Inclusion of RFID in a BSEE Curriculum

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Abstract

This paper discusses the evolution of a course in RFID which is now a required part of the curriculum in Merrimack College's BSEE program. In 2004 the department identified RFID as an important emerging technology that would be timely to introduce at the undergraduate level. Initially, the department sponsored two seminar series with sessions taught by industry professionals, followed in 2007 with a full course in RFID. Advantages of RFID as a required course include using it to introduce systems engineering concepts and introducing economic concepts and business benefits through implementations such as found in Supply Chain and Warehouse Management (SCM/WHM). In addition, RFID is a natural place to introduce ethical as well as global engineering issues. The course includes selected RFID projects incorporating business student participation on multidisciplinary teams. As a result, the department has been able to tailor the course to specifically addresses ABET[1] outcomes 3 (d), 3 (f) and 3 (h). Early experience in multidisciplinary teamwork has been favorable, one example provided by a team that evaluated possible adoption of RFID by the college's library. The role of assessment in deciding to adopt this course, and the assessment of the course itself, are both discussed in this paper.

The lecture component of this RFID course includes presentation of technical material such as antenna design and frequency of operation. The growth of RFID technology is presented across a broad spectrum of applications ranging from tracking of high-valued items in the pharmaceutical and health care sectors to the "Internet of Things." An undergraduate teaching lab has been developed in partnership with companies including TagSys, Alien, Symbol, Intermec, Radianse, and Zebra among others.

Background and Overview

The Merrimack College Department of Electrical Engineering is a unique department in that it sits in an undergraduate, Augustinian college. The department is the only ABET accredited EE Program to offer a part time evening program in all of New England, and in addition has a very active co-operative education program. A typical graduating class is on the order of 15 students, with most students going directly into industry.

In 2004 the department was approached by an Alumnus who is a retired CEO in the bar-coding and RFID industry, who was very ardent about bringing RFID to Merrimack College. While this immediately was recognized by the department as a major educational opportunity for our students, it was not clear how to staff the course and find a spot in a very tight curriculum for an RFID course. The decision was made to host a three part seminar series delivered by industry experts, including the topics: "RFID: Past Present and Future", "Wal-Mart EPC/RFID Compliance" and "Supply Chain Applications and Logistics". This was very well attended, and was expanded into a short course offered in conjunction with the Boston section of the IEEE in the Spring of 2006, again delivered by a range of industry experts.

Based on experiences gained from offering RFID as a short course, it was offered as a 3-credit advanced elective in the spring of 2007. The details of the course are presented below. The course is being offered in a similar format during the spring, 2008 semester.

During the spring of 2007 as part of its ongoing Continuing Program Improvement process, the department determined that although ABET[1] Criteria 3 (d), (f) and (h) are being achieved, more coursework addressing these criteria could prove highly valuable. The decision was made that including RFID in the curriculum, and crafting it in such a way that business students can take it at the same time, would significantly strengthen the curriculum in addressing those outcomes. The department's overall assessment process, the assessment results leading to decisions on including the course and what to include in the course, and planned course assessment are all discussed below.

First Offering of RFID

The course was offered as a 3-credit advanced elective in the spring semester 2007. There was one lead instructor, with lectures taught by one other EE department instructor and experts from industry handling several other topics, similar to those covered in the seminar series. The course had several lab modules, and also included a research project looking more in depth at a student-chosen topic of interest.

Every course in the EE department has "Points of Learning" (POLs) – a set of learning goals. These goals are formally included in the course syllabus handed out to the students at the beginning of the semester. It is emphasized to the students that these are the central points of the course, all will be covered, and student understanding of each one will be evaluated. The following six POLs were utilized for this offering of RFID:

1. Evolution of and basic overview of RFID technology; compare and contrast with other automatic data capture concepts e.g. barcodes
2. RFID engineering: implementation of various tag and reader technologies
3. An understanding of EPC and the role of RFID standards
4. Understanding integration of hardware, middleware and enterprise systems
5. Adoption of RFID at this time and going forward. Global and societal impacts; ethical considerations.
6. Ability to evaluate different potential RFID solutions to a specific business

As a rule, the points of learning are evaluated for all courses offered in the EE department. For this case the POLs were met but not all formally evaluated. Going forward the course will be thoroughly assessed as detailed below.

From the outset of the course, students were encouraged to decide on a topic to look into more thoroughly, with a final decision required by the end of the second class meeting. Working on teams was optional, as long as distinct responsibilities for each team member could be clearly identified and evaluated by the course instructors. Project topics included:

- RFID in airport security
- Use of RFID to monitor casino chips
- RFID in the Metropolitan Boston Transit Authority
- Possible RFID adoption by the college's library

- RTLS in Healthcare Delivery

While most projects were done by one student, the library project involved a team comprised of two EE students, one business student, and a librarian. This library project involved a TagSys representative coming to campus and presenting one set of solutions to the team. One EE project member visited an area library that utilizes RFID, and discussed pros and cons with one of their librarians. The other EE student identified the requirements for streamlining the library services. The librarian provided key information on the operations and the business student provided a costs-benefits assessment. The conclusion of this project was that the implementation of RFID would likely be highly cost-effective, with pay back time likely less than three years.

The two EE faculty involved in teaching the course as well as the Alumnus who encouraged the department to offer RFID attended the final project presentations. All three were involved in evaluating the presentations, and every project was awarded either an "A-" or an "A" based on quality of presentation and technical depth. The evaluators all felt that in general the students were very enthusiastic, had put in a high degree of effort, and had digested a significant amount of information.

A laboratory segment was included to provide the student a greater insight and understanding of the electrical engineering principles and concepts that are at the foundation of RFID technology. Due to a limited inventory of hardware and software in spring 2007 the lab experiments consisted of a set of demonstrations rather than a hands-on exercise. Since then a sufficient inventory of tags and readers have been obtained via corporate donations and are available for individual students to carry out the lab experiments included in the present, spring 2008 course offering.

There are three lab sessions in the course, one that is designed to work with the reader and tag hardware, a second that focuses on the characteristics and performance of active and passive implementations and a third that emphasizes the multi-access capabilities of a RFID system and measurement of operational parameters. The experiments have been structured to show how LF, HF and UHF tags and readers are designed and how they can be used to store, read and provide information. The communication link between tags and readers is examined in near field and far field system implementations. The theory presented in the class room concerning the attributes and performance limits of selected system configurations is tested. Variables such as accuracy, reader power, read range, read rates, tag orientation and the effects of object materials on read efficiency are investigated. The set of lab experiments enables the student to gain hands-on experience with both the hardware and software components of the RFID system. In particular the labs directly fortify items 2, 3 and 4 of the previously stated POLs and address ABET outcomes.

Assessment

The department, as required in order to maintain its ABET accreditation, is actively involved in ongoing Continuous Program Improvement. Both Outcomes and Objectives are assessed on a regular basis, the results are regularly evaluated, and steps are taken to improve the program. The Program Outcomes are similar to ABET Outcomes a-k, and the Program Outcomes are mapped onto the ABET a-k Outcomes to assist ABET evaluators in determining program compliance. Program Outcomes are evaluated within a matrix of assessment methodologies, including:

- Course Points of Learning (POLs), discussed above. Each course POL is mapped onto the Program Outcomes
- Advisory Board Evaluation of Senior Capstone Projects

- Pre/Post course surveys have recently been added as an assessment methodology to supplement course POLs
- Senior exit survey

The department received its first full ABET Team visit under the EC2000 criteria in September of 2004. After addressing a number of concerns brought up by the team, the department was re-accredited through fall 2010 without need for either an interim report or visit from ABET.

During the fall of 2007 the department looked at assessment data, and determined that more coursework could be done to address and provide evidence of the achievement of the following criteria[2]:

Criterion 3 (d) an ability to function on multi-disciplinary teams
Criterion 3 (f) an understanding of professional and ethical responsibility
Criterion 3 (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

It was determined by the department that a required course in RFID could prove very useful in addressing criteria 3 (d), (f) and (h) based on our experience teaching this as an advanced elective in the spring of 2007. The specifics of how this is achieved are covered in the next section. The course is being offered as an advanced elective during the spring of 2008, and then becomes part of the core required curriculum in the 08/09 academic year. Going forward the following assessment will be carried out for this course:

- Pre and post surveys filled out by the students
- Points of Learning
- External Evaluation of Projects

The pre and post survey is based on an assessment approach developed at Southern Connecticut State University[2], which directly involves students in the assessment. With the combination of three assessment methodologies the course is assessed by professors, students, and outside evaluators thus creating a "reality check" of the validity of each assessment taken separately.

Including RFID as part of required curriculum

Based on experience teaching the course, and the needs posed by tailoring the course to meet the ABET[2] criteria 3 (d), (f) and (h), the department decided to focus on a number of key goals. The first is to provide a solid introduction to this cutting edge technology, utilizing lecture, demos, and lab work. The department also wanted to provide exposure to industry experts. In addition, ethical issues and global issues pertaining to RFID are determined important. Finally a key goal is to provide significant experience working with students from other disciplines.

The topics to be covered in providing an introduction to RFID include:

- Automatic ID systems, including barcode systems, optical character recognition, smart cards and the evolution of RFID
- The physical elements of the RFID System, including transponder, reader, antenna, frequency spectrum, printers and data acquisition and processing

- Transponder types/classes - passive and active
- Electromagnetism topics including radio communications, antenna design, and HF vs. near-field UHF, frequency, range and coupling
- Manufacturing considerations including "The Path to the 5 cent Transponder", wafer processing techniques, and antenna manufacturing and attachment
- The total RFID system: transponder, reader, antennae and middleware
- Software issues including anti-collision, security, authentication and encryption, and the role of middleware
- Placing the RFID system into the "Real World", site assessments, optimizing tag placement, and reader selection and placement
- Administering and maintaining the RFID system
- Configuration and setup
- Monitoring the system

The first class of the semester provides an overview, to help them select a topic for their semester project.

To expose the students to industry experts, guest lecturers were invited to present. In the spring 2007 offering, industry presentations were made by the chief system analyst of a middleware/hardware RFID company, by a senior VP of a middleware RFID company, and by the VP of business systems of a RFID tag/reader company. Topics included supply chain management, network infrastructure, and detailed software issues. Students responded very positively to the industry visits, in many cases commenting on them as one of the most positive aspects of the course.

As mentioned above, the course is being specifically geared so that business students can take the course, as can Computer Science students. While the business students will not obtain a full understanding of the deeper technical material, the expectation is that the students will gain quite a bit of value from the combination of business and technical topics. Also, while the CS students may not understand all of the hardware aspects of the course material, they will understand some of the software issues much better than the EE students. While it is a significant challenge for the instructors to present course material to students from different majors at the same time, the department believes that the advantage of being able to form true multidisciplinary teams makes the challenge worthwhile. A major component of the course is a project involving looking deeper at the application of RFID in a real world context. The most positive experience to date has been the four-person team examining RFID adoption for the college's library. The intention is for EE, CS and business to gain from working together and the department will carefully assess this "multidisciplinary" aspect of the course going forward.

The course addresses specific business related topics including:

- Business opportunities, planning and best practices
- Supply Chain Management
- DOD and Wal-Mart Mandates
- Creating a Pilot Project Plan
- Moving from Pilot to Production
- Pharmaceutical Applications
- Cargo Security

The topic of RFID lends itself very well to discussions on the global impact of engineering solutions. For example, efforts are under development by EPC Global to standardize many aspects of RFID technology that it hopes will be adopted across the world. In addition, with its impact on the supply chain, RFID is by its very nature a technology with significant global impact, hopefully leading to more seamless, efficient, and thus profitable supply chains. Another "global" aspect is that RFID as deployed often involves components from companies from different countries, and the components need to function well together.

There are many aspects of RFID that lend themselves naturally to coursework on ethical responsibility. There is a fair amount of public concern that RFID will lead to more tools that erode individual privacy. For example, if there were an ability to track all items picked up and examined by a customer, this could lead to unwanted targeting by advertisers. There are also significant business concerns, such as pressure by consumer groups to adopt privacy guidelines that have the potential of directly slowing the growth of RFID technology. The challenge to industry is to take a more proactive position as RFID solutions become integrated into business enterprises. An interesting topic is the efforts by industry advocating EPC global as a facilitator to adopt policy guidelines for both consumers and RFID technology in business processes and practices.

Conclusions

A course in RFID has been adopted as part of the core Electrical Engineering curriculum at Merrimack College. The choice to do so was based in part by the ABET required process of Continuous Program Improvement, and in part by the department's success in teaching the coursework first as a series of seminars and then as an advanced elective. The course in its first time offering as an elective was successful, with many lessons learned in building course and lab material. The students reported a high degree of satisfaction with in particular the industry representatives that gave lectures on their areas of expertise. The projects added quite a bit of depth and value, and were evaluated to be well presented and of current significance. The library project in particular provided a cost-savings opportunity for the college, and also student experience in teamwork across multiple disciplines.

There were a number of other gains from the process of adopting RFID, including the establishment of a working relationship with the college's business school, obtaining significant equipment donations from a wide range of industry partners, and creating co-op, internship, research, and job opportunities. Going forward, the department plans to use its experience with RFID to serve as a template for including future "disruptive technologies" in the curriculum, as RFID will eventually become more of a commodity rather than the emerging technology it is now.

References

[1] CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS Effective for Evaluations During the 2007-2008 Accreditation Cycle, ABET, Baltimore, MD.
[2]Yu and Peters: "Bottom Up Program Assessment using Course Learning Outcome Measurements", Best Assessment Processes VIII, Rose-Hulman, Feb. 2006.

Biographical Information

John Adams completed his PhDEE at the University of Massachusetts in 1990, after which he joined the Engineering and Public Policy Department of Carnegie Mellon University as Research Faculty. His research interests include biological effects of electromagnetic fields, visualization of electromagnetic fields, and the use of experiential learning techniques in teaching Electromagnetics. He presently is Associate Professor and Chair of the Department of Electrical Engineering of Merrimack College.

Charles Kochakian graduated from Merrimack College with a BSEE in 1961. He has had an extensive career in industry, with much of his expertise being in RF techniques. He has been involved in many aspects of the practical application at a systems level of RFID. His research interests include RFID course development and also applying RFID in novel scenarios. He presently serves as Adjunct Professor of Electrical Engineering at Merrimack College.