Computing Across the Curriculum

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Abstract *— An introductory course in computer programming is common in all engineering programs across the globe. Such a course is offered either in the first or the second semester of the freshman year with the intent to apply the programming techniques learnt in this course in subsequent semesters. If the courses from sophomore through senior year are not structured to use the programming techniques, the effectiveness of the programming course becomes limited. The paper describes the course Computer Utilization in Engineering offered in the second semester at Wilkes University to be taken by all engineering majors. MATLAB is the programming tool used in this course. The paper also describes the plan to include the application of MATLAB programming in as many engineering courses as possible. Some of these courses are Circuits and Devices, Electronics, Digital Design, Mechatronics, Electromagnetics, Communications, Power Systems, and Control Systems for electrical engineering majors and Statics and Dynamics, Strength of Materials, Fluid Mechanics, Heat and Mass Transfer, and Machine Design for mechanical engineering majors. These courses span the final three years of the four-year curriculum. Application of the programming techniques is an integral part of the common capstone course taken by both majors during their senior year. Challenges in the implementation of the proposal and suggested methods to overcome them are also explained.*

Index Terms *— Computer programming, engineering curriculum, mathematical software*

INTRODUCTION

A course in computer programming is included in the first year curriculum of practically all engineering programs around the world. With the advent of modern microprocessors, computing power of scientific calculators and personal computers is steadily increasing. At the same time, these devices are reasonably priced and are becoming more affordable even for students in developing countries. As a result, engineering institutions all over the world include in their curriculum courses teaching advanced mathematical software as well as other engineering software using personal computers. The freshmen level course usually involves either a high-level programming language like C++ or a mathematical software like MATLAB. Usefulness of such a course will be limited if students are not exposed to the material taught in such a course during their course of study. To alleviate this problem it is better to apply the programming language learnt in the freshmen year in as many courses as possible before graduation. This paper describes such an effort at Wilkes University.

ENGINEERING PROGRAMS AT WILKES

Wilkes University is a small, private institution in northeastern Pennsylvania offering programs in arts, sciences, and engineering. The academic units are divided as the College of Arts, Humanities, and Social Sciences, the College of Science and Engineering, the Jay S. Sidhu School of Business and Leadership, and the Nesbitt College of Pharmacy and Nursing. All the engineering programs are housed in the College of Science and Engineering.

Degree programs are offered in electrical engineering, mechanical engineering, engineering management, applied science & engineering, and environmental engineering. Most of the courses taken during the first three semesters of study are common to all these programs. The Division of Engineering & Physics (DEP) monitors all these programs with the exception of the environmental engineering program. Thus, students with undeclared engineering major are able to choose a field of study by the end of the third semester. Among the programs offered, the electrical engineering, mechanical engineering, and the environmental engineering programs are accredited by the Accreditation Board for Engineering and Technology (ABET).

Academic Requirements

The electrical engineering and mechanical engineering degrees require 130 credits to graduate. Table 1 shows the suggested course sequence for electrical engineering majors and Table 2 shows a similar sequence for mechanical engineering majors. 25 credits of liberal arts and 24 credits of math and science are included in each program. Courses in

computer-aided design and drafting, materials engineering, statics and dynamics, linear systems, computer utilization in engineering, professionalism and ethics, engineering project analysis, electrical circuits and devices, electrical measurements lab, mechatronics, and control systems accounting for about 28 credits are common to both programs. Three credits of capstone courses are taken by both majors during the senior year and they can elect to take six credits of cooperative education, preferably during the junior year. Students get rich work experience in the cooperative education program and practical design experience in the capstone course. Remaining 45 credits are exclusive to each program.

Electrical engineering students can take courses in digital design, computer organization, computer architecture, microprocessor design, and a few electives to have a minor in computer engineering. Courses in semiconductor devices, microfabrication, and optoelectronics will lead to a concentration in microelectronics. Similarly, mechanical engineering majors can elect to focus on machine design or heat & mass transfer.

First Semester		Second Semester	
PHY 201 General Physics 1	4	EGR 200 Intro to Material Science	3
MTH 111 Calculus I	4	or	
FYF 101 First-Year Foundations	3	EES 202 Biogeochemistry	
ME180 CADD Lab	1	MTH 112 Calculus II	4
ENG 101 Composition	4	EGR 140 Computer Utilization	3
	16	PHY 202 General Physics II	4
		Distribution Requirement	3
			17
Third Semester		**Fourth Semester**	
CHM 113 Elements and Compounds Lab	1	EGR214 Linear Systems	3
CHM 115 Elements and Compounds	3	EE251 Electronics I	3
EE 211 Electrical Circuits and Devices	3	EGR222 Mechatronics	3
EE 283 Electrical Measurements Lab	1	EE241 Digital Design	4
MTH 211 Intro. to Differential Equations	4	Distribution Requirement	3
ME 231 Statics & Dynamics	3		16
	15		
Fifth Semester		**Sixth Semester**	
EE 252 Electronics II	4	EGR 399 Cooperative Education	6
EE 271 Semiconductor Devices	3	Or	
EE 373 CAD for Microfab	1	Technical Electives	
EE 381 Micro fabrication lab	3	EGR 201 Professionalism and Ethics	1
Technical Elective	3	Distribution Requirement	6
Distribution Requirement	3	EGM 320 Engr. Project Analysis	3
	17		16
Seventh Semester		**Eighth Semester**	
EE 314 Control System	3	EE 339 Engineering Electromagnetics II	4
EE 337 Engineering Electromagnetics 1	4	EE 382 Modern Communication Systems	4
EE 391 Senior Project I	1	EE 392 Senior Project II	2
EE 325 Energy Conversion Devices	3	Technical Elective	3
Technical Elective	3	Free Elective	3
Distribution Requirement	3		16
	17		

TABLE 1
ELECTRICAL ENGINEERING B.S DEGREE-REQUIRED COURSE AND RECOMMENDED COURSE SEQUENCE

INTRODUCTORY PROGRAMMING COURSE

The introductory programming course offered at Wilkes is EGR 140 *Computer Utlization in Engineering*. As shown in Tables 1 and 2, this course is offered in the second semester of the 4-year sequence. There are no prerequisites for this course. Students are expected to have reasonable backgound in algebra, trigonometry, and calculus. Until the early 80s, FORTRAN was used as the programming language and was replaced by C. Based on the feedback from the Industrial Advisory Board (IAB) of the Division of Engineering & Physics, a decision was made to use a mathematical software widely used in industries. MATLAB was chosen as the software tool to be taught in the course and it stayed that way over the past fifteen or so years. Textbooks by Gilat [1], Palm [2], and Etter [3] have been used by different instructors for the past few years. Text books by Hanselman [4] and Magreb et. al [5] have been used as references. Topics covered are arrays and matrices, 2-D and 3-D ploting, functions and control operators, symbolic math , statistical analysis , and import of data. Examples of applications are taken from varied disciplines to keep the students motivated.

COMPUTING ACROSS THE CURRICULUM

The intent of this paper is to emphasize the importance of maintaining continuity of the concepts taught in the introductory programming course described earlier. Possible use of the program in the entire electrical engineering and mechanical engineering curricula is explained as follows.

- EE 211 *Electrical Circuits and Devices* – Third semester common course: Referring to Tables 1 and 2, it can be seen that this course is common to both electrical engineering majors and mechanical engineering majors during the third semester of study. MATLAB can be used [6] to complete routine calculations in node/mesh analysis of dc/ac circuits, plotting transient responses, frequency responses, ac waveforms in single-phase and three-phase circuits. It can also be applied to solve some simple design problems. For example, in a dc circuit with about six resistors, one fixed voltage source, and one variable voltage source, students can be asked to write a program to find the limiting value of the variable voltage source such that the current in any resistor is below a specified limit.
- ME 231 *Statics and Dynamics* – Third semester common course: This course is also common to both electrical engineering and mechanical engineering sophomores. Calculations of centroid and moment of inertia of complex shapes, stress analysis of different frames can be systematically done using MATLAB [7]. Programs can be written

First Semester		Second Semester	
MTH 111 Calculus Lab 1	4	EGR 200 Intro to Material Science	3
FYF 101 First-Year Foundations	3	or	
ME 180 CADD Lab	1	EES 202 Biogeochemistry	
ENG 101 Composition	4	MTH 112 Calculus II	4
PHY 201 General Physics 1	4	EGR 140 Computer Utilization	3
	16	PHY 202 General Physics II	4
		Distribution Requirement	3
			17
Third Semester		**Fourth Semester**	
CHM 113 Elements and Compounds Lab	1	EGR 222 Mechatronics	3
CHM 115 Elements and Compounds	3	ME 232 Strength of Materials	3
MTH 211 Intro. to Differential Equations	4	ME 234 Statics & Dynamics II	3
EE 211 Electrical Circuits and Devices	3	ME 322 Engineering Thermodynamics	3
EE 283 Electrical Measurements Lab	1	EGR 214 Linear Systems	3
ME 231 Statics & Dynamics	3	ME 175 Intro to Mfg/Machining	1
	15		16
Fifth Semester		**Sixth Semester**	
ME 321 Fluid Mechanics	3	EGR 399 Cooperative Education	6
ME 323 Fluid Mechanics Lab	1	Or	
ME 215 Intro. To Manufacturing Processes	3	Technical Electives	6
ME 335 Engineering Modeling and analysis	3	EGR 201 Professionalism and Ethics	1
ME 333 Machine design I	3	Distribution Requirement	6
Distribution Requirement	3	EGM 320 Engr. Project Analysis	3
	17		16
Seventh Semester		**Eighth Semester**	
ME 324 Heat and Mass Transfer	3	Technical Elective	6
ME 326 Heat and Mass Transfer Lab	1	ME 392 Senior Project II	2
ME 384 Mechanical Design Lab	3	ME 332 Mechanics of Vibration	3
ME 391 Senior Project I	1	Free Elective	3
Technical Elective	3		16
EE 314 Control System	3		
Distribution Requirement	3		
	17		

TABLE 2
MECHANICAL ENGINEERING B.S DEGREE-REQUIRED COURSE AND RECOMMENDED COURSE SEQUENCE

to decide the limiting value of an applied force in a multiple-member structure such that the stress value in any member is below a specified value.

- EGR 214 *Linear Systems* – Fourth semester common course: This course deals with the application of differential equations, Laplace transforms, difference equations, Z-transforms, Fourier series, Linear algebra, and applied probability. MATLAB is extensively used in this course with the Symbolic Math Toolbox to solve problems of different levels of difficulty [8], [9]. Students are expected to solve problems without MATLAB and then use MATLAB to verify their solutions. This way they get an intuitive feeling of the subject and the ease with which the same problems can be solved using MATLAB.

- ME 333 *Machine Design I* – Fifth semester course for ME majors: This is the first course in a two-course sequence in machine design. The two courses focus on deformation and failure, strength and endurance limit, fluctuating stresses, fatigue and design under axial, bending, torsional, and combined stresses, fasteners, welds, gears, balled roller bearings, belts, chains, clutches, and brakes [10] - [12]. Majority of the problems involving design need the ability of MATLAB for an effective solution.
- EE 325 *Energy Conversion Devices* – Fifth (or seventh) semester for EE majors: Magnetic circuit calculations that involve trial and error procedures [13], power electronic circuit analysis, and transmission line design are some of the topics that MATLAB programs can handle efficiently. Few ME majors take this course as an elective.
- EE 314 *Control Systems* – Seventh semester common course: MATLAB with its Symbolic Math Toolbox and Control System Toolbox is a very effective tool to solve complex control system problems [14], [15]. Problems in time response of systems, stability, steady-state error, root locus analysis and design, frequency response analysis and design, sensitivity, and state-variable analysis and design can be efficiently solved using MATLAB. *Simulink* provides the opportunity for excellent simulation capability of control systems.
- EE 361 *Modern Communication Systems* – Eighth semester course for EE majors: Problems involving Fourier transforms, Fast Fourier Transforms (FFT), modulation techniques, antenna analysis and design, and transmission line analysis and design can be handled using MATLAB very efficiently [16].
- ME 332 *Vibration of Dynamic Systems* – Eighth semester course for ME major: The course deals with free and forced vibration of single and multi-degrees of freedom for linear and nonlinear systems. MATLAB programs are essential for the efficient solution of most of the problems [17].

Other Engineering Courses

The courses listed above show only a sample of courses in which a mathematical software tool can be effectively employed to solve complex engineering problems. Another look at the list will show that the courses are spread out in the entire engineering curriculum for both electrical engineering and mechanical engineering programs from sophomore through senior year. (Majority of students elects to take 6 credits of cooperative education or internship during the sixth semester and programming-based courses are not included in that semester). Obviously, the application of MATLAB can be extended to other courses like *Engineering Electromagnetics, Electronics, Engineering Thermodynamics, Heat and Mass Transfer [18], Fluid Mechanics, Strength of Materials,* and *Engineering Economics [19]*. It also applies to elective courses like *Digital Signal Processing, Digital Image Processing, Power Systems Analysis, Digital Control Systems,* and *Robotics*.

CHALLENGES AND SOLUTIONS

The idea of computing across the curriculum has faced a few challenges and solutions are being worked out. The details are presented as follows:

- The main opposition to the proposal came from faculty who were not conversant with MATLAB. Preference was shown to other software tools like, *Mathematica* and *MathCad*. While all these software tools have a common approach, they are still different in syntax. Since it will be impossible for a student to master different tools, faculty finally agreed to focus on one tool and chose MATLAB because of its simplicity and the extensive list of textbooks incorporating MATLAB programs.
- The next challenge to be addressed is from faculty with little or no exposure to MATLAB. It is planned to resolve this with the help of graduate teaching assistants. Faculty will be responsible for assigning problems/projects and students will be expected to solve them using MATLAB with or without the help of the teaching assistant.
- Another obstacle came from the ABET program evaluator. All engineering programs go through the accreditation process every six years. During the previous visit by ABET in Fall 2009, the electrical engineering program evaluator was of the opinion that MATLAB is only a tool and not a high-level programming language like C++ and has strongly recommended to restructure the freshmen course EGR 140 based on C++ or a similar language. While it is true that C++ (or a similar language) is more general in programming concepts when compared to MATLAB or similar software tools, the idea of computing across the curriculum will fail if C++ or a similar language is used in a freshmen course since solving engineering problems using these languages is relatively more difficult. After much deliberation, it has been tentatively agreed that an elective course in C++ will be included in the curriculum. More details have still to be worked out.
- A relatively minor problem to the proposal will be presented by students who transfer from other institutions and receive transfer credit for a programming course not based on MATLAB. A majority of these students join our programs in the third semester. It is proposed to resolve this by requiring these students to audit the introductory programming course EGR 140 and to provide enough introduction of MATLAB in EE 211 *Electrical Circuits and Devices* and/or ME 231 *Statics and Dynamics*.

CONCLUSION

A proposal to implement computing across the curriculum for the electrical engineering and the mechanical engineering programs at Wilkes University has been presented. The proposed course sequences for both programs are described. A description of the introductory level programming course is presented. While the proposal is already in implementation in many courses, the paper describes certain challenges facing the full-scale implementation. Possible solutions to these challenges have also been discussed.

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