Computing & Information Systems

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Professor and Chair of the Department
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Associate Professors
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The study of computing and information systems is central to our understanding of how the world processes, manages, and communicates information. It is a field which impacts all disciplines and has redefined how we work, interact, and conduct our day-to-day lives. The Department of Computing & Information Systems offers two streams of study: Computing Systems (major, joint-major, and minor) and Information Systems (joint-major and minor). Under the Computing Systems stream, three specializations are also offered: Computer Science, Data Analytics, and Software Engineering.

  The computing systems specialist designs, implements, and integrates software applications which may execute on any system of computing devices, from supercomputers to game boards. He or she uses theories, methodologies, and techniques that help ensure that the system is robust and useable. The information systems specialist, on the other hand, is concerned with the flow, storage, and access to information both within and across organizational boundaries, encompassing systems that are both computational and non-computational. He or she requires a broad systems perspective and an appreciation of both technical matters like databases, networks, and telecommunications, as well as non-technical matters such as ethics, law, and digital culture. The minor in Computer Studies offers the study of computing from a generalist point of view. This option may particularly appeal to students in the humanities, liberal arts, teacher education, or those with a general interest in computing.

Notes

- In addition to the program requirements listed below, students must satisfy the University degree requirements (see).
- Courses in Computing & Information Systems fulfilling University science credit requirements for the BSc are marked "Sc" in the individual course descriptions.
- The same course may not simultaneously satisfy the requirements of both programs in a joint-major degree.
- Students may not graduate with a joint-major degree in Computing Systems and Information Systems.
- Students majoring in Computing Systems and who have had some programming experience may consider enrolling in both COIS 1010H and 1020H in the Fall term to increase their options for additional COIS courses earlier in their program.
- COIS 1010H and 1020H are offered in both the Fall and Winter terms.
- Students in an Information Systems program may substitute COIS 1020H for COIS 1520H in their requirements.

- MATH 1110H and 1120H are recommended for students in a Computing Systems program who are interested in postgraduate studies.
- For the program in Computing Systems & Physics, see the relevant section of the Calendar.

Bachelor of Science Program in Computing Systems

The single-major Honours program in Computing Systems. 20.0 credits including the following 12.5 credits:
 – 4.0 COIS credits consisting of COIS 1010H, 1020H, 2020H, 2240H, 2300H, 3020H, 3380H, and 3400H
 – 2.0 COIS credits at the 4000 level
 – 2.5 COIS credits at the 3000 level or beyond in addition to the above
 – 2.0 COIS credits in addition to the above
 – 1.5 MATH credits consisting of MATH 1350H, 1550H, and 2600H
 – 0.5 MATH credit from MATH 1005H or 1110H
 – For the BSc, 14.0 science credits are required for the Honours degree

The joint-major Honours program in Computing Systems. 20.0 credits including the following 8.5 credits:
 – 3.0 COIS credits consisting of COIS 1010H, 1020H, 2020H, 2240H, 2300H, and 3400H
 – 1.0 COIS credit at the 4000 level
 – 1.5 COIS credits at the 3000 level or beyond in addition to the above
 – 1.0 COIS credit in addition to the above
 – 1.5 MATH credits consisting of MATH 1350H, 1550H, and 2600H
 – 0.5 MATH credit from MATH 1005H or 1110H
 – For the BSc, 14.0 science credits are required for the Honours degree

The single-major General program in Computing Systems. 15.0 credits including the following 9.5 credits:
 – 3.0 COIS credits consisting of COIS 1010H, 1020H, 2020H, 2240H, 2300H, and 3400H
 – 2.5 COIS credits at the 3000 level or beyond in addition to the above
 – 2.0 COIS credits in addition to the above
 – 1.5 MATH credits consisting of MATH 1350H, 1550H, and 2600H
 – 0.5 MATH credit from MATH 1005H or 1110H
 – For the BSc, 11.0 science credits are required for the General degree

Bachelor of Arts Program in Computing Systems

The joint-major Honours program in Computing Systems. 20.0 credits including the following 7.5 credits:
- 2.5 COIS credits consisting of COIS 1010H, 1620H, 2240H, 2300H, and 3400H
- 0.5 COIS credit from COIS 1020H or 1520H
- 0.5 COIS credit from COIS 2020H or 2620H
- 1.0 COIS credit at the 4000 level
- 1.5 COIS credits at the 3000 level or beyond in addition to the above
- 1.5 COIS credits in addition to the above

The single-major General program in Computing Systems. 15.0 credits including the following 8.0 credits:
- 2.5 COIS credits consisting of COIS 1010H, 1620H, 2240H, 2300H, and 3400H
- 0.5 COIS credit from COIS 1020H or 1520H
- 0.5 COIS credit from COIS 2020H or 2620H
- 2.5 COIS credits at the 3000 level or beyond in addition to the above
- 2.0 COIS credits in addition to the above

Bachelor of Arts and Bachelor of Science Programs in Information Systems

The joint-major Honours program in Information Systems. 20.0 credits including the following 7.0 credits:
- 3.5 COIS credits consisting of COIS 1010H, 1520H, 1620H, 2240H, 2620H, 3030H, and 3850H
- 0.5 COIS credit at the 4000 level
- 1.5 COIS credits at the 3000 level or beyond in addition to the above
- 1.5 COIS credits in addition to the above
- For the BSc, 14.0 science credits are required for the Honours degree, including 1.0 MATH credit

The joint-major General program in Information Systems. 15.0 credits including the following 5.0 credits:
- 2.0 COIS credits consisting of COIS 1010H, 1520H, 1620H, and 2620H
- 2.0 COIS credits at the 3000 level or beyond
- 1.0 COIS credit in addition to the above
- For the BSc, 11.0 science credits are required for the General degree, including 1.0 MATH credit

Minors in Computing & Information Systems

Students who have fulfilled the requirements for a single-major or joint-major BA or BSc Honours degree in another subject may graduate with one of the following minors in Computing & Information Systems.

The minor in Computer Studies consists of 5.0 COIS credits, at least 2.0 at the 3000 level or beyond.

The minor in Computing Systems consists of the following 6.5 credits:
– 1.5 COIS credits consisting of COIS 1010H, 1020H, and 2020H
– 2.0 COIS credits at the 3000 level or beyond
– 1.5 COIS credits in addition to the above
– 1.0 MATH credit consisting of MATH 1350H and 1550H
– 0.5 MATH credit from MATH 1005H or 1110H

The minor in Data Analytics consists of the following 5.0 credits:
– 2.0 COIS credits consisting of COIS 1010H, 3400H, 3510H, and 4400H
– 0.5 COIS credit from COIS 1020H or 1520H
– 0.5 COIS credit from COIS 2020H or 2620H
– 1.0 COIS credit at the 3000 level or beyond in addition to the above
– 1.0 COIS credit in addition to the above

The minor in Information Systems consists of the following 5.0 credits:
– 2.0 COIS credits consisting of COIS 1010H, 1520H, 1620H, and 2620H
– 2.0 COIS credits at the 3000 level or beyond
– 1.0 COIS credit in addition to the above

Specialization in Computer Science

Program Coordinator
  B. G. Patrick, BCS (Concordia), MSc (Queen's), PhD, MBA (McGill)

The computer scientist studies and develops software systems which interface most closely with the underlying hardware. These systems are grounded in both mathematical and non-mathematical paradigms such as object-orientation, relations, and complexity theory. Because the computer scientist bridges the gap between software and hardware systems, he or she develops applications which exploit the speed and power of digital computation, designing new models of computation and new methods of problem-solving. The Specialization in Computer Science fully prepares students to pursue graduate studies in both theoretical and applied computer science.

   Students who have fulfilled the requirements for a single-major Honours degree in Computing Systems may graduate with a Specialization in Computer Science if they have also successfully completed the following 8.0 credits:
– 3.0 COIS credits consisting of COIS 2320H, 3030H, 3050H, 3320H, 4050H, and 4100H
– 1.0 credit from ADMN
– 1.0 arts credit from AHCL, CAST, CUST, ENGL, FREN, HIST, PHIL, SPAN or WMST
– 1.0 science credit from BIOL, CHEM, ERSC, FRSC, GEOG, or PHYS
– 2.0 additional credits outside of COIS and MATH

Specialization in Data Analytics

Program Coordinator

   S. M. McConnell, BSc, MSc, PhD (Queen's)

Today, there is a clear trend away from single-core processors, even in contemporary desktop machines, and toward the analysis of large datasets in the realm of Big Data Science. The efficient analysis of large scientific and retail datasets will require a generation of programmers, analysts, and developers who are familiar with techniques suitable for the analysis of Big Data. The Specialization in Data Analytics provides a solid foundation in those techniques, including parallel programming, visualization, and predictive modelling.

   Students who have fulfilled the requirements for a single-major Honours degree in Computing Systems may graduate with a Specialization in Data Analytics if they have also successfully completed the following 3.5 credits:

   – 3.5 COIS credits consisting of COIS 3030H, 3510H, 3560H, 4350H, 4400H, 4470H, and 4550H

Specialization in Software Engineering

Program Coordinator

   O. Alam, BSc (King Abdulaziz), MSc (Queen's), PhD (McGill)

The software engineer works as part of a team to design, implement, test, maintain, and document software solutions. Because these solutions are typically large and complex, the software engineer must deal on several levels of abstraction and draw on sound methodologies and practices to produce software which is correct, robust, maintainable, and extensible. The software engineer therefore bridges the gap between the requirements of a client and the software solution to meet those requirements. He or she must have not only technical skills, but also interpersonal skills to work within the dynamics of a group. The capstone of the Specialization in Software Engineering is a full-year team project (COIS 4000Y) which exercises all phases of software development on a real-world application.

   Students who have fulfilled the requirements for a single-major Honours degree in Computing Systems may graduate with a Specialization in Software Engineering if they have also successfully completed the following 9.0 credits:

   – 4.0 COIS credits consisting of COIS 3030H, 3040H, 3050H, 3320H, 3420H, 3850H, and 4000Y
   – 1.0 credit from ADMN
   – 1.0 arts credit from AHCL, CAST, CUST, ENGL, FREN, HIST, PHIL, SPAN, or WMST
   – 1.0 science credit from BIOL, CHEM, ERSC, FRSC, GEOG, or PHYS
   – 2.0 additional credits outside of COIS and MATH

Computing Systems Co-Op

Program Coordinator
R. T. Hurley, BSc (New Brunswick), PhD (Waterloo)

Co-op is an opportunity for students to gain experiential learning which will help them get a head start on a career. The Computing Systems Co-op assists graduating students in achieving a competitive edge while generating experience within the industry. Specifically, Co-op gives the students a chance to obtain 12 months of practical experience on the job, develop or enhance technical skills, explore career options, network with a variety of individuals and companies, learn from mentors and tutors, enhance communication and presentation skills, and develop technical writing skills.

Program Requirements

To achieve the Co-op designation, graduating students must fulfill the requirements for a single-major Honours degree in Computing Systems and successfully complete three non-credit work term courses (COIS 2700P, 3700P, and 4700P) prior to the final academic term. Students in the Computing Systems Co-op may also choose to complete a Specialization in Computer Science, Data Analytics, and/or Software Engineering.

Co-op combines academic instruction and practical experience, allowing students to develop work skills and gain experience while obtaining a formal education. The work/study sequence in the Computing Systems Co-op consists of eight study terms interspersed with three paid work terms. Students are admitted on a full-time basis and complete the program over a four-year period.

Other than Year 1, the schedule below is not mandatory, but any deviation could result in students requiring additional time to complete the program, as not all courses required for the degree are offered in every term.

	Fall	Winter	Summer
Year 1	Study 1	Study 2	Study 3
Year 2	Work Term 1	Study 4	Work Term 2
Year 3	Study 5	Study 6	Work Term 3
Year 4	Study 7	Study 8	

Year 1

Fall (Study 1)
– 1.5 COIS credits consisting of COIS 1010H, 1020H, and 2830H
– 0.5 MATH credit from MATH 1005H or 1110H
– 0.5 additional credit*

Winter (Study 2)
– 1.5 COIS credits consisting of COIS 2240H, 2300H, COIS-ADMN 1620H
– 0.5 MATH credit consisting of MATH 1550H
– 0.5 additional credit**

Summer (Study 3)
– 1.5 COIS credits consisting of COIS 2020H, 3400H, and 3420H
– 1.0 additional credit (S61*) (S62**)
*Suggested: MATH 1005H, 1110H, 1120H, 1350H, or 1550H
**Suggested: COIS-ADMN 3850H

Notes

- Placement in the Co-op is competitive with a limited number of spaces. Students who are not admitted directly may apply for admission after commencing studies at Trent and be admitted provided there are available spaces in the program.

- To remain in the Co-op, students must achieve a minimum 75% average in COIS courses and a minimum 70% cumulative average throughout their study terms. In addition, Co-op students must continue to receive satisfactory evaluations during their work terms. Students who do not maintain these requirements will be required to meet with the departmental Co-op Committee and will considered for continuation on a case-by-case basis.

- Students in the Co-op are required to pay an administrative fee for each work term. These non-refundable fees are set by the University. Co-op students are also responsible for tuition and incidental fees related to their study terms and costs related to any Trent courses taken while completing a work term.

- Every effort is made by the department to find suitable work term placements for students enrolled in the Co-op, but the department cannot guarantee a work term opportunity for every student. The placement process is competitive and dependent upon market conditions as well as the academic performance, skills, motivation, maturity, attitude, and potential of a student. Co-op students secure positions through successful participation in the co-op interview process and/or their own job search activities. No more than two of the three placements may be with the same employer. Withdrawal from the Co-op will not normally be approved while a student is on a work term.

- Students returning from a work term must submit a report and give a presentation describing the nature of the work undertaken and the experience gained. A grade of S (satisfactory) or U (unsatisfactory) is assigned based on the report/presentation and the employer's assessment. The report is normally due within the first two weeks of the study term following the completion of a work term, with the presentation being scheduled by the department later that term.

- Students who are unable to obtain a suitable Co-op placement in an upcoming work term are expected to continue with their academic program on a full-time basis. A missed work term can be made up, but in the event that a Co-op student is unable to complete three work terms but fulfills the remainder of the degree requirements, the student will be awarded an Honours Bachelor of Science in Computing Systems (and if applicable, any of the Specializations: Computer Science, Data Analytics, and/or Software Engineering).

Please consult the academic timetable for information on courses that will be offered in 2019–2020, including when they will be scheduled.

» **COIS 1010H: The Digital World (Sc)**
Digital systems have redefined how we work, communicate, and play—just think about the World Wide Web, mobile camera phones, video games, and e-business. Core topics examine the underlying technologies of both computing and information systems and how they have become an integral and indispensable part of our daily lives.

» **COIS 1020H: Programming for Computing Systems (Sc)**
Programming for computing systems requires a solid foundation in the software development process, including algorithmic design, abstraction, implementation, testing, and documentation. Core topics include sequencing, selection, iteration, simple data types, expressions, and arrays, as well as the object-oriented notions of classes, methods, inheritance, and polymorphism. Pre- or co-requisite: COIS 1010H or PHYS 1001H or MATH 1110H. Students without prior programming experience should take COIS 1010H as a prerequisite.

» **COIS 1520H: Programming for Information Systems (Sc)**
Programming for information systems requires a solid foundation in the basic programming constructs and how programs interact with databases, networks, and human users. Core topics include sequencing, selection, iteration, simple data types, expressions, and arrays, as well as graphical user interfaces, database connectivity, programming for the web, and file management. Recommended: COIS 1010H.

» **COIS-ADMN 1620H: Introduction to Information Systems (Sc)**
Wherever and whenever information is required, an information system is also required. Core topics include the use of information systems for strategic advantage, their basic underlying technologies, the types of information systems and how they are constructed, managed, and replaced, as well as their ethical and legal use. Prerequisite: COIS 1010H.

» **COIS 2020H: Data Structures and Algorithm (Sc)**
Data structures define how data are represented, whereas algorithms define how the data structures are manipulated. Core topics include the concepts of encapsulation, information hiding, inheritance, and time complexity, as well as dynamic arrays, linked lists, binary heaps, hash tables, binary search trees, balanced trees, adjacency lists/matrices, and sorting. Prerequisite: COIS 1020H. Recommended: MATH 1350H.

» **COIS 2240H: Software Design and Modelling (Sc)**
Good software design and modelling is a necessary prerequisite for the production of software which is correct, robust, and maintainable. Using the standard Unified Modeling Language (UML) to specify design, core topics include use cases; classes and class membership; aggregation, composition, and inheritance; virtual functions and polymorphism; state diagrams; and design patterns. Prerequisite: COIS 1020H or both COIS 1520H and COIS-ADMN 2620H.

» **COIS-PHYS 2250H: Electronics (Sc) (see Physics & Astronomy)**

» **COIS 2300H: Computer Organization (Sc)**
Computer organization is the level of abstraction between the digital logic and the operating system. At this level, computing subsystems refer to hardware pieces built from lower-level building blocks. Core topics include the central processing unit, memory hierarchy, and input/output organization. Topics are supplemented with assembly language programming. Prerequisite: COIS 1020H or 1520H.

» **COIS-PHYS 2310H: Computational Physics (Sc) (see Physics & Astronomy)**

» **COIS 2320H: Digital Logic (Sc)**
Digital logic describes how computer hardware actually works at the logic gate and circuit level. Core topics include Boolean algebra, Karnaugh maps, the minimization of Boolean functions and the design of combinational and sequential circuits, including adders, decoders, multiplexers, flip-flops, and memory circuits. Prerequisite: COIS 1020H or 1520H.

» **COIS-PHIL 2410H: Symbolic Logic (Sc) (see Philosophy)**

» **COIS-MATH 2600H: Discrete Structures (Sc) (see Mathematics)**

» **COIS-ADMN 2620H: Systems Analysis and Design (Sc)**
Systems analysis and design identifies the informational needs/resources of an organization and specifies appropriate information systems to meet the needs and exploit the resources for strategic advantage. Core topics include the current methodologies, techniques, and tools used for both the analysis and design. Managerial and organizational issues are also discussed. Prerequisite: COIS-ADMN 1620H.

» **COIS-FRSC 2750H: Computer Crime and Forensics (Sc)**
Computer crime is the fastest-growing area of illegal activity in the world. Users beware! After some background information (how computers work, number systems, information-hiding algorithms), we examine the schemes and techniques used by computer criminals, the forensic techniques used to catch the criminals, and ways to prevent victimization. Recommended prerequisite: COIS 1010H.

» **COIS 2800H: Digital Culture**
Interactive digital technology and the convergence of computing, communications, public media, and entertainment have had profound cultural implications. Core topics address current concerns such as the World Wide Web, multimedia design, virtual spaces, social domains, and the blogosphere. Recommended prerequisite: COIS 1010H. This course cannot be counted as a science credit.

» **COIS 2830H: Multimedia and Design (Sc)**
Multimedia concepts, such as photo and video editing, visual effects, 3D assets, and even writing style serve as tools to explore concepts and challenges in modern user experience design, with a focus on web pages, game design, and user interfaces. Principles of design covers core concepts such as the discoverability of features, understanding diverse human users, complexity of feedback, and how computer systems interpret and react to human actions. Recommended prerequisite: COIS 1010H.

» **COIS 3020H: Data Structures and Algorithms II (Sc)**
A continuation of COIS 2020H, this course introduces more complex data structures for specific applications and extends the techniques for algorithmic design and analysis. Core topics include data structures for spell checkers, memory management, and graphs, as well as the fundamental, divide-and-conquer algorithms for sorting and order statistics. Prerequisite: COIS 2020H.

» **COIS 3030H: Software Specification and Development (Sc)**
The development of large software systems relies on sound methodologies and techniques to manage the inherent complexity and to produce quality software which satisfies the client or customer. Core topics include various software development paradigms and their usage, as well as the importance of feasibility studies, requirements analysis, and specification. Prerequisite: COIS 2240H.

» **COIS 3040H: Advanced Software Architecture and Design (Sc)**
Software architecture is concerned with the high-level design, interface, and relationships among the components that make up a software system. Testing ensures that these components work properly on their own and within an integrated system. Core topics include architecture description languages, as well as maintenance strategies and various testing methodologies. Prerequisite: COIS 2020H and 3030H.

» **COIS 3050H: Formal Languages and Automata (Sc)**
Formal languages and automata are the underlying theoretical foundations of computer science. Core topics include regular languages and finite automata, context-free languages and pushdown automata, the Turing machine and its languages. Real world applications, unsolvable problems, and their relevance to the semantics of programming are also discussed. Prerequisite: COIS 1020H. Recommended: COIS-MATH 2600H.

» **COIS-MATH 3180H: Introduction to Numerical and Computational Methods (Sc) (see Mathematics)**

» **COIS-PHYS 3200Y: Electricity and Magnetism (Sc) (see Physics & Astronomy)**

» **COIS-MATH 3210H: Mathematical Cryptography (Sc) (see Mathematics)**

» **COIS 3320H: Fundamentals of Operating Systems (Sc)**
An operating system is the software component of a computing system which is responsible for the management and accessibility of the hardware resources. Core topics include process management, synchronization, processor allocation, primary and secondary storage management, file management, security, and user interfaces. Topics are illustrated using contemporary operating systems. Prerequisite: COIS 2020H and 2300H.

» **COIS-MATH 3350H: Linear Programming (Sc) (see Mathematics)**

» **COIS-PHIL 3370H: Cyberethics (see Philosophy)**

» **COIS 3380H: Systems Programming in C (Sc)**
Systems programming produces software which provides services to the computer hardware. Using systems programming techniques in a Unix-style environment and using machine-oriented programming languages such as C/C++, core topics include procedural programming, shell programming, pipes, file processing, system calls, signals, and basic network programming. Prerequisite: COIS 2300H. Recommended: COIS 2020H.

» **COIS 3400H: Database Management Systems (Sc)**
A database is a structured collection of data, whereas a database management system facilitates the creation, querying, and maintenance of databases. Core topics include the relational model, entity-relationship diagrams, relational algebra, SQL, database application development, storage and indexing, and normalization. Topics are illustrated using a relational DBMS. Prerequisite: COIS 1020H or both COIS 1520H and COIS-ADMN 2620H.

» **COIS 3420H: Web Application Development (Sc)**
The development of web applications is an integral component of software development in an Internet-based world. Core topics include front-end design, client-side scripting, server-side programming, database connectivity, data persistence, security, extensible mark-up, usability, and accessibility. Prerequisite: COIS 2020H or 2240H. Recommended: COIS 3400H.

» **COIS 3510H: Data Visualization (Sc)**
Data visualization is a main step in the analysis of data in a wide range of scientific research areas as well as business applications. We discuss general approaches, tools, and techniques for the visualization of various types of data, including spatial data, graph data, and time series data. Prerequisite: 10.0 university credits or permission of instructor. Recommended: COIS 1020H or 1520H.

» **COIS-CUST 3533H: Game Studies (see Cultural Studies)**

» **COIS 3560H: Human-Computer Interaction (Sc)**
The study of human-computer interaction incorporates ideas from computer science, behavioural science, and design to improve interaction between people and computers. Core topics include multidisciplinary, intuitive design, computer-supported co-operative education/work, ubiquitous computing, prototyping, collaboration, social interaction, augmented reality, haptics, heuristics, interfaces, workstation independence. Prerequisite: 5.0 university credits. Excludes COIS 3950H: Human Computer Interaction.

» **COIS-ANTH 3745H: Virtual Worlds: The Anthropology of Online Communities (see Anthropology)**

» **COIS-ADMN 3750H: Principles of Online Marketing (Sc)**
Businesses today must effectively leverage the Internet and develop an online strategy which complements their traditional business practices. Core topics include website best practices, online marketing and customer relationships, positioning businesses online, and social networking for small and large enterprises. Topics are consolidated with a professional business proposal. Prerequisite: COIS-ADMN 1620H or ADMN 1000H or permission of instructor.

» **COIS 3820H: History and Impact of Computing (Sc)**
The history of digital computation is relatively recent, but all around us. By introducing the key people whose insight, inventiveness, and industry have defined the digital world, a framework is developed within which all students can appreciate the fundamental milestones of computing and their impact on the world. Prerequisite: 5.0 university credits.

» **COIS-ADMN 3850H: Fundamentals of Project Management (Sc)**
Good project management focuses on the practical realities of getting things done with limited time and resources according to specifications determined by others—with successful outcomes. This course prepares students to write the professional certification exams offered by the Project Management Institute and the Project Management Association of Canada. Prerequisite: 10.0 university credits or COIS 2240H or COIS-ADMN 2620H or permission of instructor.

» **COIS 3860H: Internship Project (Sc)**
Students work at a site external to the department for 80–120 hours. In recognition of the scope of possible projects, this work can either be performed during 2–3 one-week (not necessarily consecutive) sessions, or during 10–15 full-day sessions in consecutive weeks. Students meet on a regular basis with their faculty mentor. Prerequisite: A minimum 75% cumulative average and 10.0 university credits including 5.0 COIS credits.

» **COIS 3901H: Reading Course (Sc)**
Students are required to submit a course proposal and have it approved by the departmental curriculum committee before enrolling.

» **COIS 4000Y: Software Engineering Project (Sc)**
The software engineering project is a capstone course and provides students with the practical experience in the analysis, design, implementation, testing, and documentation of a real-world software product. Working as a team with clients, the project draws substantially on the theoretical knowledge gained in all previous COIS courses. Prerequisite: COIS 3040H. Pre- or co-requisite: COIS-ADMN 3850H. Recommended: COIS 3400H and 3420H. Excludes COIS 4850H.

» **COIS 4050H: Advanced Algorithms (Sc)**
Algorithmic techniques provide generalized approaches to solving a wide variety of problems, whereas algorithmic analysis provides the basis of comparison among different solutions. Core topics include the algorithmic techniques of divide-and-conquer, dynamic programming, and greedy algorithms, as well as the analytical techniques of problem classification, asymptotic analysis, and recurrence relations. Prerequisite: COIS 2020H and COIS-MATH 2600H. Recommended: COIS 3020H.

» **COIS 4100H: Comparative Programming Languages (Sc)**
Evaluating and selecting the most appropriate programming language for an application is a critical step in software development. Core topics include the types of programming languages as well as the principal design and implementation issues for control structures, data types, subprograms, exception handling, and concurrency. Prerequisite: COIS 2020H and 1.0 COIS credit at the 3000 or 4000 level.

» **COIS-MATH 4215H: Mathematical Logic (Sc) (see Mathematics)**

» **COIS 4310H: Computer Networks (Sc)**
A computer network links together two or more computers to enable the transfer of data. Core topics include data communication, network hardware and software, network architecture and protocols, local area and wide area networks, end-to-end routing protocols, wireless networks, Quality of Service, multimedia support, and network management. Prerequisite: COIS 3320H.

» **COIS 4350H: High Performance Computing (Sc)**
High performance computing is the use of advanced computer architectures to solve problems which require significant processing power, memory access, or storage. Core topics include advanced computer architectures, programming for shared and distributed memory machines, networking issues, caching, performance evaluation, and parallel algorithms. Topics are supplemented with case studies. Prerequisite: COIS 3320H.

» **COIS 4400H: Data Mining (Sc)**
Data mining is the extraction of previously unknown and potentially useful patterns from large data sets. Core topics include the statistical foundations of data mining, sampling mechanisms, missing data, clustering, classification, and outlier detection. Case studies cover a wide variety of applications such as astronomy and marketing. Prerequisite: 1.0 COIS credit at the 3000 or 4000 level and one of COIS 2020H or COIS-ADMN 2620H.

» **COIS 4470H: Modelling and Simulation (Sc)**
Modelling and simulation enables us to construct mathematical or computer-based representations of real-world phenomena. Three steps are typically followed: modelling the key parameters, implementing a program to simulate behaviour, and analyzing the results. Core topics include pseudo-random number generation, discrete-event and next-event simulation, output analysis, and queuing theory. Prerequisite: MATH 1550H and COIS 2020H.

» **COIS 4480H: Computer Graphics (Sc)**
Computer graphics are everywhere, from computer-animated movies and games to virtual reality and telepresence. This course introduces the fundamental mathematical and computational concepts of computer graphics. Topics include hardware, the OpenGL suite, line drawing, two-dimensional transformations, two-dimensional clipping algorithms, three-dimensional representations, three-dimensional clipping, line removal techniques, splines, and ray tracing. Prerequisite: COIS 2020H, COIS 2830H, and MATH 1350H.

» **COIS 4550H: Artificial Intelligence (Sc)**
Artificial intelligence is the study of those techniques which create perceptions of "machine intelligence" and "intelligent agents." Topics may include but are not limited to expert systems, various evolutionary learning systems such as genetic algorithms, genetic programming, and neural networks. The impact and ethics of artificial intelligence are also examined. Prerequisite: 10.0 university credits including one of COIS 1020H, 1520H, or COIS-ADMN 1620H.

» **COIS 4600H: Conceptual Analysis (Sc)**
Conceptual analysis is an important cognitive skill for systems analysis, database design, and other disciplines. Discourse analysis, including semantics and semiotics, and conceptualizing the referent world in terms of abstractions and ontologies, will be emphasized. Prerequisite: 10.0 university credits.

» **COIS 4850H: Information Systems Project (Sc)**
A capstone course which provides students with the practical experience in the analysis and design (but not implementation) of a real-world information system. Working as a team with clients, the project draws substantially on the theoretical knowledge gained in all previous COIS courses. Prerequisite: COIS-ADMN 2620H, COIS 3030H, and COIS 3850H. Recommended: COIS 3400H. Excludes COIS 4000Y.

» **COIS 4900Y, 4901H, 4902H: Advanced Reading Course (Sc)**
Students are required to submit a course proposal and have it approved by the departmental curriculum committee before enrolling.