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
36-218	Probability Theory for Computer Scientists or: (15-259 or 21-325 or 36-225) and 36-226	9
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
07-180	Concepts in Artificial Intelligence	5
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
11-441	Machine Learning for Text and Graph-based Mining	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 Processing	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	Human Robot Interaction	12
others as designated by the AI Undergraduate Program		

School of Computer Science Electives

Two general computer science electives:	Units
These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 11-423, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)	18

Ethics Course

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

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 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

Computing @ Carnegie Mellon

The following course is required of all students to familiarize them with the campus computing environment:

99-101	Computing @ Carnegie Mellon	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	8	**80**
SCS Electives	2	**18**
Ethics	1	**9**
Science/Engineering	4	**36**
Humanities/Arts (includes Cognitive Studies)	7	**63**
SCS First Year Seminar	1	**3**
Computing @ Carnegie Mellon	1	**3**
Free Electives	varies	**17**
		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/#scshonorsresearchthesistext) 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	Computing @ Carnegie Mellon	3
		49

Spring		Units
07-180	Concepts in Artificial Intelligence	5
15-150	Principles of Functional Programming	12

15-213	Introduction to Computer Systems	12
21-241	Matrices and Linear Transformations	11
21-259	Calculus in Three Dimensions	10
		50

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
85-xxx	Cognitive Studies Elective	9
xx-xxx	Science and Engineering Elective	9
xx-xxx	Humanities and Arts Elective	9
		51

JUNIOR YEAR:

Fall		Units
11-411	Natural Language Processing	12
or 16-385	Computer Vision	
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

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
		27

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)		
36-225-36-226	Introduction to Probability Theory - Introduction to Statistical Inference	18
36-218	Probability Theory for Computer Scientists	9
15-259-15-260	Probability and Computing - Statistics and Computing	15
21-325-36-226	Probability - Introduction to Statistical Inference	18
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
11-441	Machine Learning for Text and Graph-based Mining	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 Processing	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	Human Robot Interaction	12

Ethics and Human Cognition

(2 courses, one from each cluster area)

Ethics (1 course)

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.

36-225	Introduction to Probability Theory	9
or 21-325	Probability	
or 36-218	Probability Theory for Computer Scientists	
or 15-259	Probability and Computing	
15-281	Artificial Intelligence: Representation and Problem Solving	12
10-301	Introduction to Machine Learning (Undergrad)	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
11-441	Machine Learning for Text and Graph-based Mining	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 Processing	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	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 Lethal Autonomous Weapons Systems	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
88-380	Dynamic Decisions	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.