A Walk in the Infosphere: Rethinking EE Education in the Wireless Era

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***Abstract*—Do we need a new approach to electrical engineering education? Despite the obvious technological triumphs of the field in recent decades, enrollment in EE programs is flat or declining. I argue that today's students see EE-derived technologies at a higher, systems-oriented level, and that education should engage students at this level. In particular, new EE students are embedded in an "infosphere" mediated by a wide array of wireless devices, and this perspective can be used to engage them. I briefly describe two upper-division courses, in wireless sensor networks and wirelessly-networked embedded systems, that serve as a start in this direction, and furthermore as a basis for development of compelling introductory courses that integrate EE subdisciplines.**

I. Introduction

It is easy to argue that EE education is a resounding success, as it has supported the growth of information-based industries that have revolutionized commerce and daily life in the last half-century. But in the US, the number of EE graduates has been flat or declining. Then why, at the peak of the information age, are EE departments spending more and more resources on student recruitment and retention to maintain enrollment?

Electrical engineering is concerned with the generation, storage, transmission, and consumption of power and information. The importance of information has grown at an unimaginable rate in the last 50 years, far outstripping the rate of change in EE education. There have been some reforms; for example, EE educators have responded to the rise of computation: in most undergraduate curricula, digital logic is now introduced much earlier, so that students are exposed to circuits and computer engineering in the first two years.

But these changes have clearly not been sufficient—most EE departments do not have admissions wait lists. I believe that the primary reason is that today's EE curricula do not capture prospective students' imaginations. Consider a 16-bit data value, perhaps a sample of a signal from an analog-to-digital converter attached to a MEMS-based accelerometer in a Wii game controller. From the perspective of circuits and digital logic, each bit is represented by the state of a bistable logic gate that can be manipulated by computation. This viewpoint dominates undergraduate EE education, leaving unexplored other equally important perspectives that I argue are more relevant—and fascinating—to today's students. For example, in signal processing, the emphasis is on the characteristics of the sampled signal, including measurement and quantization noise. From an information-theoretic perspective, the bits of this packet are answers to specific yes/no questions, invoking the notion of sending and receiving parties. This motivates communication, and efficient methods for representing and protecting that information when it is stored or transmitted. Finally, in the act of communication, this information becomes an exquisitely-designed packet of radio-frequency electromagnetic energy formed by a transmitter for recovery by the receiver.

Another consideration is how the world shapes incoming students' views of EE technology. We are far past the days when we took apart radios to find discrete components, and then learned about them in circuits classes. Today's students live in a wireless "infosphere" with a cloud of wireless-enabled gadgets. What is more real to today's students, a text message arriving over the air, or a passive linear device?

II. Thinking About Systems

Clearly, there is a richness to what we do as engineers, involving the weaving of analog and digital circuits, communications, and microwave/RF disciplines among others, that is not well-captured in undergraduate education.

Today's EE education is dominated by a bottom-up approach: we start with electronic devices and slowly build up to circuits, subsystems, and systems. I am simplifying, but this seems analogous to introducing ecology students to cells, moving slowly to trees, and finally forests. Clearly, a walk in the woods to experience the biosphere is a more appropriate start. Similarly, I suspect many prospective civil engineering students are inspired not by the mechanics of materials but by soaring cable-stayed suspension bridges. What is meaningful to, and motivating for, EE students today? Why not let them build from their experience in today's exciting infosphere?

III. A First Step

A radical response would be to invert EE education by introducing systems-level thinking and exploration in the first two years. However, the pace of innovation in engineering education is slow; we tend to teach what we were taught, how we were taught, when we were taught. Thus radical reform of EE curricula, while attractive, might be difficult to sell to entire departments and accreditation teams.

The most freedom is in senior-level electives, where changes do not upset the dependency graph of prerequisite courses. Thus, as part of a multi-university curriculum development project called Multi-University Systems Education (MUSE; www.uvm.edu/∼muse/), we have taken an interim step and developed a first-semester senior-level "MUSE course" that uses wireless sensor networks as motivating, concrete example for learning about the design of complex-engineered systems [1]. The course is developed around the representation and flow of information from a physical transducer through a sensor node over multiple wireless links to the network hub. Along the way, we interweave component topics, including mixed-signal design, signal processing, communication systems, RF circuit and antenna design, and embedded systems. One of our goals is to demonstrate how the subdisciplines of electrical engineering and computing are tightly coupled, especially in energy-efficient designs, so that students explicitly see how topics from their core courses are blended in the design of relevant systems. For maximum portability, the MUSE course is divided into web-based video learning modules, so that adopters at other universities can create mashups of the videos with with their own live and web-based content.

I am also restructuring a traditional embedded systems course to emphasize wirelessly networked embedded systems. The course has been very successful, since students enjoy hands-on design projects that connect theory to tangible results. In the spring semester 2009 offering, we are introducing the Texas Instruments (TI) eZ430-RF2500 wireless development tool as the experimental platform (Figure 1). Major requirements that drove selection of this platform were:

- Integrated wireless connectivity. Each kit includes two USB-programmable wireless nodes, allowing students to explore wirelessly-networked system design.
- Availability of a modern software development toolchain. TI allows free download a of memory-limited version of their integrated development environment.
- Low cost. The kit is $50; this allows students to work on design projects at any time using a PC or laptop.
- Support of energy-efficient design techniques. The eZ430-RF2500 is based on a low-power TI MSP430 MCU, which provides a rich set of software "control knobs" for minimizing power consumption.

The course begins with a quick overview of embedded C programming, the development environment, and the hardware target. Laboratory projects include I/O, timers, serial communication, and random number generation. These projects form the foundation for development of wireless systems and networks. We will supply a basic software template for wireless transmission and reception that students will be able to build upon for projects in received power measurement and BER/PER testing, promoting hands-on understanding of wireless communication channels. We will also use spectrum analyzers to provide visualization of RF spectra. As students develop skills in configuring and testing the radios, they will gain an appreciation for the crucial roles of frequency, phase, and bit timing synchronization.

Fig. 1. Texas Instruments eZ430-RF2500 development tool. USB programmer/communication interface is at upper left. Two 2.4 GHz wireless MCU nodes are at right; one node (lower right) has an attached battery carrier.

Due to its small size and cost, one disadvantage of the eZ430-RF2500 tool is is the lack of on-board peripherals and sensors. We are currently working on a design for a "MUSEboard" that will allow students to interface the tool with a range of transducers. This will provide a platform for rich hands-on experimentation in the MUSE course, and the MUSEboard design will be published for adopters of MUSE learning modules.

IV. Looking Ahead

The MUSEboard could easily be integrated into a new kind of introductory course that introduces students to the fundamental concepts underlying the gadgets that are ubiquitous in modern life. I believe that today's students, raised in a world of wireless cloud computing, can be captivated by the diverse technologies that make these systems not only possible, but mundane. By using a systems-oriented, top-down approach to explain engineering, we can show tomorrow's engineers how information is generated, transmitted, and processed at multiple interacting levels of design.

In electrical engineering, unlike in other engineering disciplines, most of what we study—electrons, currents, fields, waves, even information itself—is invisible and abstract, and indeed difficult to distinguish from magic for a prospective EE student. On the other hand, this magic is used to build the infosphere that students casually use via myriad wirelessly-connected devices with more dexterity than their teachers. There is a great opportunity for EE departments to leverage the revealing of this magic in motivating and educating tomorrow's technologists.

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References

[1] Frolik, J., T. Weller, P. Flikkema, and W. Shiroma, *Work in progress - MUSE - Multi-University Systems Education*, FIE 2008.