



NEW GRADUATE PROGRAM PROPOSAL EXTERNAL REVIEWERS' ASSESSMENT REPORT

Name of Proposed Program(s):	Doctor of Philosophy (PhD) in Computer Science
Sponsoring Academic Unit(s) and College(s):	School of Computer Science (SoCS) College of Engineering and Physical Sciences (CEPS)
Date of Site Visit:	Monday, March 1, 2021 – Wednesday, March 3, 2021
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External Reviewers:	Dr. Patricia Evans, University of New Brunswick Dr. Marc Moreno-Maza, University of Western Ontario

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1 Objectives

- (a) Comment, as you are able, on the apparent consistency of the proposed program(s) with the plans of the Department/School and College and the University's Strategic Framework

Over the past 5 years, the School of Computer Science (SoCS) of the University of Guelph (UoG) has seen significant changes in its Faculty body, leading to a substantially improved research profile and more research funding. These changes align with the *path forward* initiated in 2015 in the Strategic Framework of the UoG.

In order to consolidate this research profile, the Faculty members of the SoCS of UoG need to perform research in the core topics of Computer Science. This requires the creation of a Computer Science PhD Program alongside the existing PhD program in Computational Sciences.

We believe that it is critical to strengthen research and innovation in Computer Science, since advances in the core topics of the field are not enabled by the existing PhD program in Computational Sciences. This addition of the proposed Computer Science PhD Program would enable the School of Computer Science at UoG to stand on its own and grow its research independently.

We note that supporting both fundamental and applied research is part of the objectives of the Strategic Framework of the UoG. Referring to the University's Strategic Framework, we observe that the plans of the SoCS of UoG fit into the "Inspiring Learning and Inquiry" (specifically graduate education) and "Catalyzing Discovery and Change" (supporting research) themes of the strategic framework.

- (b) Describe the extent to which the program(s)'s aims and learning outcomes are clear and in alignment with the University of Guelph's Graduate Learning Outcomes.

The learning outcome of *Critical and creative thinking* is properly addressed in the proposed program. In particular, the research component for the proposed PhD program fits into the Mastery column for the *Critical and creative thinking* rubric.

In the same rubric, one should notice that Computer Science PhD programs at various Ontario universities address the associated skill of *Breadth of Understanding* by means of a comprehensive exam or undergraduate course coverage, in addition to requiring graduate courses as part of students' graduate studies.

The learning outcome of *Literacy* is also properly addressed in the proposed program. In particular, one should notice that the component *qualifying exam (QE)* of the proposed program clearly contributes to the learning outcome of *Literacy*.

The learning outcome of *Global Understanding* is properly addressed in the proposed program.

The learning outcome of *Communicating* is properly addressed in the proposed program, in particular, with the course *CIS*6890: Technical communications*. Moreover, the thesis would include work of the reinforce and potentially mastery levels of the *Literacy* and *Communicating* rubrics.

The learning outcome of *Professional and ethical behaviour* is addressed in the proposed

program. We note that materials for this associated skill are presented in the *Univ 7100* Academic Integrity For Graduate Students* module during the orientation of new graduate students at UoG. We also observe that work as part of a research team and potential industrial collaboration is appropriate for the *Professional and ethical behaviour* rubric.

- (c) Comment on the appropriateness of proposed degree nomenclature (e.g., MSc, MAsC, MEng, etc).

The proposed degree nomenclature (PhD Program in Computer Science) is clearly appropriate.

2 Admission Requirements

- (a) Comment on the appropriateness of the program(s)'s admission requirements and their alignment with the program(s)'s learning outcomes. Do the requirements reflect the foundations required to successfully pursue the program(s)?

The program's admission requirements and the program's learning outcomes are aligned. The program's admission requirements are similar with those of the leading Computer Science Departments in Ontario.

These admission requirements are appropriate and would show students' ability to succeed in the program. A master's degree in CS, or in exceptional circumstances an outstanding undergraduate degree with research experience, shows suitable initial research experience, and the GPA requirement is essential to show that students can work at the graduate level.

To strengthen the associated skill of *Breadth of Understanding*, the newly enrolled PhD students, when they have not acquired basic knowledge in the traditional core topics of Computer Science (say: theoretical computer science, computer architecture, analysis of algorithms, programming languages, operating systems, software engineering) during their undergraduate degrees, could either take a comprehensive exam or take courses (undergraduate or graduate) on those topics.

- (b) If applicable, comment on the appropriateness of, and justification for, any alternate requirements for admission (e.g., minimum grade point average, additional languages, portfolio submissions, recognition of prior work or learning experience, etc.) above the University's alternate admission criteria.

There are no proposed alternate requirements.

3 Program Structure and Requirements

- (a) Comment on the appropriateness of the program(s)'s structure and requirements for the level of degree offered and to meet the intended learning outcomes.

The program's structure and requirements (in particular the coursework, qualifying exam, and defended thesis) are appropriate for the level of degree offered and for meeting the intended learning outcomes.

In fact, the program's structure and requirements are similar to those of the leading Computer Science Departments in Ontario.

However, as mentioned before, we note that the requirement for *breadth of understanding* is commonly satisfied (in Ontario universities) through a review of the students' background in core areas of CS, or writing exams on these topics. Instead, this program proposal indicates that it satisfies breadth by requiring students to take 8 graduate courses in total over Master's and PhD studies. However, there is no requirement in this program that these courses cover a variety of areas or the Computer Science core, and the Master's degree prerequisite will not necessarily ensure that incoming students have covered the CS undergraduate core. Satisfying the CS core through background review or comprehensive examinations is normally considered to be a PhD breadth requirement in addition to taking graduate courses.

- (b) Comment on the appropriateness of the proposed program length, stated milestones (e.g., qualifying examinations), and whether the proposed program requirements can be reasonably completed within the proposed timeframe

The proposed program length and stated milestones are appropriate and can reasonably be met. In fact, they are similar to those of the leading Computer Science Departments in Ontario. In particular, the timing of the qualifying exam (term 5) is appropriate and sets a brisk pace for the research while hopefully preventing students from continuing too long without showing their competency and project suitability.

- (c) For graduate programs with a culminating research task, comment on the nature and suitability of the major research requirements for degree completion.

The qualifying examination (to be held in the fifth semester for a full-time student), the composition and the role of its examining committee, the two publicly announced research seminars together with the objectives and evaluation mechanisms of the thesis form appropriate milestones for degree completion.

4 Program Content

- (a) To what extent does the curriculum address the current state of the discipline or area of study? If fields have been identified, please consider the ways in which the proposed curriculum addresses field-specific concerns.

The proposed curriculum addresses the concerns of the researchers in the fields of artificial intelligence and machine learning, cybersecurity, human computer interaction, algorithms and theory, computer vision, and hardware and distributed computing, where the SoCS of

UoG has recognized expertise.

We observe that the graduate course offering is being revitalized to address current areas of CS. Moreover, the proposed program enables CS to be studied as a discipline in itself, and for research to advance Computer Science knowledge. Indeed, research in Computer Science requires the field to be studied and advanced as fundamental CS rather than requiring an interdisciplinary context (as is needed for the current PhD in Computational Sciences). In addition, the proposed program enables collaboration within the SoCS of UoG.

- (b) Identify any particularly unique, innovative, or creative components of the proposed program(s).

The School of Computer Science (SoCS) has a one-year course-based master's program in Cybersecurity and Threat Intelligence (MCTI). Having a PhD degree in CS will provide a valuable extension to MCTI. We also note the Collaborative Specialization in Artificial Intelligence. More generally, with the addition of a PhD degree in Computer Science, the SoCS will have a very competitive portfolio of CS degree programs in Ontario.

5 Mode of Delivery

- (a) Comment on the appropriateness of the proposed mode(s) of delivery (i.e., means or medium used in delivering a program, including online, in-person lecture, multiple campuses, etc.) to meet the program(s)'s intended learning outcomes.

The proposed modes of delivery are appropriate. We observe that the program is to be delivered largely through in-person research and coursework, which will enable significant research interaction critical to the development of students as researchers.

We also note the expectation that PhD students would “contribute and participate actively in the full academic life of the School, including regular attendance at School seminars, and to provide leadership and counseling to undergraduate and MSc students.” This is, indeed, crucial to maintain research interactions between SoCS members as well as for developing the *professional and ethical behaviour* of PhD students.

6 Assessment

- (a) How appropriate are the proposed methods of assessment for evaluating student achievement of intended course, program, and University learning outcomes?

They are completely appropriate.

- (b) Comment on the plans for documenting and demonstrating the level of performance of students, their progress toward degree completion, and their progress toward achievement of learning outcomes.

The proposed assessment methods are semesterly student progress reports, the qualifying examination, and the thesis defence.

Semesterly progress assessment are frequently used; they are potentially a bit onerous but should catch problems before they develop significantly, and encourage students. The on-line progress assessment and its items look suitable.

The level of performance can be difficult to assess for research quality, particularly in earlier stages, and will require care by experienced faculty.

However, the SoCS of UoG is already using the proposed assessment methods (in particular student progress reports) for the PhD in Computational Sciences. Therefore, the SoCS of UoG already has a solid practice of assessing graduate student progress.

7 Resources

- (a) Comment on plans to utilize existing human (faculty and staff), physical, and financial resources to achieve the goals of the program, and/or on plans to attain necessary resources in step with implementation of the program

Recent hiring of more research-oriented faculty has provided the critical mass essential to support this program. The SoCS has now 24 tenure-track/tenured faculty members covering a sufficiently large range of CS research fields: Cybersecurity and threat intelligence, Artificial intelligence and machine learning, Data science and big data analysis, Human computer interaction, Computer vision, Bioinformatics, Hardware and distributed systems, Applied modeling and theory.

The SoCS includes sufficiently many researchers to supervise and examine thesis work, and provide appropriate graduate courses.

Graduate financial resources and research grants are in place and would be used for students in the new program. This includes a special MOU between MITACS and the MCTI program and a CFI grant which was awarded to the Cybersecurity group. We also note the role of CARE-AI, a new institute on campus to help (among other things) building collaboration with industry.

Students (and the resources used to support them) would be somewhat shifted from the existing Computational Sciences PhD. However, this is an appropriate shift due to the researchers' work on advancing CS itself, and filtering that work through the interdisciplinary program is causing significant impediments to these students and their research, as well as faculty members' research programs.

Competition for teaching resources with the undergraduate program means that the number of graduate courses taught each year is quite low, especially considering those not directed towards the professional Master's program in cybersecurity. This is primarily a problem for students completing their Master's with the same university, though the more advanced courses needed by PhD students can be particularly difficult to offer when resources are low.

Planned hiring of some teaching-focused faculty should free up some teaching resources for the graduate programs. Cross-listed courses (offered to both senior undergraduate students and junior graduate students, and presenting an introduction to a research area) are another way to free up teaching resources, in particular for advanced graduate courses.

- (b) Comment on evidence that there are adequate resources to sustain graduate students' scholarship and research activities, including library support, information technology support, and laboratory access.

Library support is particularly excellent, with specific resources and guidance available for graduate student research and thesis writing. Staff is proactive in resource assessment, renewal, and improvement.

Laboratory support is appropriate, including IT resources. All students have a computer and work area provided, and additional space and equipment as needed for their work. The SoCS has identified a need for additional space for student laboratories to support increased graduate student numbers and new researchers.

- (c) Comment on evidence of sufficient consultation with Academic Units outside of the home Department/School that are expected to contribute to the program(s).

Letters of support attached to the Self-Study (from the Associate Chair of the Department of Mathematics & Statistics and the Associate Director of Graduate Studies of the School of Engineering) demonstrate that colleagues in other academic units outside of the SoCS see favorably the development of the proposed Computer Science PhD program. These other units are those identified by the SoCS as those offering courses that might be taken by students in the new PhD program.

- (d) Comment on evidence that financial assistance for students will be sufficient to ensure adequate quality and numbers of students.

For PhD students, both domestic and international, the financial assistance is at a level similar to other Ontario universities.

We note that the proportion of students who were/are awarded external scholarships (Tri-Council, OGS, Vector) is also at a level similar to other Ontario universities.

8 Quality Indicators

- (a) Comment on indicators that provide evidence of the quality of the faculty and their ability to foster an appropriate intellectual environment, such as:
- faculty qualifications (e.g., recent research, innovations, and scholarly records and/or professional/clinical expertise);
 - proportion of program delivered by tenured, tenure-track, emeriti, and adjunct faculty;

- commitment to development of professional and transferable skills among graduate students;
- the overall quality and availability of graduate supervision and mentorship in the program(s); and
- if applicable, how supervisory responsibilities will be distributed.

The program is intended to be delivered almost entirely by tenured and tenure-track faculty, with minor co-supervisory involvement by two non-tenure-track faculty.

These faculty include active researchers and many with excellent research records, 20 with recent publications and 15 with significant active research grants. These include a Tier II Canada Research Chair, other senior researchers with well-developed research programs, and faculty members with industry research experience. The proportion of Tri-Council grant holders is a bit low for a research-oriented unit, but their numbers and concentrations are more than sufficient to support a PhD program. All faculty members in the SoCS participate in graduate research, through supervision or by serving on students' committees, and almost all have been doing both regularly.

Significant development of specific areas, such as Cybersecurity, Human-Computer Interaction, Computer Vision, and Artificial Intelligence, enable high quality supervision and relevant expertise for advisory committee participation and thesis examination.

Faculty activities with their research groups are described as being very hands-on, with weekly group meetings and individual student-supervisor meetings. Students and supervisors work closely together. Faculty members and School administration express high commitment to development of transferable skills in students, suitable for both academic research and industry, and their recent record of graduate student education shows success. Faculty members' involvement in professional organizations, editorships, industry boards, and conference committees is broad, and their good recent record of publications also demonstrate the types of involvement that they would encourage in their students.

The eligible graduate students in the existing programs have shown a small but noticeable record of success with Tri-Council and OGS scholarships.

The supervisory capacity can support the projected enrolment of 20 students, with 5 new students per year. This would be an average of less than 2 per currently active supervisor, which is appropriate for their capacity and their track records. Their funding also appears to be sufficient to provide the research support component of funding for these students; some individual grants are relatively modest while others are far greater, and together they should support the projected student growth. This capacity may include some currently used by students in the Computational Sciences PhD, but several students are expected to move to the new program, since it is more appropriate for their needs. The new program would also enable faculty to grow their research programs, expanding the grant monies available to fund graduate students.

- (b) Comment on aspects of the program(s)'s structure (e.g., seminars, colloquia, conferences) that will contribute to the intellectual quality of the student experience.

All students are required to take a course in which they will give a short talk and a short lecture, as well as participate in reviews and critiques of others' work. They will also be expected to present two public seminars, in addition to the usual qualifying examination and thesis defence.

Education through the program is supplemented by a seminar series with speakers from outside the local faculty ranks.

Individual research groups further broaden students' education through conference participation and presentations, and industrial internships.

9 Other

- (a) Use this space to address any other outstanding issues.

10 Summary and Recommendations

- (a) Use this space to provide a summary of your appraisal. List recommendations that address the quality of the proposed program(s) and identify any matters of concern.

This proposed PhD program in Computer Science is of high quality and similar to those offered at other universities, including others in Ontario. It will form part of a competitive set of offerings by the School of Computer Science at the University of Guelph. The structure, content, and resources available are appropriate to enable the program to be supported and to thrive. An increase in graduate course offerings and graduate student research space would improve this support, especially as student numbers increase.

The thesis and its assessment clearly meet the normal depth requirements for the degree. The course requirements are similar to those of other CS PhD programs. The proposed PhD program, however, lacks the additional breadth component that is common to many PhD programs in Computer Science, to ensure coverage of a wide variety of core Computer Science through either comprehensive examinations or an assessment of students' backgrounds, often undergraduate backgrounds. The proposal instead presents the number of graduate courses taken as its breadth component, but this does not satisfy the need to have covered core Computer Science, nor does it ensure breadth of studies.

This program is essential to the growth of research and scholarship in Computer Science at Guelph, which would be in keeping with the university's Strategic Framework and the School's plans, and recent advances in the SoCS will be threatened without it.

We recommend that the PhD program in Computer Science at the University of Guelph be approved.

A handwritten signature in black ink, appearing to read "P. Evans". The "P" is enclosed in a circle.

Patricia Evans
Professor
University of New Brunswick

A handwritten signature in blue ink, appearing to read "Marc Moreno-Maza".

Marc Moreno-Maza
Professor & Graduate Chair
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