Updating the contents and structure of Computer Engineering – Part II

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5 July 2017

1 Introduction

Last November, I submitted a report to the Department describing possible changes to Computer Engineering at Dalhousie University, including the addition of a new second year course for Computer Engineers, suggested modifications to existing courses, and increasing the number of academic terms.[1]

The growing interest in Computer Engineering (evidenced by the number of students registered for Dalhousie Computer Engineering), coupled with the level of unpreparedness exhibited by this summer's Computer Engineering students, means the need to update the program has become all the more important.

This report compares Dalhousie Computer Engineering with the sample Computer Engineering program developed by ACM-IEEE for Electrical and Computer Engineering departments (ACM-IEEE, 2016). It identifies courses missing from Dalhousie Computer Engineering and suggests ways of including them, through the addition of two new courses and the complete redesign of an existing course.

2 The programs

2.1 Dalhousie

Students in Dalhousie Computer Engineering are registered as Electrical Engineering students. Rather than taking the full Electrical Engineering program, Computer Engineering students take five distinct courses: *Systems Analysis*, *Data Structures*, *Microprocessors, Computer Architecture*, *Operating Systems, Communication Networks,* and *Real Time Systems*. In addition, they take three computer-related courses as Electrical Engineers: *Computer Methods*, *Microprocessors*, and *Data Structures & Numerical Methods*. The courses common to all Electrical Engineering students and those required by students taking Dalhousie Computer Engineering are shown in Table 1.

The structure of Dalhousie Computer Engineering is such that students take a total of three computer-related courses in Term 5 and two in Terms 6. Not only is this proving to be an overly demanding workload for many students, especially in the second term, some of them learn, halfway through their penultimate year that they have no interest whatsoever in Computer Engineering.

[1] In the original report, a brief history of Computer Engineering at Dalhousie was presented, from its inception in the 1990s as an option, to a degree in the mid-2000s, and the abeyance of the degree in 2012. What was unknown at the time was that students registering after 2012 would no longer even receive a Computer Engineering designation on their transcripts. Since Dalhousie now offers neither a degree nor an option, this report simply refers to Dalhousie Computer Engineering.

Table 1: Dalhousie Computer Engineering courses[2]

Course	Description	Course	Description
Term 1		*Term 2*	
ENGI 1101	Engineering Design & Graphics I	ENGI 1202	Mechanics of Materials
MATH 1280	Engineering Mathematics I	MATH 1290	Engineering Mathematics II
ENGM 1081	Computer Methods	ENGM 1041	Applied Linear Algebra
CHEM 1021	Engineering Chemistry I	PHYC 1290	Physics II
PHYC 1280	Physics I	CHEM 1022	Engineering Chemistry II
Term 3		*Term 4*	
BIOL 1030	Biology for Engineers	ENGI 2203	Engineering Design II
HSTC 1800	History of Engineering I	HSTC 1801	History of Engineering II
ENGM 2101	Applied Vector Calculus	ENGM 2022	Applied Differential Equations
ENGM 2032	Probability and Statistics		Discipline-specific elective 1
ECED 2000	Electric Circuits		Discipline-specific elective 2
ENGI 2102	Thermo-Fluid Engineering I		Discipline-specific elective 3
Term 5		*Term 6*	
ECED 3003	Networks and Systems	CSCI 3120	Operating Systems
ECED 3201	Introduction to Electronics	ECED 3202	Analog Electronics
ECED 3204	Microprocessors	ECED 3403	Computer Architecture
ECED 3401	System Analysis	ECED 3511	Communication Systems
ECED 3500	Signal Analysis	ECED 3600	Modern Control Systems
ENGM 3282	Data Structures & Numerical Methods	ECED 3901	Electrical Engineering Design II
Term 7		*Term 8*	
ECED 4404	Computer Networks & Communications	CPST 3030	Engineering in Society II
ECED 4502	Digital Signal Processing	ECED 4102	Electromechanics
ECED 4513	Communication Networks	ECED 4900	Senior Year Project I
ECED 4901	Senior Year Project II	ECED 4402	Real Time Systems
	Humanities Elective		Technical Elective
	Technical Elective		

2.2 ACM-IEEE Computer Engineering Program

The ACM-IEEE Joint Task Group on Computer Engineering Curricula has developed four sample Computer Engineering program curricula, including, for example, ones for programs offered by universities in the EU and in China. The sample curricula shown here is for programs offered by Electrical and Computer Engineering departments.

The ACM-IEEE program recognizes the importance of software design, with at least one course in programming, data structures, or algorithms in the first five semesters (see Table 2 for the

[2] Colour coding for table:

Courses shared with Electrical Engineering students	Courses unique to Dalhousie Computer Engineering	Courses required by all students in Electrical Engineering

complete program). This is considered a sufficient foundation for higher-level courses in, for example, data communications, embedded systems, and operating systems. Moreover, the level of software education enables students to take electives in Computer Engineering, Computer Science, or both; in fact, the ACM-IEEE Joint Task Group recommends that students not be restricted to taking courses in Electrical Engineering.

Table 2: ACM-IEEE Sample Computer Engineering Program
(Courses highlighted in green are in programming, data structures, or algorithms)

Course	Description	Credit	Course	Description	Credit
Semester 1			*Semester 2*		
MTH 101	Calculus I	3	MTH 102	Calculus II	3
CHM 101	Chemistry I & Lab	4	PHY 101	Physics I	3
CSC 101	Programming I & Lab	4	CSC 102	Programming II & Lab	4
	English Composition I	3	ECE 101	Introduction to ECE	2
	Humanities Elective	3		English Composition II	3
	Total Credit Hours	17		*Total Credit Hours*	15
Semester 3			*Semester 4*		
MTH 201	Calculus III	3	MTH 203	Differential Equations	3
PHY 201	Physics II	3	MTH 204	Discrete Structures	3
ECE 201	Digital Devices & Lab	4	ECE 202	Microprocessors & Lab	4
CSC 201	Data Structures	3	ECE 203	Circuits/Electronics I	3
MTH 202	Linear Algebra	3	MTH 205	Probability & Statistics	3
	Total Credit Hours	16		*Total Credit Hours*	16
Semester 5			*Semester 6*		
CSC 301	Introduction to Algorithms	3	CSC 302	Client/Server Programming	3
ECE 301	Circuits/Electronics II & Lab	4	ECE 303	Signals & Systems	3
ECE 302	Digital System Design & Lab	3	ECE 304	Data Communication	3
	Humanities Elective	3	ECE 305	Computer Architecture	3
				Social Science Elective	3
	Total Credit Hours	13		*Total Credit Hours*	15
Semester 7			*Semester 8*		
ECE 401	CE Design I	2	ECE 402	CE Design II	2
ECE 403	Embedded Systems & Lab	3	ECE 404	Computer Security	3
ENG 401	Writing for Engineers	3	ECE 405	Operating Systems	3
	CE Elective	3		CE Elective	3
	Fine Arts Elective	3		Social Science Elective	3
	Total Credit Hours	14		*Total Credit Hours*	14

3 Comparing Dalhousie Computer Engineering with the ACM-IEEE program

Although Dalhousie Computer Engineering has undergone no significant changes over the 25 years of its existence, 74 percent of the courses in the sample ACM-IEEE program are met by Dalhousie Computer Engineering. Seven of the eight computer-related courses in Dalhousie Computer Engineering have an ACM-IEEE equivalent (see Table 3).

Table 3: ACM-IEEE courses met by existing Dalhousie courses (Dalhousie computer-related courses highlighted in green)

	ACM-IEEE		Dalhousie
Course	**Description**	**Course**	**Description**
MTH 101	Calculus I	MATH 1280	Engineering Mathematics I
CHM 101	Chemistry I & Lab	CHEM 1021	Engineering Chemistry I
CSC 101	Programming I & Lab	ENGM 1081	Computer Methods
	English Composition I	CPST 3030	Engineering in Society II
	Humanities Elective		Humanities Elective
MTH 101	Calculus II	MATH 1290	Engineering Mathematics II
PHY 101	Physics I	PHYC 1280	Physics I
CSC 102	Programming II & Lab		
ECE 101	Introduction to ECE		
	English Composition II		
MTH 201	Calculus III	ENGM 2101	Applied Vector Calculus
PHY 201	Physics II	PHYC 1290	Physics II
ECE 201	Digital Devices & Lab	ECED 3201	Introduction to Electronics
CSC 201	Data Structures	ENGM 3282	Data Structures & Numerical Methods
MTH 202	Linear Algebra	ENGM 1041	Applied Linear Algebra
MTH 203	Differential Equations	ENGM 2022	Applied Differential Equations
MTH 204	Discrete Structures		
ECE 202	Microprocessors & Lab	ECED 3204	Microprocessors
ECE 203	Circuits/Electronics I	ECED 2000	Electric Circuits
MTH 205	Probability & Statistics	ENGM 2032	Probability and Statistics
CSC 301	Introduction to Algorithms		
ECE 301	Circuits/Electronics II & Lab	ENGI 2203	Engineering Design II
ECE 302	Digital System Design & Lab	ECED 4502	Digital Signal Processing
	Humanities Elective		
	Social Science Elective		
CSC 302	Client/Server Programming	ECED 4404	Computer Networks & Communications
ECE 303	Signals & Systems	ECED 3500	Signal Analysis
ECE 304	Data Communication	ECED 4513	Communication Networks
ECE 305	Computer Architecture	ECED 3403	Computer Architecture
ECE 401	CE Design I	ECED 4900	Senior Year Project I
ECE 403	Embedded Systems & Lab	ECED 4402	Real Time Systems
ENG 401	Writing for Engineers		
	CE Elective		Technical Elective
	Fine Arts Elective		
ECE 402	CE Design II	ECED 4901	Senior Year Project II
ECE 404	Computer Security		
ECE 405	Operating Systems	CSCI 3120	Operating Systems
	CE Elective		Technical Elective
	Social Science Elective		

There are five Computer Engineering specific courses omitted from Dalhousie Computer Engineering; their ACM-IEEE number, description, and contents are:

CSC 102: Intermediate Computer Programming. Object-oriented problem solving, design, and programming; introduction to data structures, algorithm design and complexity.

ECE 101: Introduction to ECE. What it means to be an engineer, engineering ethics, engineering modeling, the design process, areas of ECE, communication skills.

MTH 204: Discrete Structures. Concepts of algorithms, induction, recursion, proofs, logic, set theory, combinatorics, graph theory fundamental to study of computer science.

CSC 301: Introduction to Algorithms. Study of complexity of algorithms and algorithm design; tools for analyzing efficiency; design of algorithms, including recurrence, divide-and-conquer, dynamic programming and greedy algorithms.

ECE 404: Information Security. Basic and advanced concepts in cryptography and network security: symmetric and asymmetric cryptography, key management, wired and wireless network security protocols, network systems security.

There are 17 courses in Dalhousie Computer Engineering that have no direct ACM-IEEE counterpart; this includes ECED 3401, System Analysis (see Table 4).

Table 4: Dalhousie Computer Engineering courses with no ACM-IEEE counterpart

Course	Description	Course	Description
ENGI 1101	Engineering Design & Graphics I		Discipline-specific elective 3
ENGI 1202	Mechanics of Materials	ECED 3003	Networks and Systems
CHEM 1022	Engineering Chemistry II	ECED 3202	Analog Electronics
BIOL 1030	Biology for Engineers	ECED 3401	System Analysis
HSTC 1800	History of Engineering I	ECED 3511	Communication Systems
ENGI 2102	Thermo-Fluid Engineering I	ECED 3600	Modern Control Systems
HSTC 1801	History of Engineering II	ECED 3901	Electrical Engineering Design II
	Discipline-specific elective 1	ECED 4102	Electromechanics
	Discipline-specific elective 2		

4 Incorporating the ACM-IEEE program into the Dalhousie program

The current structure of Dalhousie's four-year Electrical Engineering program precludes meeting all the courses listed in the sample ACM-IEEE program. Accordingly, this section considers ways in which some of the course material in the five computer-related courses in the ACM-IEEE program could be incorporated into Dalhousie Computer Engineering.

The contents of the six courses are such that they can be combined into two stand-alone courses (one introductory and one introducing advanced software design concepts) and one specialized course; for example:

Introduction to Computer Engineering. An introductory course in Computer Engineering created by combining CSC 102 (Programming II & Lab) and ECE 101 (Introduction to ECE). It would introduce students to Computer Engineering concepts and include more complex software design methods. This would need to replace an existing Term 4 course.

Introduction to Algorithms. A course examining advanced structures and algorithms, enabling students to design better software solutions. It combines the material covered in MTH 204 (Discrete Structures) and CSC 301 (Introduction to Algorithms). This new course could replace ECED 3403 (Systems Analysis).

Computer Security. A course in computer security, examining the physical, cyber, and human aspects of computer security. The course would be based on the contents of ECE 404 (Information Security). This would mean replacing an existing an existing third or fourth year ECED (non-computer Electrical Engineering) course.

In addition to the above, ECED 4402 (Real Time Systems) would continue to increase its focus on embedded systems, based on ECE 403 (Embedded Systems & Lab) recommendations.

4.1 Eight term (four year) structures

Table 5 shows one possible eight-term structure, with the following changes:

1. Data Structures & Numerical Methods is moved to Term 3. Such a move is seen as beneficial as it means that students are gaining exposure to programming in Year 2. This also means that Computer Engineering students are not having three computer-related courses taught in Term 5. In this and subsequent examples, it is assumed that Data Structures & Numerical Methods has been moved.
2. *Introduction to Computer Engineering* is in Term 4. This introduces students to computer engineering concepts at an earlier stage in their studies.
3. *Introduction to Algorithms* is in Term 5, thereby ensuring that students have the foundations necessary for subsequent computer engineering and computer science courses.
4. *Computer Security* is in Term 8.

Table 5: Dalhousie Computer Engineering – Eight-terms version 1

Year	Term	Description
1	1	Programming I
	2	
2	3	Data Structures & Numerical Methods
	4	*Introduction to Computer Engineering*
3	5	Microcomputers *Introduction to Algorithms*
	6	Computer Architecture Operating Systems
4	7	Computer Networks & Communications
	8	Real Time Systems *Computer Security*

Advantages: Data Structures & Numerical Methods and the three new courses are in a logical sequence.

Disadvantages: The course load in Term 6 remains unchanged.

By moving the Operating Systems course from Term 6 to Term 7, the course-load problems in Term 6 could be reduced. One possible solution is to move Operating Systems to Term 7, as shown in Table 6.

Table 6: Dalhousie Computer Engineering – Eight terms version 2

Year	Term	Description
1	1	Programming I
	2	
2	3	Data Structures & Numerical Methods
	4	*Introduction to Computer Engineering*
3	5	Microcomputers *Introduction to Algorithms*
	6	Computer Architecture
4	7	Computer Networks & Communications Operating Systems
	8	Real Time Systems *Computer Security*

The benefits of both of these approaches means that very little is changed (i.e., the eight term program remains), although it requires moving Data Structures & Numerical Methods to Term 3. The new courses are in a logical sequence.

4.2 A nine-term structure

If the workload in the eight-term structures proved to be too onerous for most students, a nine-term structure could be adopted, such as that shown in Table 7.

Table 7: Dalhousie Computer Engineering – Nine terms

Year	Term	Description
1	1	Programming I
	2	
2	3	Data Structures & Numerical Methods
	4	*Introduction to Computer Engineering*
3	5	Microcomputers *Introduction to Algorithms*
	6	Computer Architecture
4	7	Operating Systems
	8	Computer Networks & Communications Real Time Systems
5	9	*Computer Security*

4.3 A ten-term (five year) structure

If it was not possible to reduce the number of third or fourth year non-Computer Engineering courses, a ten-term structure could be adopted. The structure shown in Table 8 offers Dalhousie Computer Engineering courses in an order similar to that offered in four-year ACM-IEEE program. This essentially treats Dalhousie's Years 3, 4, and 5 as ACM-IEEE's Years 2, 3, and 4, respectively.

Table 8: Dalhousie Computer Engineering – Ten terms

Year	Term	Description
1	1	Programming I
	2	
2	3	Data Structures & Numerical Methods
	4	*Introduction to Computer Engineering*
3	5	Microcomputers
	6	*Introduction to Algorithms*
4	7	Computer Architecture
	8	Operating Systems
5	9	Computer Networks & Communications Real Time Systems
	10	*Computer Security*

5 Recommendations

A number of international organizations and the Canadian government recognize that there is a demand for highly-skilled Computer Engineers (for example, see (Schwab, 2016; Government of Canada, 2017)). If Dalhousie's Department of Electrical and Computer Engineering is to contribute Canada's growing demand for highly-skilled graduates in fields such as Computer Engineering, it should:

1. Restore the Computer Engineering designation on undergraduate transcripts immediately.
2. Move Data Structures & Numerical Methods to Term 3.
3. Develop and introduce the three new courses (*Introduction to Computer Engineering*, *Introduction to Algorithms*, and *Computer Security*) in the 2018-2019 academic year.
4. Restructure Computer Engineering to nine or ten terms.
5. Reintroduce the Computer Engineering degree immediately after the next accreditation.

Unless actions are take soon, student dissatisfaction will harm the Department's reputation, with students opting for other programs related to information technology, such as those offered in the Faculty of Computer Science and the Faculty of Management.

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