

Artificial Intelligence Program

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www.cs.cmu.edu/bs-in-artificial-intelligence (<http://www.cs.cmu.edu/bs-in-artificial-intelligence/>)

Overview

Carnegie Mellon University has led the world in artificial intelligence education and innovation since the field was created. It's only natural, then, that the School of Computer Science would offer the nation's first bachelor's degree in Artificial Intelligence, which started in Fall 2018.

The BSAI program gives students the in-depth knowledge needed to transform large amounts of data into actionable decisions. The program and its curriculum focus on how complex inputs — such as vision, language and huge databases — can be used to make decisions or enhance human capabilities. The curriculum includes coursework in computer science, math, statistics, computational modeling, machine learning and symbolic computation. Because Carnegie Mellon is devoted to AI for social good, students will also take courses in ethics and social responsibility, with the option to participate in independent study projects that change the world for the better — in areas like healthcare, transportation and education.

Just as AI unites disciplines from machine learning to natural language processing, instruction in the BSAI program includes faculty members from the school's Computer Science Department, Human-Computer Interaction Institute, Institute for Software Research, Language Technologies Institute, Machine Learning Department and Robotics Institute.

Students in the BSAI program within the School of Computer Science are expected to acquire the following skills upon graduation:

- Understand how to distill a real-world challenge as an artificial intelligence problem, involving explicit representation and learning of symbolic and numeric models; reasoning about such models; and using such models for decision making, action selection, and interaction with humans.
- Design, analyze, implement, and use state-of-the-art AI and machine learning techniques for dealing with real-world data, including data involving vision, language, perception, and uncertainty.
- Master the core concepts of computer science, with emphasis on data structures, programming, computing systems, and algorithm design, performance, and correctness across a variety of metrics (e.g., time, space, parallel vs. sequential implementation, what is computable).
- Master the fundamentals of discrete mathematics, logic, theorem proving and explanation, probability and statistics, and optimization.
- Describe, specify, and develop large-scale, open-ended artificial intelligence systems subject constraints such as performance, available data, and need for transparency. Communicate technical material effectively to technical and non-technical audiences.
- Work productively both individually and in teams.
- Recognize the social impact of artificial intelligence and the underlying responsibility to consider the ethical, privacy, moral, and legal implications of artificial intelligence technologies.

Students who graduate with a bachelors degree in AI, will have the computer science savvy and skills our students are known for, with the added expertise in machine learning and automated reasoning that you'll need to build the AI of tomorrow.

How to Apply

If you're applying to CMU, you need to be accepted into the School of Computer Science. Once you're at CMU and enrolled in SCS, you can declare a BSAI major in the spring of your first year or transfer into the program in your sophomore or junior year. If you are already at CMU but not in SCS, you can apply to transfer into the program after your sophomore year. Consult with the director or the program administrator of the BSAI program for information.

Curriculum

BSAI majors will take core courses in math and statistics, computer science, artificial intelligence and ethics, along with general education courses in science and engineering, and humanities and arts.

Math and Statistics

| All of the following: | | Units |
|--|---|-------|
| 15-151 | Mathematical Foundations for Computer Science (if not offered, substitute 21-127) | 12 |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-259 | Calculus in Three Dimensions or 21-266, or 21-268, or 21-269 | 10 |
| Probability and Statistics (one of the following options): | | |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| 15-259 | Probability and Computing | 12 |
| 21-325-36-226 | Probability - Introduction to Statistical Inference | 18 |
| 36-225-36-226 | Introduction to Probability Theory - Introduction to Statistical Inference | 18 |
| 36-235-36-236 | Probability and Statistical Inference I-II | 18 |
| plus Modern Regression: | | |
| 36-401 | Modern Regression | 9 |

Computer Science

| All of the following: | | Units |
|-----------------------|---|-------|
| 15-122 | Principles of Imperative Computation (students without credit or a waiver for 15-112, Fundamentals of Programming and Computer Science, must take 15-112 before 15-122) | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Artificial Intelligence

| All of the following AI core courses: | | Units |
|--|---|-------|
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| plus one of the following AI core courses: | | |
| 16-385 | Computer Vision | 12 |
| 11-411 | Natural Language Processing | 12 |
| One Decision Making and Robotics course (min. 9 units): | | Units |
| 15-386 | Neural Computation | 9 |
| 15-482 | Autonomous Agents | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-350 | Planning Techniques for Robotics | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |
| 16-384 | Robot Kinematics and Dynamics | 12 |
| others as designated by the AI Undergraduate Program | | |
| One Machine Learning course from the following (min. 9 units): | | |
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| 10-418 | Machine Learning for Structured Data | 12 |
| 10-422 | Foundations of Learning, Game Theory, and Their Connections | 12 |
| 10-423 | Generative AI | 12 |
| 10-425 | Introduction to Convex Optimization | 12 |
| 11-441 | Machine Learning with Graphs | 9 |
| 11-485 | Introduction to Deep Learning | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| others as designated by the AI Undergraduate Program | | |

One Perception and Language course from the following (min. 9 units):

| | | |
|--------|---|----|
| 11-442 | Search Engines | 9 |
| 11-492 | Speech Technology for Conversational AI | 12 |
| 15-387 | Computational Perception | 9 |
| 15-463 | Computational Photography | 12 |
| 16-421 | Vision Sensors | 12 |

others as designated by the AI Undergraduate Program

One Human-AI Interaction course from the following (min. 12 units):

| | | |
|--------|--|----|
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-318 | Human AI Interaction | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| 16-467 | Introduction to Human Robot Interaction | 12 |

others as designated by the AI Undergraduate Program

School of Computer Science Electives

Two general computer science electives: Units 18
 These electives can be from any SCS department (Computational Biology [02-], Human-Computer Interaction [05-], Interdisciplinary [07-], Machine Learning [10-], Language Technologies [11-], Computer Science [15-], Robotics [16-], or Software & Societal Systems [17-]). They must be 200-level or above and at least 9 units each, with the following exceptions: Students who take two of the major-intro mini-courses (02-180, 05-180, 07-180, or 16-180) during their first year may combine these two mini-courses together to count as one SCS elective; The following courses do NOT count as SCS electives: 02-201, 02-223, 02-250, 02-261, 05-200, 11-423, 15-351, 16-211, 16-223, 16-224, 16-397, 16-480, 17-200, 17-333, 17-562; Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Always consult with an AI undergraduate advisor before registration to determine eligibility for this requirement.

Ethics Course

| | |
|--|-------|
| One of the following courses: | Units |
| 16-161 ROB Seminar: Artificial Intelligence and Humanity | 12 |
| 16-735 Ethics and Robotics | 12 |
| 17-200 Ethics and Policy Issues in Computing | 9 |
| 80-249 AI, Society, and Humanity | 9 |

SCIENCE AND ENGINEERING

All candidates for the bachelor's degree in Artificial Intelligence must complete a minimum of 36 units offered by the Mellon College of Science (MCS) and/or the College of Engineering (CIT). These courses offer students an opportunity to explore scientific and engineering domains that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (<http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/#genedtext>).

Humanities and Arts

All candidates for the bachelor's degree in Artificial Intelligence must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (<http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/#genedtext>). **SPECIAL NOTE FOR AI STUDENTS: AI majors must satisfy Category 1 of the General Education requirements by taking one of the following Cognitive Studies (Category 1A) courses:**

- 85-211 Cognitive Psychology
- 85-213 Human Information Processing and Artificial Intelligence
- 85-370 Perception
- 85-408 Visual Cognition
- 85-421 Language and Thought

SCS First year seminar

The following course is designed to acquaint incoming students with computer science at CMU:

| | | |
|--------|-------------------------------|---|
| 07-128 | First Year Immigration Course | 3 |
|--------|-------------------------------|---|

CoRE@CMU

The following course is required of all CMU students:

| | | |
|--------|----------|---|
| 99-101 | Core@CMU | 3 |
|--------|----------|---|

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements

| Area | Courses | Units |
|--|---------|------------|
| Mathematics | 7 | 71 |
| Computer Science | 5 | 60 |
| Artificial Intelligence | 7 | 70 |
| SCS Electives | 2 | 18 |
| Ethics | 1 | 9 |
| Science/Engineering | 4 | 36 |
| Humanities/Arts (includes Cognitive Studies) | 7 | 63 |
| SCS First Year Seminar | 1 | 3 |
| Core@CMU | 1 | 3 |
| Free Electives | varies | 27 |
| | | 360 |

Undergraduate Research Thesis

AI majors may use the SCS Honors Research Thesis as part of their degree. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Up to 18 units can be counted toward SCS elective requirements (9 per semester for 2 semesters maximum). Students interested in research may also consider using 07-300 Research and Innovation in Computer Science in their junior year since this course will introduce students to various research projects going on in the School of Computer Science that may lead to a senior thesis. This course leads to a subsequent practicum that allows students to complete a small-scale research study or experiment and present a research poster. Students who use the practicum to start their senior thesis can use these units toward the required 36 units.

For more information about the SCS Honors Research Thesis, refer to the SCS Honors Research Thesis (<http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/#scshonorsresearchthesis>) section for learning objectives, application requirements and expected outcomes.

BSAI Roadmap: Sample Course Sequence

The sample given below is for a student who already has credit for introductory programming and introductory calculus. Students with no credit for introductory programming will take 15-112 in their first semester and shift some CS courses to later semesters after consulting with their academic advisor; students with no credit for calculus will take 21-120 in their first semester and shift 21-122 and 21-259 to subsequent semesters. These students should still be able to complete their degree in four years given the light load of their senior year. Students with credit for 21-120 and 21-122 may start with a more advanced math class (e.g. 21-241) in their first year. It is recommended that students keep their academic load lighter for their senior fall semester to account for offsite job interviews or for their senior spring semester to account for visits to graduate schools.

FRESHMAN YEAR:

| Fall | Units |
|--|-------|
| 07-128 First Year Immigration Course | 3 |
| 15-122 Principles of Imperative Computation | 12 |
| 15-151 Mathematical Foundations for Computer Science | 12 |

| | | |
|--------|---|-----------|
| 21-122 | Integration and Approximation | 10 |
| 76-101 | Interpretation and Argument | 9 |
| 99-101 | Core@CMU | 3 |
| | | 49 |
| Spring | | Units |
| xx-180 | Two Major Introduction Minis (02-180, 05-180, 07-180, 16-180) | 10 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 21-241 | Matrices and Linear Transformations | 11 |
| | | 45 |

SOPHOMORE YEAR:

| | | |
|--------|---|-----------|
| Fall | | Units |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| xx-xxx | Science and Engineering Elective | 9 |
| xx-xxx | Ethics Elective | 9 |
| | | 51 |
| Spring | | Units |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 85-xxx | Cognitive Studies Elective | 9 |
| xx-xxx | Humanities and Arts Elective | 9 |
| | | 52 |

| | | |
|--------|---|-----------|
| Fall | | Units |
| 11-411 | Natural Language Processing or 16-385 Computer Vision | 12 |
| 36-401 | Modern Regression | 9 |
| xx-xxx | AI Elective: Machine Learning | 9 |
| xx-xxx | Humanities and Arts elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 48 |
| Spring | | Units |
| xx-xxx | AI Elective: Human-AI Interaction | 12 |
| xx-xxx | AI Elective: Decision Making and Robotics | 9 |
| xx-xxx | Science and Engineering elective | 9 |
| xx-xxx | Humanities and Arts elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 48 |

JUNIOR YEAR:

| | | |
|--------|---|-----------|
| Fall | | Units |
| 11-411 | Natural Language Processing or 16-385 Computer Vision | 12 |
| 36-401 | Modern Regression | 9 |
| xx-xxx | AI Elective: Machine Learning | 9 |
| xx-xxx | Humanities and Arts elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 48 |
| Spring | | Units |
| xx-xxx | AI Elective: Human-AI Interaction | 12 |
| xx-xxx | AI Elective: Decision Making and Robotics | 9 |
| xx-xxx | Science and Engineering elective | 9 |
| xx-xxx | Humanities and Arts elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 48 |

| | | |
|--------|--------------------------------------|-----------|
| Fall | | Units |
| xx-xxx | AI Elective: Perception and Language | 9 |
| xx-xxx | SCS Elective | 9 |
| xx-xxx | Science and Engineering Elective | 9 |
| xx-xxx | Humanities and Arts Elective | 9 |
| | | 36 |
| Spring | | Units |
| xx-xxx | SCS Elective | 9 |
| xx-xxx | Humanities and Arts Elective | 9 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Science and Engineering Elective | 9 |
| | | 36 |

SENIOR YEAR:

| | | |
|--------|--------------------------------------|-----------|
| Fall | | Units |
| xx-xxx | AI Elective: Perception and Language | 9 |
| xx-xxx | SCS Elective | 9 |
| xx-xxx | Science and Engineering Elective | 9 |
| xx-xxx | Humanities and Arts Elective | 9 |
| | | 36 |
| Spring | | Units |
| xx-xxx | SCS Elective | 9 |
| xx-xxx | Humanities and Arts Elective | 9 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Science and Engineering Elective | 9 |
| | | 36 |

Minimum number of units required for the degree:360

The flexibility in the curriculum allows many different schedules, of which the above is only one possibility. Some elective courses are offered only once per year (Fall or Spring). AI cluster electives (decision making and robotics, machine learning, perception and language, and human-AI

interaction) may be taken in any order and in any semester if prerequisites are met and seats are available. Constrained electives are shown in the specific semesters in the schedule above as an example only. Students should consult with their academic advisor to determine the best elective options depending on course availability, their academic interests and their career goals.

Additional Major in Artificial Intelligence

Students interested in pursuing an additional major in Artificial Intelligence should first consult with the Program Administrator (bsai@cs.cmu.edu). Students must have all prerequisites completed, 21-112 or 21,120, 15-122, 15-150, one of 15-210, 15-213, or 15-251, as well as 15-281 or 10-315. Students must earn a "B" average in all prerequisite coursework in order to be admitted to the additional major. The additional major requires 6 mathematics courses, 5 computer science courses, 2 artificial intelligence courses, 4 courses from AI cluster areas, 1 course in ethics, and 1 course in human cognition.

Prerequisites

| | | |
|------------|--|-------|
| (1 course) | | Units |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

The following courses are required for the Addition Major in Artificial Intelligence:

Math and Statistics Core

| | | |
|-------------------------------------|--|-------|
| (6 courses) | | Units |
| 21-112 | Calculus II | 10 |
| or 21-120 | Differential and Integral Calculus | |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| or 15-151 | Mathematical Foundations for Computer Science | |
| 21-122 | Integration and Approximation | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| Probability and Statistics (one of) | | |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| 15-259 | Probability and Computing (if taken Sp24 or later) | 12 |
| 21-325-36-226 | Probability - Introduction to Statistical Inference | 18 |
| 36-225-36-226 | Introduction to Probability Theory - Introduction to Statistical Inference | 18 |
| 36-235-36-236 | Probability and Statistical Inference I-II | 9 |
| Modern Regression Course | | |
| 36-401 | Modern Regression | 9 |

Computer Science Core

| | | |
|-------------|--|-------|
| (5 courses) | | Units |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Artificial Intelligence Core

| | | |
|-------------|---|-------|
| (2 courses) | | Units |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |

AI Cluster Electives

| | | |
|---|--|-------|
| (4 courses, one from each cluster area) | | Units |
| Cognition and Action Cluster (1 course) | | |
| 15-386 | Neural Computation | 9 |
| 15-482 | Autonomous Agents | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-350 | Planning Techniques for Robotics | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |

| | | |
|--|---|----|
| 16-384 | Robot Kinematics and Dynamics | 12 |
| Machine Learning Cluster (1 course) | | |
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| 10-418 | Machine Learning for Structured Data | 12 |
| 10-422 | Foundations of Learning, Game Theory, and Their Connections | 12 |
| 10-423 | Generative AI | 12 |
| 10-425 | Introduction to Convex Optimization | 12 |
| 11-441 | Machine Learning with Graphs | 9 |
| 11-485 | Introduction to Deep Learning | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| Perception and Language Cluster (1 course) | | |
| 11-411 | Natural Language Processing | 12 |
| 11-442 | Search Engines | 9 |
| 11-492 | Speech Technology for Conversational AI | 12 |
| 15-387 | Computational Perception | 9 |
| 15-463 | Computational Photography | 12 |
| 16-385 | Computer Vision | 12 |
| Human-AI Interaction Cluster (1 course) | | |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-318 | Human AI Interaction | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| 16-467 | Introduction to Human Robot Interaction | 12 |

Ethics and Human Cognition

(2 courses, one from each cluster area)

Ethics (1 course)

| | | |
|----------------------------|--|----|
| 16-161 | ROB Seminar: Artificial Intelligence and Humanity | 12 |
| 16-735 | Ethics and Robotics | 12 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| Human Cognition (1 course) | | |
| 85-211 | Cognitive Psychology | 9 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-370 | Perception | 9 |
| 85-345 | Meaning in Mind and Brain | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |

*Note that Concepts in Artificial Intelligence (07-180) is not required for additional majors, although students interested in the additional major in AI are encouraged to take 07-180 prior to taking 15-281 or 10-315.

Double Counting Restrictions

Students pursuing an additional major in AI can double count at most **five courses** total, from the Computer Science Core, the Artificial Intelligence Core, and the AI Cluster Electives, towards all other majors and minors they're pursuing. The Mathematics, Ethics, and Human Cognition courses may double count without restriction, except for 36-402 (Advanced Methods for Data Analysis), which is part of the Machine Learning Cluster. Students with majors that overlap substantially with AI should consult with the Program Administrator (bsai@andrew.cmu.edu) to review their audit for any potential issues.

Artificial Intelligence Minor

Students interested in pursuing a minor in Artificial Intelligence should first consult with the Program Administrator (bsai@cs.cmu.edu) after completion of the prerequisites and 15-281 or 10-301/10-315. Students must earn a "C" average in all prerequisite coursework (including 15-281 or 10-301/10-315) in order to be admitted to the minor. The minor includes 3 required core courses, and 5 courses from AI cluster areas.

Prerequisites

| | | |
|-------------|---|-------|
| (4 courses) | | Units |
| 15-122 | Principles of Imperative Computation | 12 |
| 21-112 | Calculus II | 10 |
| or 21-120 | Differential and Integral Calculus | |
| or 21-259 | Calculus in Three Dimensions | |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| or 15-151 | Mathematical Foundations for Computer Science | |
| 21-240 | Matrix Algebra with Applications | 10 |
| or 21-241 | Matrices and Linear Transformations | |

The following courses are required for the Minor in Artificial Intelligence:

Required Core

| | | |
|--|---|-------|
| (3 courses) | | Units |
| *Two mini courses can be combined to form one 9 unit course. | | |
| 15-259 | Probability and Computing | 9-12 |
| or 21-325 | Probability | |
| or 36-218 | Probability Theory for Computer Scientists | |
| or 36-225 | Introduction to Probability Theory | |
| or 36-235 | Probability and Statistical Inference I | |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 10-301 | Introduction to Machine Learning | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |

Technical Electives

| | | |
|---|---|-------|
| (2 courses from any of the three areas) | | Units |
| Cognition and Action Cluster | | |
| 15-386 | Neural Computation | 9 |
| 15-482 | Autonomous Agents | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-350 | Planning Techniques for Robotics | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |
| 16-384 | Robot Kinematics and Dynamics | 12 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |
| Machine Learning Cluster | | |
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| 10-418 | Machine Learning for Structured Data | 12 |
| 10-422 | Foundations of Learning, Game Theory, and Their Connections | 12 |
| 10-423 | Generative AI | 12 |
| 10-425 | Introduction to Convex Optimization | 12 |
| 11-441 | Machine Learning with Graphs | 9 |
| 11-485 | Introduction to Deep Learning | 9 |
| 15-388 | Practical Data Science | 9 |
| or 67-364 | Practical Data Science | |
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| Perception and Language Cluster | | |
| 11-411 | Natural Language Processing | 12 |
| 11-442 | Search Engines | 9 |
| 11-492 | Speech Technology for Conversational AI | 12 |
| 15-387 | Computational Perception | 9 |
| 15-463 | Computational Photography | 12 |
| 16-385 | Computer Vision | 12 |
| 85-370 | Perception | 9 |

| | | |
|--------|---------------------------|---|
| 85-345 | Meaning in Mind and Brain | 9 |
| 85-408 | Visual Cognition | 9 |

Societal Aspects of AI

(1 course from one of the two cluster areas) Units
 *Two mini courses can be combined to form one 9 unit course.

| | | |
|------------------------------|--|----|
| Human-AI Interaction Cluster | | |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-318 | Human AI Interaction | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| 16-467 | Introduction to Human Robot Interaction | 12 |
| AI and Humanity Cluster | | |
| 16-735 | Ethics and Robotics | 12 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 79-302 | Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 90-442 | Critical AI Studies for Public Policy | 6 |
| 94-441 | Ethics and Politics of Data | 6 |

Double Counting Restriction

Students pursuing a minor in AI can double count, at most, **two courses** total from the AI course requirements towards all other majors and minors they're pursuing. Students with majors that overlap substantially with AI should consult with the Program Administrator (bsai@andrew.cmu.edu) to review their audit for any potential issues.