UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

**Report No. 3714 Revised**

# MEMORANDUM

**To:** Executive Committee of Faculty Council (February 1, 2022)
Faculty Council (February 18, 2022)

**From:** Professor Julie Audet
Chair, Engineering Graduate Education Committee (EGEC)

**Date:** January 28, 2022; revised February 1, 2022

**Re:** **EGEC Information Update**

## REPORT CLASSIFICATION

This is a routine or minor policy matter that has been approved by the Engineering Graduate Education Committee on behalf of Faculty Council[1]. It will be considered by the Executive Committee for endorsing and forwarding to Faculty Council for information.

**MAJOR MODIFICATION** (to a program in the Faculty of Arts and Science which will impact the Faculty of Applied Science and Engineering)

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| Master of Science in Applied Computing (MScAC) (offered through the Department of Computer Science) | Creation of a new concentration in Artificial Intelligence (AI) in partnership with the Department of Statistical Sciences and the Faculty of Applied Science and Engineering (FASE). See Appendix I. |

## RECOMMENDATION FOR FACULTY COUNCIL

For information.

[1] As a result of the 2005 Task Force on Graduate Education at the University of Toronto, EGEC has delegated authority to "consider and approve on behalf of Faculty Council and/or recommend to Faculty Council and/or SGS, matters relating to graduate curriculum, policy, new initiatives, program and course changes".

# University of Toronto
# Major Modification Proposal:

## New Field or Concentration Within an Existing Graduate Program

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| **Program:** | Master of Science in Applied Computing (MScAC) (offered through the Department of Computer Science) |
| **Existing fields or concentrations:** | Data Science,<br>Applied Math,<br>Quantum Computing |
| **Proposed new field or concentration:** | Artificial Intelligence (AI), Master's |
| **Unit (if applicable):** | Department of Computer Science in partnership with<br>Department of Statistical Sciences, and<br>Faculty of Applied Science and Engineering (FASE). |
| **Faculty/academic division:** | Faculty of Arts and Science (FAS)<br>Faculty of Applied Science and Engineering (FASE). |
| **Dean's office contact:** | Antoinette Handley (Vice-Dean Graduate) / Sharon Kelly (staff) |
| **Graduate unit contact:** | Arvind Gupta, Annie En-Shiun Lee |
| **Version date:** | January 28, 2022 |

# Summary

We propose a new concentration, Artificial Intelligence (AI), as part of the current Master of Science in Applied Computing (MScAC). The MScAC is offered through the Department of Computer Science (DCS), and the new Artificial Intelligence concentration will be offered in partnership with the Department of Statistical Sciences (DoSS) from the Faculty of Arts and Science (FAS), and the Faculty of Applied

Science and Engineering (FASE). Interested students will apply to the MScAC-AI concentration through the Department of Computer Science in the Faculty of Arts & Science.

The MScAC program began in 2010 and subsequently built concentrations in Data Science [DS] (introduced in 2017 jointly with the Department of Statistical Sciences); Applied Math [AM] (2019 jointly with Department of Mathematics), and Quantum Computing [QC] (2020 jointly with the Department of Physics). Interest from industry and students for the MScAC program has far exceeded the most optimistic projections. Recently, Forbes recognized the MScAC Data Science concentration as one of "The 10 Best Artificial Intelligence and Data Science Master's Courses For 2021". Leveraging the success of the program and the positioning of University of Toronto (U of T) as one of the best universities for AI research in the world, we propose to build an Artificial Intelligence concentration within the MScAC program.

The proposed AI concentration reflects the university's strength in Artificial Intelligence as the birthplace of Deep Learning through the work of Turing Award winner Geoffrey Hinton. In recognition of the increasing importance of many aspects of AI , curricular development in this area is critical to the research and training missions of these units. Leveraging faculty strength in this area is also aligned with the University's ambitions to become the global leader in Artificial Intelligence.

The demand for trainees with an expertise in Artificial Intelligence has become acute, as massive computational power and data storage became ubiquitous and simple to acquire. The proposed concentration in Artificial Intelligence builds on the current MScAC infrastructure by bringing in expertise from Artificial Intelligence, to meet:

1. Current student needs for master's level education in Artificial Intelligence;
2. Industrial demand for Artificial Intelligence experts (i.e., scientists, researchers, engineers);
3. Student demand for research experience with firms addressing significant challenges using techniques in Artificial Intelligence; and
4. UofT's burgeoning research emphasis in Artificial Intelligence.

# Effective Date

Effective September 1, 2022. In-progress students who have taken the required coursework will be allowed to switch to the concentration as of September 1, 2022.

# Academic Rationale

Artificial Intelligence (AI) germinated from a desire to imitate human behaviours with computational means. While much of AI is centered in Computer Science, the field draws on tool, techniques, and expertise from many disciplines including statistics, mathematics, and engineering. Today, AI includes intellectual focus such as knowledge representation, probabilistic and statistical theory, machine learning (deep learning), computational linguistics and natural language processing, computer vision, and robotics; AI is also being applied to a wide range of scientific domains, from medicine to the humanities. The efficacy of AI is embraced in industry as we witness rapid adoption from recommenders in e-commerce to self-driving vehicles in transportation. The COVID pandemic has accelerated this demand, as nearly every facet of human endeavour becomes digitally enabled. As such, there is an increasing need for automating processes, analyzing massive datasets, and modeling human tasks. Clearly this need will continue to grow, a trend that will substantially expand the need of the Artificial Intelligence expert.

An AI expert requires proficiency in AI techniques and methods; training in data management and distributed computing; and experience in scientific or industry collaboration. The proposed concentration in AI is unique at the University of Toronto and would become the pre-eminent program in Canada due to the strength and expertise in the partnering academic units. In addition, the fast-growing AI ecosystem in the Greater Toronto Area and the unrivalled wealth of potential collaborators in hospitals, research labs, and other entities would further enhance the quality and the attraction of the program. Note that many other institutions are also introducing graduate level programming in AI. For example, the University of Montreal, Carnegie Mellon University, and Northeastern University all offer several pathways to professional graduate-level education in AI. However, this MScAC concentration would be unique in offering industry-oriented applied research opportunities between collaborating faculties.

Currently, at the undergraduate level, the Department of Computer Science offers a focus in AI as part of its majors while the FASE offers a minor in AI engineering and a certificate in AI engineering. At the graduate level, students may choose to undertake research in AI through the research-based MSc or PhD programs or through an AI emphasis applied to areas such as in Health Policy, Management and Evaluation or Public Health. However, there are no disciplinary focused AI programs at the graduate level in either FAS or FASE. The structure of the MScAC program can readily accommodate a concentration in AI, and the curricular demand for training AI is best met through an AI concentration offered through the MScAC program.

This proposed new concentration within the current MScAC is characterised by the strong involvement of academic units within FAS and FASE that are responsible for a significant portion of the curriculum. This concentration also enhances and complements the current concentrations in the MScAC program. The concentration bears the name of the broad discipline of Artificial Intelligence, which couples interest from students for training in advanced computing, statistics, and engineering. With the growing demand for roles in industry with increasingly more sophistication in AI methodologies, this calls for customized curricula and training within the overall framework of the general MScAC program for an AI Concentration.

In summary, the massive growth in computational power, dataset availability, and problem complexity encountered by practitioners and researchers has been accompanied by increasing demand for specialized expertise lying at the interface of computational, statistical, and engineering sciences. This need is acutely felt in finance, life sciences, material sciences, and other crucial applications as the AI models used required either increased complexity or fundamentally different ways of problem solving. The partnership proposed for the AI concentration creates a seamless ecosystem that allows students to study AI from the vantage point of each of these disciplines. We believe that the proposed concentration will help meet demand, further integrating the activities between the partnering academic units, elevate the quality of training within those units, and align with the University's ambitions in and commitments to Artificial Intelligence.

# Need and Demand

Media reports constantly remind us of the emergence of large-scale complex problems in nearly every facet of life. These reports speak to the already enormous demand for expertise at the interface of technology in society and the growing opportunities for employment.

Nearly 50% of applications to the MScAC program indicate strong interest in AI. While students in the program could take relevant AI courses and strive to secure an AI research project, we believe this concentration will:

- Bring together expertise from across campus to build a focal point for AI teaching;
- Act as a clear marker for industry to secure AI talent;
- Pool resources in various academic units to enhance AI offerings;
- Clearly demarcate students interested in AI who could then have some priority in securing seats in graduate level AI courses in FAS and FASE; and
- Establish U of T as a centre for applied AI research and training.

We note that this concentration is part of the strategy for planning and forecasting the course and supervisor capacity in AI graduate education to better plan for ongoing demand.

In addition to the flow of student interest in AI, industrial demand for AI experts also contributes to the advancement of this field. This demand is highly evident in the MScAC program. MScAC has a long list of employers interested in engaging AI talent including Layer 6 AI, Modiface, Samsung AI Research, Vanguard, SOTI, and a long list of many more. This is not a fleeting trend. There has been a massive increase in companies looking to establish AI capabilities by engaging an AI proficient workforce. As an exciting kick-off to the 2022 new year, Forbes has named Toronto as the most important AI hub (#8 in the 10 AI Predictions for 2022). With Toronto as a global centre for AI research, it is little wonder multinational firms are establishing AI labs in the city while there is a burgeoning AI start-up and SME ecosystem within the Greater Toronto Area.

# Table 1: Graduate Enrolment Projections*

| Year in Program | Academic Year 2021-22 | | | Academic Year 2022-23 | | | Academic Year 2023-24 | | | Academic Year 2024-25 | | | Academic Year 2025-26 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total # | # in Conc | # Dom. | Tot # | # in Conc | # Dom | # | # | # | # | # | # | # | # | # |
| **1** | 79 | 0 | 15 | 90 | 30 | 20 | 105 | 35 | 25 | 120 | 40 | 30 | 135 | 45 | 35 |
| **2** | 64 | 0 | 22 | 79 | 15* | 15 | 90 | 30 | 20 | 105 | 35 | 25 | 120 | 40 | 30 |
| **Total** | 143 | 0 | 37 | 169 | 45 | 35 | 195 | 65 | 45 | 225 | 75 | 55 | 255 | 85 | 65 |

*reflects current MScAC students who can choose to opt into the AI concentration with the approval of the MScAC director.

Students admitted into the concentration will apply directly to the concentration through the MScAC program (i.e., the concentration is not open to students enrolled in Statistical Sciences or FASE graduate programs).

Notes:

1. Number of domestic students is an estimate of domestic enrolment across all MScAC concentrations (i.e. not just only the AI concentration). Traditionally about 35% of MScAC enrolments have been domestic but COVID seems to have disrupted this. We are projecting those domestic students will comprise a larger share of students going forward but not back to the pre-COVID numbers.
2. We are aware that some students who began the program in September 2021 may wish to be in the AI concentration once approved. We are providing an estimate of the number of such requests that may be granted in Summer, 2022. There is no material impact on the program for granting such a request since those students must show they will have fulfilled the academic requirements for this concentration by December 2022.
3. Admission targets in the table are conservative, based on:

a. Staffing: We are in discussions with FAS to expand the MScAC team commensurate with growth in the program.

b. Faculty supervision and available seats in courses: Targets are set in consultation with each partner department. We are being conservative in projecting the numbers in the table.

c. Space to house students: The program is housed at 700 University. There are currently 135 dedicated desks for MScAC and we plan to assign these to incoming students in first year (row marked as 1 for Year in the Program) since second year students will be spending the majority of their time at their internship and thus are not assigned seating (row marked as 2 for Year in the Program).
d. New concentrations: Discussions are on-going to build four additional concentrations. This may expand the partnership to additional departments which would increase resources and allow the program to expand further.
e. Quality of Applicants: Admission targets may not be met if there are insufficient applicants who meet the quality standards of the program.

These projections are commensurate with known demand. For example, the AI sector in Toronto has seen a rapid increase in demand for AI Experts in recent years. For the 2019 MScAC cohort, 41/54 (77%) of the internship projects involve some aspect of AI or Data Science; for the 2020 cohort, this demand has increased to 52/64 (81%). Student demand for AI courses also continues to increase.

# Admission Requirements

Students entering the Artificial Intelligence concentration of the MScAC program at the University of Toronto will register in the Department of Computer Science. The minimum admission requirements listed below are consistent with those criteria in the Department of Computer Science MSc program, and are similar to those of the current MScAC program concentrations.

**Minimum Admission Requirements:**

- Applicants are admitted under the General Regulations of the School of Graduate Studies. Applicants must also satisfy the Department of Computer Science's additional admission requirements stated below.
- An appropriate bachelor's degree from a recognized university in a related area such as physics, computer science, mathematics, statistics, engineering, or any discipline where there is a significant quantitative component. The completed bachelor's degree must include significant exposure to computer science or statistics or engineering including coursework in, calculus, linear algebra, probability and statistics,

programming languages, and computational methods as well as data structures and algorithms and computer systems.

- A standing equivalent to at least B+ in the final year of undergraduate studies.
- Applicants whose primary language is not English and who have graduated from a university where the primary language of instruction is not English must submit results of the Test of English as a Foreign Language (TOEFL) and International English Language Testing System (IELTS) with the following minimum scores: Internet-based TOEFL: 93/120 and 22/30 on the writing and speaking sections. IELTS: an overall score of 7.0, with at least 6.5 for each component.
- If students complete a portion of their degree in English, or part of their degree at another university where English is the language of instruction, applicants must still provide proof of English-language proficiency.
- Three letters of reference from faculty and/or employers, with preference for at least one such letter from a faculty member in Artificial Intelligence.
- Answers to four questions explaining applicant's interest in Artificial Intelligence and objectives for the program.
- Applicants must indicate a preference for a concentration in AI in their application. Admission to the AI concentration is on a competitive basis. Students admitted to the MScAC program are not automatically admitted to the AI concentration upon request.

As noted in the minimum admission requirements, admission to the AI Concentration is competitive. Achievement of the minimum standards does not guarantee admission into the program. Those accepted will normally have achieved a standing considerably higher than the minimum B+ standing and/or have demonstrated exceptional ability through appropriate workplace experience.

# 6 Program Requirements

## Program Requirements

- **Coursework.** Students must successfully complete a total of **3.0 full-course equivalents (FCEs)** as follows:
  - 1.5 FCEs of coursework in the area of Artificial Intelligence
    - 1.0 FCE selected from the core list of AI courses (see list below)[1] from at least two different research areas
    - 0.5 FCE selected from additional AI courses outside the core list.
- 1.0 FCE in required courses:
  CSC2701H *Communication for Computer Scientists* (0.5 FCE)
  CSC2702H *Technical Entrepreneurship* (0.5 FCE)
- The remaining 0.5 FCE of coursework will be chosen from outside of AI.
  - Course selections should be made in consultation with and approved by the Program Director. Appropriate substitutions may be possible with approval.
  - A maximum of 1.0 FCE may be chosen from outside the Computer Science (CSC course designator) graduate course listings.
- An eight-month industrial **internship**, CSC2703H (3.5 FCEs). The internship is coordinated by the department and evaluated on a pass/fail basis.

Please see Appendix B for a full list of the course numbers and titles. Note that these are existing courses offered by the participating departments. The creation of the AI concentration does not, has prompted the cross-listing of a new cross-listing of a robotics course at the graduate level. Students enrolled in the AI concentration will select existing courses from the Department of Computer Science, Department of Statistical Sciences, and Faculty of Applied Science and Engineering.

The AI concentration program requirements follow the structure of the existing MScAC program. The existing program and new concentration are designed as a 16-month (4 session, F/W/S/F) full-time program comprised of 4 half courses (2.0 FCEs) that will be completed in 8-months (2 sessions), 2 required courses in technical communications and entrepreneurship (1.0 FCE) and an 8-month (2 session) industrial internship (3.5 FCE).

Students in the new AI concentration, like those in the existing MScAC program, follow a course of study that is fully integrated; course projects and assignments will be designed to integrate the material learned from a variety of the courses and to utilize it in a practical context. Excellent communication and presentation skills will be emphasized in both the oral and written components of the projects and assignments. The program contains an 8-month internship component from May – December. The students will enter the internship immediately after coursework is completed at the end of the Winter term.

The required course work can be completed during the regular academic year. The course load of two half courses per session is identical to that of the current MScAC program.

In addition to the 4 half courses taken during the first 2 sessions, an additional two specialized half courses (in Technical Communication, and in Technical Entrepreneurship) are required. One of these courses is taken during the first eight months of the student's study, while the other is taken during the eight-month internship period.

Whereas the Province's Quality Assurance Framework requires that students complete a minimum of 2/3 courses at the graduate level, the University of Toronto requires graduate students to complete all their course requirements from amongst graduate level courses. This proposed AI Concentration complies with this requirement.

Among the total 2.0 FCEs, a minimum 1.0 FCE will come from the Computer Science graduate course listings, while a maximum of 1.0 FCE may be taken outside of Computer Science. Course selection must be approved by the program director.

Within the MScAC program support for establishing and maintaining industrial partners for internships is key to attracting students. The internship provides a critical experiential learning component, and helps students improve their communication skills. Students will not only gain practical experience in knowledge and technology transfer but will also have access to well-trained professional support staff in their

[1] Please refer to the proposed SGS calendar copy in Appendix A to see the list of core courses that students can choose from.

host company to realize their vision and make further connections in industry. An internship will be required for all students in the AI Concentration. This concentration would make MScAC interns even more attractive to employers.

For academic supervision, students in the AI concentration may choose a supervisor from any of the partner academic units (DCS, DoSS, FASE). Supervisors from other units may be chosen with approval of the program director. Note that the selection of an appropriate academic supervisor is facilitated by the program director once the student has accepted a qualifying internship placement.

All students in the MScAC, including students in the new concentration, receive individualized advising to ensure that they select courses that a) meet the program requirements, including any requirements specific to the concentration; b) have sufficient academic preparation for each course; and c) support their professional goals.

Students currently enrolled in the MScAC program may, as of September 2022, apply to join the AI concentration and will be considered on a case-by-case basis.

# Degree Level Expectations (DLEs), Program Learning Outcomes and Program Structure

## Table 2: Master's DLEs

| **Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs)** | **Master's Program Learning Outcomes** | **How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes** |
|---|---|---|
| **Expectations:** This AI Concentration in the MScAC program is awarded to students who have demonstrated: | | |
| Depth and Breadth of Knowledge<br><br>A systematic understanding of knowledge, and a critical awareness of current problems and/or new insights, much of which is at, or informed by, the forefront of the academic discipline, field of study or area of professional practice. | Depth and breadth of knowledge is understood in the MScAC program as the ability to explore, manipulate, and visualize complex data and models into informed decisions.<br><br>This is reflected in students who are able to:<br>• Use advanced problem-solving skills utilizing appropriate computational tools.<br>• Perform deep quantitative analysis of a given problem across a variety of domains. | Students will be able to understand the concepts of AI; use a variety of computational resources; and develop new AI algorithms to fit specific application areas. Relevant AI courses include:<br>CSC2515 - Introduction to Machine Learning<br>ECE1513 - Introduction to Machine Learning<br>CSC2516 - Neural Networks and Deep Learning<br>MIE1517 - Introduction to Deep Learning<br>CSC2502 - Knowledge Representation & Reasoning<br>CSC2533 - Foundations of Knowledge Representation<br>CSC2503 - Foundations of Computer Vision |

| Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs) | Master's Program Learning Outcomes | How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes |
|---|---|---|
| | • Use abstract reasoning and demonstrable critical and logical thinking. | ECE1512 - Digital Image Processing and Applications<br>CSC2501 - Computational Linguistics<br>CSC2511 - Natural Language Computing<br>AER1513 - State Estimation for Aerospace Vehicles (State Estimation for Robotics)<br>AER1517 - Control for Robotics<br>CSC2630 - Introduction to Mobile Robotics<br><br>The program design and requirement elements that ensure these student outcomes for depth and breadth of AI knowledge are the CSC, STA and/or FASE graduate courses selected by the student, or relevant courses from other departments. This includes 1.5 FCEs of coursework in the area of Artificial Intelligence with 1.0 FCE selected from the core list of AI courses (see list above) from at least two different research areas for breadth and 0.5 FCE |

| **Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs)** | **Master's Program Learning Outcomes** | **How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes** |
|---|---|---|
| | | selected from selected from additional AI courses outside the core list for depth. |
| Research and Scholarship<br><br>A conceptual understanding and methodological competence that<br>• Enables a working comprehension of how established techniques of research and inquiry are used to create and interpret knowledge in the discipline.<br>• Enables a critical evaluation of current research and advanced research and scholarship in the discipline or area of professional competence. | Research and Scholarship is defined in the MScAC program as the ability to abstract information.<br><br>This is reflected in students who are able to:<br>• Apply quantitative techniques to produce effective designs and solutions to a given problem.<br>• Identify, analyze and synthesize scholarly literature relevant to the problem at hand.<br>• Formulate hypotheses, and test these against given data.<br>• Create, review, validate and refine quantitative models to validate hypotheses. | In achieving these learning outcomes, students in the Artificial Intelligence concentration will be able to<br>• Define and describe AI techniques and where these differ from classical techniques,<br>• Identify when where there is an advantage to using AI in the broader context of enterprise-wide AI efforts and algorithm development,<br>• Formulate AI methods, spanning existing techniques and algorithms, which are tailored to new problems and applications,<br>• Communicate models and their analysis to non-experts verbally and in written form. |

| **Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs)** | **Master's Program Learning Outcomes** | **How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes** |
|---|---|---|
| • Enables a treatment of complex issues and judgments based on established principles and techniques; and, on the basis of that competence, has shown at least one of the following:<br>  • the development and support of a sustained argument in written form; or<br>  • originality in the application of knowledge. | | The MScAC program offers professional courses (CSC2701 – Communication for Computer Scientists and technical entrepreneurship and business CSC2702 – Technical Entrepreneurship ) designed to assist students in presenting themselves and their work as well as in scientific communications and business writing.<br><br>The program requirements that ensure these student outcomes for research and scholarship come from coursework training – students must select courses that have been vetted for appropriate technical content. Relevant courses could include:<br>CSC2416 - Machine Learning Theory<br>CSC2506 - Probabilistic Learning, Uncertainty, and Reasoning<br>CSC2518 - Spoken Language Processing<br>CSC2523 - Object Modelling and Recognition<br>CSC2528 - Advanced Computational Linguistics |

| Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs) | Master's Program Learning Outcomes | How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes |
|---|---|---|
| | | CSC2532 - Statistical Learning Theory<br>CSC2534 - Decision Making Under Uncertainty<br>CSC2539 - Topics in Computer Vision<br>CSC2541 - Topics in Machine Learning<br>CSC2542 - Topics in Knowledge Representation & Reasoning<br>CSC2545 - Kernel Methods & Support Vector Machines<br>CSC2547 - Current Algorithms and Techniques in Machine Learning<br>CSC2548 - Machine Learning in Computer Vision<br>CSC2556 - Algorithms for Collective Decision Making<br>CSC2558 - Human Computation, Randomized A/B Experiments and Statistical Machine Learning<br>CSC2559 / ECE1784 - Trustworthy Machine Learning<br>CSC2606 - Introduction to Continuum Robotics<br>CSC2621 - Topics in Robotics<br>CSC2626 - Imitation Learning for Robotics |

| **Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs)** | **Master's Program Learning Outcomes** | **How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes** |
|---|---|---|
| Level of Application of Knowledge<br><br>Competence in the research process by applying an existing body of knowledge in the critical analysis of a new question or of a specific problem or issue in a new setting. | Level of application of knowledge is defined in the MScAC program as the ability for systematic inquiry involving the practical application of quantitative techniques in a professional setting (company site, hospital, etc.) during an applied research internship.<br><br>This is reflected in students who are able to:<br>• Demonstrate competence in applying an existing body of knowledge in the critical analysis of a new question or of a specific problem or issue in a new setting.<br>• Deploy advanced theories, knowledge, methodologies, and techniques for a specific, often stated, business or client-driven challenge.<br>• Showcase an ability to take unstructured problems and deploy empirical methodologies. | The program design and requirement elements that ensure these student outcomes for level of application of knowledge are:<br><br>The application of research knowledge is assured through an industrial research internship that is jointly supervised by an academic AI expert and an industrial expert. During the internship, students will be required to apply their knowledge of AI to real-world problems in an industrial setting.<br>Internships are carefully procured and are reviewed by the MScAC program to ensure students are presented with problems requiring quantitative solutions with insights coming from the capabilities of AI.<br>The industry supervisor ensures problems are well formulated, and resources such as data are adequately provided while the academic supervisor is responsible for ensuring the student |

| **Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs)** | **Master's Program Learning Outcomes** | **How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes** |
|---|---|---|
| | | is utilizing advanced AI techniques and helps the student develop new techniques as needed. |
| Professional Capacity/Autonomy<br><br>• The qualities and transferable skills necessary for employment requiring<br>  • the exercise of initiative and of personal responsibility and accountability; and<br>  • decision-making in complex situations; | Professional capacity/autonomy is defined in the MScAC program as the qualities and transferable skills necessary for employment requiring the exercise of initiative and of personal responsibility and accountability; decision-making in complex situations; the intellectual independence required for continuing professional development; the ethical behaviour consistent with academic integrity and the use of appropriate guidelines and procedures for responsible conduct of research; and the ability to appreciate the broader implications of applying knowledge to particular contexts.<br><br>This is reflected in students who are able to:<br>• Prepare written reports and deliver oral presentations to | The program design and requirement elements that ensure these student outcomes for professional capacity/autonomy are:<br><br>• The industrial research internship that focuses on the exploration of new or specific problems, coupled with the students' quantitative skills and statistical rationale all with the aim of solving practical issues in an environment requiring complex AI techniques.<br>• In addition, as outlined in section 6, there is a special course on technical communications CSC2701 – Communication for Computer Scientists and technical entrepreneurship and business |

| **Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs)** | **Master's Program Learning Outcomes** | **How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes** |
|---|---|---|
| • The intellectual independence required for continuing professional development.<br>• The ethical behavior consistent with academic integrity and the use of appropriate guidelines and procedures for responsible conduct of research.<br>• The ability to appreciate the broader implications of applying knowledge to particular contexts. | expert (quantitative teams) and non-expert audiences (upper management)<br>• Provide a holistic perspective on advanced problem solving utilizing quantitative techniques in industry problems in a real-world setting. | CSC2702 – Technical Entrepreneurship. This is a required course.<br>• Students attend regularly scheduled meetings with both their academic and industrial supervisors and, at the industry site, with a broader team.<br>• Students present their research findings to both their supervisors in a research report that is assessed for their ability to apply knowledge in a new and creative manner, for their intellectual independence, and their ability to abstract their own work into a broader setting. |
| Level of Communication Skills | Level of communication skills is defined in the MScAC program as the ability to communicate ideas, issues, and conclusions clearly. | The program design and requirement elements that ensure these student outcomes for level of communication skills are: |

| **Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs)** | **Master's Program Learning Outcomes** | **How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes** |
|---|---|---|
| | This is reflected in students who are able to:<br>• Construct a credible argument and present it in appropriate formats<br>• Construct detailed research reports and executive summaries<br>• Deliver professional presentations to expert (quantitative teams) and non-expert audiences (upper management) | • The required written report on the internship experience is designed for students to connect their course work with their industrial experience.<br>• The oral presentation in front of faculty, industry experts and students will require students to discuss and critically assess their success at applying their academic knowledge to specific problems they encountered in their internship.<br>In addition, as outlined in section 6, there is a special course on technical communications skills; CSC2701 – Communication for Computer Scientists. This is a required course. |
| Awareness of the Limits of Knowledge<br><br>Cognizance of the complexity of knowledge and of the | This DLE and its PLOs are being developed through the current CSC UTQAP review. | Will be documented via the current CSC UTQAP review. |

| Master's Degree Level Expectations (Based on the Ontario Council of Academic Vice-Presidents [OCAV] DLEs) | Master's Program Learning Outcomes | How the Program Design and Requirement Elements Support the Attainment of Student Learning Outcomes |
|---|---|---|
| potential contributions of other interpretations, methods, and disciplines. | | |

# Assessment of Teaching and Learning

- Please describe the methods of evaluation for the various program requirements as they relate to the proposed field or concentration.
- Describe how the methods for assessing student achievement are appropriate and effective relative to established program learning outcomes and DLEs (in other words, how will faculty be able to determine whether students have learned and can do what we expect them to by the end of the program).
- How will the program document and demonstrate the level of performance of students consistent with the University's DLEs?

Student performance in the program will be assessed through a variety of methods including reports, presentations, assignments, case studies, and exams. Students will receive letter grades for their performance in all courses except that CR/NCR is given for their written reports on industrial internship.

The MScAC program has several formal processes in place to ensure the quality and excellence of the student's performance at each stage in the program.
Entering students create a relevant study plan that is assessed for what they have already studied, what they plan to study, and then ascertain whether that meets the PLO's, program requirements, and the student's personal learning objectives. This study plan is assessed by the concentration lead who works with the students on refining it; the final plan is assessed by the program director and finally the DCS graduate chair.

There is also a formal process to ensure each of the procured internships contains an appropriate level of applied research for the program by three MScAC research and business development officers. Any revision request discrepancies are further assessed by the program director.

Lastly, the MScAC program has a formal review process to ensure that the MScAC academic requirements are met for each student. Three individuals must sign off on the final research report – the industry supervisor, the academic supervisor, and the program Director. The MScAC program will assess the final report to decide whether the final report should require minor revisions or major revisions.

| Teaching and Learning Outcomes | Assignments | Projects | Exam | Presentations | Internship |
|---|---|---|---|---|---|
| **1. Depth and Breadth of Knowledge** | | | | | |
| Display expertise in AI methods and algorithms | Yes | Yes | Yes | Yes | Yes |
| Critically assess a problem that is complex and has alternative design approaches | | Yes | | Yes | Yes |
| Adjust communications to address different audiences | Yes | | | Yes | Yes |
| Identify key debates that result from conflicting practitioner/scientists/business views | | Yes | | Yes | Yes |
| 2. Scholarship | | | | | |
| Conceptualize, design, implement an AI project | Yes | Yes | | Yes | Yes |
| Make informed judgments on complex issues in the context of complex analysis | Yes | Yes | Yes | Yes | Yes |
| Articulate those strategies and judgments | Yes | Yes | | Yes | Yes |
| **3. Application of Knowledge** | | | | | |
| Assess a complex problem from the viewpoints of practitioners/scientists/business | Yes | Yes | | | Yes |
| **4. Professional Capacity** | | | | | |
| Complete the degree requirements in a timely manner | Yes | Yes | | Yes | Yes |
| Demonstrate project management skills | Yes | Yes | | Yes | Yes |
| **5. Communication Skills** | | | | | |
| Communicate complex ideas effectively | Yes | Yes | | Yes | Yes |

| | | | | | |
|---|---|---|---|---|---|
| Prepare reports and presentations that outline the problem, option, and solutions | Yes | Yes | | Yes | Yes |

# Consultation

The proposed AI concentration is the result of a lengthy discussion with faculty members from various departments from FAS and FASE.
There has been broad consultation for the AI concentration within the Department of Computer Science. Starting in 2019, faculty in the Department began discussing the potential for a Masters in AI. In 2020, the DCS graduate affairs committee created a working group to consider how best to construct an AI concentration within the MScAC program. The working group concluded that we should explore a partnership with the Department of Statistical Sciences, and Faculty of Applied Science and Engineering (primarily but not exclusively with the Department of Electrical and Computer Engineering and the Department of Mechanical and Industrial Engineering). A working group of these four departments was established in Summer 2021, resulting in this major modification proposal. Additional consultations took place with current students and alumni of the MScAC program, the latter through the MScAC alumni association. A roundtable was held with industry partners in April, 2021 to discuss the concentration. This was followed by a focused roundtable in August, 2021 with AI leaders in the Toronto tech . All verified that an AI concentration would be extremely well received.

With respect to the broader University of Toronto community, we consulted with the Office of the Vice-Provost, Research and Innovation about broader research interests in AI at U of T. We also consulted with the Industry Partnership Office and verified they are also witnessing significant demand for advanced AI in the Toronto Information Technology ecosystem. We consulted with a number of other academic units, primarily through a Data Science working group established by the Faculty of Arts and Science. This consultation included representatives from the Faculty of Medicine, Faculty of Applied Science and Engineering, the Dalla Lana School of Public Health, as well as departments in FAS. This consultation allowed us to position the AI concentration and the existing MScAC Data Science concentration as unique and non-overlapping.  A number of meetings have been held with the leadership in FASE

including with the Office of the Dean and with the Chairs of ECE and MIE. All were very supportive of jointly building this concentration.

We are cognizant that Artificial Intelligence is a strategic priority for the university and that a number of other academic units are planning to bolster their faculty complement in this area. This should create additional opportunities for partnership with the MScAC AI concentration. We welcome discussions with any academic unit that may be interested in participating in this concentration (or more broadly in the MScAC program).

# Resources

As the program grows, there will be resource implications on various fronts.
The concentration will be housed within the MScAC space at 700 University and additional space needs will be minimal (see Space/Infrastructure section). There are currently 135 dedicated desks for MScAC and we plan to assign these to incoming first year students, since second year outgoing students will be at their internship location.

Administrative staffing will be handled by the MScAC program and will be funded through revenues from the concentration itself. No new central funds will be required as this is intended to be a self-sustaining concentration within the existing MScAC program. MScAC revenue consists of student tuition, ancillary fees, and funds from industry; these funds are sufficient to cover all incremental expenses.

Our research and business team procures and reviews applied research internships from industry partners to help match students to high quality research projects. Therefore, incremental increase of enrolment targets is retrospectively adjusted based on the number of internships seen in the previous year by the team. The research and business development team are starting to build demand outside the Greater Toronto Area; there should be significant potential in other major Canadian tech centres (Waterloo, Ottawa, Montreal, Vancouver, etc).
The internships are fully funded by the industry partner who will provide salary for the student, the project may also be eligible for MITACS funding. Our current relationship with Mitacs Inc indicates that these internships should qualify for partial funding under the Mitacs Accelerate Canada program, which would offset $10,000 of the employer's costs. Note that current average total compensation is $63,000 per

student over eight months. The MScAC provides a loan structure for those students who demonstrate need and students are able to pay back the loan based on their internship and post-graduate job.

The program will continue to communicate annually with each of the collaborating departments on available resources in supervision and seats in courses in order to project admission targets. The DoSS and FASE will contribute in course/teaching capacity (see Appendix B) and in supervisory capacity (see Table 4). The MScAC has developed a revenue sharing model across academic units facilitating students taking courses or being supervised outside DCS. Simultaneously, the working group that was formed for the AI Concentration composed of faculty members from both FAS and FASE will continue to meet annually to provide oversight on the AI course offerings, such as removing courses that are no longer offered and adding new courses to the list, and the curriculum more broadly.

# Faculty Complement

The U of T Strategic Research Plan identifies artificial intelligence as one of the thematic areas for research excellence and collaboration due to U of T researchers being world-leaders in advancing artificial intelligence in areas such as computer vision, computational linguistic and natural language processing, knowledge representation and reasoning, cognitive robotics, and machine learning.
The concentration will require faculty expertise in various areas of AI as listed above and DCS is currently in the process of hiring several FTEs in the area of Artificial Intelligence. The Department of Chemical Engineering and Applied Chemistry has recently hired a faculty member in AI. There are faculty members working in AI or using AI in every FASE Department, with the advancement goal of having an AI/DS faculty member in each department. In the coming years, given the significant focus on AI within these departments and across the University, we expect additional faculty hiring in AI related areas, which will be in-sync with the expected growth rate of the proposed concentration: Knowledge Representation and Reasoning, Computer Vision and Computational Imaging, Systems, including Data Systems, Security and Cryptography, and Machine Learning with a focus on Deep Learning.

# Table 4: Detailed Listing of Committed Faculty

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Arvind Gupta, Professor and Director of MScAC | *Computer Science, FAS | Innovation policy |
| James Stafford, Professor & Vice-Dean of Academic Operations | * Statistical Sciences, FAS | Data Science |
| Chris J. Maddison, Assistant Professor | *Computer Science, FAS<br>*Statistical Sciences, FAS<br>Vector Institute | Machine learning |
| Marsha Chechik, Professor & Chair | *Computer Science, FAS | Software engineering |
| Graeme Hirst, Professor & Graduate Chair | *Computer Science, FAS | Computational linguistics |
| Suzanne Stevenson, Professor & Vice Chair | *Computer Science, FAS | Computational linguistics |
| Sven Dickinson, Professor | *Computer Science, FAS<br>Samsung Toronto AI Research Center | Computer vision |
| Michael Brudno, Professor | *Computer Science, FAS<br>University Health Network<br>Vector Institute | Computational medicine |
| Peter Marbach, Professor | *Computer Science, FAS | Social networks |
| Eyal de Lara, Professor, Associate Chair, Research | *Computer Science, FAS | Systems & mobile |
| Daniel Wigdor<br>Professor<br>Associate Chair, Partnerships and Innovation | *Computer Science, FAS<br>Facebook Research Science | Input sensors |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Sam Toueg, Professor | Computer Science, FAS | Distributed computing |
| Richard Zemel, Professor | *Computer Science, FAS<br>Vector Institute | Machine learning methods, with a specific focus on unsupervised learning, and probabilistic models of neural representations |
| Ravin Balakrishnan, Professor | *Computer Science, FAS | Human-computer interaction (HCI) |
| Geoffrey Hinton, Distinguished Emeritus Professor | *Computer Science, FAS<br>Google<br>Vector Institute | Machine learning |
| Anna Goldenberg, Associate Professor | Computer Science, FAS<br>SickKids Research Institute<br>Vector Institute | Machine learning |
| Allan Borodin, University Professor | *Computer Science, FAS | Theoretical computer science |
| Amir-Massoud Farahmand, Assistant Professor, Status-Only | Vector Institute<br>Computer Science, FAS<br>Mechanical and Industrial Engineering, FASE | Reinforcement learning |
| Sushant Sachdeva, Associate Professor | *Computer Science, FAS<br>Vector Institute | Theoretical computer science |
| Frank Rudzicz, Associate Professor, Status-Only | St. Michael's Hospital<br>Surgical Safety Technologies<br>Computer Science, FAS | Computational linguistics |
| Fanny Chevalier, Assistant Professor | *Computer Science, FAS<br>*Statistical Science, FAS | Information visualization |
| Igor Gilitschenski, Assistant Professor | *Computer Science, FAS | Robotics, computer vision |
| Florian Shkurti, Assistant Professor | *Computer Science, FAS | Robotics, computer vision |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Bo Wang, Assistant Professor | *Computer Science, FAS<br>Vector Institute<br>Faculty of Medicine<br>University Health Network | Machine learning |
| David Duvenaud, Assistant Professor | *Computer Science, FAS | Machine learning |
| Daniel Roy, Assistant Professor | *Statistical Sciences, FAS<br>*Computer Science, FAS<br>Electrical and Computer Engineering, FASE | Machine learning |
| Sanja Fidler, Associate Professor | *Computer Science, FAS<br>NVIDIA | Computer vision |
| Raquel Urtasun, Professor | *Computer Science, FAS<br>Waabi<br>Vector Institute | Autonomous driving |
| Jimmy Ba, Associate Professor | *Computer Science, FAS<br>Vector Institute | Deep learning |
| Roger Grosse, Associate Professor | *Computer Science, FAS<br>Vector Institute | Neural networks |
| Animesh Garg, Associate Professor | *Computer Science, FAS<br>Mechanical and Industrial Engineering, FASE<br>Vector Institute<br>NVIDIA | Reinforcement learning, Robotics |
| Gerald Penn, Professor | * Computer Science, FAS | Spoken language processing |
| Alán Aspuru-Guzik, Professor | * Computer Science, FAS | Machine learning |
| Anthony Bonner, Associate Professor | * Computer Science, FAS | Machine learning |
| Steve Easterbrook, Professor | * Computer Science, FAS | Sustainability informatics |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Murat Erdogdu, Assistant Professor | * Computer Science, FAS | Machine learning |
| Nick Koudas, Professor | * Computer Science, FAS | Data management systems |
| Rahul G. Krishnan, Assistant Professor | * Computer Science, FAS | Computational medicine |
| Kyros Kutulakos, Professor | * Computer Science, FAS | Computer vision |
| David Lindell, Assistant Professor | * Computer Science, FAS | Computer graphics |
| Maryam Mehri Dehnavi, Assistant Professor | * Computer Science, FAS | Systems |
| Gennady Pekhimenko, Assistant Professor | * Computer Science, FAS | Computer architecture |
| Toniann Pitassi, Professor | * Computer Science, FAS | Theoretical Computer Science |
| Bianca Schroeder, Professor | * Computer Science, FAS | Computer systems |
| Nisarg Shah, Assistant Professor | * Computer Science, FAS | Theoretical computer science |
| Florian Shkurti, Assistant Professor | * Computer Science, FAS | Robotics, computer vision |
| Nandita Vijaykumar, Assistant Professor | * Computer Science, FAS | Computer architecture, |
| Joseph Jay Williams, Assistant Professor | * Computer Science, FAS | Computer science & education |
| Fahiem Bacchus, Professor | * Computer Science, FAS | Knowledge Representation |
| David Fleet, Professor | * Computer Science, FAS | Computer vision |
| Kyros Kutulakos, Professor | * Computer Science, FAS | Computer vision |
| Sheila McIlraith, Professor | * Computer Science, FAS | Knowledge representation and reasoning |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Jessica Burgner-Kahrs, Associate Professor | * Computer Science, FAS | Robotics |
| Ashton Anderson, Assistant Professor | * Computer Science, FAS | Computational social science |
| Parham Arabi, Associate Professor | * Electrical & Computer Engineering, FASE<br>Founder & CEO ModiFace Inc | Internet Search |
| Ravi Adve, Professor | * Electrical & Computer Engineering, FASE | Wireless communications |
| Jason Anderson, Professor | * Electrical & Computer Engineering, FASE<br>Chief Scientific Advisor and Co-Founder of LegUp Computing Inc. | CAD |
| Vaughn Betz, Professor | * Electrical & Computer Engineering, FASE<br>Faculty Affiliate, Vector Institute for Artificial Intelligence | CAD |
| Paul Chow, Professor | * Electrical & Computer Engineering, FASE | Computer architectures |
| Stark Draper, Professor | * Electrical & Computer Engineering, FASE | Information theory |
| Brendan Frey, Professor | * Electrical & Computer Engineering, FASE<br>CEO Deep Genomics | AI biology, medicine and healthcare |
| Dimitrios Hatzinakos, Professor | * Electrical & Computer Engineering, FASE<br>Co-founder and Director of Identity, Privacy and Security Institute (IPSI) | Signal Processing |
| Ashish Khisti, Professor | * Electrical & Computer Engineering, FASE | Communication systems |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Deepa Kundur, Professor and Chaire | * Electrical & Computer Engineering, FASE | Cybersecurity |
| Alberto Leon-Garcia, Professor | * Electrical & Computer Engineering, FASE<br>CTO of AcceLight Networks | Application platforms |
| Ben Liang, Professor | * Electrical & Computer Engineering, FASE | Networked systems |
| Xilin Liu, Assistant Professor | * Electrical & Computer Engineering, FASE | IC and system design |
| Mo Mojahedi, Professor | * Electrical & Computer Engineering, FASE | Electromagnetics |
| Kostas Plataniotis, Professor | * Electrical & Computer Engineering, FASE | Image/signal processing |
| Joanathan Rose, Professor | * Electrical & Computer Engineering, FASE | Applied mental health |
| Ervin Sejdic, Professor | * Electrical & Computer Engineering, FASE | Biomedical signal processing |
| Ali Sheikholeslami, Professor | * Electrical & Computer Engineering, FASE | Integrated circuits |
| Shahrokh Valaee, Professor | * Electrical & Computer Engineering, FASE | Wireless networks |
| Wei Yu, Professor | * Electrical & Computer Engineering, FASE | Network information theory |
| Shurui Zhou, Assistant Professor | * Electrical & Computer Engineering, FASE | Software collaboration |
| David Lie, Professor | * Electrical & Computer Engineering, FASE | Security |
| Andreas Moshovos, Professor | * Electrical & Computer Engineering, FASE | High-performance processor |
| Nicolas Papernot, Assistant Professor | * Electrical & Computer Engineering, FASE<br>Faculty Member at the Vector Institute<br>Canada CIFAR AI Chair | Security and privacy |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Christopher Lawson, Assistant Professor | * Chemical Engineering, FASE | Microbiome engineering |
| Arun Ramchandran, Associate Professor | * * Chemical Engineering, FASE | Microscale/nanoscale interactions |
| Edgar Acost, Professor | Chemical Engineering, FASE | Colloids and formulation engineering |
| Will Cluett, Professor | * Chemical Engineering, FASE | Process identification |
| Radhakrishnan Mahadevan, Professor | * Chemical Engineering, FASE | Systems biology |
| Christopher Yip, Professor and Dean | * Chemical Engineering, FASE | Molecular self-assembly |
| Tamer El-Diraby, Associate Professor | * Civil & Mineral Engineering, FASE | Asset management |
| Sebastian Goodfellow, Assistant Professor | * Civil & Mineral Engineering, FASE | Laboratory experimentation |
| Kamran Esmaeili, Associate Professor | * Civil & Mineral Engineering, FASE | Mining Engineering |
| Baher Abdulhai, Professor | * Civil & Mineral Engineering, FASE | Intelligent Transportation Systems |
| Michael Garton, Assistant Professor | * Institute of Biomedical Engineering, FASE | Computational protein design |
| Azadeh Kushki, Assistant Professor | * Institute of Biomedical Engineering, FASE | Pattern analysis and machine learning |
| Babak Taati, Assistant Professor | * University Health Network Institute of Biomedical Engineering, FASE Computer Science | Health & assistive technology |
| Azadeh Yadollahi, Assistant Professor (cross appointed) | * University Health Network Institute of Biomedical Engineering, FASE | Biological Systems |
| Rodrigo Fernandez-Gonzalez, Associate Professor | Institute of Biomedical Engineering, FASE | Cell coordination |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| José Zariffa, Associate Professor | * Institute of Biomedical Engineering, FASE | Rehabilitation technology |
| Jonathan Rocheleau | * Institute of Biomedical Engineering, FASE | Biological Interaction |
| Chirag Variawa, Assistant Professor Teaching Stream | * Institute for Studies in Transdisciplinary Engineering, FASE | Engineering Education |
| Yu Zou, Assistant Professor | * Materials Science & Engineering, FASE | Material Engineering |
| Kinnor Chattopadhyay, Associate Professor and Dean's Catalyst Professor | * Materials Science & Engineering, FASE | Material Engineering |
| Chandra Veer Singh, Associate Professor | * Materials Science & Engineering, FASE | Computational materials science |
| Jason Hattrick-Simpers, Professor | * Materials Science & Engineering, FASE | Corrosion Resistant Complex Alloy Coatings |
| Jonathan Kelly, Assistant Professor | * University of Toronto Institute for Aerospace Studies (UTIAS), FASE | Robotics |
| Angela Schoellig, Assistant Professor | * University of Toronto Institute for Aerospace Studies (UTIAS), FASE | Robotics |
| Tim Barfoot, Associate Professor | * University of Toronto Institute for Aerospace Studies (UTIAS), FASE | Robotics |
| Steven Waslander, Associate Professor | * University of Toronto Institute for Aerospace Studies (UTIAS), FASE | Autonomous driving. |
| Dionne M. Aleman, Associate Professor | * Mechanical & Industrial Engineering, FASE | Medical applications |
| Samin Aref , Assistant Professor, Teaching Stream | * Mechanical & Industrial Engineering, FASE | Data science |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Fae Azhari, Assistant Professor | * Mechanical & Industrial Engineering, FASE | Structural health monitoring |
| Christopher Beck, Professor | * Mechanical & Industrial Engineering, FASE | Optimization |
| Kamran Behdinan, Professor | * Mechanical & Industrial Engineering, FASE | Multidisciplinary Engineering Design |
| Beno Benhabib, Professor | * Mechanical & Industrial Engineering, FASE | Robotics |
| Amy Bilton, Associate Professor | * Mechanical & Industrial Engineering, FASE | Energy systems |
| Merve Bodur, Assistant Professor | * Mechanical & Industrial Engineering, FASE | Optimization |
| Michael W. Carter, Professor | * Mechanical & Industrial Engineering, FASE | Healthcare resourcing |
| Timothy C. Y. Chan, Professor | * Mechanical & Industrial Engineering, FASE | Operations research |
| Mark H. Chignell, Professor | * Mechanical & Industrial Engineering, FASE | Human factors |
| Eldan Cohen, Assistant Professor | * Mechanical & Industrial Engineering, FASE | Machine learning |
| Sinisa Colic, Assistant Professor, Teaching Stream | * Mechanical & Industrial Engineering, FASE | Mental Health |
| Mariano P. Consens, Associate Professor | * Mechanical & Industrial Engineering, FASE | Data management |
| Eric Diller, Associate Professor | * Mechanical & Industrial Engineering, FASE | Micro-scale robotics |
| Birsen Donmez, Professor | * Mechanical & Industrial Engineering, FASE | Human factors |
| Mark S. Fox, Professor | * Mechanical & Industrial Engineering, FASE | Reasoning |
| Daniel M. Frances, Professor, Teaching Stream | * Mechanical & Industrial Engineering, FASE | Simulation techniques |

| Faculty Name and Rank | Home Unit (*) & Major Affiliations | Area(s) of Specialization |
|---|---|---|
| Michael Gruninger, Professor | * Mechanical & Industrial Engineering, FASE | Ontologies |
| Michael Guerzhoy, Assistant Professor, Teaching Stream | * Mechanical & Industrial Engineering, FASE | Machine learning |
| Greg A. Jamieson, Professor | * Mechanical & Industrial Engineering, FASE | Human interaction automation |
| Elias B. Khalil, Assistant Professor | * Mechanical & Industrial Engineering, FASE | Machine learning |
| Roy H. Kwon, Professor | * Mechanical & Industrial Engineering, FASE | Mathematical optimization |
| Chi-Guhn Lee, Professor | * Mechanical & Industrial Engineering, FASE | Logistics problems |
| Xinyu Liu, Professor | * Mechanical & Industrial Engineering, FASE | Microfluidics and lab-on-a-chip |
| Matthew Mackay, Associate Professor | * Mechanical & Industrial Engineering, FASE | Vision |
| Scott Sanner, Associate Professor | * Mechanical & Industrial Engineering, FASE | Data Analysis and AI |
| Vahid Sarhangian, Assistant Professor | * Mechanical & Industrial Engineering, FASE | Stochastic modelling |
| Anthony N. Sinclair, Professor | * Mechanical & Industrial Engineering, FASE | Material characterization |
| David Sinton, Professor | * Mechanical & Industrial Engineering, FASE | Energy; environment; fluid mechanics |
| Yu Sun, Professor | * Mechanical & Industrial Engineering, FASE | Robotics and automation |
| Edmond Young, Associate Professor | * Mechanical & Industrial Engineering, FASE | Microfluidics |

# Space/Infrastructure

Students in the concentration will be provided office space in the new MScAC space at 700 University Ave, alongside the current MScAC students. IT support is provided by a 0.25 FTE IT staff member in the Department of Computer Science. There is no lab space or specialized

| |
|---|
| equipment requirement for the program beyond that which is already made available to DCS graduate students. |

# UTQAP Process

The UTQAP pathway is summarized in the table below.

| **Steps** | **Approval** |
|---|---|
| Development/consultation within unit | Fall 2021 / Winter 2022 |
| Consultation with Dean's office (and VPAP) | Winter / Spring 2022 (October 3rd, 2021) |
| VPAP | January 20, 2022 |
| Graduate unit approval as appropriate | Fall 2021 |
| Faculty/divisional council | GCC: February 3rd, 2022<br>A&S Council: February 9, 2022 |
| Submission to Provost's office | February 9, 2022 |
| Report to AP&P | May 2022 |
| Report to Ontario Quality Council | July 2022 |

# Appendix A: Calendar Entry

## 2021-22 SGS Calendar: Computer Science

Exported on June 14, 2021. For editing purposes only.

## Computer Science: Introduction

### Faculty Affiliation

Arts and Science

### Degree Programs

#### Applied Computing

**MScAC**

- Concentrations:
  - Applied Mathematics;
  - Artificial Intelligence;
  - Data Science;
  - Quantum Computing

## Computer Science

**MSc and PhD**

## Collaborative Specializations

The following collaborative specializations are available to students in participating degree programs as listed below:

- Genome Biology and Bioinformatics
  - Computer Science, PhD
- Knowledge Media Design
  - Computer Science, MSc, PhD
- Neuroscience
  - Computer Science, MSc, PhD

# Overview

Graduate faculty in the Department of Computer Science are interested in a wide range of subjects related to computing, including programming languages and methodology, software engineering, operating systems, compilers, distributed computation, networks, numerical analysis and scientific computing, financial computation, data structures, algorithm design and analysis, computational complexity, cryptography, combinatorics, graph theory, artificial intelligence, neural networks, knowledge representation, computational linguistics, computer vision, robotics, database systems, graphics, animation, interactive computing, and human-computer interaction.

For further details, consult the graduate student handbook prepared by the department and available online.

# Contact and Address

## MSc and PhD Programs

Web: web.cs.toronto.edu
Email: gradapplications@cs.toronto.edu
Telephone: (416) 978-8762

Department of Computer Science Graduate Office
University of Toronto
Bahen Centre for Information Technology
40 St. George Street
Toronto, Ontario M5S 2E4
Canada

## MScAC Program

Web: mscac.utoronto.ca
Email: mscac@cs.toronto.edu
Telephone: (416) 978-5180

University of Toronto
700 University Avenue, 9th Floor
Toronto, ON M5G 1Z5
Canada

# Computer Science: Applied Computing MScAC

## Master of Science in Applied Computing

### Program Description

The MScAC program is offered as a general Computer Science program (i.e., no concentration) or as a concentration in

- Applied Mathematics~~,~~ offered jointly by the Department of Computer Science and the Department of Mathematics;
- Artificial Intelligence, offered jointly by the Department of Computer Science, the Department of Statistical Sciences, and the Faculty of Engineering and Applied Science;
- Data Science, offered jointly by the Department of Computer Science and the Department of Statistical Sciences; or
- Quantum Computing, offered jointly by the Department of Computer Science and the Department of Physics.

~~The Applied Mathematics concentration is offered jointly by the Department of Computer Science and the Department of Mathematics. The Data Science concentration is offered jointly by the Department of Computer Science and the Department of Statistical Sciences. The Quantum Computing concentration is offered jointly by the Department of Computer Science and the Department of Physics. The Artificial Intelligence concentration is offered jointly by the Department of Computer Science and collaborating units: the Department of Statistical Sciences, and the Faculty of Engineering and Applied Science.~~

There is no thesis requirement.

## MScAC General Program (No Concentration)

### Minimum Admission Requirements

- Applicants are admitted under the General Regulations of the School of Graduate Studies. Applicants must also satisfy the Department of Computer Science's additional admission requirements stated below.
- An appropriate bachelor's degree from a recognized university in computer science or a related discipline.
- A standing equivalent to at least B+ in the final year of undergraduate studies.

- Applicants whose primary language is not English and who have graduated from a university where the primary language of instruction is not English must submit results of the Test of English as a Foreign Language (TOEFL) and International English Language Testing System (IELTS) with the following minimum scores:
  - Internet-based TOEFL: 93/120 and 22/30 on the writing and speaking sections.
  - IELTS: an overall score of 7.0, with at least 6.5 for each component.
- If students complete a portion of their degree in English, or part of their degree at another university where English is the language of instruction, applicants must still provide proof of English-language proficiency.
- Three letters of support from faculty and/or employers.
- A statement of purpose explaining the applicant's interest in computer science and objectives for the program.

## Program Requirements

- **Coursework.** Students must successfully complete a total of **3.0 full-course equivalents (FCEs)** including:
  - 1.0 FCE in required courses: technical communications (CSC2701H) and technical entrepreneurship (CSC2702H).
- An eight-month industrial **internship**, CSC2703H (3.5 FCEs). The internship is coordinated by the department and evaluated on a pass/fail basis.
- ~~There is no thesis requirement.~~

## Program Length

4 sessions full-time (typical registration sequence: F/W/S/F)

## Time Limit

3 years full-time

# MScAC Program (Artificial Intelligence Concentration)

## Minimum Admission Requirements

- Applicants are admitted under the General Regulations of the School of Graduate Studies. Applicants must also satisfy the Department of Computer Science's additional admission requirements stated below.

- An appropriate bachelor's degree from a recognized university in a related area such as physics, computer science, mathematics, statistics, engineering, or any discipline where there is a significant quantitative component. The completed bachelor's degree must include significant exposure to computer science or statistics or engineering including coursework in, calculus, linear algebra, probability and statistics, programming languages, and computational methods as well as data structures and algorithms and computer systems.
- ~~A minimum average grade of B+ over the final two years of undergraduate studies.~~ A standing equivalent to at least B+ in the final year of undergraduate studies.
- Applicants whose primary language is not English and who have graduated from a university where the primary language of instruction is not English must submit results of the Test of English as a Foreign Language (TOEFL) and International English Language Testing System (IELTS) with the following minimum scores: Internet-based TOEFL: 93/120 and 22/30 on the writing and speaking sections. IELTS: an overall score of 7.0, with at least 6.5 for each component.
- If students complete a portion of their degree in English, or part of their degree at another university where English is the language of instruction, applicants must still provide proof of English-language proficiency.
- Three letters of reference from faculty and/or employers, with preference for at least one such letter from a faculty member in Artificial Intelligence.
- Answers to four questions explaining applicant's interest in Artificial Intelligence and objectives for the program.
- Applicants must indicate a preference for a concentration in AI in their application. Admission to the AI concentration is on a competitive basis. Students admitted to the MScAC program are not automatically admitted to the AI concentration upon request.

## Program Requirements

- **Coursework.** Students must successfully complete a total of **3.0 full-course equivalents (FCEs)** as follows:

1.5 FCEs of coursework in the area of Artificial Intelligence

- 1.0 FCE selected from the core list of AI courses (see list below) from at least two different research areas

- 0.5 FCE selected from additional AI courses outside the core list.

1.0 FCE in required courses:

- CSC2701H *Communication for Computer Scientists* (0.5 FCE)
- CSC2702H *Technical Entrepreneurship* (0.5 FCE)

Remaining 0.5 FCE of coursework will be chosen from outside of AI .

- Course selections should be made in consultation with and approved by the Program Director. Appropriate substitutions may be possible with approval.
- A maximum of 1.0 FCE may be chosen from outside the Computer Science (CSC course designator) graduate course listing.

- An eight-month industrial **internship**, CSC2703H (3.5 FCEs). The internship is coordinated by the department and evaluated on a pass/fail basis.

## Artificial Intelligence Core Courses

| Course Code | Title |
|---|---|
| CSC2515H* | Introduction to Machine Learning (exclusion: ECE 1513H) |
| ECE1513H* | Introduction to Machine Learning (exclusion: CSC 2515H) |
| CSC2516H** | Neural Networks and Deep Learning (exclusion: MIE 1517H) |
| MIE1517H** | Introduction to Deep Learning (exclusion: CSC 2516H) |
| CSC2502H | Knowledge Representation & Reasoning |
| CSC2533H | Foundations of Knowledge Representation |
| CSC2503H | Foundations of Computer Vision |
| ECE1512H | Digital Image Processing and Applications |
| CSC2501H | Computational Linguistics |
| CSC2511H | Natural Language Computing |
| AER1513H | State Estimation for Aerospace Vehicles (State Estimation for Robotics) |
| AER1517H | Control for Robotics |
| CSC2630H | Introduction to Mobile Robotics (pending governance approval – April 2022) |

*different courses with same title, offered by different faculties.

**different courses with similar titles, offered by different faculties.

# MScAC Program (Applied Mathematics Concentration)

## Minimum Admission Requirements

- Applicants are admitted under the General Regulations of the School of Graduate Studies. Applicants must also satisfy the Department of Computer Science's additional admission requirements stated below.

- An appropriate bachelor's degree from a recognized university in a related area such as applied mathematics, mathematics, physics, computational mathematics, statistics, computer science, or any discipline where there is a significant quantitative and/or mathematical component. The completed bachelor's degree must include significant exposure to advanced mathematics, statistics, and computer science, including coursework in advanced and multivariate calculus (preferably analysis), linear algebra, probability and statistics, programming languages, and general computational methods.
- A standing equivalent to at least B+ in the final year of undergraduate studies.
- Applicants whose primary language is not English and who have graduated from a university where the primary language of instruction is not English must submit results of the Test of English as a Foreign Language (TOEFL) and International English Language Testing System (IELTS) with the following minimum scores:
  - Internet-based TOEFL: 93/120 and 22/30 on the writing and speaking sections.
  - IELTS: an overall score of 7.0, with at least 6.5 for each component.
- If students complete a portion of their degree in English, or part of their degree at another university where English is the language of instruction, applicants must still provide proof of English-language proficiency.
- Three letters of reference from faculty and/or employers, with preference for at least one such letter from a faculty member in Mathematics or Applied Mathematics.
- A statement of purpose explaining the applicant's interest in applied mathematics and objectives for the program.
- Applicants must indicate a preference for the concentration in Applied Mathematics in their application. Admission is competitive, and students who are admitted into the MScAc program are not automatically admitted to this concentration upon request.
- There is no thesis requirement.

## Program Requirements

- **Coursework.** Completion of **3.0 full-course equivalents (FCEs)** including:

- 1.0 FCE chosen from the MAT 1000-level courses or higher. This may include courses cross-listed as APM400 level.
- 1.0 FCE chosen from the Computer Science (CSC course designator) graduate course listings.
- 1.0 FCE in required courses:

CSC2701H *Communication for Computer Scientists* (0.5 FCE) and
CSC2702H *Technical Entrepreneurship* (0.5 FCE).

- Course selections should be made in consultation with the Program Director.

- An eight-month industrial **internship**, CSC2703H (3.5 FCEs). The internship is coordinated by the department and evaluated on a pass/fail basis.

## Program Length

4 sessions full-time (typical registration sequence: F/W/S/F)

## Time Limit

3 years full-time

# MScAC Program (Data Science Concentration)

## Minimum Admission Requirements

- Applicants are admitted under the General Regulations of the School of Graduate Studies. Applicants must also satisfy the Department of Computer Science's additional admission requirements stated below.
- An appropriate bachelor's degree from a recognized university in a related area such as statistics, computer science, mathematics, or any discipline where there is a significant quantitative component. The completed bachelor's degree must include significant exposure to statistics, computer science, and mathematics, including coursework in advanced calculus, linear algebra, probability and statistics, programming languages, and computational methods.
- A standing equivalent to at least B+ in the final year of undergraduate studies.
- Applicants whose primary language is not English and who have graduated from a university where the primary language of instruction is not English must submit results of the Test of English as a Foreign Language (TOEFL) and International English Language Testing System (IELTS) with the following minimum scores:
  - Internet-based TOEFL: 93/120 and 22/30 on the writing and speaking sections.
  - IELTS: an overall score of 7.0, with at least 6.5 for each component.
- If students complete a portion of their degree in English, or part of their degree at another university where English is the language of instruction, applicants must still provide proof of English-language proficiency.
- Three letters of support from faculty and/or employers.
- A statement of purpose explaining the applicant's interest in data science and objectives for the program.
- Applicants must indicate a preference for the concentration in Data Science in their application. Admission is competitive, and students who are admitted to the MScAC program are not automatically admitted to this concentration upon request.

## Program Requirements

- **Coursework.** Completion of **3.0 full-course equivalents (FCEs)** including:

- 1.0 FCE chosen from the STA 2000-level courses or higher. This may include a maximum of 0.5 FCE chosen from the STA 4500-level of six-week modular courses (0.25 FCE each).
- 1.0 FCE chosen from the Computer Science (CSC course designator) graduate course listings.
- 1.0 FCE in required courses:

CSC2701H *Communication for Computer Scientists* (0.5 FCE) and
CSC2702H *Technical Entrepreneurship* (0.5 FCE).

- Course selections should be made in consultation with the Program Director.

- An eight-month industrial **internship**, CSC2703H (3.5 FCEs). The internship is coordinated by the department and evaluated on a pass/fail basis.
- There is no thesis requirement.

## Program Length

4 sessions full-time (typical registration sequence: F/W/S/F)

## Time Limit

3 years full-time

# MScAC Program (Quantum Computing Concentration)

## Minimum Admission Requirements

- Applicants are admitted under the General Regulations of the School of Graduate Studies. Applicants must also satisfy the Department of Computer Science's additional admission requirements stated below.
- An appropriate bachelor's degree from a recognized university in a related area such as physics, computer science, mathematics, or any discipline where there is a significant quantitative component. The completed bachelor's degree must include significant exposure to physics, computer science, and mathematics, including coursework in advanced quantum mechanics, multivariate calculus, linear algebra, probability and statistics, programming languages, and computational methods.
- A standing equivalent to at least B+ in the final year of undergraduate studies.

- Applicants whose primary language is not English and who have graduated from a university where the primary language of instruction is not English must submit results of the Test of English as a Foreign Language (TOEFL) and International English Language Testing System (IELTS) with the following minimum scores:
  - Internet-based TOEFL: 93/120 and 22/30 on the writing and speaking sections.
  - IELTS: an overall score of 7.0, with at least 6.5 for each component.
- If students complete a portion of their degree in English, or part of their degree at another university where English is the language of instruction, applicants must still provide proof of English-language proficiency.
- Three letters of reference from faculty and/or employers, with preference for at least one such letter from a faculty member in Physics.
- A statement of purpose explaining the applicant's interest in quantum computing and objectives for the program.
- Applicants must indicate a preference for the concentration in Quantum Computing in their application. Admission is competitive, and students who are admitted to the MScAC program are not automatically admitted to this concentration upon request.

## Program Requirements

- **Coursework.** Completion of **3.0 full-course equivalents (FCEs)** as follows:
  - 1.0 FCE chosen from the Physics (PHY course designator) graduate course listings. Of eligible courses, the following are examples that are particularly relevant to the Quantum Computing concentration:

PHY1500H *Statistical Mechanics* (0.5 FCE)
PHY1520H *Quantum Mechanics* (0.5 FCE)
PHY1610H *Scientific Computing for Physicists* (0.5 FCE)
PHY2203H *Quantum Optics I* (0.5 FCE)
PHY2204H *Quantum Optics II* (0.5 FCE)
PHY2211H *Quantum Information Theory* (0.5 FCE)
PHY2212H *Entanglement Physics* (0.5 FCE)

  - 1.0 FCE chosen from the Computer Science (CSC course designator) graduate course listings. Of eligible courses, the following are examples that are particularly relevant to the Quantum Computing concentration:

CSC2305H *Numerical Methods for Optimization Problems* (0.5 FCE)

CSC2414H *Topics in Applied Discrete Mathematics* (0.5 FCE)
CSC2421H *Topics in Algorithms* (0.5 FCE)
CSC2451H *Quantum Computing, Foundations to Frontier* (0.5 FCE)

- 1.0 FCE in required courses:

CSC2701H *Communication for Computer Scientists* (0.5 FCE)
CSC2702H *Technical Entrepreneurship* (0.5 FCE)

- Course selections should be made in consultation with the Program Director. Appropriate substitutions may be possible with approval.

- An eight-month industrial **internship**, CSC2703H (3.5 FCEs). The internship is coordinated by the department and evaluated on a pass/fail basis.
- There is no thesis requirement.

### Program Length

4 sessions full-time (typical registration sequence: F/W/S/F)

### Time Limit

3 years full-time

## Computer Science: Computer Science MScAC, MSc, PhD Courses

Not all courses are offered every year. Please consult the department for course offerings.

| | |
|---|---|
| CSC2104H | Formal Methods of Program Design |
| CSC2107H | Compilers and Interpreters |
| CSC2108H | Automated Verification |
| CSC2125H | Algorithmic Program Verification |
| CSC2206H | Computer Systems Modelling |
| CSC2208H | Advanced Operating Systems |
| CSC2209H | Computer Networks |
| CSC2221H | Introduction to Distributed Computing |

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|---|---|
| CSC2222H | Applications of Parallel and Distributed Computing |
| CSC2224H | Parallel Computer Architecture and Programming |
| CSC2226H | Topics in Verification |
| CSC2227H | Topics in the Design and Implementation of Operating Systems |
| CSC2228H | Topics in Mobile, Pervasive, and Cloud Computing |
| CSC2231H | Topics in Computer Systems |
| CSC2233H | Topics in Storage Systems |
| CSC2305H | Numerical Methods for Optimization Problems |
| CSC2306H | High Performance Scientific Computing |
| CSC2310H | Computational Methods for Partial Differential Equations |
| CSC2321H | Matrix Calculations |
| CSC2326H | Topics in Numerical Analysis |
| CSC2401H | Introduction to Computational Complexity |
| CSC2404H | Computability and Logic |
| CSC2405H | Automata Theory |
| CSC2410H | Introduction to Graph Theory |
| CSC2412H | Algorithms for Private Data Analysis<br>(Prerequisite: CSC 373 or equivalent, or permission of the instructor.) |
| CSC2414H | Topics in Applied Discrete Mathematics |
| CSC2415H | Advanced Topics in the Theory of Distributed Computing |
| CSC2416H | Machine Learning Theory |
| CSC2417H | Algorithms for Genome Sequence Analysis |
| CSC2419H | Topics in Cryptography |
| CSC2420H | Algorithm Design, Analysis, and Theory |

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|---|---|
| CSC2421H | Topics in Algorithms |
| CSC2426H | Fundamentals of Cryptography |
| CSC2427H | Topics in Graph Theory |
| CSC2429H | Topics in the Theory of Computation |
| CSC2431H | Topics in Computational Molecular Biology |
| CSC2451H | Quantum Computing, Foundations to Frontier<br>(Exclusion: MAT1751H Quantum Computing, Foundations to Frontier.) |
| CSC2501H | Computational Linguistics |
| CSC2502H | Knowledge Representation and Reasoning |
| CSC2503H | Foundations of Computer Vision |
| CSC2504H | Computer Graphics |
| CSC2506H | Probabilistic Learning and Reasoning |
| CSC2508H | Advanced Management Systems |
| CSC2510H | Topics in Information Systems |
| CSC2511H | Natural Language Computing |
| CSC2512H | Constraint Satisfaction Problems |
| CSC2513H | Critical Thinking for Human Computer Interaction<br>(Prerequisite: CSC 318 or equivalent, or permission of the instructor.) |
| CSC2514H | Human-Computer Interaction |
| CSC2515H | Introduction to Machine Learning |
| CSC2516H | Neural Networks and Deep Learning |
| CSC2518H | Spoken Language Processing |
| CSC2520H | Geometry Processing |
| CSC2521H | Topics in Computer Graphics |

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|---|---|
| CSC2523H | Object Modelling and Recognition |
| CSC2524H | Topics in Interactive Computing |
| CSC2525H | Research Topics in Database Management |
| CSC2526H | HCI: Topics in Ubiquitous Computing |
| CSC2527H | The Business of Software |
| CSC2528H | Advanced Computational Linguistics |
| CSC2530H | Computer Vision for Advanced Digital Photography |
| CSC2532H | Statistical Learning Theory<br>(Prerequisite: CSC2515H.) |
| CSC2533H | Foundations of Knowledge Representation |
| CSC2534H | Decision Making Under Uncertainty |
| CSC2536H | Topics in Computer Science and Education |
| CSC2537H | Information Visualization |
| CSC2539H | Topics in Computer Vision |
| CSC2540H | Computational Cognitive Models of Language |
| CSC2541H | Topics in Machine Learning |
| CSC2542H | Topics in Knowledge Representation and Reasoning |
| CSC2546H | Computational Neuroscience |
| CSC2547H | Current Algorithms and Techniques in Machine Learning |
| CSC2548H | Machine Learning in Computer Vision |
| CSC2549H | Physics-Based Animation |
| CSC2552H | Topics in Computational Social Science |
| CSC2556H | Algorithms for Collective Decision Making |
| CSC2558H | Topics in Multidisciplinary HCI |
| CSC2600H | Topics in Computer Science |

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|---|---|
| CSC2604H | Topics in Human-Centred and Interdisciplinary Computing |
| CSC2606H | Introduction to Continuum Robotics<br>(Prerequisite: Introduction to Robotics; e.g, CSC376 offered at UTM or AER525. Exclusion: CSC476 offered at UTM.) |
| CSC2611H | Computational Models of Semantic Change |
| CSC2612H | Computing and Global Development<br>(Prerequisite: CSC 318 or equivalent, or permission of the instructor.) |
| CSC2621H | Topics in Robotics<br>(Prerequisite: CSC411H or CSC2515H or ECE521H.) |
| CSC2626H | Imitation Learning for Robotics<br>(Prerequisite: CSC411/2515 Machine Learning and Data Mining or ECE521 Inference Algorithms and Machine Learning or equivalent.) |
| CSC2699H | Special Reading Course in Computer Science |
| CSC2701H | Communication for Computer Scientists |
| CSC2702H | Technical Entrepreneurship |
| CSC2703H | MScAC Internship |
| CSC2720H | Systems Thinking for Global Problems |
| CSC4000Y | MSc Research Project in Computer Science |
| ECE1785H | Empirical Software Engineering |

# Appendix B: List of Courses associated with the new concentration

All students in the MScAC, including students in the new concentration, receive individualized advising to ensure that they select courses http://www.cs.toronto.edu/dcs/graddocs/Grad_CourseDescriptions_ResearchArea.pdf that a) meet the program requirements, including any requirements specific to the

concentration; b) have sufficient academic preparation for each course; and c) support their professional goals.

Students pursuing the new concentration in AI may select graduate-level courses from the participating departments, in compliance with the requirements listed in the SGS calendar, and subject to approval of the program director.

For these graduate courses, the content can change yearly depending on the faculty member delivering the course, therefore the syllabus must be reviewed for each non-CS course every single year and revise the classification and permission for whether MScAC students can take them accordingly. Permission is granted based on technical content within the course.

# Courses related to or in AI

Introductory/Fundamental Courses:

(captured in calendar copy in Appendix A, as well).

| Course Code | Title | Methodology | Research Area | Exclusion |
|---|---|---|---|---|
| CSC2515 | Introduction to Machine Learning | 2 Cont Models | 12 ML | ECE1513 |
| ECE1513 | Introduction to Machine Learning | 2 Cont Models | 12 ML | CSC2515 |
| CSC2516 | Neural Networks and Deep Learning | 2 Cont Models | 12 ML | MIE1517 |
| MIE1517 | Introduction to Deep Learning | 2 Cont Models | 12 ML | CSC2516 |
| CSC2502 | Knowledge Representation & Reasoning | 1 Disc Models | 11 KR | |
| CSC2533 | Foundations of Knowledge Representation | 1 Disc Models | 11 KR | |

| | | | | |
|---|---|---|---|---|
| CSC2503 | Foundations of Computer Vision | 2 Cont Models | 7 CV | |
| ECE1512H | Digital Image Processing and Applications | 2 Cont Models | 7 CV | |
| CSC2501 | Computational Linguistics | 4 Human-Centred & Interdisciplinary | 4 CL | |
| CSC2511 | Natural Language Computing | 4 Human-Centred & Interdisciplinary | 4 CL | *new cross-listed course |
| AER1513 | State Estimation for Aerospace Vehicles (State Estimation for Robotics) | 2 Cont Models | 16 Robotics | |
| AER1517 | Control for Robotics | 2 Cont Models | 16 Robotics | |

*Footnote: CSC2515 and ECE1513 are different courses from different faculties, the content and instructors are different

Additional courses students may choose to take to meet their AI course requirements are available. Other courses may be eligible. Please consult with the program director for approval.