MASTER OF COMPUTER SCIENCE SPECIALIZATION IN BIOINFORMATICS

Summary

• Degree offered: Master of Computer Science (MCS)
• Registration status options: Full-time; Part-time
• Language of instruction: English
• Primary program: Computer Science
• Collaborative specialization: Bioinformatics
• Program options (expected duration of the program):
  • with thesis (6 full-time terms; 24 consecutive months)
  • with thesis and co-op (6 full-time terms and 2 work terms; 32 consecutive months)
• Academic units: Faculty of Engineering (http://engineering.uottawa.ca), School of Electrical Engineering and Computer Science (http://engineering.uottawa.ca/eecs), Ottawa-Carleton Institute for Computer Science (http://ocics.site.uottawa.ca) (OCICS).

Program Description

Students who wish to pursue studies in computer science leading to the degree of Master of Computer Science (MCS) or Doctor of Philosophy in Computer Science (PhD) can do so in joint programs offered by the School of Electrical Engineering and Computer Science (EECS) at the University of Ottawa and the School of Computer Science at Carleton University under the auspices of the Ottawa-Carleton Institute for Computer Science (OCICS).

The Institute is responsible for supervising these programs and for providing a framework for interaction between the universities in graduate computer science education.

In addition to the faculty members from the two computer science programs, the Institute also has members with computer science expertise from other departments.

The School of Computer Science is a participating unit in the collaborative program in bioinformatics at the master’s level.

Collaborative Program Description

Bioinformatics is an emerging and increasingly important scientific discipline dedicated to the pursuit of fundamental questions about the structure, function and evolution of biological entities through the design and application of computational approaches.

Fundamental research in these areas is expected to increase our understanding of human health and disease which translates into innovation in industry.

Bioinformaticians today must be able to appreciate significant research in other fields and therefore require an understanding of the basic principles of other disciplines.

To meet this challenge Carleton University and the University of Ottawa offer a collaborative program leading to a master of science degree in the primary program with specialization in Bioinformatics or, in the case of computer science, a master of computer science degree with specialization in Bioinformatics.

Other Programs Offered Within the Same Discipline or in a Related Area

• Master of Computer Science (MCS)
• Doctorate in Philosophy Computer Science (PhD)
• Graduate Diploma Mobile Device Applications
• Graduate Diploma Modelling and Animation for Computer Games Technology

Fees and Funding

• Program fees:
  The estimated amount for university fees (https://www.uottawa.ca/university-fees) associated with this program are available under the section Finance your studies (http://www.uottawa.ca/graduate-studies/programs-admission/finance-studies).

International students enrolled in a French-language program of study may be eligible for a differential tuition fee exemption (https://www.uottawa.ca/university-fees/differential-tuition-fee-exemption).

• To learn about possibilities for financing your graduate studies, consult the Awards and financial support (https://www.uottawa.ca/graduate-studies/students/awards) section.

Notes

• Programs are governed by the general regulations (http://www.uottawa.ca/graduate-studies/students/general-regulations) in effect for graduate studies and the regulations in effect at Carleton University.
• In accordance with the University of Ottawa regulation, students have the right to complete their assignments, examinations, research papers, and theses in French or in English. In addition, research activities can be conducted in either English or French or both depending on the language used by the professor and the members of the research group.
• Students may include courses from both universities in their programs, and may select a supervisor from either university, but they should apply to the university with which their supervisor is associated. Their study program is administered by the university at which they are enrolled and is subject to its regulations.
Program Contact Information
Graduate Studies Office,
Faculty of Engineering (http://engineering.uottawa.ca/about/programs/graduate)
161 Louis-Pasteur, Colonel By Hall,
Room B111
Ottawa, Ontario, Canada
K1N 6N5

Tel.: 613-562-5347
Email: engineering.grad@uottawa.ca

Twitter | Faculty of Engineering
(https://twitter.com/uOttawaGenie?lang=en)
Facebook | Faculty of Engineering
(https://www.facebook.com/uottawa.engineering)

Admission Requirements
For the most accurate and up to date information on application deadlines, language tests and other admission requirements, please visit the specific requirements (http://www.uottawa.ca/graduate-studies/programs-admission/apply/specific-requirements) webpage.

To be eligible, candidates must:

- Have a bachelor of science degree with honours in computer science (or equivalent), with a minimum average of B (70%).
  Note: International candidates must check the admission equivalencies (https://www.uottawa.ca/graduate-studies/international/study-uottawa/admission-equivalencies) for the diploma they received in their country of origin.
- Pay the $100 ($CDN non-refundable) application fee.
- Identify at least one professor who is willing to supervise your research and thesis. We recommend that you contact potential thesis supervisors as soon as possible. The thesis director must be a member of the collaborative program. The choice of supervisor will determine the primary campus location of the student. It will also determine which university awards the degree.
- Be sponsored into the collaborative specialization by a faculty member of the collaborative program, normally the thesis supervisor, who must be appointed, cross-appointed or stand as an adjunct at the primary program.

Language Requirements
Applicants must be able to understand and fluently speak the language of instruction (English) in the program to which they are applying. Proof of linguistic proficiency may be required.

Applicants whose first language is neither French nor English must provide proof of proficiency in the language of instruction.

Language tests recognized by the University of Ottawa:

- TOEFL: 570 (Paper-based) or 88-89 (Internet-based); or
- IELTS: Overall 6.5 – Individual 6.0 (Paper-based or internet-based); or
- An equivalent language test (http://www.uottawa.ca/graduate-studies/programs-admission/apply/required-documents).

Note: Candidates are responsible for any fees associated with the language tests.

Notes
- The admission requirements listed above are minimum requirements and do not guarantee admission to the program.
- Admissions are governed by the general regulations (http://www.uottawa.ca/graduate-studies/students/general-regulations) in effect for graduate studies.
- Candidates must apply to the primary program and indicate in their application for admission to the master’s program in computer science that they wish to be accepted into the collaborative specialization in bioinformatics. Students are normally informed about their acceptance into the collaborative program at the same time as being informed about their admission into the primary program.

Documents Required for Admission
In addition to the documents required (http://www.uottawa.ca/graduate-studies/programs-admission/apply/required-documents) for graduate and postdoctoral studies, candidates must submit the following documents:

- A resume
- A letter of intent
  Letter outlining your professional goals and proposed research area.
- Three confidential letters of recommendation, including one from a professor willing and available to act as a thesis supervisor.
  You are strongly encouraged to contact your referee(s) prior to submitting your application in order to confirm their email address and their availability to complete your letter of recommendation.
- Transcripts from all universities attended:
  - You must submit official transcripts from all the universities you have attended.
  - This applies to all courses and programs at any university you attended, including regular programs (completed or not), exchanges, letters of permission, online or correspondence courses, courses taken as a special student or visiting student, etc.
• If the transcript and degree certificate are not in English or French, a certified translation (signed and stamped/sealed) must be submitted.
• The preference form (http://engineering.uottawa.ca/downloads/pdf/CSI_Preference.pdf)

Note: Documents that are not required for admission will not be consulted, conserved or returned to the student. These documents will be destroyed according to our administrative procedures.

Applying to the Co-op Option
In order to apply to the co-op option, you must first be admitted to a program that offers co-op. The co-op option is not available to MCS students in the Accelerated Stream.

Your application must be submitted by the end of the first month of enrollment in your primary program, i.e., by the end of September.

Admission to the co-op option occurs on a competitive basis and is managed by the Co-op Office (https://coop.uottawa.ca/en). Enquiries should be directed to that office.

To be admitted to the co-op option, you must:
• Be enrolled as a full-time student in the master’s in computer science;
• Have a cumulative grade point average of 7.0 or 75%;
• Begin the program in the Fall term;
• Be a Canadian citizen or permanent resident;
• Pay the required CO-OP fees.

Qualifying Program
Applicants who lack the required undergraduate preparation may be admitted to a qualifying-year program. The basis for admission to the qualifying year of the Master’s program will normally be an honours degree in a related discipline with a B average (70%), provided that the honours program in question includes the equivalent of three years of an honours computer science program. A major degree holder with superior academic standing may be considered for admission to the qualifying year with suitable background preparation.

Information about how to apply to this program is available under the Apply Now (http://www.uottawa.ca/graduate-studies/programs-admission/apply/#apply-now) section.

Students should complete and submit their online application with supporting documentation (if applicable) by the deadline indicated above.

Program Requirements
Master’s with Collaborative Specialization
The Department may require students to take additional courses, depending on their backgrounds.

Students must meet the following requirements for the master’s with collaborative specialization:

Compulsory Courses:
BNF 5106 Bioinformatics 3 Units
9 course units in computer science (CSI) at the graduate level, including: 1

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<th>Subject</th>
<th>Title</th>
<th>Units</th>
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<td>CSI 7999</td>
<td>Master of Computer Science Thesis</td>
<td>0 Unit</td>
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Note(s)
1 Course selection must be approved by the student’s academic advisor. A maximum of two three-unit courses at the 4000 level are permitted.
2 The seminar course in bioinformatics involves a written report, the presentation of a seminar, and regular attendance at departmental seminars.
3 Students must make a successful presentation and satisfy the attendance requirement as specified in the student handbook. The graduate seminar requirements must be fulfilled within two consecutive terms.
4 A student may be permitted to carry out thesis work off campus provided suitable arrangements are made for supervision and experimental work, and prior approval is obtained from the Joint Program Committee.
5 Presentation and defence of a research thesis on a topic in bioinformatics based on original research carried out under the supervision of a faculty member participating in the Bioinformatics collaborative program.
6 Students are responsible for ensuring they have met all of the thesis requirements (http://www.uottawa.ca/graduate-studies/students/theses).

Co-op Option
(Available to students enrolled in the thesis option or the coursework and project option.)

To complete a master’s with coursework and project, you must meet the following requirements:
• Be enrolled as a full-time student in the master’s in computer science;
• Maintain a cumulative grade point average of 7.0 or 75%;
• Obtain a satisfactory grade (P) for each co-op work term:
  • CSI 6001
  • CSI 6002

Notes:
• Each work term is graded P/F (pass/fail), based on the employer’s report and on the written report completed by the student. (The report must be 30 pages long, including appendices.) The report is evaluated by the professor in charge of the graduate co-op option in Computer Science.
• The units awarded for co-op terms may not be used to obtain equivalences for other courses. In other words, the co-op units are additional to the minimum requirements of the degree.
Fast-Track from the Master’s to the PhD
Students enrolled in the master’s program in computer science at the University of Ottawa may be eligible to fast-track directly into the doctoral program without writing a master’s thesis. For additional information, please consult the “Admission Requirements” section of the PhD program.

Note: Students in the Accelerated Stream of the MCS are not eligible for fast-track to the PhD.

Minimum Requirements
The passing grade in all courses is B.

Students who fail 6 units, or whose research progress is deemed unsatisfactory are required to withdraw from the program.

Research
Research Fields & Facilities
Located in the heart of Canada’s capital, a few steps away from Parliament Hill, the University of Ottawa is among Canada’s top 10 research universities.

uOttawa focuses research strengths and efforts in four Strategic Areas of Development in Research (SADRs):

• Canada and the World
• Health
• e-Society
• Molecular and Environmental Sciences

With cutting-edge research, our graduate students, researchers and educators strongly influence national and international priorities.

Research at the Faculty of Engineering
Areas of research:

• Chemical and Biological Engineering
• Civil Engineering
• Electrical Engineering and Computer Science
• Mechanical Engineering

For more information, refer to the list of faculty members and their research fields on Uniweb (https://uniweb.uottawa.ca/#!arts/themes).

Courses
Not all of the listed courses are given each year. The course is offered in the language in which it is described.

A 3-unit course at the University of Ottawa is equivalent to a 0.5-unit course at Carleton University.

CSI 5100 Data Integration (3 units)
Materialized and virtual approaches to integration of heterogeneous and independent data sources. Emphasis on data models, architectures, logic-based techniques for query processing, metadata and consistency management, the role of XML and ontologies in data integration; connections to schema mapping, data exchange, and P2P systems. This course is equivalent to COMP 5306 at Carleton University.

Course Component: Lecture
Prerequisite: CSI 2132.

CSI 5101 Knowledge Representation (3 units)
KR is concerned with representing knowledge and using it in computers. Emphasis on logic-based languages for KR, and automated reasoning techniques and systems; important applications of this traditional area of AI to ontologies and semantic web. This course is equivalent to COMP 5307 at Carleton University.

Course Component: Lecture

CSI 5102 Topics in Medical Computing (3 units)
Introductory course on data structures, algorithms, techniques, and software development related to medical computing (in particular spatial modeling). Topics may include: computational geometry algorithms for cancer treatment, medical imaging, spatial data compression algorithms, dynamic programming for DNA analysis. Courses CSI 5102, CSI 5140 (COMP 5900) cannot be combined for units. This course is equivalent to COMP 5308 at Carleton University.

Course Component: Lecture

CSI 5103 Topic in Information and Systems Science (3 units)

Course Component: Lecture

CSI 5105 Network Security and Cryptography (3 units)
Advanced methodologies selected from symmetric and public key cryptography, network security protocols and infrastructure, identification, secret-sharing, anonymity, intrusion detection, firewalls, defending network attacks and performance in communication networks. This course is equivalent to COMP 5406 at Carleton University.

Course Component: Lecture
Prerequisites: familiarity with basic concepts in networks, network security, and applied cryptography.

CSI 5106 Cryptography (3 units)

Course Component: Lecture
Prerequisites: MAT 2371, CSI 3105 or (in case of graduate students) permission of the instructor.

CSI 5110 Principles of Formal Software Development (3 units)
Methodologies in formal software specification, development, and verification. The use of theorem proving, automated deduction, and other related formal methods for software correctness. Applications in program verification, mobile code safety, and protocol verification. This course is equivalent to COMP 5707 at Carleton University.

Course Component: Lecture
CSI 5111 Software Quality Engineering (3 units)
Software quality issues. Quality components and metrics. Software process quality. Software reliability engineering. Software design for testability. Requirements capture and validation. Systematic design validation; grey-box approach, test design, implementation and management, case studies in validation and verification of communications software. Object-oriented design and test. Theoretical aspects. This course is equivalent to COMP 5501 at Carleton University.
Course Component: Lecture

CSI 5112 Software Engineering (3 units)
Topics of current interest in Software Engineering, such as software development systems, structured systems analysis and design, management of software, software tools, validation and verification, programming environments. This course is equivalent to COMP 5207 at Carleton University.
Course Component: Lecture

CSI 5113 Foundations Programming Languages (3 units)
Advanced study of programming paradigms from a practical perspective. Paradigms may include functional, imperative, concurrent, distributed, generative, aspect- and object-oriented, and logic programming. Emphasis on underlying principles. Topics may include: types, modules, inheritance, semantics, continuations, abstraction and reflection. This course is equivalent to COMP 5001 at Carleton University.
Course Component: Lecture

CSI 5115 Database Analysis and Design (3 units)
The dimensional and multidimensional data models for data warehousing. Data dependencies and decomposition. Structure and use of data definition and manipulation languages. Database economics, engineering, deployment and evolution. Issues in integrity, security, the Internet and distributed databases. Relationships to decision support systems. This course is equivalent to COMP 5503 at Carleton University.
Course Component: Lecture
Prerequisite: CSI 3317 or equivalent

CSI 5116 Authentication and Software Security (3 units)
Specialized topics in security including advanced authentication techniques, user interface aspects, electronic and digital signatures, security infrastructures and protocols, software vulnerabilities affecting security, non-secure software and hosts, protecting software and digital content. This course is equivalent to COMP 5407 at Carleton University.
Course Component: Lecture
Prerequisites: Basic course in Statistics

CSI 5117 Mini-Microcomputer Operating Systems Design (3 units)
Course Component: Lecture

CSI 5118 Automated Verification and Validation of Software (3 units)
Topics in formal test derivation methods, test management, high-level, CASE-based verification and validation, data-flow & control-flow measures and metrics for assessing quality of designs and code, regression analysis & testing. This course is equivalent to COMP 5302 at Carleton University.
Course Component: Lecture
Prerequisite: A four-year undergraduate degree in computer science, computer engineering, or software engineering.

CSI 5121 Advanced Data Structures (3 units)
Simple methods of data structure design and analysis that lead to efficient data structures for several problems. Topics include randomized binary search trees, persistence, fractional cascading, self-adjusting data structures, van Emde Boas trees, tries, randomized heaps, and lowest common ancestor queries. This course is equivalent to COMP 5408 at Carleton University.
Course Component: Lecture

CSI 5122 Software Usability (3 units)
Design principles and metrics for usability. Qualitative and quantitative methods for the evaluation of software system usability: Heuristic evaluation, usability testing, usability inspections and walkthroughs, cognitive walkthroughs, formal usability experimentation. Ethical concerns when performing studies with test users. Economics of usability. Integration of usability engineering into the software engineering lifecycle. This course is equivalent to COMP 5301 at Carleton University.
Course Component: Lecture

CSI 5124 Computational Aspects of Geographic Information Systems (3 units)
Computational perspective of geographic information systems (GIS). Data representations and their operations on raster and vector devices: e.g., quadtrees, grid files, digital elevation models, triangular irregular network models. Analysis and design of efficient algorithms for solving GIS problems: visibility queries, point location, facility location. This course is equivalent to COMP 5204 at Carleton University.
Course Component: Lecture

CSI 5125 Advanced Computational Geometry (3 units)
Fundamental mathematical and algorithmic concepts underlying computational molecular biology; physical and genetic mapping, sequence analysis (including alignment and probabilistic models), genomic rearrangement, phylogenetic inference, computational proteomics and systems modelling of the whole cell. This course is equivalent to COMP 5108 at Carleton University.
Course Component: Lecture

CSI 5126 Algorithms in Bioinformatics (3 units)
Fundamental mathematical and algorithmic concepts underlying computational molecular biology; physical and genetic mapping, sequence analysis (including alignment and probabilistic models), genomic rearrangement, phylogenetic inference, computational proteomics and systems modelling of the whole cell. This course is equivalent to COMP 5108 at Carleton University.
Course Component: Lecture

CSI 5127 Applied Computational Geometry (3 units)
Computer-based representation and manipulation of geometric objects. Design and analysis of efficient algorithms for solving geometric problems in applied fields such as Computer-Aided Design and Manufacturing, Cartography, Materials Science, and Geometric Network Design. This course is equivalent to COMP 5409 at Carleton University.
Course Component: Lecture

CSI 5128 Swarm Intelligence (3 units)
Collective computation, collective action, and principles of self-organization in social agent systems. Algorithms for combinatorial optimization problems, division of labour, task allocation, task switching, and task sequencing with applications in security, routing, wireless and ad hoc networks and distributed manufacturing. This course is equivalent to COMP 5002 at Carleton University.
Course Component: Lecture

CSI 5129 Advanced Database Systems (3 units)
In-depth study on developments in database systems shaping the future of information systems, including complex object, object-oriented, object-relational, and semi-structured databases. Data structures, query languages, implementation and applications. This course is equivalent to COMP 5305 at Carleton University.
Course Component: Lecture
CSI 5130 Applications Design for Mobile Devices (3 units)
Course Component: Lecture

CSI 5131 Parallel Algorithms and Applications in Bioinformatics (3 units)
Multiprocessor architectures from an application programmer's perspective: programming models, processor clusters, multi-core processors, GPUs, algorithmic paradigms, efficient parallel problem solving, scalability and portability. Projects on high performance computing in Data Science, including data analytics, bioinformatics, simulations. Programming experience on parallel processing equipment. This course is equivalent to COMP 5704 at Carleton University.
Course Component: Lecture

CSI 5134 Fault Tolerance (3 units)
Hardware and software techniques for fault tolerance. Topics include modeling and evaluation techniques, error detecting and correcting codes, module and system level fault detection mechanisms, design techniques for fault-tolerant and fail-safe systems, software fault tolerance through recovery blocks, N-version programming, algorithm-based fault tolerance, checkpointing and recovery techniques, and survey of practical fault-tolerant systems. This course is equivalent to COMP 5004 at Carleton University.
Course Component: Lecture

CSI 5135 Information Visualization and Visual Analytics (3 units)
Principles, techniques, technology and applications of information visualization for visual data analysis. Topics include human visual perception, cognitive processes, static and dynamic models of image semantics, interaction paradigms, big data visual analysis case studies. This course is equivalent to COMP 5209 at Carleton University.
Course Component: Lecture

CSI 5136 Computer Security and Usability (3 units)
Design and evaluation of security and privacy software with particular attention to human factors and how interaction design impacts security. Topics include current approaches to usable security, methodologies for empirical analysis, and design principles for usable security and privacy. This course is equivalent to COMP 5110 at Carleton University.
Course Component: Lecture

CSI 5140 Selected Topics in Computer Science (3 units)
Selected topics, not covered by other graduate courses. Details will be available from the School at the time of registration. This course is equivalent to COMP 5900 at Carleton University.
Course Component: Lecture

CSI 5142 Protocols for Mobile and Wireless Networks (3 units)
Link and network layer protocols of wireless networks; applications of wireless networks may be discussed. Topics may include: protocol implementation, mobile IP, resource discovery, wireless LANs/PANs, and Spread Spectrum. Courses CSI 6136 (SYSC 5306), CSI 5142 (COMP 5402) cannot be combined for units. This course is equivalent to COMP 5402 at Carleton University.
Course Component: Lecture
Precludes additional credit for SYSC 5306.

CSI 5146 Computer Graphics (3 units)
Course Component: Lecture

CSI 5147 Computer Animation (3 units)
Theories and techniques in 3D modeling and animation. Animation principles, categories, and history. Forward and inverse kinematics. Motion capture, editing and retargeting. Flexible bodies. Particle animation. Behavioral animation. Human modeling. Facial animation. Cloth animation and other sub-topics. This course is equivalent to COMP 5201 at Carleton University.
Course Component: Lecture

CSI 5148 Wireless Ad Hoc Networking (3 units)
Self-organized, mobile, and hybrid ad hoc networks. Physical, medium access, networks, transport and application layers, and cross-layering issues. Power management. Security in ad hoc networks. Topology control and maintenance. Data communication protocols, routing and broadcasting. Location service for efficient routing. This course is equivalent to COMP 5103 at Carleton University.
Course Component: Lecture

CSI 5149 Graphical Models and Applications (3 units)
Bayesian networks, factor graphs, Markov random fields, maximum a posteriori probability (MAP) and maximum likelihood (ML) principles, elimination algorithm, sum-product algorithm, decomposable and non-decomposable models, junction tree algorithm, completely observed models, iterative proportional fitting algorithm, expectation-maximization (EM) algorithm, iterative conditional modes algorithm, variational methods, applications. Courses CSI 5149 (COMP 5007), ELG 5131 (EAGJ 5131) and ELG 7177 (EACJ 5605) cannot be combined for units. This course is equivalent to COMP 5007 at Carleton University.
Course Component: Lecture

CSI 5151 Virtual Environments (3 units)
Course Component: Lecture

CSI 5152 Evolving Information Networks (3 units)
Convergence of social and technological networks with WWW. Interplay between information content, entities creating it and technologies supporting it. Structure and analysis of such networks, models abstracting their properties, link analysis, search, mechanism design, power laws, cascading, clustering and connections with work in social sciences. This course is equivalent to COMP 5310 at Carleton University.
Course Component: Lecture
Prerequisites: introductory-level background in networks, algorithms, and probability.
S**V* 5153 Data Management for Business Intelligence (3 units)**
Data management problems and information technology in decision making support in business environments. Topics include advanced data modeling, semantic modeling, multidimensional databases and data warehousing, on-line-analytical processing, elements of data mining, context in data management, data quality assessment, data cleaning, elements of business process modeling. This course emphasizes concepts and techniques rather than specific applications or systems/ implementations. This course is equivalent to COMP 5111 at Carleton University.

**Course Component:** Lecture

S**V* 5154 Algorithms for Data Science (3 units)**
Algorithmic techniques to handle (massive/big) data arising from, for example, social media, mobile devices, sensors, financial transactions. Algorithmic techniques may include locality-sensitive hashing, dimensionality reduction, streaming, clustering, VC-dimension, external memory, core sets, link analysis and recommendation systems. This course is equivalent to COMP 5112 at Carleton University.

**Course Component:** Lecture

S**V* 5160T Topic in Mini and Micro-Computer System (2 crédits / 2 units)**
Volet / Course Component: Cours magistral / Lecture

S**V* 5161 Principles of Distributed Simulation (3 units)**
Distributed simulation principles and practices. Synchronization protocols: Optimistic vs Conservative, Deadlock detection in conservative simulations, Time warp simulation. Distributed interactive simulation: Data distribution management, Interest management, High Level Architectures (HLA), Run Time Infrastructure (RTI). Distributed web-based simulation. Distributed agent based simulation. Real time applications of distributed simulation. Distributed and collaborative virtual simulations. This course is equivalent to COMP 5606 at Carleton University.

**Course Component:** Lecture

S**V* 5163 Algorithm Analysis and Design (3 units)**
Topics of current interest in the design and analysis of computer algorithms for graph-theoretical applications; e.g. shortest paths, chromatic number, etc. Lower bounds, upper bounds, and average performance of algorithms. Complexity theory. This course is equivalent to COMP 5703 at Carleton University.

**Course Component:** Lecture

S**V* 5164 Computational Geometry (3 units)**
Study of design and analysis of algorithms to solve geometric problems; emphasis on applications such as robotics, graphics, and pattern recognition. Topics include: visibility problems, hidden line and surface removal, path planning amidst obstacles, convex hulls, polygon triangulation, point location. This course is equivalent to COMP 5008 at Carleton University.

**Course Component:** Lecture

S**V* 5165 Combinatorial Algorithms (3 units)**
Design of algorithms for solving problems that are combinatorial in nature, using both sequential and parallel models of computation. Parallel algorithms for enumerating basic combinatorial objects (permutations, combinations, set partitions) and for solving optimization problems (knapsack, minimal cover, branch-and-bound). Polyminoes, polygonal systems, enumeration and classification and benzenoid and coronoid hydrocarbons in chemistry. Combinatorial geometry (Voronoi diagrams, polytopes arrangements). Algorithmic problems in many-valued logics (base enumeration, tautology checking, minimization, finding the spectra). This course is equivalent to COMP 5709 at Carleton University.

**Course Component:** Lecture

S**V* 5166 Applications of Combinatorial Optimization (3 units)**
Topics in combinatorial optimization with emphasis on applications in Computer Science. Topics include network flows, various routing algorithms, polyhedral combinatorics, and the cutting plane method. This course is equivalent to COMP 5805 at Carleton University.

**Course Component:** Lecture

S**V* 5167 Human-Computer Interaction Models, Theories and Frameworks (3 units)**
A basis for graduate study in HCI with an emphasis on the application of theory to user interface design. Review of main theories of human behaviour relevant to HCI including especially Cognitive Dimensions of Notations Framework, Mental Models, Distributed Cognition, and Activity Theory, and their application to design and development of interactive systems. This course is equivalent to COMP 5210 at Carleton University.

**Course Component:** Lecture

S**V* 5168 Digital Watermarking (3 units)**
Overview of recent advances in watermarking of image, video, audio, and other media. Spatial, spectral, and temporal watermarking algorithms. Perceptual models. Use of cryptography in steganography and watermarking. Robustness, security, imperceptibility, and capacity of watermarking. Content authentication, copy control, intellectual property, digital rights management, and other applications. This course is equivalent to COMP 5309 at Carleton University.

**Course Component:** Lecture

S**V* 5169 Wireless Networks and Mobile Computing (3 units)**
Computational aspects and applications of design and analysis of mobile and wireless networking. Topics include Physical, Link Layer, Media Access Control, Wireless, Mobile LANs (Local Area Networks), Ad-Hoc, Sensor Networks, Power Consumption optimization, Routing, Searching, Service Discovery, Clustering, Multicasting, Localization, Mobile IP/TCP (Internet Protocol/Transmission Control Protocol), File Systems, Mobility Models, Wireless Applications. Courses CSI 5169, ELG 6168 cannot be combined for units. This course is equivalent to COMP 5304 at Carleton University.

**Course Component:** Lecture

S**V* 5173 Data Networks (3 units)**
Mathematical and practical aspects of design and analysis of communication networks. Topics include: basic concepts, layering, delay models, multi-access communication, queueing theory, routing, fault-tolerance, and advanced topics on high-speed networks, ATM, mobile wireless networks, and optical networks. This course is equivalent to COMP 5203 at Carleton University.

**Course Component:** Lecture

S**V* 5174 Validation Methods for Distributed Systems (3 units)**
Review of formal specification and description techniques for distributed and open systems. Verification techniques. Correctness proofs. Verification of general properties of distributed systems. Analysis and relief strategies. Testing techniques. Test generation strategies. Test architectures. This course is equivalent to COMP 5604 at Carleton University.

**Course Component:** Lecture
CSI 5175 Mobile Commerce Technologies (3 units)
Wireless networks support for m-commerce; m-commerce architectures and applications; mobile payment support systems; business models; mobile devices and their operating systems; mobile content presentation; security issues and solutions; relevant cross layer standards and protocols; case studies. Courses EBC 5175, CSI 5175 cannot be combined for units.
Course Component: Lecture
Exclusion: EBC 5175

CSI 5180 Topics in Artificial Intelligence (3 units)
A programming-oriented introduction to selected topics in Artificial Intelligence (A.I.). Topics for consideration include: A.I. programming techniques, pattern matching systems, natural language systems, rule-based systems, constraint systems, learning systems, and cognitive systems. Assignments will be both (a) programming-oriented, requiring implementation and/or extensions of prototypes in Lisp and/or Prolog and (b) research-oriented, requiring readings of special topics in current A.I. journals. This course is equivalent to COMP 5100 at Carleton University.
Course Component: Lecture

CSI 5183 Evolutionary Computation and Artificial Life (3 units)
Study of algorithms based upon biological theories of evolution, applications to machine learning and optimization problems. Possible topics: Genetic Algorithms, Classifier Systems, and Genetic Programming. Recent work in the fields of Artificial Life (swarm intelligence, distributed agents, behavior-based AI) and of connectionism. This course is equivalent to COMP 5206 at Carleton University.
Course Component: Lecture

CSI 5185 Statistical and Syntactic Pattern Recognition (3 units)
Topics include a mathematical review, Bayes decision theory, maximum likelihood and Bayesian learning for parametric pattern recognition, non-parametric methods including nearest neighbor and linear discriminants. Syntactic recognition of strings, substrings, subsequences and tree structures. Applications include speech, shape and character recognition. This course is equivalent to COMP 5107 at Carleton University.
Course Component: Lecture

Precludes additional credit for COMP 4107.

CSI 5200 Projects on Selected Topics (3 units)
Course Component: Lecture

CSI 5308 Principles of Distributed Computing (3 units)
Formal models; semantics of distributed computations; theoretical issues in the design of distributed algorithms; computational complexity; reducibility and equivalence of distributed problems. Related topics: systolic systems and computations, oligarchical systems and control mechanisms. This course is equivalent to COMP 5003 at Carleton University.
Course Component: Lecture

CSI 5311 Distributed Databases and Transaction Processing (3 units)
Principles involved in the design and implementation of distributed databases and distributed transaction processing systems. Topics include: distributed and multi-database system architectures and models, atomicity, synchronization and distributed concurrency control algorithms, data replication, recovery techniques, and reliability in distributed databases. This course is equivalent to COMP 5101 at Carleton University.
Course Component: Lecture

CSI 5312 Distributed Operating Systems Engineering (3 units)
Design issues of advanced multiprocessor distributed operating systems: multiprocessor system architectures; process and object models; synchronization and message passing primitives; memory architectures and management; distributed file systems; protection and security; distributed concurrency control; deadlock; recovery; remote tasking; dynamic reconfiguration; performance measurement, modeling, and system tuning. This course is equivalent to COMP 5102 at Carleton University.
Course Component: Lecture

CSI 5314 Object-Oriented Software Development (3 units)
Issues in modeling and verifying quality and variability in object-oriented systems. Testable models in model-driven and test-driven approaches. System family engineering. Functional conformance: scenario modeling and verification, design by contract. Conformance to non-functional requirements: goals, forces and tradeoffs, metrics. This course is equivalent to COMP 5104 at Carleton University.
Course Component: Lecture

CSI 5320 Systems and Architectures for Electronic Commerce (3 units)
Content and transactions in e-commerce systems. System architecture with a focus on frameworks, tools and development process. Application frameworks. Information management. Security, standards, and regulatory compliance. Current research issues. Hands-on experience with an integrated set of current e-commerce tools. E-commerce development project. This course is equivalent to COMP 5405 at Carleton University.
Course Component: Lecture

Prerequisite: CSI 5320

CSI 5321 Object-Oriented Database Systems (3 units)
Object-oriented data models; object-oriented databases; object-oriented database management systems; object-oriented database queries; object-oriented database transactions and concurrency control; object-oriented database recovery; object-oriented database security and integrity; object-oriented database administration; object-oriented database performance; object-oriented database administration; object-oriented database maintenance.
Course Component: Lecture

Prerequisite: CSI 5300 or permission of the instructor

CSI 5341 Data Mining and Concept Learning (3 units)
Course Component: Lecture

CSI 5387 Data Mining and Concept Learning (3 units)
Course Component: Lecture
CSI 5389 Électronique et commerce (3 unités)
Prérequis : CSI 4110 ou équivalent.

CSI 5565 Algorithmes combinatoires (3 crédits)
Conception d'algorithmes d'optimisation, base et parallèles. Théorie des jeux pour l'analyse et la conception d'algorithmes. Les algorithmes parallèles pour l'enchaînement d'objets combinatoires de base (permutations, partitions, combinaisons), et pour résoudre des problèmes d'optimisation (optimisation de l'emballage, recouvrement minimal, méthode branch-and-bound); système polygonal, applications en chimie; géométrie combinatoire (diagrammes de Voronoi, polytopes, arrangements); problèmes en logique à valeur multiple, énumération de base, vérification de tautologie, minimisation, recherche de spectre. Ce cours est équivalent à COMP 5709 à la Carleton University.

Volet : Cours magistral

CSI 5566 Thématique : Concepts et logiciels (3 crédits)
Volet : Cours magistral

CSI 5567 Thématique : Intelligence artificielle (3 crédits)
Concepts et méthodes de base de l'intelligence artificielle. Représentation des connaissances. Traitement du langage naturel. Stratégies de recherche et de jeu. Ce cours est équivalent à COMP 5510 ou équivalent à COMP 5405 à la Carleton University.

Volet : Cours magistral

CSI 5568 Thématique : Systèmes et architectures des logiciels pour le commerce électronique (3 crédits)

Volet : Cours magistral
Prérequis : CSI 5389

CSI 5569 Thématique : Technologies du commerce électronique (3 crédits)

Volet : Cours magistral
Prérequis : CSI 4110 ou équivalent.

CSI 5570 Thématique : Projets de recherche en informatique / Graduate Projects in Computer Science (3 crédits / 3 unités)
Ce cours est équivalent à COMP 5902 à la Carleton University. / This course is equivalent to COMP 5902 at Carleton University.

Volet / Course Component : Cours magistral / Lecture
CSI 5901 Études dirigées / Directed Studies (3 crédits / 3 units)
A course of independent study under the supervision of a member of the School of Computer Science. Ce cours est équivalent à COMP 5901 à la Carleton University. / This course is equivalent to COMP 5901 at Carleton University.
Volet / Course Component: Recherche / Research
CSI 5903 Stage en commerce électronique / Electronic Commerce Work Term (3 crédits / 3 units)
Expérience en milieu de travail. Noté S (satisfaisant) ou NS (non satisfaisant) selon les résultats du rapport écrit et l'évaluation de l'employeur. Préalable : être accepté au programme de certificat en commerce électronique (option technologie) et recevoir la permission du Comité du programme. / Practical experience. Graded S (Satisfactory) / NS (Not satisfactory), to be based on the grades obtained for the written report as well as on the evaluations of the employer.
Volet / Course Component: Cours magistral / Lecture
CSI 5904 Projet de recherche avancé en commerce électronique / Graduate Project in Electronic Commerce (3 crédits / 3 units)
Projet sur un sujet précis en commerce électronique mené sous la direction d'un professeur. Les cours CSI 5904, CSI 5903 ne peuvent être combinés pour l'obtention de crédits. / Project on a specific topic in electronic commerce under the supervision of a professor. Courses CSI 5904, CSI 5903 cannot be combined for units.
Volet / Course Component: Cours magistral / Lecture
Exclusion: CSI 5903.
CSI 5905 Projet / Project (3 crédits / 3 units)
Développement d'une application pour appareils mobiles. L'étudiant identifie un projet, qui doit comprendre une importante part du logiciel s'exécutant sur l'appareil mobile et se prête à une évaluation raisonnablement indépendante d'autres logiciels. Le projet est dirigé par un professeur approuvé par la direction du programme. Le projet est normalement complété en une session. Noté S (satisfaisant) ou NS (non satisfaisant) par le directeur du projet et un autre professeur nommé par le directeur du programme. Préalable : approbation de la direction du programme. / Development of an application for mobile devices. Students identify a project that must include a significant portion of software running on device, and should be reasonably self contained. Graded S (Satisfactory) or NS (Not satisfactory) by the supervisor and by another professor appointed by the program director. The project can normally be completed in one session.
Volet / Course Component: Cours magistral / Lecture
CSI 6900 Projet sur un sujet précis en commerce électronique (3 crédits / 3 units)
Envergure du projet de recherche exigé dans ce cours est deux fois plus grande que dans le cas de CSI 5900. Les cours CSI 6900, CSI 5900 ne peuvent être combinés pour l'obtention de crédits. Cours ouvert uniquement aux étudiants inscrits à la maîtrise sans thèse. Ce cours est équivalent à COMP 5903 à la Carleton University. / A two-session course. The project is twice the scope of projects in CSI 5900. Courses CSI 6900, CSI 5900 cannot be combined for units. Not to be taken in the thesis option. This course is equivalent to COMP 5903 at Carleton University.
Volet / Course Component: Recherche / Research
CSI 7131 Advanced Parallel and Systolic Algorithms (3 units)
Continuation of CSI 5131 (COMP 5704). This course is equivalent to COMP 6100 at Carleton University.
Course Component: Lecture
CSI 7160 Advanced Topics in the Theory of Computing (3 units)
This course is equivalent to COMP 6601 at Carleton University.
Course Component: Lecture
CSI 7161 Advanced Topics in Programming Systems and Languages (3 units)
This course is equivalent to COMP 6603 at Carleton University.
Course Component: Lecture
CSI 7162 Advanced Topics in Computer Applications (3 units)
This course is equivalent to COMP 6604 at Carleton University.
Course Component: Lecture
CSI 7163 Advanced Topics in Computer Systems (3 units)
This course is equivalent to COMP 6605 at Carleton University.
Course Component: Lecture
CSI 7170 Advanced Topics in Distributed Computing (3 units)
This course is equivalent to COMP 6602 at Carleton University.
Course Component: Lecture
CSI 7314 Advanced Topics in Object-Oriented Systems (3 units)
Advanced object-oriented software engineering, in particular the issues of reuse and testing. Sample topics include: interaction modeling; class and cluster testing; traceability; design patterns and testing; the C++ standard template library. Students will carry out research. This course is equivalent to COMP 6104 at Carleton University.
Course Component: Lecture
CSI 7561 Études avancées en systèmes et langages de programmation (3 crédits)
Ce cours est équivalent à COMP 6603 à la Carleton University.
Volet : Cours magistral
CSI 7900 Projets de recherche en informatique / Graduate Projects in Computer Science (3 crédits / 3 units)
Ce cours est équivalent à COMP 6902 à la Carleton University. / This course is equivalent to COMP 6902 at Carleton University.
Volet / Course Component: Cours magistral / Lecture
CSI 7901 Études dirigées / Directed Studies (3 crédits / 3 units)
Ce cours est équivalent à COMP 6901 à la Carleton University. / This course is equivalent to COMP 6901 at Carleton University.
Volet / Course Component: Recherche / Research
CSI 7999 Thèse de maîtrise en informatique / Master of Computer Science Thesis
Ce cours est équivalent à COMP 5905 à la Carleton University. / This course is equivalent to COMP 5905 at Carleton University.
Volet / Course Component: Recherche / Research
CSI 9901 Colloque / Seminar
Volet / Course Component: Séminaire / Seminar
CSI 9902 Colloque / Seminar
Volet / Course Component: Recherche / Research
CSI 9997 Proposition de thèse de doctorat / Doctoral Thesis Proposal
Within 8 terms following initial registration in the program, a document, generally defining the problem addressed, relating it to the literature, outlining the hypotheses, goals, research methodology, initial results and validation approach, must be submitted to an examination committee and successfully defended. Ce cours est équivalent à COMP 6908 à la Carleton University. This course is equivalent to COMP 6908 at Carleton University.
Volet / Course Component: Recherche / Research
CSI 9998 Examen général de doctorat / Ph.D. Comprehensive
A committee must be assembled and must approve at least 3 topics for written examination: typically, a major and two minor areas. An oral examination occurs if the written exam is passed. Both elements must take place within the first 4 terms following initial registration in the program. The comprehensive examination may be failed, passed conditionally (i.e., with extra course requirements) or passed unconditionally. If failed, this course may be retaken at most one time. Ce cours est équivalent à COMP 6907 à la Carleton University. This course is equivalent to COMP 6907 at Carleton University.

Volet / Course Component: Recherche / Research

CSI 9999 Thèse de doctorat / Ph.D. Thesis
Ce cours est équivalent à COMP 6909 à la Carleton University. / This course is equivalent to COMP 6909 at Carleton University.

Volet / Course Component: Recherche / Research

BNF 5106 Bioinformatics (3 units)
Major concepts and methods of bioinformatics. Topics may include, but are not limited to: genetics, statistics & probability theory, alignments, phylogenetics, genomics, data mining, protein structure, cell simulation and computing.

Course Component: Lecture

BNF 5107 Applied Bioinformatics (3 units)
Computational knowledge discovery in and the dynamic nature of cellular networks. Includes, but is not limited to, knowledge representation, large scale data integration, data mining and computational systems biology. This course is equivalent to BIOL 5516 at Carleton University.

Course Component: Lecture

BNF 5506 Bioinformatique (3 crédits)
Concepts et méthodes en bioinformatique. Les sujets abordés peuvent inclure, entre autres, la génétique, les statistiques et les théories des probabilités, les alignements, la phylogénétique, la génomique et la structure de protéines.

Volet : Cours magistral

BNF 6100 MSc Seminar (3 units)
Current topics in bioinformatics presented by program professors and invited speakers. Oral presentation and written report required. Graded S (Satisfactory) / NS (Not satisfactory).

Course Component: Lecture

BNF 6500 Séminaire de maîtrise (3 crédits)
Sujets courants en bioinformatique présentés par des professeurs membres du programme et des conférenciers invités. Présentation orale et rapport écrit requis. Noté S (satisfaisant) ou NS (non satisfaisant).

Volet : Cours magistral