details.

The Program in Neural Computation also offers a summer training program for undergraduate students from any U.S. undergraduate college. The students will engage in a 10-week intense mentored research and attend a series of lectures in neural computation. See http://www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/ for application information.

Robotics Additional Major

Director: Dr. Howie Choset
Administrative Coordinator: Barbara (B.J.) Fecich
Website: http://addlmajor.ri.cmu.edu/

The Additional Major in Robotics focuses on the theme that robotics is both multidisciplinary and interdisciplinary. This means that it draws from many fields, such as mechanical engineering, computer science and electrical engineering, and it also integrates these fields in a novel manner. The foundation of this program lies in motion and control. Upon this base, sensing, cognition, and action are layered. Since robotics involves building artifacts that embody these fundamentals, foci, and systems thinking, there is a "hands-on" course requirement. These foci are brought together by a unique systems perspective special to robotics. Students will complete a capstone course that will tie together previously learned skills and knowledge.

Admission

The Additional Major in Robotics is available to all Carnegie Mellon undergraduate students. Students should apply for the Robotics Additional Major their freshman year. Students in their sophomore year may apply, provided they meet the requirements and their schedule can accommodate the courses. The application is due early February and decisions on admittance to the Additional Major will be emailed to students in time for Fall registration. Application materials include:

- Full name and email address
- Home college, expected graduation date, and list of all declared Majors and Minors
- Statement of purpose (maximum 1 page, single spaced, to articulate why the student wants to pursue the Robotics Additional Major)
- Proposed schedule of required courses
- Unofficial Transcript (can be downloaded from SIO)

Curriculum

Prerequisites

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-259</td>
<td>Calculus in Three Dimensions</td>
<td>9</td>
</tr>
<tr>
<td>18-202</td>
<td>Mathematical Foundations of Electrical Engineering</td>
<td>12</td>
</tr>
<tr>
<td>21-240</td>
<td>Matrix Algebra with Applications</td>
<td>10</td>
</tr>
<tr>
<td>21-241</td>
<td>Matrices and Linear Transformations</td>
<td>9</td>
</tr>
<tr>
<td>21-260</td>
<td>Differential Equations</td>
<td>9</td>
</tr>
<tr>
<td>24-311</td>
<td>Numerical Methods</td>
<td>12</td>
</tr>
<tr>
<td>15-122</td>
<td>Principles of Imperative Computation or knowledge and experience programming in C</td>
<td>10</td>
</tr>
</tbody>
</table>

Carnegie Mellon University
Required Courses

Choose 10 courses total (one from each category plus two electives):

<table>
<thead>
<tr>
<th>Overview</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-311</td>
<td>12</td>
</tr>
</tbody>
</table>

**Required Courses**
- 06-464 Chemical Engineering Process Control 9
- 16-362 Mobile Robot Programming Laboratory 12
- 16-370 Fundamentals of Control 12
- 18-451 Feedback Control Systems 12
- 18-369 Upper-level RI course with instructor and Program Director's permission 9-12

**Kinematics**
- 16-384 Robot Kinematics and Dynamics 12
- 16-355 Kinematics and Dynamics of Mechanisms (not offered regularly) 9
- 16-xxx Upper-level RI course with instructor and Program Director's permission 9-12

**Machine Perception**
- 15-463 Computational Photography 12
- 15-385 Computer Vision 9
- 16-421 Vision Sensors 12
- 85-370 Perception 9
- 16-xxx Upper-level RI course with instructor and Program Director's permission 9-12

**Cognition and Reasoning**
- 10-601 Introduction to Machine Learning (Masters) 12
- 11-345 Machine Learning in Practice 12
- 15-381 Artificial Intelligence: Representation and Problem Solving 9
- 15-494 Cognitive Robotics: The Future of Robot Toys 12
- 16-xxx Upper-level RI course with instructor and Program Director's permission 9-12

*“Hands-on Course”*
- 16-362 Mobile Robot Programming Laboratory 12
- 18-578 Mechatronic Design 12
- 16-xxx Upper-level RI project course e.g., 16-861 or 16-865 or independent study with instructor and Program Director's permission 9-12

**Systems Engineering**
- 16-450 Robotics Systems Engineering 12

**Capstone Course**
- 16-474 Robotics Capstone 12

**Required Electives (choose two)**
- 10-601 Introduction to Machine Learning (Masters) 12
- 11-345 Machine Learning in Practice 12
- 15-381 Artificial Intelligence: Representation and Problem Solving 9
- 15-424 Foundations of Cyber-Physical Systems 12
- 15-463 Computational Photography 12
- 15-494 Cognitive Robotics: The Future of Robot Toys 12
- 16-264 Humanoids 12
- 16-362 Mobile Robot Programming Laboratory 12
- 16-385 Computer Vision 9
- 16-421 Vision Sensors 12
- 16-423 Designing Computer Vision Apps 12
- 16-597 Undergraduate Reading and Research Var.
- 18-348 Embedded Systems Engineering 12
- 18-349 Introduction to Embedded Systems 12
- 18-549 Embedded Systems Design 12

**Required Courses**
- 18-578 Mechatronic Design 12
- 85-370 Perception 9
- 85-395 Applications of Cognitive Science 9
- 85-412 Cognitive Modeling 9
- 85-419 Introduction to Parallel Distributed Processing 9
- 85-426 Learning in Humans and Machines 9

Students may count up to 12 units of 16-597 Undergraduate Reading and Research towards the degree requirements. A student can also take additional courses from the core; e.g., a student who takes 16-385 as a core can take 16-421 as an elective.

Graduate level Robotics courses may be used to meet elective requirement with permission from the Program Director. Graduate level Mechanical Engineering and Electrical and Computer Engineering courses that are relevant to robotics may be used to meet the elective requirement with permission from the Program Director.

A 3.0 GPA in the Additional Major curriculum is required for graduation. Courses that are taken Pass/Fail or audited cannot be counted for the Additional Major.

**Double-Counting Restriction**

Students are permitted to double count a maximum of six courses from their Primary Major towards the Additional Major in Robotics. CS Majors are permitted to double count a maximum of five courses from their Primary Major towards the Additional Major in Robotics.

**Robotics Minor**

Director: Dr. Howie Choset
Administrative Coordinator: Barbara (B.J.) Fecich
Website: http://www.ri.cmu.edu/education/ugrad_minor.html

The Minor in Robotics provides an opportunity for undergraduate students at Carnegie Mellon to learn the principles and practices of robotics through theoretical studies and hands-on experience with robots. The Minor is open to students in any major of any college at Carnegie Mellon. Students initially learn the basics of robotics in an introductory robotics overview course. Additional required courses teach control systems and robotic manipulation. Students also choose from a wide selection of electives in robotics, perception, computer vision, cognition and cognitive science, or computer graphics. Students have a unique opportunity to undertake independent research projects, working under the guidance of Robotics Institute faculty members; this provides an excellent introduction to robotics research for those considering graduate studies.

All Robotics Minors are required to take Introduction to Robotics (16-311). This course is designed to help students understand the big picture of what is going on in robotics through topics such as kinematics, mechanisms, motion planning, sensor-based planning, mobile robotics, sensors, and vision. The minor also requires students to take a controls class and a kinematics class. These courses provide students with the necessary intuition and technical background to move on to more advanced robotics courses. In addition to the required courses, students must take 2 electives. The student must have course selection approved by the Director during the application submission process.

A 2.5 GPA in the Minor curriculum is required for graduation. Courses that are taken Pass/Fail or audited cannot be counted for the Minor.

**Admission**

Admission to the Undergraduate Minor in Robotics is limited to current Carnegie Mellon students. Students interested in signing up for the minor should fill out the application form (https://www Preview.ri.cmu.edu/education/apply/ugrad_appform.html).

**Prerequisite**

Successful candidates for the Robotics Minor will have prerequisite knowledge of C language, basic programming skills, and familiarity with basic algorithms. Students can gain this knowledge by taking 15-122 Principles of Imperative Computation.

**Required Courses**

<table>
<thead>
<tr>
<th>Overview</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-311</td>
<td>12</td>
</tr>
</tbody>
</table>

**Controls (choose one of the following):**
- 06-464 Chemical Engineering Process Control 9
- 24-451 Feedback Control Systems 12
- 18-370 Fundamentals of Control 12
16-299 Introduction to Feedback Control Systems 12
16-xxx Upper-level RI course with instructor and Program Director's permission

Kinematics (choose one of the following):
16-384 Robot Kinematics and Dynamics 12
24-355 Kinematics and Dynamics of Mechanisms 9
16-xxx Upper-level RI course with instructor and Program Director's permission

Electives
Two Electives (chosen from the following): Units
10-601 Introduction to Machine Learning (Masters) 12
11-344 Machine Learning in Practice 12
15-381 Artificial Intelligence: Representation and Problem Solving 9
15-424 Foundations of Cyber-Physical Systems 12
15-462 Computer Graphics 12
15-463 Computational Photography 12
15-494 Cognitive Robotics: The Future of Robot Toys 12
16-264 Humanoïds 12
16-362 Mobile Robot Programming Laboratory 12
16-385 Computer Vision 9
16-421 Vision Sensors 12
16-423 Designing Computer Vision Apps 12
16-597 Undergraduate Reading and Research Var.
18-342 Fundamentals of Embedded Systems 12
18-348 Embedded Systems Engineering 12
18-349 Introduction to Embedded Systems 12
18-549 Embedded Systems Design 12
18-578 Mechatronic Design 12
85-370 Perception 9
85-395 Applications of Cognitive Science 9
85-412 Cognitive Modeling 9
85-419 Introduction to Parallel Distributed Processing 9
85-426 Learning in Humans and Machines 9

Graduate level Robotics courses may be used to meet the elective requirement with permission from the Program Director. Graduate level Mechanical Engineering and Electrical and Computer Engineering courses that are relevant to robotics may be used to meet the elective requirement with permission from the Program Director.

Students may count up to 12 units of 16-597 Undergraduate Reading and Research towards the degree requirements.

Double-Counting Restriction
Courses being used to satisfy the requirements for the Robotics Minor may not be counted towards another minor. Students are permitted to double count a maximum of two courses from their Major (excluding General Education requirements) towards the Minor in Robotics. Free electives are not subject to the double counting policy.

Software Engineering Minor
Director: Claire Le Goues (clelegoues@cs.cmu.edu)
Website: http://isri.cmu.edu/education/undergrad/

The Software Engineering minor is designed to teach the fundamental tools, techniques, and processes of software engineering. Through internships and a mentored project experience, students gain an understanding of the issues of scale and complexity that motivate software engineering tools and techniques. The core curriculum includes material both on engineering the software product and on the process, teamwork, and management skills that are essential to successful engineering. Graduates of the program should have the technical, process, and teamwork skills to be immediately productive in a mature engineering organization.

Admission
The Software Engineering Minor is open to undergraduate students in any major in the university. For priority consideration, applications are due 10 days before the beginning of Spring and Fall course registration. Students may petition the Director for admission outside this schedule.

To apply, send the directors an email. Include in your email:
• Full name
• Andrew ID
• Preferred email address (if different)
• Semester you intend to graduate
• GPA
• Statement of purpose (maximum 1 page) - Describes why you want to take this minor and how it fits into your career goals
• Proposed schedule of required courses and internship (this is your plan, NOT a commitment)

Prerequisite
Units

Core Course Requirements
Units
15-313 Foundations of Software Engineering 12
15-414 Software Engineering Practicum 12

Electives
The minor requires three elective courses, one selected from each of the following categories:

1. One domain-independent course focused on technical software engineering material:

Units
15-414 Bug Catching: Automated Program Verification and Testing 9
17-609 Global Software Development 9
17-615 Software Process Definition 9
17-619 Introduction to Real-Time Software and Systems 12
17-651 Models of Software Systems 12
17-652 Methods: Deciding What to Design 12
17-653 Managing Software Development (prereq: 15-413 or an internship) 12
17-654 Analysis of Software Artifacts 12
17-655 Architectures for Software Systems (prereq: 15-413 or an internship) 12
17-664 Enterprise Application Integration 12
17-690 Seminar in Software Process Var.
17-xxx Other Software Engineering graduate classes may be taken; get preapproval from the program director.

2. One engineering-focused course with a significant software component:

Units
15-410 Operating System Design and Implementation 15
15-412 Operating System Practicum Var.
15-437 Web Application Development 12
15-440 Distributed Systems 12
15-441 Computer Networks 12
15-610 Engineering Distributed Systems 12
17-643 Hardware for Software Engineers Var.
18-549 Embedded Systems Design 12
18-649 Distributed Embedded Systems 12

Other courses may be acceptable, with prior approval from the director of the minor.

3. One course that explores computer science problems related to existing and emerging technologies and their associated social, political, legal, business, and organizational contexts:

Units
08-200 Ethics and Policy Issues in Computing 9
08-532 Law of Computer Technology 9
08-533 Privacy, Policy, Law and Technology 9
08-781 Mobile and IoT Computing Services 9
08-801 Dynamic Network Analysis 12
08-810 Computational Modeling of Complex Socio-Technical Systems 12
15-390 Entrepreneurship for Computer Science 9
15-421 Information Security and Privacy 12
### Additional Majors and Minors in SCS

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-402</td>
<td>Telecommunications Technology, Policy &amp; Management</td>
<td>12</td>
</tr>
<tr>
<td>70-311</td>
<td>Organizational Behavior</td>
<td>9</td>
</tr>
<tr>
<td>70-414</td>
<td>Entrepreneurship for Engineers</td>
<td>9</td>
</tr>
<tr>
<td>70-421</td>
<td>Entrepreneurship for Computer Scientists</td>
<td>9</td>
</tr>
<tr>
<td>70-471</td>
<td>Supply Chain Management</td>
<td>9</td>
</tr>
<tr>
<td>88-260</td>
<td>Organizations</td>
<td>9</td>
</tr>
<tr>
<td>88-341</td>
<td>Organizational Communication</td>
<td>9</td>
</tr>
</tbody>
</table>

Other courses may be acceptable, with prior approval from the director of the minor.

### Required Internship and Reflection Course

A software engineering internship of a minimum of 8 full-time weeks in an industrial setting is required. The student must be integrated into a team and exposed to industry pressures. The intern may work in development, management, quality assurance, or other relevant positions. The director of the SE minor program has sole discretion in approving an internship experience based on these criteria. Students should confirm that an internship position is appropriate before accepting it, but internships that fulfill the criteria will also be accepted after the fact.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-413</td>
<td>Software Engineering Reflection</td>
<td>6</td>
</tr>
</tbody>
</table>

Each student will write an issue-focused reflection and analysis of some personal software engineering experience, typically (but not always) based on the engineering internship above. This report must be passed by one SCS faculty member and one SE Ph.D. student, for both technical content and effective written communication. Initial course meetings will cover the reflective, writing, and speaking process. In later meetings, each student will present his or her experience through a 30-45 minute talk, which will be evaluated for communication skills and critical reflective content. This course is limited to enrollment of 16, and students who are admitted to the minor program are given first priority.

### Double Counting Rule

At most 2 of the courses used to fulfill the minor requirements may be counted towards any other major or minor program. This rule does not apply to 15-214 (a prerequisite for the minor) or courses counted for general education requirements.