Major Modifications Proposal

1. **Program**: Graduate Program in Electrical Engineering & Computer Science
2. **Degree Designation**: Master of Science in Computer Science
3. **Type of Modification**: Addition of a specialization. The specialization has different degree requirements.
4. **Effective Date**: Fall 2018
5. **Provide a general description of the proposed changes to the program.**
   We propose an addition of an Artificial Intelligence (AI) specialization to the Master of Science in Computer Science degree program. Students complete several graduate courses in AI and some other graduate courses. In addition, students conduct a research project that applies AI to a practical problem under the supervision of faculty members and in collaboration with partners in the private or public sector.
6. **Provide the rationale for the proposed changes.**
   In the last two years, the Department of Computer Science and Electrical Engineering has hired eight faculty members. Six have research interests that overlap with AI. The department has 18 other faculty members who do AI related research.

   In the last few years, the interest of applicants to our graduate program in AI has increased significantly. Last year, the program received more than 600 applications. Of the complete applications for 2017-18, a staggering 50% of the applicants expresses an interest in AI. Despite the fact that we can only advertise the specialization in February 2018 at the earliest, we expect to admit 5-10 students in the specialization for 2018-19. We anticipate that the number of students in the specialization will grow in the coming years.

   Given an emerging critical mass of faculty members in the area of AI and the recent growth of interest in AI by applicants to our graduate program, the introduction of a specialization in AI is timely.

   The Ontario government is partnering with the Vector Institute to accelerate growth in Master’s graduates in AI. Its goal is to graduate 1,000 applied Master’s students in AI-related fields per year, within five years. Vice-President Academic & Provost Lisa Philipps recently expressed that York University is eager to contribute towards this goal. This proposal is one step on the way towards training more Master’s students specializing in AI.
7. **Comment on the alignment between the program changes with Faculty and/or University academic plans.**

This proposal aligns with the priority “enhanced quality in teaching and student learning” of the University Academic Plan by providing an experiential component in the form of a research project in collaboration with partners in the private and public sector. This collaboration aligns with the priority “enhanced community engagement.” By expanding the graduate program, this proposal also aligns with the priority “advancing exploration, innovation and achievement in scholarship, research and related creative activities.”

The Lassonde School of Engineering has five research priorities. One of them is “intelligent and interactive systems.” This proposal contributes to an intensification of research in that area.

8. **Provide a detailed outline of the changes to the program and the associated learning outcomes, including how the proposed requirements will support the achievement of program learning objectives (i.e., the mapping of the requirements to the program learning outcomes).**

A specialization in AI is added to the Master of Science in Computer Science. The degree requirements of this specialization are the following. Students in the specialization have to complete three courses from the following list:

- Introduction to Artificial Intelligence (EECS 5326)
- Introduction to Machine Learning and Pattern Recognition (EECS 5327)
- Machine Learning Theory (EECS 6127)
- Probabilistic Models & Machine Learning (EECS 6327)
- Data Mining (EECS 6412)

Students in the specialization have to complete two other courses from the following list:

- Computer Vision (EECS 5323)
- An Introduction to Robotics (EECS 5324)
- Introduction to Artificial Intelligence (EECS 5326)
- Introduction to Machine Learning and Pattern Recognition (EECS 5327)
- Machine Learning Theory (EECS 6127)
- Neural Networks and Deep Learning (EECS 6322)
- Advanced Topics in Computer Vision (EECS 6323)
- Mobile Robot Motion Planning (EECS 6325)
- Probabilistic Models & Machine Learning (EECS 6327)
- Speech and Language Processing (EECS 6328)
- Statistical Visual Motion Analysis (EECS 6332)
- Multiple View Image Understanding (EECS 6333)
- Embodied Intelligence (EECS 6340)
- Knowledge Representation (EECS 6390A)
- Computational Models of Visual Perception (EECS 6390D)
- Data Mining (EECS 6412)
- Data Analytics and Visualization (EECS 6414)
Students have to complete one other graduate three-credit course. Students must also conduct a research project that applies AI to a practical problem under the supervision of faculty members and in collaboration with partners in the private or public sector.

Students must take at least one course from each of the following three areas:
- Theory of Computing & Scientific Computing (second digit is a 1 or 2)
- Artificial Intelligence & Interactive System (second digit is 3)
- Systems: Hardware & Software (second digit is 4 or 5)

Students may take at most two integrated courses (first digit is 5).

The courses EECS 6323 and EECS 6333 have the course EECS 5323 as a prerequisite. The course EECS 6322 has either the course EECS 5327 or the course EECS 6327 as a prerequisite. All other courses mentioned above do not have any specific prerequisites.

The program already has a project option. These projects usually do not have any involvement with partners in the private or public sector. Although such involvement has its merits, a project with a partner usually includes additional work such as getting familiar with the partner and their technical infrastructure (contributing to item 4 of the program learning outcomes) and interacting on a regular basis not only with the supervisor but also with the partner (contributing to item 5 of the program learning outcomes). To balance the extra work, a student in the AI specialization has to complete six three-credit courses whereas a student in the project option has to complete seven three-credit courses.

The program learning outcomes are provided in the appendix.

9. **Summarize the consultation undertaken with relevant academic units, including commentary on the impact of the proposed changes on other programs. Provide individual statements from the relevant program(s) confirming consultation and their support.**

A draft of this proposal was extensively discussed by the members of the Graduate Program in Electrical Engineering & Computer Science during a meeting on December 15, 2017. Informal feedback was obtained from the chair of FGS’s APPC and the secretary of Senate’s ASCP. All students currently enrolled in the program were provided with the opportunity to provide feedback on a draft of this proposal. Further feedback from the members of the program was incorporated into the final version of this proposal. The final version was approved in an evote by the full and associate members of the Graduate Program in Electrical Engineering & Computer Science.
The proposed changes do not impact other programs and other options within this program.

10. **Are changes to the program's admission requirements being proposed coincident with the program change(s)? If so, outline the admission changes, and comment on the appropriateness of the revised requirements to the achievement of the program learning outcomes.**

No changes to the admission requirements are proposed.

11. **Describe any resource implications and how they are being addressed (e.g., through a reallocation of existing resources). If new/additional resources are required, provide a statement from the relevant Dean(s)/Principal confirming resources will be in place to implement the changes.**

Some additional resources would be required to ensure that the courses EECS 5326, EECS 5327, EECS 6127, EECS 6327 and EECS 6412 are offered every year and that a sufficient breadth of the optional courses are routinely offered. It is anticipated that three additional courses within the area of AI need to be offered on a yearly basis. Further, some additional resources in the form of appropriate laboratory hardware may be required for the two new courses (EECS 6127, EECS 6322). In particular, modern AI makes heavy use of specialized computer processing hardware known as GPUs. Current lab facilities may need to be updated to accommodate this requirement. If the specialization grows in size beyond 10 students, some additional administrative staff to manage the contacts with the project partners might be needed as well.

Faculty members have existing ongoing collaborations and interactions with a number of partners in the private and public sector including Bell Canada, Borealis AI, Canadian Space Agency, Clearpath Robotics, Crosswing Robotics, Dapasoft Inc., Defence Research and Development Canada, iNAGO Inc., Independent Robotics, MDA, National Research Council Canada, Independent Robotics, Royal Canadian Mounted Police, Shaftesbury, The Globe and Mail, Toronto Police Services, Trans-Plan, and TwentyBN. Further, the Vector Institute has offered to assist in building connections with new partners.

A statement from the Dean and letters of support from partners are provided in the appendix.

12. **Is the mode of delivery of the program changing? If so, comment on the appropriateness of the revised mode(s) of delivery to the achievement of the program learning outcomes.**

The research project of the AI specialization is somewhat different from the research project of the project option in that the former includes involvement of a partner from the private or public sector, whereas the latter usually does not. The additional interaction with the partner further contributes to the student's professional capacity/autonomy (item 4 of the program learning outcomes) and communication skills (item 5 of the program learning outcomes).
13. **Is the assessment of teaching and learning within the program changing? If so, comment on the appropriateness of the revised forms of assessment to the achievement of the program learning outcomes.**
   There are no changes to the assessment of teaching and learning.

14. **Provide a summary of how students currently enrolled in the program will be accommodated.**
   The proposed changes do not impact students currently enrolled in the program.

15. **Provide as an appendix a side-by-side comparison of the existing and proposed program requirements as they will appear in the Undergraduate or Graduate Calendar.**
### Existing Program/Graduate Diploma Information (change from)

#### Electrical Engineering & Computer Science

The Graduate Program in Electrical Engineering & Computer Science offers the degrees of Master of Science (MSc), Master of Applied Science (MASc) and Doctor of Philosophy (PhD). The MSc program covers Computer Science. The MASc program concentrates on Computer Engineering and Electrical Engineering. The PhD program covers Computer Engineering, Computer Science, Electrical Engineering and Software Engineering.

#### Master of Science Program

**Admission Requirements**

Graduates with an honors degree in Computer Science or equivalent, with at least a B+ average in the last two years of study, may be admitted as candidates for the Masters of Science program in computer science. In addition, those admitted must have completed the equivalent of a senior-level course in the area of theoretical computer science. The following are the minimum English language test scores (if required):

- TOEFL 577 (paper-based) or 90-91 (Internet-based)
- IELTS 7
- York English Language Test 4

The Graduate Record Examination general test and computer science subject test are strongly recommended, especially for applicants who did their work outside of Canada and/or the United States.

**Degree Requirements**

Students are expected to choose between the degree by thesis or by project before the end of their second term. There is a breadth requirement on the selected graduate courses. At least one course must be from each of the following three areas:

- Theory of Computing & Scientific Computing
- Artificial Intelligence & Interactive Systems

### Proposed Program/Graduate Diploma Information (change to)

#### Electrical Engineering & Computer Science

The Graduate Program in Electrical Engineering & Computer Science offers the degrees of Master of Science (MSc), Master of Applied Science (MASc) and Doctor of Philosophy (PhD). The MSc program covers Computer Science. The MASc program concentrates on Computer Engineering and Electrical Engineering. The PhD program covers Computer Engineering, Computer Science, Electrical Engineering and Software Engineering.

#### Master of Science Program

**Admission Requirements**

Graduates with an honors degree in Computer Science or equivalent, with at least a B+ average in the last two years of study, may be admitted as candidates for the Masters of Science program in computer science. In addition, those admitted must have completed the equivalent of a senior-level course in the area of theoretical computer science. The following are the minimum English language test scores (if required):

- TOEFL 577 (paper-based) or 90-91 (Internet-based)
- IELTS 7
- York English Language Test 4

The Graduate Record Examination general test and computer science subject test are strongly recommended, especially for applicants who did their work outside of Canada and/or the United States.

**Degree Requirements**

Students are expected to choose between the degree by thesis or by project or by Artificial Intelligence specialization before the end of their second term. There is a breadth requirement on the selected graduate courses. At least one course must be from each of the following three areas:

- Theory of Computing & Scientific Computing
- Artificial Intelligence & Interactive Systems
- Systems: Hardware & Software
- Systems: Hardware & Software
No more than one-third of the course requirements can be integrated with undergraduate courses.

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<tr>
<th>MSc Degree by Thesis</th>
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<td>Candidates for the MSc degree must complete five graduate three-credit courses and successfully defend a master’s thesis. Candidates must conduct a piece of approved research under the general direction of a supervisor. The resulting thesis should demonstrate the Candidates’ research ability in the research subject.</td>
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<th>MSc Degree by Project</th>
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<td>Candidates for the MSc degree must complete seven graduate three-credit courses and conduct a research project. The research project will have a more limited scope and/or degree of originality than a thesis. The project is under the general direction of a supervisor. A paper describing the project must be submitted and graded by the supervisory committee.</td>
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<th>MSc Degree by Artificial Intelligence Specialization</th>
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<td>Candidates for the MSc degree must complete three courses from the following list:</td>
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<td>- EECS 5326,</td>
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<td>and two other courses from the following list:</td>
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<td>- EECS 6333,</td>
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Time Requirements

Students are expected to complete all of their master's degree requirements in no more than five terms (twenty months). For more details refer to the program's supplemental calendar.

- EECS 6340,
- EECS 6390A,
- EECS 6390D,
- EECS 6412,
- EECS 6414,
and one other graduate three-credit course. Candidates must also conduct a research project that applies Artificial Intelligence to a practical problem under the supervision of faculty members and in collaboration with partners in the private or public sector.

Time Requirements

Students are expected to complete all of their master’s degree requirements in no more than five terms (twenty months). For more details refer to the program’s supplemental calendar.
Program Learning Outcomes

MSc degree program in Computer Science
Specialization in Artificial Intelligence

The MSc degree in Computer Science is awarded to students who have demonstrated the degree level expectations described in the following table. This table contains

- the degree level expectations as specified by the Ontario Universities Council on Quality Assurance,
- the description for each degree level expectation provided by the Ontario Universities Council on Quality Assurance,
- the program learning outcomes for each degree level expectation, and
- the degree requirements associated with those program learning outcomes.

1. Depth and breadth of knowledge

A systematic understanding of knowledge, including, where appropriate, relevant knowledge outside the field and/or discipline, and a critical awareness of current problems and/or new insights, much of which are at, or informed by, the forefront of their academic discipline, field of study, or area of professional practice.

A. Review, analyze, assimilate and interpret a body of scientific literature in Artificial Intelligence (AI) and related topics.
B. Be able to apply AI techniques to research problems.

A. Core courses.
B. Project.

2. Research and scholarship

A conceptual understanding and methodological competence that:

a. enables a working comprehension of how established techniques of research and inquiry are used to create and interpret knowledge in the discipline;

b. enables a critical evaluation of current research and advanced research and scholarship in the discipline or area of professional competence; and

c. enables a treatment of complex issues and judgments based on established principles and techniques; and,

On the basis of that competence, has shown at least one of the following:

d. development and support of a sustained argument in written form; or

e. originality in the application of knowledge.

A. Evaluate whether an AI method is appropriate for a given research problem. (a)
B. Apply an appropriate AI method to address a research problem. (a)
C. Critique approaches taken by other researchers to address a research problem. (b)
D. Analyze a research problem based on AI established techniques. (c)
E. Present a research problem, its significance, approaches to tackling the problem, in written form. (d and e)
3. Level of application of knowledge

*Competence in the research process by applying an existing body of knowledge in the critical analysis of a new question or of a specific problem or issue in a new setting.*

| A. | Conduct supervised research appreciating the limitations of one’s knowledge. |
| B. | Solve a research problem using established AI methods or new variations of those methods. |
| C. | Identify limitations of AI methods and propose revised methods for future research. |

4. Professional capacity/autonomy

*a. The qualities and transferable skills necessary for employment requiring:*
   *i. exercise of initiative and of personal responsibility and accountability; and*
   *ii. decision-making in complex situations;*
*b. The intellectual independence required for continuing professional development;*
*c. The ethical behavior consistent with academic integrity and the use of appropriate guidelines and procedures for responsible conduct of research; and*
*d. The ability to appreciate the broader implications of applying knowledge to particular contexts.*

| A. | Accept responsibility for one’s research. (a) |
| B. | Evaluate individual progress towards meeting degree requirements and timelines. (b) |
| C. | Develop a solution to a research problem that takes ethical, social, environmental, and legal influences into account. (c) |
| D. | Comply with relevant laws, regulations and intellectual property guidelines. (d) |

5. Level of communications skills

*The ability to communicate ideas, issues, and conclusions clearly.*

| A. | Present material in a coherent and organized way, using an appropriate combination of media, to a variety of audiences. |
| B. | Construct a credible argument and design an appropriate format to convey the argument. |
| C. | Present material in the literature relevant to the research problem in one’s own words. |

| A. | Courses and project. |
6. Awareness of limits of knowledge

Cognizance of the complexity of knowledge and of the potential contributions of other interpretations, methods, and disciplines.

A. Justify the strengths and limitations of the proposed solution to the research problem.
B. Propose research questions and methods to solve those questions.

The core courses are
- Introduction to Artificial Intelligence (EECS 5326)
- Introduction to Machine Learning and Pattern Recognition (EECS 5327)
- Machine Learning Theory (EECS 6127)
- Probabilistic Models & Machine Learning (EECS 6327)
- Data Mining (EECS 6412)

The supervisor plays a crucial role in the selection of the courses. Students have to submit a course selection form at the start of their studies. Each term, students have to complete a progress report. Both are used to monitor that students achieve the program learning outcomes.
Dear Franck

I am happy to write in support of the proposed major modification to the Master of Science in Computer Science to add a specialization in Artificial Intelligence (AI).

This proposal is both timely and important in view of the high degree of government and industry interest in AI and the demand anticipated for education in this field. The EECS Department already has significant research and teaching expertise in AI and closely related fields so the proposed Specialization both naturally extends and formalizes the graduate program’s offerings.

I have discussed resource requirements with the Chair of Department and I understand that the initially projected enrolment of 10 students will be accommodated with only modest impact on the Department’s resources. Any such adjustment in the quantity and balance of graduate teaching will be addressed during the normal teaching and enrolment planning process between the Department and Dean’s Office.

If demand for the Specialization proves to be high, it is understood that an increase in administrative support for the graduate program may be necessary. The staff workload will be reviewed on an ongoing basis and resources will be allocated as appropriate.

The Lassonde School of Engineering maintains a fund to support the acquisition and renewal of teaching equipment. Should it be necessary to update the Department’s IT infrastructure in support of the AI Specialization, the Dean’s Office will work with the Chair and GPD to develop a strategy for funding the required equipment, within the context of the Department’s overall priorities.

Best wishes for the success of the proposed new Specialization, and thank you and your colleagues for working on this valuable new initiative.

Sincerely,

Richard Hornsey
Interim Dean and University Professor
Dec 11, 2017

Prof. Franck von Breugel  
Director, Graduate Program in Electrical Engineering and Computer Science  
Lassonde School of Engineering  
York University  
4700 Keele Street  
Toronto, ON M3J 1P3

Subject: Support for proposed Master of Science Specialization in Artificial Intelligence at York University.

Dear Prof. von Breugel,

I would like to confirm the enthusiastic support of TRANS-PLAN for the proposed Master of Science Specialization in Artificial Intelligence in the Department of Electrical Engineering and Computer Science at York University's Lassonde School of Engineering. TRANS-PLAN is a Canadian professional traffic and Transportation Engineering Company that creates thoughtful plans for movement in urban environments.

We are founded on the principles of innovation & efficiency. We have a desire to make this industry better by creating simple digital tools and applications to design better transportation systems. Our vision is to help turn Canadian cities into smart cities and livable communities where people and infrastructures are communicating with one another. We are registered MTO, RAQS, and licensed PEO Professional Engineering firm in Ontario. We solve challenging pedestrian, bicycle, transit, and automobile transportation problems by applying our expert knowledge and utmost care in Traffic & Transportation, planning, design and collaboration with other professionals. We provide urban transportation advisory services to public and private clients across Canada. We provide responsive and innovative solutions in Transportation & Traffic planning to private sector owners, architects, contractors, investors and government clients across Canada. We have been working closely with Prof. J. Elder of your department to develop innovative AI technologies that improve the efficiency and accuracy of our technology, and have
been hosting PhD interns from your graduate program. I believe that the proposed specialization in AI will produce exactly the kind of computer scientists we will be hiring over the next ten years as we grow this technology.

I therefore enthusiastically support this initiative and look forward to working with York in the future to ensure that this innovative program has impact in the domain of urban traffic analytics.

Sincerely,

Shadi Hagag, Founder & CEO
1 (877) 668-8784 X: 101
shadihagag@trans-plan.com
December 20, 2017

Re: York University’s MSc program with Specialization in AI

To Whom It May Concern:

We are writing to express the strong support of the Royal Bank of Canada for the development of a new MSc program with specialization in Artificial Intelligence.

Royal Bank has different teams that do work both in the fields of Machine Learning and Data Science.

In particular, Borealis AI, a RBC Institute for Research, is a curiosity-driven research centre dedicated to achieving state-of-the-art in machine learning. Established in 2016, with Labs in Toronto, Edmonton and soon Montreal, we support open academic collaborations and partner with world-class research centres in Artificial Intelligence. With a focus on ethical AI that will help communities thrive, our machine learning scientists perform fundamental and applied research in areas, such as reinforcement learning, natural language processing, deep learning, and unsupervised learning to solve ground-breaking problems in diverse fields.

In addition, the DNA Data Science team in RBC works to analyze, design and implement data science solutions using RBC’s enterprise suite of analytics tools. Data Science allows us to better understand the implications of what information means, identify trends, anticipate future behaviours, perform pattern matching, discover the golden path clients take that leads to a future decision and predict the outcomes of future events. The group specializes in taking full advantage of large data sets to explore and discover new insights that would have not been possible with traditional analytics. The group is equipped with capabilities in text
analytics/Natural Language Processing, social media analytics, Big Data advanced analytics and Machine Learning.

Artificial Intelligence and Data Science are core to what we do at RBC, as we invest in our future. Leveraging leading edge technologies and capabilities, the teams apply machine learning and statistical modelling techniques to help RBC understand the changing business environment, discover new growth opportunities, and determine where business improvements can be made. The goal of the Royal Bank is to continually be at the forefront of the data-driven transformation of our industry. To maintain our leadership we need to recruit talent in Machine Learning and with the recent popularity of Artificial Intelligence, the competition for new and skilled talent is fierce.

The proposed Master’s program in AI will create a bigger pool of talent in Artificial Intelligence. It will provide students with strong scientific expertise and give them the training to quickly ramp up and become vital contributors in Artificial Intelligence in the industry. A master’s program specializing in AI will allow us to hire more talent and grow quickly.

Globally we are at a critical juncture in the rapid scaling of the Artificial Intelligence Industry, given that the demand for trained people in Machine Learning and Artificial Intelligence is significantly higher than the supply. As Canada and RBC strive to build this capability, we are faced with intense competition from the global digital and innovation leaders. RBC is committed to becoming a digitally enabled relationship bank and recognizes that, in order to execute on this mission, it is imperative to establish ourselves as a viable destination for top talent. In accordance with this objective, RBC has established one of the few industrial R&D centres in Canada, which is focused on solving fundamental business problems using machine learning. The areas of focus thus far have included fraud detection and risk analysis, which stand to positively impact RBC’s 12 million clients. Furthermore, we are confident that there are a myriad of additional applications that will generate additional value for our clients.

We recognize the importance of identifying highly skilled scientists in artificial intelligence and machine learning for our teams, in order to enable RBC’s innovation strategy to better serve our clients and our communities. Hiring skilled graduates from such a Master’s program specializing in AI would be of interest to RBC, as they will increase the likelihood of us being able to attract and develop other similar top AI and Machine Learning talent to the company and Canada more broadly.

We are excited about this opportunity to add valuable experience and high caliber talent to RBC from York’s master’s program in Artificial Intelligence.
We would like to encourage this worthwhile program. It will yield significant expertise, socio-economic benefit, and prosperity for Canadian Industry.

Sincerely,

Foteini Agrafioti
Head, Borealis AI
Royal Bank of Canada
Toronto, December 29th, 2017

To whom it may concern,

I would like to confirm the enthusiastic support of Twenty Billion Neurons for the proposed Master of Science Specialization in Artificial Intelligence in the Department of Electrical Engineering and Computer Science at York University’s Lassonde School of Engineering.

Twenty Billion Neurons (TwentyBN) teaches machines to perceive the world like humans. Using a unique crowd-acting platform on which humans demonstrate the world to machines, the company trains camera systems to become aware of what they are looking at. TwentyBN partners with enterprise customers to bring visual sensing capabilities to robots, home devices and cars.

I believe that the proposed specialization in AI will produce exactly the kind of computer scientists we will be looking to hire over the next years as we grow our company. I therefore enthusiastically support this initiative and look forward to working with York in the future.

Sincerely,

[Signature]

Roland Memisevic,
Chief Scientist, Twenty Billion Neurons
roland.memisevic@twentybn.com
New Course Proposal Form

1. **Program:** Electrical Engineering & Computer Science

2. **Course Number:** GS/EECS 6127

3. **Credit Value:** 3

4. **Long Course Title:** Machine Learning Theory

5. **Short Course Title:** Machine Learning Theory

6. **Effective Session:** Fall 2018

7. **Calendar (Short) Course Description:**

   This course takes a foundational perspective on machine learning and covers some of its underlying mathematical principles. Topics range from well-established results in learning theory to current research challenges. We start with introducing a formal framework, and then introduce and analyze learning methods, such as Nearest Neighbors, Boosting, Support Vector Machines (SVMs) and Neural Networks. Finally, students present and discuss recent research papers.

8. **Expanded Course Description:**

   The course starts with providing a framework for analysis of classification tasks, covering the basics of statistical learning theory. This part introduces the PAC (probably approximately correct) framework of learnability and statistical risk bounds within this framework. We identify the Vapnik-Chervonenkis-dimension (VC-dimension) as a measure of complexity of a class of models, that characterizes whether this class of models is learnable or not. After getting acquainted with this notion through understanding examples of the VC-dimension of simple classes, we study the VC-dimension of various practical classes such as linear halfspace classifiers and simple ensembles such as weighted majority votes. This part also presents a basic “No-Free-Lunch” theorem stating the fundamental limitations of learning in the absence of prior knowledge. The main goal of this section of the course is to get familiarized with the notions of risk and generalization and how these depend on both the complexity of the model class and the model fit (bias-complexity tradeoff).

   The second part of the course shifts the focus from statistical analysis of machine learning to computational feasibility. It introduces algorithms for machine learning and analysis for these methods based on the introduced formal framework. Specifically, the course covers methods for linear classification (ranging from the simple perceptron algorithm to support vector machines). We introduce convex learning problems and stochastic gradient descent as the most prominent optimization method employed in machine learning. The course will discuss neural networks and point out current research challenges for machine learning theory. Time permitting, it introduces Boosting, a very successful practical tool that enjoys solid theoretical justifications. The course may also cover kernel methods and nearest neighbor classification, as an example of a non-parametric method. The goal of this part of the course is not only to get acquainted with some practical methods (out of the wide range machine learning tools) but to understand how to view these methods through
a formal framework of analysis and thereby to realize how such methods can be understood and analyzed in a principled way.

Throughout the course, we also turn to current research challenges. Each student picks a recent research paper, presents it in class, and leads a discussion of the chosen work. The student then also prepares a written report on this. All students are responsible for also reading and participating in the discussion of the papers presented throughout the course.

9. Rationale:

Machine learning is currently an influential subfield of Computer Science. With applications in numerous fields, including information technologies, medicine, physics, and finances, Machine Learning has an ever growing influence on science and society. It is likely that many students of the EECS graduate program will encounter (or even employ) machine learning methods during the course of their career. Gaining a deeper and systematic understanding of the underlying principles, possibilities, and fundamental limitations of these methods is thus highly valuable to students graduating from the EECS graduate program.

The overall learning goal is to get acquainted with tools and frameworks of analysis for machine learning methods. An important general lesson to take from this course is how the success of various learning methods depends on specific characteristics of a given learning problem. Students learn how to formally evaluate the capabilities of specific machine learning tools.

Concrete learning outcomes include:

Part one

- understand and be able to reproduce definitions of the basic framework of learning theory, such as notions of risk and model complexity

- produce simple mathematical proofs within this framework

- produce examples and counterexamples to simple statements within this framework

Part two

- describe and reproduce the various machine learning methods presented in class

- apply notions from part one of the course to analyse these methods

- demonstrate examples of input data on which the learnt methods would work well (or do not work well), and provide simple proofs for this

Part three

- summarize and critique a recent work of research

- identify the research question addressed

- evaluate the validity of the proposed solution

- identify open research directions related to the chosen work
During part one and two of the course, the targeted learning outcomes are practised through exercises (in class and take home; exercises are not part of the evaluation; written exercises are graded for purpose of feedback). Whether the outcomes are achieved is assessed in the midterm and final exam.

The learning outcomes of part three will be practised and evaluated through oral presentations and group discussions in class during the term, as well as in the written report at the end of the term.

10. Evaluation:

Students take two exams (midterm and final) on the taught material and prepare a report and discussion of the chosen research paper.

- Midterm: 25%
- Final exam: 30%
- Paper presentation: 10%
- Paper discussions: 10%
- Written paper report: 25%

11. Integrated Courses:

N.A.

12. Crosslisted Courses:

N.A.

13. Faculty Resources:

Ruth Urner, Marcus Brubaker

14. Physical Resources:

Need only lecture hall.

15. Bibliography and Library Statement:

The first two parts of the course will be following closely material of the textbook


Throughout the course students will discuss papers from journals such as

- Journal of machine learning research (JMLR); http://www.jmlr.org/

and conferences such as
- Conference On Learning Theory (COLT)
- Algorithmic Learning Theory (ALT)
- Conference on Neural Information Processing Systems (NIPS)
- International Conference on Machine Learning (ICML)

The concrete list of research papers discussed will vary from year to year, some examples of suitable publications are:


Please submit completed forms and required supporting documentation by email to the Coordinator, Faculty Governance – mmschiff@yorku.ca
MEMORANDUM

To: Franck van Breugel, Graduate Program Director, Department of Electrical Engineering and Computer Science
From: John Dupuis, Lassonde Librarian
Re: EECS 6127 – Machine Learning Theory
Date: August 14, 2017

I have reviewed the course proposal and attached bibliography EECS 6127 – Machine Learning Theory and can state that the York University Libraries have the required resources to support this graduate level course.

Please be aware that the library offers the following service to help students with research assignments:

- A librarian can go to the classroom or tutorial and help introduce students to the various resources available at the library including standards, ejournals, ebooks and databases. Many students are not aware of what they can access via the library and how it can help them in their assignments.
- The library maintains a series of Library Research Guides highlighting the main resources in the various scientific and technical fields. Two of the relevant ones for this course are Computer Science (http://researchguides.library.yorku.ca/cse?hs=a) and Mathematics (http://researchguides.library.yorku.ca/mathematics?hs=a).

The following electronic resources licensed by the library may be of help to the students in this course:

- **Books24x7 IT Pro; Engineering Pro; Access Engineering; Morgan and Claypool Synthesis** – extensive ebook packages with valuable information for all computer science and engineering subject areas
- **ACM Digital Library and IEEE Digital Library** are the standard sources for journals and conferences in computer science.
- **MathSciNet** is the main bibliographic database for mathematics
- **Compendex** is the main bibliographic database in engineering and it covers all the engineering disciplines.
- **INSPEC** is a bibliographic database that specialized in physics, computer and electrical engineering.
- **Web of Science and Scopus** are bibliographic databases provides more complete and advanced coverage of computer science and engineering topics.

If you have any questions, please do not hesitate to contact me.
New Course Proposal Form

The following information is required for all new course proposals. To facilitate the review/approval process, please use the headings below (and omit the italicized explanations below each heading).

1. **Program:** Electrical Engineering & Computer Science

2. **Course Number:** GS/EECS 6322

3. **Credit Value:** 3.0

4. **Long Course Title:** Neural Networks and Deep Learning

5. **Short Course Title:** Neural Networks and Deep Learning

6. **Effective Session:** Fall 2018

7. **Calendar (Short) Course Description:**
   This is the description of the course as it will appear in the University course repository and related publications. Calendar (short) course descriptions should be written in the present tense and may be a maximum of 60 words. Please include information with respect to any pre-/co-requisites and/or crosslisting or integration in the course description. Please indicate if the language of instruction is other than English.
   This course covers the theory and practice of deep learning and neural networks. Topics covered include training methods and loss functions, automatic differentiation and backpropagation, network architectures for different learning problems, validation, model selection and software tools.
   Prerequisites: EECS 5327 or EECS 6327 or permission of instructor

8. **Expanded Course Description:**
   This is the detailed course description that will be published in course outlines, program handbooks, etc.
   Neural Networks and Deep Learning have become a dominant method in many areas of artificial intelligence and machine learning. They now constitute the state-of-the-art techniques to solve problems such as speech recognition, object detection and recognition, face recognition, text translation, image synthesis, speech synthesis and many others.

   Neural networks, originally inspired by the functioning of the brain, are made up of numerous simple computational operations (i.e., neurons) which are combined together in structured ways to enable arbitrarily complex computations known as a neural network. These neurons are typically grouped into layers which perform their computation in parallel before producing an output which is used in the subsequent layer. The connections between layers and neurons are defined by a high dimension set of parameters known as weights. The problem of learning these weights from data is the central problem in neural
networks. Historically networks were “shallow” meaning that they contained relatively small numbers of layers between their inputs and their outputs due to difficulties in learning the weights. Recent advances have changed this with modern networks routinely having 10’s to 100’s of layers, leading to the new nomenclature of “deep learning”.

This course will cover a review of existing methods and state-of-the-art methods in the field of Neural Networks and Deep Learning. Topics include the following:
1. Fundamentals of neural network architectures (e.g., convolution, activation functions, pool operations, normalization operations)
2. Training neural networks (e.g., gradient computations, backprop, forward/backward automatic differentiation, stochastic gradient descent and its many variations)
3. Software frameworks for building neural networks (e.g., TensorFlow, PyTorch, etc)
4. Architectures for specific problem types (e.g., image labelling, pixel labelling, text processing, image synthesis, text synthesis, time series modelling, etc)
5. Techniques for reducing data requirements and improving generalization (e.g., regularization techniques, dropout, data augmentation, transfer learning, multi-output networks)

9. Rationale:
 Please indicate how the proposed course will contribute to the academic objectives of the program. Please provide a description of the learning outcomes/objects for the course. As well, please indicate the relationship of the proposed course to other existing options, particularly with respect to focus/content/approach. If overlap with other existing courses exists, please indicate the nature and extent of consultation that has taken place. Additionally, please append the graduate program’s existing learning outcomes as a separate document.

There are no courses like this at York University. The most closely related courses are EECS 5327 and EECS 6327. These courses serve as a pre-requisite for this course and provide a foundation of methods and concepts which are built upon in this course. Neither of these courses provides in depth, concentrated coverage of the subject matter to be covered in the proposed course.

Neural Networks and Deep Learning are now dominant techniques in numerous areas of artificial intelligence including: machine learning, natural language processing and computer vision. Graduates with skills in this area are in demand in many industries and research areas, including many outside of traditional artificial intelligence. It also is an area of active research and expertise in the Department of Electrical Engineering and Computer Science. This course will give students a basic background in machine learning and in depth understanding of neural networks and deep learning, including how to apply them to new problems.

10. Evaluation:
 Please supply a detailed breakdown of course requirements, including the type and percentage value of each assignment. The expectation is that course assignments can normally be accomplished within the course period. If applicable, details regarding expectations and corresponding grading requirements with respect to attendance and participation should be provided.

Proposed evaluation:
- 2 seminars (individual) 40%
- course project (individual) 60%

The seminars will be critical reviews/analysis of papers drawn from the current and classic literature. They will be presented to the class and evaluated in terms of presentation and...
content. Seminars will be scheduled regularly throughout the term.

Students will propose and execute an applied project using the methods in the course. The specific topic of the project will be decided in conjunction with the instructor. Grading will be based on a final report and presentation describing the details and outcome of the project to be presented at the end of the semester.

11. Integrated Courses:
Graduate courses may be integrated only with undergraduate courses at the 4000-level, where it is understood that 4000-level indicates an advanced level. Graduate students will be expected to do work at a higher level than undergraduates. If the proposed course is to be integrated, please provide a grading scheme that clearly differentiates between the work that undergraduate and graduate students perform, including a description of how the work performed by graduate students is at a higher level. As well, please indicate the course information for the undergraduate course (i.e., Faculty/unit/course number/credit value) and include a statement from the relevant undergraduate chair or undergraduate director indicating agreement to the integration.
N/A

12. Crosslisted Courses:
Crosslisted courses are offered between two or more graduate programs. For crosslisted courses, please include a statement of agreement from the director of the other graduate program(s).
N/A

13. Faculty Resources:
Provide the names of faculty members in your program qualified to teach this course. Stipulate the frequency with which you expect this course to be offered, including the impact that this course will have on faculty resources.
A number of faculty members are qualified to teach this course, including:

M. Brubaker, R. Wildes, H. Jiang, R. Urner, J. Elder

It is proposed that one section of the course be offered no more than once per year. The section will be limited to 15 students for pedagogical reasons.

14. Physical Resources:
Please provide a statement regarding the adequacy of physical resources (equipment, space, labs, etc.), including whether or not additional/other physical resources are required and how the need for these additional/other physical resources will be met.
No new physical labs are required for this course. However, it is required that suitable computing hardware is available to students in existing labs. In particular, specialized computing hardware (e.g., servers, GPUs) are required to efficiently and effectively process the volume of data required for training modern neural networks. This may require upgrades to existing departmental labs and servers or the purchase of suitable amounts of time from cloud-based hardware services (e.g., AWS or Google Cloud).

15. Bibliography and Library Statement:
Please provide an appropriate and up-to-date bibliography in standard format. A statement from the University librarian responsible for the subject area certifying that adequate library resources are available for the new course must be provided.
The core readings will consist of research papers and monographs drawn from both important contributions of the past as well as recent notable additions to the literature. A primary source is likely to be the textbook:

Related Textbooks:


As this area is rapidly changing, it is expected that much of the material will be drawn from leading journals and the proceedings of top conferences in the area. These are listed below.

Relevant Journals and Proceedings:

Journal of Machine Learning Research (JMLR)

International Conference on Learning Representations (ICLR)

IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)

Neural Information Processing Systems (NIPS)

International Conference on Machine Learning (ICML)

Please submit completed forms and required supporting documentation by email to the Coordinator, Faculty Governance – mmschiff@yorku.ca
MEMORANDUM

To: Franck van Breugel, Graduate Program Director, Department of Electrical Engineering and Computer Science

From: John Dupuis, Computer Science Librarian

Re: EECS 6322 – Neural Networks and Deep Learning

Date: January 5, 2018

I have reviewed the course proposal and attached bibliography EECS 6322 – Neural Networks and Deep Learning and can state that the York University Libraries have the required resources to support this graduate level course.

Please be aware that the library offers the following service to help students with research assignments:

- A librarian can go to the classroom or tutorial and help introduce students to the various resources available at the library including standards, ejournals, ebooks and databases. Many students are not aware of what they can access via the library and how it can help them in their assignments.
- The library maintains a series of Library Research Guides highlighting the main resources in the various scientific and technical fields. Two of the relevant ones for this course are Computer Science (http://researchguides.library.yorku.ca/cse?hs=a) and Mathematics (http://researchguides.library.yorku.ca/mathematics?hs=a).
- The Libraries actively support the use of citation management software such as Mendeley. Training sessions can be arranged.

The following electronic resources licensed by the library may be of help to the students in this course:

- Books24x7 IT Pro; Engineering Pro; Access Engineering; Morgan and Claypool Synthesis – extensive ebook packages with valuable information for all computer science and engineering subject areas
- ACM Digital Library and IEEE Digital Library are the standard sources for journals and conferences in computer science.
- MathSciNet is the main bibliographic database for mathematics
- Compendex is the main bibliographic database in engineering and it covers all the engineering disciplines.
- INSPEC is a bibliographic database that specialized in physics, computer and electrical engineering.
- Web of Science and Scopus are bibliographic databases provides more complete and advanced coverage of computing topics.

If you have any questions, please do not hesitate to contact me.