Building A New Computer Engineering Program At The University of Akron

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Abstract

The new computer engineering degree program at The University of Akron has doubled our department enrollment in just two years. The program was developed in response to the needs of both students and their future employers. It combines a year of science and mathematics and a half year of humanities and social studies with over two years of electrical engineering and computer science courses. In developing this program we sought a low risk strategy that could be implemented within the existing resources of the department, extending the strengths of the existing electrical engineering program to the new computer engineering program. Our planning also had to anticipate the task of meeting ABET self assessment requirements for two degree programs. Key elements of our program include using area requirements instead of specific course requirements for electives, a two semester senior design project, and a co-op program which affords a year of industrial experience before the senior year. This paper focuses on the curriculum design process, including the trade-offs and rationale that lead to our current program, future enhancements to the program, and lessons learned along the way.

1. Introduction

At the Department of Electrical Engineering at The University of Akron, we have recently launched a new degree program in computer engineering. The first class of new freshmen was admitted to the program in the fall of 1997, and within one year we experienced a 100% increase in enrollment in the department.

The program was developed in response to the needs of both students and their future employers. Although we offered many elective courses in computer engineering areas, we felt that many students were looking to other institutions that offered a specific computer engineering degree program. We considered offering a combined electrical and computer engineering degree as many institutions have, but opted instead for separate degree programs for reasons described in this paper.

The program combines a year of science and mathematics and a half year of humanities and social studies with over two years of electrical engineering and computer science courses.

Eighty percent of our students participate in a co-op program, which affords a year of industrial experience before senior year specialized electives are chosen. Extensive design experience is aquired during the program, culminating in a two-semester senior design project.

The process of designing the curriculum began early in 1996. A large part of the process involved reconciling our “optimal” program with university and ABET requirements, as well as the needs and capabilities of the existing electrical engineering and the computer science curricula. This paper focuses on the curriculum design process, including the trade-offs and rationale that lead to our current program, future enhancements to the program, and lessons learned along the way.

We sought a low risk strategy offering a computer engineering program within the existing resources of the department, without creating a new official or de facto body of faculty within the college. The department would then evolve in response to the enrollments in the electrical and computer engineering programs. We wanted the strengths of the existing engineering programs to be extended to the computer engineering program. These strengths include a thorough grounding in engineering fundamentals, a tradition of faculty involvement in all instruction, cross training in other engineering disciplines, and the engineering co-op program which is a hallmark of the College of Engineering. Our planning also had to anticipate the task of meeting ABET self assessment requirements for two degree programs.

2. Survey of Other Programs

One of the first steps we took when planning our computer engineering curriculum was to survey similar curriculums at other universities. We wanted to see what strategies others have used, what courses they offered, what problems they encountered, and how successful their program has become. We weren't looking to copy any one program. Rather, given the particular needs and resources of our university, we were looking for ideas that could help to plan our program. In short, we didn't want to "reinvent the wheel."

The survey was conducted exclusively via the internet. Most universities that offer computer engineering maintain a web-page describing their curriculum. Typical information that can be found is the curriculum's mission, a listing of courses offered, and degree requirements. Occasionally found is a brief description of the history of the program, with one of the best offered by the Electrical and Computer Engineering Department of Carnegie Mellon University. They provide an on-line detailed report their computer engineering program that was extremely helpful to us when planning our program [1].

The survey uncovered approximately one hundred universities offering a computer engineering curriculum. It was conducted using the search engine Yahoo as a starting point, which provides a listing of all universities both within and outside the United States. The balance of this section highlights some of the more important results of this survey that helped to shape our present program.

2.1 Collaboration.

Computer engineering is an interdisciplinary field which involves the study of the design and construction of computing hardware and software. As such, formulating an effective computer

engineering program requires the collaboration of faculty from computer science who have knowledge of software systems (e.g., algorithms, data structures, and operating systems), and faculty from electrical engineering who have knowledge of hardware systems (e.g., electrical networks, electronics, and VLSI). When formulating a program in computer engineering, most universities call on the talents of individuals from both fields to support the effort.

Very early in the planning process we sought and obtained the cooperation of faculty from the department of computer science at our university. A committee of faculty members from computer science and electrical engineering worked aggressively for roughly one year to define the computer engineering curriculum. After vigorous debate, and the not unexpected occasional heated argument, the faculty unanimously endorsed the overall structure of the proposed curriculum.

2.2 Curriculum.

Clearly, one of the primary reasons for performing the survey was to determine what courses, and their sequence, other universities offer within their computer engineering curriculum. Most curriculums share common points, particularly during the first two years where students take a set of required technical courses (e.g., circuits, electronics, programming, and data structures), along with the college-wide requirements in mathematics and the sciences. After these two years, however, the curriculums vary widely due to philosophical differences and differences in the specialty areas of available faculty.

During the first two years our computer engineering curriculum follows those of most universities, with one important exception. It is always interesting to ask a student just entering the university why they choose a particular field, such as electrical or computer engineering. For the most part - and no real surprise - the answer is usually very vague; such as "I want to work with computers," or "I want to design electronic circuits." Typically, students have a reasonably good idea that they want to work in the general area of electrical or computer engineering, but lack an understanding of the difference between the two. The problem is to educate students to make an informed choice.

Our computer engineering curriculum offers broad career orientationtinformation in the Tools for Electrical and Computer Engineering course, that strives to provide an overview of electrical engineering, computer engineering, and computer science, and importantly, the difference among these fields. In addition to the standard course material, guest lecturers expose students to specialized areas in each field. Following the course, which is taken during the first semester at the university, students have a better understanding of the these fields, their differences, and what career opportunities exist within each field. Moreover, one of the course's goals is to generate for the students real enthusiasm for their chosen career path.

2.3 Depth vs. Breadth.

One of the largest struggles seen at universities teaching computer engineering centers on the "depth vs. breadth" debate. In the depth camp reside faculty who believe students should acquire well-focused expertise in a given discipline, enabling them to confront challenging problems within the area. They believe technological leaps are the products of specialists. They also believe that this approach positions students to better meet the requirements of job

opportunities that are advertised along specialty lines. Those universities sharing this philosophy offer a select list of computer engineering areas from which the student selects one to specialize in.

Those faculty favoring a breadth approach to education believe that the most creative contributions are often made by individuals versed in several disciplines. There are two good arguments that support this position. First, industry is placing increasing value on individuals who can apply their skills across disciplinary lines, and can evaluate intelligently the broader consequences of their actions. Second, diversity breeds broad intelligent problem-solving skills, enabling strategic thinking in multiple domains. This is especially important in a rapidly-expanding discipline such as computer engineering, where the half-life of a bachelor's degree in the field is probably less than a decade, and a broad understanding of the field forms the necessary base to acquire new skills. Computer engineering programs following this approach typically require students to sample courses from several areas, obtaining some skills in each area, and more importantly, acquiring a view of the "big picture."

Within our computer engineering program we have taken a balanced approach to this issue. Our program has a set of computer-related areas aligned with the specialties of our faculty. Students are required to select at least one course from three of the four areas, and a two course sequence from one area. Individual courses are not prescribed. Rather, students can flexibly select the courses of their choice from the available specialty areas. In effect we force a breadth exposure to computer engineering on students, but permit them to continue along the breadth line or to focus in any one area. The choice is theirs. Within this framework, flexible plans of study can be formulated, some favoring depth, some favoring breadth, others somewhere in between.

To add a further degree of depth and flexibility, and to provide students with a real-world engineering design experience, our program includes a required senior design project which students take over two semesters. In the first semester, the student chooses an area to work within and a faculty member from the area to direct the effort. Together, they choose an appropriate project. During the semester the student creates a conceptual design and obtains the approval of faculty before proceeding. During the second semester the student completes the design, again with the direction and approval of faculty. The entire process is mirrored after industry practice, where the student must accomplish such tasks as write a project proposal, set and meet time-related deliverables, and write and present a final report.

3. Description of Our Environment

The Department of Electrical Engineering enrolls over 450 under-graduates and over 100 full and part-time graduate students. Active research and course work include topics in computer architecture, microprocessor systems, fault-tolerance, interconnection networks, parallel and distributed systems, expert systems, fuzzy logic, software engineering, algorithms, and programmable logic. We are part of The College of Engineering which is nationally recognized for strong undergraduate programs and prominent research programs. Over 80 percent of our engineering students participate in the co-op program, yet we currently have more available jobs than we have students.

The Computer Science program at The University of Akron is a division of the Department of Mathematical Sciences (along with applied mathematics and statistics) in College of Arts and Sciences. While a cordial relationship has always existed between faculty, there were no organizational ties to aid our two faculties in bridging culture gaps. Fortunately, one of the authors spent a year as visiting faculty with the computer science division before joining our department, and joint appointments are being explored.

4. The Implementation Process

Contrary to popular belief, university faculty actually do live in the real world- a world where events are driven by politics, the art of the possible. We succeeded in large part because computer engineering and computer science faculties recognized at the outset that the project would be abandoned if it proved impossible to combine existing courses taken by majors in both areas. This was clear because we had sought and received the endorsement of our engineering college faculty for a computer engineering program, based on this principle. The proposal implied a strong commitment, endorsed by all, to software design and programming. It also acknowledged that the traditional general engineering curriculum, the cross-training component mentioned earlier, would not be present in the new program. We remain grateful to our colleagues in the College of Engineering for endorsing the computer engineering program for the common good, to the possible short term detriment of their departmental credit hour production.

The principle of combining majors courses also brought to light basic differences in approach to operating systems and machine organization, which could have, and we suspect have in many instances, wrecked a spirit of cooperation between well intentioned computer engineering and computer science faculty. Here are the nature of these controversies in our case, and our remedies.

In the operating systems area, the originally proposed joint use of the computer science division course was abandoned when our specific proposals for revisions were, rightly so, rejected by the computer science division. In their view of computer science, operating systems serves to extend the programming training to the systems level. It can be a proof by fire confirmation of those skills. In our view of computer engineering, the course is engineering science, covering the kernel elements of process coordination and resource sharing. We have addressed this within the original proposal by adapting an existing computer engineering elective course to this purpose.

The existing sequence in machine organization was traditional assembly language and systems programming courses contemporaneous with the data structures and algorithms sequence, followed by junior level Computer Organization course. This introduces the topic too late for computer engineering majors, who are taking circuits and digital design as sophomores alongside electrical engineering majors.

The compromise reached here is remarkable. The computer engineering program begins this sequence with a sophomore level course introducing computer systems hardware contemporaneous with the traditional electrical engineering course in digital design, and following courses in discrete mathematics and introductory high level language (C++). A strong assembly language segment is included in this course. Computer science majors will

have an extra credit hour in their assembly language course devoted to machine organization issues. The Computer Organization course will be upgraded for the better prepared students of both programs.

5. The Current Program

After two years of operation and minor adjustments, the curriculum for computer engineering indeed largely combines core electrical engineering and computer science courses taken by majors in these areas, with four new required courses. These are the sophomore level Introduction to Computer Systems mentioned earlier, core courses in VLSI design and Electromagnetic Compatibility, and a senior elective Advanced Processor Design. The latter three are available to electrical engineering majors as senior year electives. Prior to VLSI design, they have a required course in programmable logic, which is an elective for electricals. They are strongly advised to take a computer interfacing laboratory course as an elective.

	Fall	Spring	Summer
First Year	English Comp I Calculus I Natural Science Tools for Elec. & CpE Physical Education	English Comp II Calculus II Physics I Discrete Math Public Speaking	
Second Year	Calculus III Physics II Circuits I Intro to Comp. Science Humanities	Differential Equations Intro to Comp. Sys. Circuits Lab Data Struct. & Alg. I Switching & Logic	
Third Year	Circuits II Signals & Systems Physical Electronics Data Struct. & Alg. II	Engineering Coop	Programmable Logic Computer Organization
Fourth Year	Engineering Coop	Operating Systems VLSI Design Comm. & Sig Proc. EM Compatability	Engineering Coop
Fifth Year	Senior Project I Comp. Engr. Electives General Ed Electives	Senior Project II Comp. Engr. Electives General Ed Electives	

Table 1 - Computer Engineering Curriculum

Computer engineering majors take EM compatibility course in place of a two semester sequence in electromagnetics. They have the entire circuits sequence, the required four credit course in signals and systems, and the first course in electronics. The programs share the required first course in communications. A two course controls sequence is available to them for the senior electives requirement.

Electrical and computer engineers share a freshman level course in computer tools and career orientation which includes motivational projects and guest faculty lectures on career orientation of components of the electrical and computer engineering and computer science curricula.

With the exception of abandoning general engineering courses like statics, mechanics of solids, thermal science and material science, the computer engineering program matches the profile of the electrical engineering program exactly. Computer engineering majors have a wide choice of such electives from electrical and computer engineering and from the computer science division.

Both programs now have a two course senior design project, originally proposed in the computer engineering program, and then added to the electrical engineering program. Approved for students entering Fall 1997 or later, these courses are more our future than our present, and are discussed further in the next section.

Most co-op employers have designated positions for computer engineering, with no net reduction in electrical engineering positions. Co-op demand is currently intense in both fields.

As mentioned earlier, we opted to increase the number of elective courses and employ an "area requirements" policy in place of specific course requirements. The computer engineering electives have been grouped into four areas: hardware, software, communications and control, and scientific computing (see Table 2). Students must select at least one course from three of the four areas, and a two course sequence from one area.

Hardware	Comm. & Controls	Software	Scientific Computing
Electronic Design	Data Comm. & Networks	Object Oriented Prog.	Intro To Numerical Anal.
Integrated Sys Design	Random Signals	Analysis of Algorithms	Num.Solns of PDEs
MicroP Interfacing	Digital Communications	Compiler Design	Adv. Engr. Math I
Adv.Proc. Design	Control Systems I	Computer Graphics	Adv. Engr. Math II
Parallel Proc Arch	Control Systems II	AI & Heuristic Prog.	Computer Methods
Data Processorss	Distrib. Proc. Systems	Database Management	Controls I
		Parallel Prog. Sys	System Simulation
		Expert Sys Design	
		Knowledge Engineering	
		Frame-based Exp. Sys	
		Fuzzy Logic Exp. Sys	
		Neural Networks	

Table 2 - Computer Engineering Electives

Although we regard the administrative impact of having separate computer engineering and electrical engineering as being minimal, the impact on the student is quite large. With the wide diversity of electrical and computer engineering topics, ranging from applied physics to software engineering, we did not feel that we could satisfy both the depth and the breadth requirements simultaneously in a combined program. It was only by abandoning some general engineering courses like statics, mechanics of solids, thermal science and material science, and developing an EM Compatibility course in place of the seven credit hour electrical engineering core in electromagnetics that we could provide the schedule space for the student to achieve both depth and breadth in computer engineering.

In the second year of operation, electrical engineering and computer engineering enrollments are both up, with computer engineering equaling electrical engineering. After a first year orientation course, students are switching between electrical and computer engineering, and

computer science about equally, and in small numbers. A small number of students have transferred to computer engineering, and anecdotally consisting of students heretofore preferring the major but unwilling to leave the area.

Thus by all indications, the original motivations for initiating the program are thus far confirmed.

6. Where Do We Go From Here

We expect a growing enrollment in electrical engineering, with extra demand from a newly initiated undergraduate biomedical engineering program, to be accompanied by an equal to double growth in computer engineering. Thus we are in for a challenging period of faculty recruitment. We are happy that the computer engineering program is in place, because in addition to simple growth, we face two inexorable, if exciting challenges. One is to deliver on the promise of a senior design project sequence. Senior design projects are chosen by most of our students subsequent to of a full year of industrial experience in co-op, and to further interests sparked in core courses. We plan to enlist our co-op employers in the definition and monitoring of worthwhile projects. Our challenge is to provide the faculty resources and to develop the administrative infrastructure to use student and faculty effort effectively in this component of our programs.

Another inexorable challenge is to implement for both programs our plan for an active outcomes assessment process that properly distributes accountability and provides all parties with the feedback necessary to improve educational performance. It is a problem posed by ABET to all accredited engineering programs and is by no means unique to the programs we have been describing. We believe this real world requirement, along with the inability to magically expand faculty resources, will engender a cooperative form of university politics that will be unifying, and will work for the good of engineering education.

Our experience with the implementation of our computer engineering program was an insightful prelude to these further challenges. We'll have to honestly confront differences and allow for accommodation, while following principle. It will be interesting.

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