Master of Science in Artificial Intelligence

College of Computer and Information Science

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Acknowledgments:

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1. Introduction

The College of Computer and Information Science (CCIS) proposes a new Master of Science program in Artificial Intelligence (AI). The proposed program is designed to give students a comprehensive framework for Artificial Intelligence with specialization in one of 5 areas: Vision, Intelligent Interaction, Robotics and Agent-Based Systems, Machine Learning, and Knowledge Management and Reasoning. Students will engage in an extensive core intended to develop depth in all core concepts that build foundation for Artificial Intelligence theory and practice. Students will also be given the opportunity to build on the core knowledge of AI by taking a variety of elective courses selected from colleges throughout campus, to explore key contextual areas or more complex technical applications. Program graduates will be well positioned to attain research and development positions in a rapidly growing field or to progress into doctoral degrees related fields.

The Master of Science in Artificial Intelligence is comprised of eight (8) courses; five (5) core courses, two electives to be chosen from one of 5 specialization areas, and two other electives. The core courses are designed and developed by CCIS faculty. Elective courses consist of graduate courses offered in CCIS and other partner colleges, including CAMD, COE, COS, CSSH, and Law.

2. Why Create a Master of Science in Artificial Intelligence?

2.1 Market Needs

Over the last year, there were ~5,500 job postings at the MS level seeking professionals with skills in artificial intelligence and ~29,000 for skills in machine learning, according to Burning Glass' LaborInsight database. Additionally, spending on cognitive and artificial intelligence (AI) systems is forecast to reach $57.6 billion in 2021, according to a recent update of the Worldwide Semiannual Cognitive Artificial Intelligence Systems Spending Guide from the International Data Corporation (IDC).

According to a Gartner CIO Survey of IT Senior Leaders, only 4% of surveyed organizations have already invested and deployed AI initiatives, but 46% have short- to long-term plans. Further, the Gartner survey shows that Senior IT leaders face two main challenges in exploring and adopting Artificial Intelligence: the availability of skilled and experience staff, and the lack of IT and business understanding of AI's potential.

Given the projected increase in demand and industrial investment, it is imperative that the university train skilled leaders in the creation of AI systems that will function seamlessly alongside humans. This MS program is aimed at achieving this goal, as well addressing the emerging needs of this market. The MS in AI will educate students in the creation of systems that can reason and respond to this complex set of realities.

2.2 Relationship of AI with Data Science, Machine Learning, and Robotics

The terms Artificial Intelligence, Data Science, Machine Learning, and Robotics are so commonly used in the popular press that it is difficult to attach precise meanings to these terms. Nevertheless, from a technical perspective there is a shared understanding of what these terms stand for. While it is very unlikely that experts in these domains will all agree on ironclad definitions for the terms, we discuss in this section, at a high-level, the relationship between these four areas.

Paraphrasing Wikipedia, **Artificial Intelligence** (AI) is the development of intelligent algorithms and systems that allow such systems to act or be perceived to act intelligently. AI has traditionally been pursued as a subarea of computer science; research in the area brings in innovative ideas from other fields including mathematics, philosophy, psychology, social science, and linguistics.

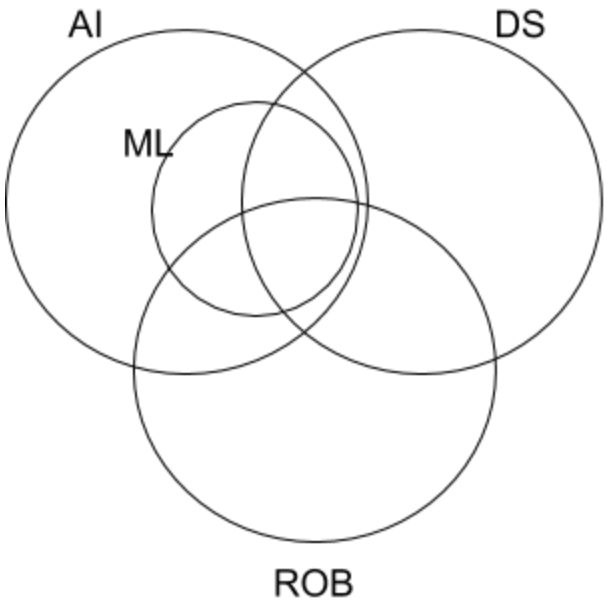
Following Wikipedia, "**Machine learning** is a field of computer science that gives computer systems the ability to "learn" with data, without being explicitly programmed." Historically, Machine Learning (ML) has been a subarea pursued within AI, but in the last decade, it has transformed into a major research area of computer science with phenomenal advances in the algorithmic and mathematical techniques, on the one hand, and in the underlying hardware capabilities, on the other.

Following Wikipedia**, "Data Science** is an interdisciplinary field of scientific methods, processes, algorithms and systems to extract knowledge or insights from data in various forms, either structured or unstructured."

Following Wikipedia**, "Robotics** is an interdisciplinary branch of engineering and science that includes mechanical engineering, electrical engineering, computer science, and others. Robotics deals with the design, construction, operation, and use of robots, as well as computer systems for their control, sensory feedback, and information processing."

AI intersects with Data Science (DS) and Robotics (ROB), with techniques from Machine Learning (ML) playing a major role in all three areas. AI includes subareas such as knowledge representation, cognitive modeling, perception, human-computer interaction, and natural language processing that are not well-represented in Data Science and Robotics.

The following diagram loosely captures the relationship among AI, DS, ML, and ROB. We have placed ML as a sub-field of AI; there may be some disagreement on this, as machine learning has emerged into a separate field of its own.



2.3 Research and Teaching Needs

From the perspective of the units that will teach these courses, there has been a rapid growth in the hiring of professors who are working in AI as well as in closely related areas that either exploit AI techniques or provide some of the basic science used to develop those techniques. This is evidenced by the fact that professors from CCIS, COE, CAMD and COS will be involved in this current proposed list of courses. In CCIS alone, there has been a rapid growth in the hiring in AI, such that there are now over a dozen professors involved in the teaching of existing AI courses. Nevertheless there are gaps in the currently available courses that need to be filled to ensure our graduate students at the MS and PhD levels have sufficient educational backgrounds. This program will fill those gaps.

Another important motivation is from a research perspective. Given the number of active researchers in AI, there will be opportunities for professors and students to come together on the many AI research projects being pursued at Northeastern, as well as the possibility for MS students to continue onto a PhD program in Computer Science or related domains.

3. Competition from Other Programs

Artificial Intelligence is generally considered a subset of Computer Science with regard to measuring MS graduates over the past five years. To this end, computer science related programs continue to grow at a fast pace (over 100% between 2012 and 2016). Artificial Intelligence, however, is an emerging field on its own. The direct competitor programs across the nation remains limited. While there are a handful of AI degrees in the market, there is not

available data pointing to how successful they have been in attracting students. Below is an overview of the immediate competitors in the Artificial Intelligence Masters program space:

Institution	***Program***	***Cost***	***Notes***
Northwestern University	MS in Artificial Intelligence	$69,652	Cohort program; plans a maximum intake of 40 students per year; 15 month program; Practicum required
University of Georgia	MS in Artificial Intelligence	$33,957 (out of state)	30 credit hours required, with a thesis (33 total); No student intake goals listed on site
Carnegie Mellon University	MS in Machine Learning	$43,000 per AY (degree to be completed in 1.5-2 years)	8 courses required; Practicum required

*University of Georgia and Northwestern University's AI Masters programs are only offered in a full-time, on-campus format. Carnegie Mellon's machine learning program offers limited opportunities for part time study. Both Northwestern and Georgia's programs include practicum or internship experiences.

There are also a number of graduate certificate programs in artificial intelligence emerging at top US institutions, such as Stanford, MIT, Columbia, and Georgetown. A comprehensive overview of these offerings is included in the market analysis as a separate attachment.

4. Curriculum

4.1 Program Overview

The MS in Artificial Intelligence program features **five core courses Programming Design Paradigms**, **Algorithms, Foundations of AI, Machine Learning, and Intelligent Interaction** that represent the essential knowledge for research and development in Artificial Intelligence. These courses examine the foundational representations and processes used across AI systems, how machine learning can be used to acquire this knowledge and the various ways AI systems interact with people, as well as an understanding of the ethical concerns in developing AI technologies responsibly. The courses are tailored toward technically or mathematically trained students.

(A) Core Courses:

CS 5010 **Programming Design Paradigm** (4 SH)
CS 5800 **Algorithms** (4 SH)
CS 5100 **Foundations of AI** (4 SH)
CS 6140 **Machine Learning** (4 SH)
CS XXXX **Intelligent Interaction (new course)** (4 SH)

(B) 2 Elective Courses drawn from one of 5 specializations (each 4 SH)

Vision
- CS 5330 Pattern Recognition and Computer Vision
- EECE 5639 Computer Vision
- EECE 7360 Advanced Computer Vision
- CS 7180 Special Topics in AI: Learning and Inference in Vision

Intelligent Interaction
- CS 6130 Affective Computing
- CS 5150 Game Artificial Intelligence
- GSND 6350 Data-Driven Player Modeling
- CS 7340 Theory and Methods in Human-Computer Interaction
- CS XXXX Cognitive Modeling (new)
- CS XXXX Intelligent User Interfaces (new)

Robotics and Agent-based systems
- CS 5335 Robotic Planning and Perception
- EECE 5698 Special Topics: Mobile Robotics
- EECE 5698: Special Topics: Robotics Sensing and Navigation
- CS XXXX Reinforcement Learning and Sequential Decision-Making (to be offered F18)
- CS XXXX Autonomous Agents & Multi-Agent Systems (new)

Machine Learning
- CS 7140/EECE 7397 Advanced Machine Learning
- DS 5230 Unsupervised Learning and Data Mining
- CS XXXX Deep Learning (to be offered S19)
- MATH XXXX Introduction to Statistical Learning Theory and Algorithms (new)

Knowledge Management and Reasoning
- CS 6120 Natural Language Processing
- CS 6200 Information Retrieval
- CS 6220 Data Mining Techniques
- CS XXXX Knowledge Representation and Planning (new)
- PHIL 4515 (soon to be changed to 5000-level) Advanced Logic
- PHIL 5XXX Formal Epistemology (new)

(C) 1 Other Elective Course (4 SH)

Any course from an MS in AI specialization area outside the student's specialization can be an elective course. Additionally, the elective course can be drawn from CCIS and other partner colleges. Suggested courses include:

CS 7180 Special Topics in Artificial Intelligence
CS 6800 Applications of Information Theory
EECE 7337 Information Theory
PSYC XXXX Cognition (new)
GSND 5110: Game Design and Analysis
LAW 7639 Internet Law
PHI 5XXX AI and Ethics (new)
ECON 5XXX Information Economics and Game Theory

Students in the program will also have the option of pursuing (i) an **MS Project** by completing a 1-semester project (through an MS Project course in lieu of an elective), or (ii) an **MS Thesis** by completing a 2-semester thesis project (two MS Thesis courses in lieu of two electives).

4.2 Core Curriculum Course Descriptions

1. **CS5010: Programming Design Paradigms** introduces modern program design paradigms. Starts with functional program design, introducing the notion of a design recipe. The latter consists of two parts: a task organization (ranging from the description of data to the creation of a test suite) and a data-oriented approach to the organization of programs (ranging from atomic data to self-referential data definitions and functions as data). The course then progresses to object-oriented design, explaining how it generalizes and contrasts with functional design. In addition to studying program design, students also have an opportunity to practice pair-programming and public code review techniques, as found in industry today.

2. **CS5800: Algorithms** will present the mathematical techniques used for the design and analysis of computer algorithms. Focuses on algorithmic design paradigms and techniques for analyzing the correctness, time, and space complexity of algorithms. Topics may include asymptotic notation, recurrences, loop invariants, Hoare triples, sorting and searching, advanced data structures, lower bounds, hashing, greedy algorithms, stochastic search algorithms, dynamic programming, graph algorithms, and NP-completeness.

3. **CS5100: Foundations of AI** introduces the fundamental problems, theories, and algorithms of the artificial intelligence field. Topics include heuristic search and game trees, knowledge representation, problem solving and planning, reasoning under uncertainty and introduction to machine learning. Required coursework includes the creation of working programs that solve problems, reason, and/or improve their own performance using techniques presented in the course.

4. **CS6140: Machine Learning** provides a broad look at a variety of techniques used in machine learning and data mining, and also examines issues associated with their use. Topics include algorithms for supervised learning including decision tree induction, artificial neural networks, instance-based learning, probabilistic methods, and support vector machines;

unsupervised learning; and reinforcement learning. Also covers computational learning theory and other methods for analyzing and measuring the performance of learning algorithms. Course work includes a programming term project.

5. **CSXXXX: Intelligent Interaction** provides an overview of the wide range of AI techniques that exploit knowledge of the domain and humans to a) facilitate interaction between humans and systems, b) mediate human-human interaction, c) leverage humans to improve system performance, and d) promote beneficial outcomes at the social and individual level. Topics can include AI/human computation, plan and activity recognition, smart sensing/homes, active learning, preference elicitation, intelligent/adaptive user interfaces and mixed human-agent simulations. The course teaches how to design and develop intelligent interaction technologies, while also critically assessing their social and ethical impact. (Jointly developed with CSSH, which will provide faculty expertise for integrating ethics and responsible development in the course.)

4.3 New Specialization Courses and Electives

1. **Intelligent User Interfaces** (IUIs) combines Human Computer Interaction and AI with the goal of building intelligent and smart user interfaces, where the system's behavior can have an impact on the user experience improving performance or usability in critical ways. IUIs usually are designed with capabilities to model and understand the user, including how to perceive, interpret, learn, use language, reason, plan, and decide. The course will review the theory and the foundational concepts for developing IUIs as well as current research approaches. The course will also engage students in developing proposing and developing IUIs, given their domains or applications of interest.
2. **Autonomous Agents and Multi-Agent Systems** covers the design, development and evaluation of agents, Agents are programs that observe their environment, make decisions on what actions to take based on those observations and execute those actions in the environment. They can perform these steps autonomously, without human control. Multi-agent research additionally addresses how multiple agents interact with each other, across different kinds of roles and relations, such as teammates, competitors or peers.
3. **Reinforcement Learning and Sequential Decision Making** introduces reinforcement learning and the underlying computational frameworks. After introducing the Markov decision process framework, we will cover a variety of reinforcement learning algorithms including: model-based, model-free, value function, policy gradient, actor-critic, and monte carlo methods. We will also study hierarchy and abstraction in reinforcement learning, commonly used representations including deep learning representations, and approaches to partially observable problems. Students will be expected to have a working knowledge of probability and linear algebra and to complete programming assignments.
4. **Deep Learning** begins by reviewing linear methods for classification, stochastic gradient descent and regularization strategies. We then cover multilayer perceptrons, back-propagation, convolutional networks, and activation functions. We move on to training strategies, including initialization of weights, dropout, and batch normalization. We discuss applications in computer vision, including object detection and image segmentation. We then discuss recurrent neural

networks and their applications in natural language processing. We conclude with discussions of variational autoencoders, generative adversarial networks and deep reinforcement learning.

5. **Knowledge Representation and Planning** will cover topics that are essential for Artificial Intelligence specifically on how to represent knowledge about the domains AI is applied and how to develop problem solvers or planning algorithms that use this knowledge to solve problems. In particular, it will discuss different approaches to knowledge representation, such as graphical probabilistic graphs and logic (e.g., first order logic and temporal logic). The course will also cover reasoning about action, situation and change, and inference methods given different knowledge representations. In addition to Knowledge representation, the course will also cover planning which is a fundamental topic in AI. It is concerned with the ability to develop systems that allow software agents or robots to construct a sequence of actions to achieve particular goals. The course will cover several topics including reactive planning systems, hierarchical and abstract planning, case-based planning, machine learning approaches to planning as well as multi-agent collaboration and planning systems. It will also discuss various important topics to planning, such as planning under uncertainty as well as cover some applications and domains that have extensively used planning systems. The course will be lecture oriented with hands-on experience through projects and assignments that allows students to get a practical experience choosing knowledge representations and building planning systems for domains of their interest.

6. **Cognitive Modeling** offers an introduction to computational theories of human cognition and behavior. Fundamental issues include perception, knowledge representation, memory, decision-making, learning, and motor control. Readings and assignments will explore a variety of approaches, including formal/theoretic, neural, probabilistic, and symbolic/architectural. A focus of the course will be how to evaluate and compare models against each other and empirical data.

7. **Special Topics in AI: Learning and Inference in Vision** prepares students in foundations of computer vision, studies advances in machine learning to address computer vision tasks and discusses practical approaches to build real vision systems. The course covers important research topics in computer vision, including recognition, detection, segmentation and summarization tasks and discusses advanced inference and learning techniques, including deep convolutional and recurrent neural networks, sparse coding and graphical models for visual data analysis. The course will cover data sources, features and learning algorithms useful for understanding, manipulating and decision making with visual data.

8. **Cognition** provides a graduate-level introduction to human cognition. Topics include pattern recognition, attention, memory, categorization and concept formation, problem solving, and aspects of cognitive development. Examines current theories of cognitive processing and related experimental findings.

9. **Artificial Intelligence and Ethics:** Artificial intelligence, and the systems within which it is and will be embedded, raises a variety of ethical challenges. This course takes up these challenges with an eye towards developing a foundation of ethical tools for addressing them. In addition to covering specific topics in AI ethics, we will look at broader issues in the philosophy of technology concerning how the introduction of new

technologies alters existing practices and how to incorporate ethical concerns to engage in "value-sensitive design" and "reflective implementation," how to design technologies with values in mind and deploy them in ethically sensitive ways.

10. **Formal Epistemology** explores theories and results in formal epistemology. Topics include Bayesian approaches to epistemology, updating on evidence, principles of rationality, utility theory and choice under uncertainty. Connections to information, misinformation, and measures of accuracy are also explored. Students will learn the foundations and methods of formal epistemology and rational choice theory as well as their applications.

11. **Information Economics and Game Theory** offers an advanced course on the economics of information, including moral hazard and adverse selection; game theory; and mechanism design. Formally considers alternative solution concepts, such as Nash equilibrium and rationalizability for simultaneous move and sequential move games under complete information about payoffs and preferences, as well as solution concepts, such as Bayesian-Nash equilibrium to analyze selection, screening, and incentives in games of incomplete or asymmetric information. Covers optimal incentives or mechanism design, including the optimal design of contracts, auctions, and other mechanisms. Prior exposure to game theory recommended.

4.4 Placement Exam

We plan to follow the placement model similar to the MS Data Science program. Each incoming student, *regardless of his/her background*, takes a placement exam administered one week prior to the beginning of the semester on basic statistics, probability, and linear algebra. If the student does not get a B or above in a placement exam, then the student must take an introductory course.

i. **Introduction to Statistics and Linear Algebra:** The introductory course on basics of statistics, probability, and linear algebra covers random variables, frequency distributions, measures of central tendency, measures of dispersion, moments of a distribution, discrete and continuous probability distributions, Chain Rule, Bayes Rule, correlation theory, basic sampling, matrix operations, trace of a matrix, norms, linear independence and ranks, inverse of a matrix, orthogonal matrices, range and nullspace of a matrix, the determinant of a matrix, positive semidefinite matrices, eigenvalues and eigenvectors.

5. Program Learning Objectives

Graduate Students who complete the MS degree will be able to:

1. Understand representations, algorithms and techniques used across works in Artificial Intelligence, and be able to apply and evaluate them in applications as well as develop their own.

2. Understand the basic processes that an agent must perform, from perceiving its environment, making decisions on how to act and performing those actions, as well be able to develop and evaluate the technology that can be used to perform these processes.
3. Understand and apply machine learning techniques, in particular to draw inferences from data and help automate the development of AI systems and components.
4. Understand the various ways and reasons humans are integrated into mixed human-AI environments, whether it is to improve overall integrated system performance, improve AI performance or influence human performance and learning.
5. Understand the ethical concerns in developing responsible AI technologies.
6. Model human behavior, develop Human-AI systems, and evaluate their performance.
7. Demonstrate knowledge of the use of AI algorithms and processes in one of the specialization areas: robotics and agent-based systems, vision, intelligent interaction, machine learning, and knowledge representation and reasoning.

6. Admissions Criteria and Process

Successful applicants to the Masters in Artificial Intelligence program will have a background in STEM fields, with prior exposure to programming and statistics or linear algebra. Strong candidates from the social sciences (e.g., Economics, Psychology), with prior exposure to programming, statistics, and linear algebra would also be considered.

Admission criteria for the Masters program are:

- Undergraduate degree with a minimum GPA of 3.000
- Statement of purpose including description of relevant work experience.
- GRE- 150V/155Q/4.0A
- TOEFL- 100 (for international applicants with a Bachelor's degree from a non-native English speaking country)
- Three (3) letters of recommendation from professional and/or academic reference.

The admissions committee will be comprised of CCIS program faculty and administration who will oversee the review process for the applications.

7. Contribution to the University Mission

The university's long range plan calls for an increase in the number of flexible high quality degree programs that align with emerging fields and new career opportunities. These programs should be "interdisciplinary areas where we have a competitive advantage…" Market research

has demonstrated that there are few fields with as much projected growth over the next 10 years as artificial intelligence. Creating a high quality Masters degree program that caters to the more technical aspects of the discipline is imperative for the university.

The Masters degree in Artificial Intelligence represents an opportunity for the university to build on the already strong portfolio of dynamic masters programs. This program will support the university's effort to build a robust academic pathway to both research and professional careers in AI. Furthermore, the program will allow students to build their technical skills and to further understand the complex human systems in which they will be implemented.

8. Impact on Existing Programs at Northeastern

The creation of a Masters program in Artificial Intelligence will impact the following programs.

First, the Masters in Data Science program (joint with COE) will see an impact from the creation of this program. The fundamental skills required for admission to this program will not differ greatly from those required for admission to the Data Science program. This program also represents a specific set of skills sometimes associated with Data Science. As such, the creation of this program stands to impact the potential applicant pool for Data Science. However, the curricular foci of the two programs are different. While the MSDS program emphasizes large-scale data collection, storage, retrieval, and processing, ML and optimization methods for mining diverse data sets and visualization of complex data, the MS AI program emphasizes foundations of AI systems, knowledge representation, cognitive modeling, how ML can be used to acquire this knowledge, and interaction between AI systems and humans. Furthermore, given the growth of the program (nearly 800 applicants for the Fall 2018 semester, year two of the program) and continued increasing market demand for professionals with these skill sets, we see the impact as being limited.

The Masters in Computer Science (MSCS) will also be affected by the creation of the Artificial Intelligence Masters degree. The MSCS program contain a number of Artificial Intelligence foundation and elective courses. Additionally, many of our current students are interested in an artificial intelligence concentration as they look toward employment with some of the larger tech firms (Amazon, Google, Twitter, etc). We see potential impact on our application numbers for the MSCS program with our international applicants.

Given that the MSCS program is currently at capacity at our Boston campus and our admission rate is presently 10% (3,100 applications) for the Fall 2018 semester, CCIS remains confident that the qualified applicant pipeline is robust enough to sustain the creation of a related MS program in the college.

Additional impact at the university could include programs that offer elective course areas. CCIS expects that the growth of the Artificial Intelligence Masters program will support higher enrollments in elective courses in related technical or contextual areas. Partner colleges will be

consulted on the approval of their courses for this program. This proposal details elective areas outside of CCIS.

9. Assessment Plan for the MS in Artificial Intelligence

The assessment plan for the new courses in the MS in Artificial Intelligence degree (including four core courses) uses both direct and indirect assessment to assess how well students are achieving the core outcomes of each individual course.

Direct assessments will include an anonymized assessment of student coursework to be sampled at random from the core courses. Selected work will be cumulative and synthetic to each course, such as final projects. The program faculty will develop quality rubric to assess the outcomes of each course and the level of achievement by current students. Coursework will be sampled annually.

Indirect assessments of the program and new core courses will include standard institutional metrics including but not limited application statistics, enrollment data, completion and persistence rates, TRACE evaluations, student surveys (current and graduate), and student-employer co-op reviews. The program will also conduct student interviews (group and individual) to understand student perceptions of program and course operation.

Annual assessments of the program will be conducted for the first four years in an effort to continually improve the admissions rubric, identify curricular gaps, employment/co-op trends, as well as program strengths and weaknesses. Below is a tentative timeline for program assessment, starting in Fall 2019. A comprehensive program review will be conducted at the close of the program's fifth year.

Assessment Plan	***Timeline***	***AY 19/20***			***AY 20/21***			***AY 21/22***			***AY 22/23***			***AY 23/24***		
		F	*Sp*	*Su*	*F*	*Sp*	*Su*	*F*	*Sp*	*Su*	*F*	*Sp*	*Su*	*F*	*Sp*	*Su*
Current Student Survey	*Every summer*			*x*			*x*			*x*			*x*			*x*
Co-op Placement	*Every Co-op Cycle (C1/C2)%*				*C1*		*C2*	*C1*		*C2*	*C1*		*C1*	*C2*		*C1*

Graduate Surveys	*Annually after graduation for first cohort*		*x*			*x*			*x*			*x*			*x*	
TRACE Evaluation	*Every Semester*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*X*	*x*	*x*	*x*	*x*	*x*
*Program Data**	*Every Summer*			*x*			*x*			*x*			*x*			*x*
Student Coursework	*Every Summer*			*x*			*x*			*x*			*x*			*x*

%CCIS Co-Op runs on two entry cycles: Cycle 1 runs Summer-Fall and Cycle 2 runs Spring-Summer.

* Program data to include admissions rubric review, persistence and completion rate, and grade distribution review.

APPENDIX: CCIS Artificial Intelligence Faculty

Christopher Amato is an Assistant Professor at Northeastern University. He received a BA from Tufts University and an MS and a PhD from the University of Massachusetts, Amherst. Before joining Northeastern, Dr. Amato was a Research Scientist at Aptima, Inc. and a Postdoc and Research Scientist at MIT as well as an Assistant Professor at the University of New Hampshire. He has published papers in leading artificial intelligence and robotics conferences (including winning a best paper prize at AAMAS-14 and being nominated for the best paper at RSS-15). He also successfully co-organized several tutorials on team decision making and co-authored a book on the same subject. His research focuses on decision making under uncertainty in multi-agent and multi-robot systems.

Javed Aslam is a Professor and Senior Associate Dean for Academic Affairs in the College of Computer and Information Science at Northeastern University. Prior to joining Northeastern University, he was an assistant professor in the Department of Computer Science at Dartmouth College. Professor Aslam has also held a postdoctoral position in the School of Engineering and Applied Sciences at Harvard University. Professor Aslam received his BS in Electrical Engineering from the University of Notre Dame and his PhD in Computer Science from MIT.

Professor Aslam's research interests include information retrieval, machine learning, and the design and analysis of algorithms. In machine learning, he has developed models and algorithms for multi-label classification and for learning in the presence of noisy or erroneous training data. In information retrieval, he applied techniques from machine learning, statistics, information theory, and social choice theory to develop algorithms for automatic information organization, metasearch, and efficient search engine training and evaluation. He has also been involved in the fields of human computation, transportation, computer security, wireless networking, and medical informatics. Prof. Aslam served as the General co-Chair for the 2009 ACM SIGIR Conference on Research and Development in Information Retrieval, and he also served as the Program co-Chair for SIGIR 2016.

Ricardo Baeza-Yates is the Director of Computer Science programs at Northeastern University Silicon Valley and part-time Professor of Practice. He is also the CTO of NTENT, a semantic search technology company based in California since June 2016. Prior to these roles, he was the VP of Research at Yahoo Labs, based in Sunnyvale, California, from August 2014 to February 2016. Before joining Yahoo Labs in California, he founded and led the Yahoo labs in Barcelona and Santiago de Chile from 2006 to 2015. Between 2008 and 2012 he oversaw Yahoo Labs in Haifa, Israel, and started the London lab in 2012.

Ricardo obtained a PhD in Computer Science from the University of Waterloo, Canada, in 1989. He also holds two masters (M.Sc. CS & M.Eng. EE) and the electronics engineer degree from the University of Chile in Santiago. Additionally, Baeza-Yates is a co-author of the best-seller

Modern Information Retrieval textbook, published in 1999 by Addison-Wesley with a second enlarged edition in 2011, which won the ASIST 2012 Book of the Year award. He is also a co-author of the 2nd edition of the Handbook of Algorithms and Data Structures, Addison-Wesley, 1991; and co-editor of Information Retrieval: Algorithms and Data Structures, Prentice-Hall, 1992, among more than 600 other publications. In 2009, he was named ACM Fellow and in 2011 IEEE Fellow.

Timothy W. Bickmore is a Professor in the College of Computer and Information Science at Northeastern University. Prior to joining Northeastern in 2005, he was an assistant professor of medicine at the Boston University School of Medicine. He completed his PhD at the Massachusetts Institute of Technology Media Laboratory.

Professor Bickmore's interdisciplinary research is at the intersection of human-computer interaction, natural language processing (dialogue systems), animation, and health/medical/behavioral informatics. The focus of his research is on the development and evaluation of computer agents that emulate face-to-face interactions between health providers and patients for use in health education and long-term health behavior change interventions, with a particular focus on the emotional and relational aspects of these interactions. His research has received funding from NSF, NIH, AHRQ, HRSA, and PCORI.

Professor Bickmore has chaired or co-chaired several meetings, including Intelligent Virtual Agents, and AAAI symposia and CHI workshops on health informatics and virtual agents. He is an associate editor of the Interacting with Computers journal.

Carla E. Brodley is the Dean of the College of Computer and Information Science at Northeastern University. Prior to joining Northeastern, she was a professor of the Department of Computer Science and the Clinical and Translational Science Institute at Tufts University (2004-2014). Before joining Tufts she was on the faculty of the School of Electrical Engineering at Purdue University (1994-2004).

A Fellow of the ACM and the Association for the Advancement of Artificial Intelligence (AAAI), Dean Brodley's interdisciplinary machine learning research led to advances not only in computer and information science, but in many other areas including remote sensing, neuroscience, digital libraries, astrophysics, content-based image retrieval of medical images, computational biology, chemistry, evidence-based medicine, and predictive medicine.

Dean Brodley's numerous leadership positions in computer science as well as her chosen research fields of machine learning and data mining include serving as program co-chair of ICML, co-chair of AAAI, and serving as associate editor of the Journal of AI Research, and the Journal of Machine Learning Research. She has previously served on the Defense Science Study Group, the board of the International Machine Learning Society, the AAAI Council and DARPA's Information Science and Technology (ISAT) Board. She is currently serving on the CRA Board of Directors, the executive committee of the Northeast Big Data Hub, and as a member-at-large of the section on Information, Computing, and Communication of AAAS.

Seth Cooper is an Assistant Professor in the College of Computer and Information Science and a member of the Playable Innovative Technologies Lab. Prior to joining Northeastern, Seth was the Creative Director of the Center for Game Science at the University of Washington. He previously worked in industry at Square Enix, Electronic Arts, and Pixar Animation Studios.

A pioneer of the field of scientific discovery games, Seth's PhD dissertation, "A Framework for Scientific Discovery through Video Games", won the 2011 ACM Doctoral Dissertation Award. His work has shown that video game players are able to outperform purely computational methods for certain types of structural biochemistry problems, effectively codify their strategies, and integrate with the lab to help design real synthetic proteins. In addition to developing video games to solve problems and involve the public in science, he's published research in character animation and crowd simulation.

Nate Derbinsky is a Teaching Associate Professor in CCIS at Northeastern. His research interests combine artificial intelligence, optimization, machine learning, and database systems. He recently helped invent the Boundary Forest Algorithm, an online instance-based approach for supervised and unsupervised learning, as well as the Three-Weight Algorithm, a general & distributed algorithm based on the Alternating Direction Method of Multipliers (ADMM) that has been effectively applied to large-scale problems in robotics, control, protein folding, and multi-dimensional packing. He also works with the Soar cognitive architecture, enabling a broad range of AI systems that are endowed with effective and efficient long-term memory.

Teaching is Nate's passion, and developing and delivering quality CS education content is his mission. He has been involved in teaching Computer Science, in some form or other, for nearly 20 years, including at the K-12, (community) college, and graduate levels. He constantly seeks new ways to make complex CS topics accessible, and bring an increasingly diverse group to understand how fun and transformative computing can be. He has recently dipped his toes in the waters of CS education, investigating effective methods of service learning and grad-school preparation.

Nate joined the Wentworth Institute of Technology in 2014, where he was recently awarded the 2017 President's Award for Distinguished Scholarship. Prior to WIT he was a Postdoctoral Associate at Disney Research, where he specialized in large-scale optimization and machine-learning algorithms, and before that briefly worked as a Visiting Research Associate at the University of Hertfordshire, where he researched applications of cognitive architecture for scalable Human-Robotic Interaction studies. Nate earned his PhD from the Computer Science and Engineering Division at the University of Michigan where he worked in the Soar group under the supervision of John Laird. He received an M.S. in Computer Science and Engineering from the University of Michigan and a B.S. in Computer Science from North Carolina State University, where he studied as a Park Scholar.

Ehsan Elhamifar is an Assistant Professor in the College of Computer and Information Science and is affiliated with the Department of Electrical and Computer Engineering at Northeastern University. Previously, he was a postdoctoral scholar in the Electrical Engineering and

Computer Sciences Department at the University of California, Berkeley. He obtained his PhD in Electrical and Computer Engineering from the Johns Hopkins University in 2012. Dr. Elhamifar obtained two Master degrees, one in Electrical Engineering from Sharif University of Technology in Iran in 2006 and another in Applied Mathematics and Statistics from the Johns Hopkins University in 2010. He was a visiting researcher at Stanford University, University of Minnesota and Duke University for several months during 2011 and 2012.

Prof. Elhamifar's research areas are machine learning, computer vision, optimization and algorithms. He is broadly interested in developing efficient, robust and provable algorithms that can address challenges of complex and large-scale high-dimensional data. He works on applications of these tools in computer vision and robotics. Specifically, he uses tools from convex geometry and analysis, optimization, sparse and low-rank modeling, high-dimensional statistics and graph theory to develop algorithms and theory and applies them to solve real-world problems, including motion and activity segmentation in videos, object detection and recognition, video summarization, active learning and more.

Tina Eliassi-Rad is an Associate Professor of Computer Science at Northeastern University. She is also on the faculty of the Network Science Institute. Prior to joining Northeastern, Professor Eliassi-Rad was an associate professor of computer science at Rutgers University; and before that a member of technical staff and principal investigator at Lawrence Livermore National Laboratory. She earned her PhD in Computer Sciences (with a minor in mathematical statistics) at the University of Wisconsin-Madison. Her research is rooted in data mining and machine learning; and spans theory, algorithms, and applications of massive data from networked representations of physical and social phenomena. Professor Eliassi-Rad's work has been applied to personalized search on the World-Wide Web, statistical indices of large-scale scientific simulation data, fraud detection, and cyber situational awareness. Her algorithms have been incorporated into systems used by the government and industry (e.g., IBM System G Graph Analytics) as well as open-source software (e.g., Stanford Network Analysis Project). In 2010, she received an Outstanding Mentor Award from the US DOE Office of Science.

Yun (Raymond) Fu received the B.Eng. degree in information engineering and the M.Eng. degree in pattern recognition and intelligence systems from Xi'an Jiaotong University, China, respectively, and the M.S. degree in statistics and the Ph.D. degree in electrical and computer engineering from the University of Illinois at Urbana-Champaign, respectively. He is an interdisciplinary faculty member affiliated with College of Engineering and the College of Computer and Information Science at Northeastern University since 2012.

His research interests are Machine Learning, Computational Intelligence, Big Data Mining, Computer Vision, Pattern Recognition, and Cyber-Physical Systems. He has extensive publications in leading journals, books/book chapters and international conferences/workshops. He serves as associate editor, chairs, PC member and reviewer of many top journals and international conferences/workshops. He received seven Prestigious Young Investigator Awards from NAE, ONR, ARO, IEEE, INNS, UIUC, Grainger Foundation; seven Best Paper Awards from IEEE, IAPR, SPIE, SIAM; three major Industrial Research Awards from Google, Samsung,

and Adobe, etc. He is currently an Associate Editor of the IEEE Transactions on Neural Networks and Leaning Systems (TNNLS). He is fellow of IAPR, a Lifetime Senior Member of ACM and SPIE, Lifetime Member of AAAI, OSA, and Institute of Mathematical Statistics, member of Global Young Academy (GYA), INNS an Beckman Graduate Fellow during 2007-2008.

Wolfgang Gatterbauer is an Associate Professor in the College of Computer and Information Science. Prior to joining Northeastern University, he was an Assistant Professor in the Tepper school of Business at Carnegie Mellon University; and before that a PostDoc in the database group of University of Washington. His main research interests are data and information management. His work was published in venues such SIGMOD, VLDB, AAAI, and WWW. He is a recipient of the NSF CAREER award and a “best-of-conference” mention from VLDB 2015.

Kevin Gold received his Ph.D. from Yale University in 2008 for research on how robots could learn the meanings of pronouns and other abstract words from examples. He was the Norma Wilentz Hess Visiting Assistant Professor in the Computer Science Department at Wellesley College, then an Assistant Professor in the Interactive Games and Media department at the Rochester Institute of Technology. Dr. Gold had brief interlude in which he worked for industry, including a research scientist position at Lincoln Laboratory and a software engineering position at Google. He is happy to have returned to teaching, now as an Assistant Teaching Professor at Northeastern University’s College of Computer and Information Science.

Stacy Marsella is a Professor in the College of Computer and Information Science with a joint appointment in Psychology. Prior to joining Northeastern, he was a research professor in the Department of Computer Science at the University of Southern California and a research director at the Institute for Creative Technologies (ICT). Before joining ICT, he was at USC’s Information Sciences Institute (1996-2009) and Bell Labs (1995-1996).

Professor Marsella’s multidisciplinary research is grounded in the computational modeling of human cognition, emotion and social behavior as well as the evaluation of those models. Beyond its relevance to understanding human behavior, the work has seen numerous applications, including health interventions, social skills training and planning operations. His more applied work includes frameworks for large-scale social simulations of towns and a range of techniques and tools for creating virtual humans, facsimiles of people that can engage people in face-to-face interactions.

Professor Marsella’s leadership positions in computer science include serving as a general chair of AAMAS (Autonomous Agents and Multiagent Systems) and chair of IVA (Intelligent Virtual Agents). In 2010, he received an ACM SIIGART career award for his contributions to agent research. He is an associate editor of the IEEE Transactions on Affective Computing, currently is a board member of the International Foundation for Autonomous Agents and Multiagent Systems, and is on the steering committee for IVA. He is a fellow of the Society of Experimental

Social Psychologists, a member of AAAI and a member of the International Society for Research on Emotions.

Misha Pavel holds a joint faculty appointment in the Northeastern University College of Computer & Information Science and Bouvé College of Health Sciences. His background comprises electrical engineering, computer science and experimental psychology, and his research is focused on multiscale computational modeling of behaviors and their control, with applications ranging from elder care to augmentation of human performance. Professor Pavel uses these model-based approaches to develop algorithms transforming unobtrusive monitoring from smart homes and mobile devices to useful and actionable knowledge for diagnosis and intervention. Under the auspices of the Northeastern-based Consortium on Technology for Proactive Care, Professor Pavel and his colleagues target technological innovations to support the development of economically feasible, proactive, distributed, and individual-centered healthcare. In addition, Professor Pavel is investigating approaches to inferring and augmenting human intelligence using computer games, EEG and transcranial electrical stimulation. Previously, Professor Pavel was the director of the Smart and Connected Health Program at the National Science Foundation, a program co-sponsored by the National Institutes of Health. Earlier, he served as the chair of the Department of Biomedical Engineering at Oregon Health & Science University, a Technology Leader at AT&T Laboratories, a member of the technical staff at Bell Laboratories, and faculty member at Stanford University and New York University. He is a senior life member of IEEE.

Robert Platt is an Assistant Professor in the College of Computer Science at Northeastern. Prior to that, Professor Platt was a Research Scientist at MIT and a Robotics Engineer at NASA. He earned his PhD in Computer Science in 2006 from the University of Massachusetts, Amherst. Most of his work focuses on perception, planning, and control for robotic manipulation. He is particularly interested in the intersection between robotic perception and planning/control. The goal is to enable robots to perform manipulation tasks robustly in the context of real-world perceptual uncertainties.

David A. Smith is an assistant professor in the College of Computer and Information Science and a founding member of the NULab for Texts, Maps, and Networks, Northeastern's center for the digital humanities and computational social sciences.

Before earning his PhD in Computer Science from Johns Hopkins University, he received a Bachelor of Arts summa cum laude in Classics (Greek) from Harvard. He also worked for Tufts' Perseus Digital Library Project, one of the most widely-used linguistic and cultural research systems in the humanities field. Prior to joining Northeastern, he was a research assistant professor at the University of Massachusetts, Amherst. Professor Smith has published widely in the areas of natural language processing and computational linguistics, information retrieval, digital libraries, digital humanities, and political science. His research has been funded by the NSF, NEH, DARPA, ONR, AFRL, the Mellon Foundation, and Google.

Olga Vitek holds a BS degree from the University of Geneva, Switzerland, and a MS in Mathematical Statistics and a PhD in Statistics from Purdue University. She interned at Eli Lilly & Company in Indianapolis and held a position of post-doctoral associate in the Aebersold Lab at the Institute for Systems Biology in Seattle. Between 2006-2014 she was an assistant professor, and then an associate professor with tenure at Purdue University, with a joint appointment in the Department of Statistics and Department of Computer Science. In the summer of 2014 she joined Northeastern University, with a joint appointment in the College of Science and the College of Computer and Information Science.

Professor Vitek was named the Sy and Laurie Sternberg Interdisciplinary Associate Professor at Northeastern University, and University Faculty Scholar at Purdue University. While at Purdue, she was recognized with an Outstanding Assistant Professor Teaching Award, a Graduate Student Mentoring Award, and a Teaching for Tomorrow Award. She is a recipient of the National Science Foundation CAREER Award. She serves on the Board of Directors of the US Human Proteome Organization.

Jan-Willem van de Meent is an assistant professor of Computer Science at Northeastern University's College of Computer and Information Science. Prior to joining Northeastern, Professor van de Meent held positions as a postdoctoral researcher at the University of Oxford and Columbia University. Professor van de Meent holds a PhD in Theoretical Physics from Leiden University.

Professor van de Meent's interests lie at the interface of programming languages and machine learning research. He is one of the creators of Anglican, a probabilistic programming system integrated with the Clojure language. His research aims to understand how probabilistic programs can be used to define structured and composable models in machine learning and artificial intelligence. His past contributions span granular physics, biological fluid mechanics, and machine learning for single-molecule biophysics.

Magy Seif El-Nasr is an Associate Professor in the Colleges of Computer and Information Sciences and Arts, Media and Design at Northeastern University. Professor Seif El-Nasr directs the PLAIT (Playable Innovative Technologies) Lab. Prior to joining Northeastern, she was an assistant professor at the School of Interactive Arts and Technology at Simon Fraser University (2007-2011). Before that she was an assistant professor at the School of Information Science and Technology at Pennsylvania State University (2003-2007).

Professor Seif El-Nasr believes that problems we currently face in the areas of health, education, resilience, and cybersecurity require an interdisciplinary approach and most often require us to understand human behavior, learning, and human cognition at a deep level which we currently do not possess. Her research focuses on building a framework to facilitate the use of virtual environments (e.g., games, VR, apps, social media or interactive narrative) as a methodology to understand human behavior and cognition, with the goal of facilitating computational solutions to national problems in health, education and security. To address this

vision, she develops tools and automated techniques to help author virtual environments (e.g., interactive narratives, believable characters, etc.), as well as data driven analytics to model human behavior in such environments, which can be used to assess as well as personalize the environments towards effective use in solving national problems, such as health and learning.

Professor Seif El-Nasr has chaired and co-chaired several conferences in areas related to AI, HCI, and games. She has also served on several NSF panels throughout her career, and has severed on numerous SIGs, including ACM Representative for TC14 IFIP on Entertainment Computing. In 2017, Dr. Self El-Nasr was selected among 30 game scholars named as fellows for the Higher Education Video Game Association, an association that aims to cultivate a community on game scholarship and education around the world. This was to recognize her leadership role in pioneering and developing games as a field of scholarship and education.

Byron Wallace is an assistant professor in the College of Computer and Information Science at Northeastern University. He earned his PhD from Tufts University in 2012, at which point he joined Brown University as research faculty. He joins Northeastern from the University of Texas at Austin, where he was an assistant professor in the School of Information from 2014-2016.

Byron's research areas include artificial intelligence, data science, machine learning, natural language processing and information retrieval, with emphasis on applications in health informatics. Byron is a member of the applied machine learning group and the Data Science and Analytics Lab at Northeastern.

Much of Byron's work has concerned developing machine learning and natural language processing methods that make synthesizing the vast biomedical evidence-base more efficient. He also works on core machine learning and natural language processing methods. Some of his recent work concerns Convolutional Neural Network (CNN) architectures for text. And he has recently been developing hybrid, interactive human/machine learning systems that aim to robustly combine human and machine intelligence.

Byron's work has been supported by grants from the Army Research Office (ARO), and the National Institutes of Health (NIH), the National Science Foundation (NSF). He won the Tufts University 2012 Outstanding Graduate Researcher award and his thesis work was recognized as The Runner Up for the 2013 ACM Special Interest Group on Knowledge Discovery and Data Mining (SIG KDD) Dissertation Award. He recently co-authored the winning submission for the Health Care Data Analytics Challenge at the 2015 IEEE International Conference on Healthcare Informatics.

Lu Wang is an Assistant Professor in the College of Computer and Information Science at Northeastern University. She earned her PhD in Computer Science from Cornell University, her BS in Intelligence Science and Engineering and her B.Econ in Economics from Peking University. Professor Wang is interested in developing natural language processing and machine learning techniques to help people efficiently and effectively understand and absorb knowledge from large-scale text data with inherent noise. She received an outstanding short paper award at ACL 2017 and a best paper nomination award at SIGDIAL 2012.

Rose Yu will be an Assistant Professor in the College of Computer and Information Science starting Fall 2018. Previously, she was a postdoctoral researcher in Caltech Computing and Mathematical Sciences. She earned her Ph.D. in Computer Sciences at the University of Southern California and was a visiting researcher at Stanford University.

Her research focuses on developing machine learning techniques for large-scale time series and spatiotemporal data. She is generally interested in the theory and applications of sequential decision making, optimization, and spatiotemporal modeling. Her work has been successfully applied to intelligent transportation, climate informatics, and social media anomaly detection. Among her awards, she was nominated as one of the 2015 “MIT Rising Stars in EECS”.