

**AC 2009-1519: AN ON-LINE RFID LABORATORY LEARNING ENVIRONMENT
AND THE ASSESSMENT OF ITS USERS' EDUCATION**

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An Online RFID Laboratory Learning Environment and the Assessment of its User's Education

Abstract

Due to the increasing demand for RFID expertise and the existence of a knowledge gap between industry and academia in this domain, work has been stimulated to help spread understanding in this field and bridge the gap between theoretical examinations and industrial practices. Amongst the encouraged work, there is the I-ATMUS project (Integrated Auto-ID Technology for Multidisciplinary Undergraduate Studies) that involved developing a remotely controllable RFID laboratory system. Technological resources can now be accessed by learners through the Web technology to apply appropriate configurations to the system, conduct experiments using RFID technology, and perform statistical analysis on the acquired data. Furthermore, the developed educational tool was used by a class of student that showed improvements in their confidence, knowledge, and skills.

Introduction

For some technologies, the supply of their qualified users struggles to match the pace of the associated growing demand. In other words, the growth of the skilled-user-community may not be able to keep up with the rapid evolution or emergence of these technologies. Companies may use outsourcing or internal training to obtain the necessary expertise, but that does not always solve the problem in a time or cost effective manner. While that might be a constraint, a relatively great number of potential expert users of a specific technology are supplied from schools and universities.

One solution would be to expose more engineering students to the newest technologies, such as Radio Frequency Identification (RFID), while they are still in school. This can lead to an increase in the supply of acquainted users, who can become experts at later times. The problem with such a strategy is that a technology might not be available or accessible to enough institutions to see the desired educational results. Whether or not that is due to affordability, novelty, or safety issues, the problem is likely to persist until some type of collaboration is established between organizations that teach different kinds of technologies.

A way to promote educational collaboration and instructional instrument sharing is the utilization of ubiquitous Web technology to provide remote access to the scarce technological resources of a certain institution. For this reason, it would be desirable to develop learning environments that yield remote access to technological resources as well as collaborative learning. In fact, several institutions started promoting online educational tools from which students at different locations can greatly benefit by accessing remote laboratory equipment and obtaining hands-on experience [1-7]. Not only that, but Web technology is also able to provide new teaching techniques that are appealing to students [5].

On the other hand, RFID is one of the new technologies that is more visible than ever and has a high potential of being used extensively in the near future. The existence of RFID laboratories in educational environments will serve the purpose of providing testing results and conclusions, as well as giving the involved students the opportunity to obtain hands-on experience, making them potential RFID experts and valuable assets to RFID stakeholders. This is important for

employers who want to adopt RFID since the majority of them believe that there are not enough RFID-skilled people to hire [8].

It is therefore very valuable to have an automated RFID laboratory whose equipment is remotely controlled, and whose graphical user interface (GUI) is linked to a knowledge base about RFID technology and related matters. A learning environment of this kind has the potential of satisfying corporate needs, supporting collaborative educational programs, and promoting RFID technology. The contribution of this paper is (1) the development of an online learning environment that targets teaching RFID with an emphasis on the practical aspect of the technology, (2) automated easy control of the laboratory hardware devices, and (3) the student assessment to the created value of the developed learning environment.

Technology Background

Radio Frequency Identification (RFID) is a data collection technology that utilizes a wireless radio communication (radio frequency signals) to identify, track, and categorize objects. The basic RFID system consists of three main components:

- The RFID reader, which by itself contains the processing unit, antennas, and the cables joining them; its main task is send electromagnetic waves to the surrounding environment and listen for electromagnetic responses from the RFID tags. Upon receipt of the tags' data, the reader submits the RFID reads to the target database.
- The RFID tag, which is a microchip that is bound to a small antenna and that transmits the data stored in it as the electromagnetic response to the reader.
- The database where all the raw read data is to be amassed, and maybe converted into meaningful numbers and patterns.

This system can be extended with a set of middleware devices, a variety of soft-controllers, a network of readers, and a powerful database management system (DBMS) to ease data-acquisition and data-management in a large information system.

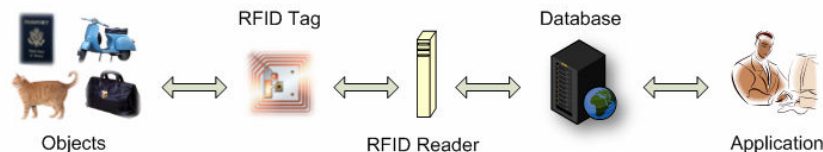


Figure 1: Object/device interactions in an RFID system

With its capability of storing a relatively large amount of data, an RFID tag can outperform a barcode tag, which can identify the kind of an item only, one item at a time, and has to be scanned with line of sight. When an RFID tag utilizes batteries to function, it is called *Active*, it can be read from far distances (up to 100 feet), and it uses a specific range of radio frequencies. *Passive* tags on the other hand do not require batteries; they are powered by the electromagnetic waves sent by the reader, and that is why their read-distance is limited to a number of feet. The main advantage that Passive technology has over its Active counterpart is the significant cost and maintenance reductions.

Learning Environment

Concept

Science fields have been enriched by physical laboratory experiments; however, it is difficult for students to fully comprehend many modern systems due to the limited access to laboratory equipment [8, 5]. Recent research has revealed that students learn and retain information best through interactive examples and experiments [1, 3, 7]. With the evolution of technology and the Internet, many researchers in all fields are focused on creating Web-based laboratories to ease the learning of students by providing them with the ability of studying anywhere and anytime [4, 6, 8]. Online laboratories also have the advantage of assisting researchers stimulate the interest of learners with new teaching techniques provided by Web technology [10]. Following the footsteps of previous successful work, we provide a similar, but novel, system that targets teaching and evaluating RFID.

To achieve that, the I-ATMUS project efforts and its associated funding were spent in developing an educational tool that uses Web technology to give remote access to RFID laboratory resources (see Figure 2). Such development targeted the following main milestones:

1. Building hardware and software applications that aid users in working with RFID.
2. Constructing an automated online testing system on top of the developed software and hardware.
3. Using the RFID testing system to give students hands-on experience by conducting experiments, collecting data, and perform statistical analyses.
4. Using the RFID testing system and the developed the statistical models to measure the reliability and limitations of Passive RFID technology.

During and after the development stages, the implementers of the I-ATMUS project focused on three different aspects: (1) constructing a cutting-edge architecture for the system, (2) building a robust and inexpensive hardware setup that yields multiple configurations, and (3) developing a complete programming language (called NBL) specific to this system.

Hardware Setup

The hardware design of the RFID laboratory system is based on the different requirements of testing RFID technology. The factors involved during the tests include the motion of RFID tags, their distance from the RFID antenna, the tag density in the RFID envelope, and the angle of the RFID antenna. That is why the system design incorporates degrees of freedom in the hardware that allow treating those factors as variables.

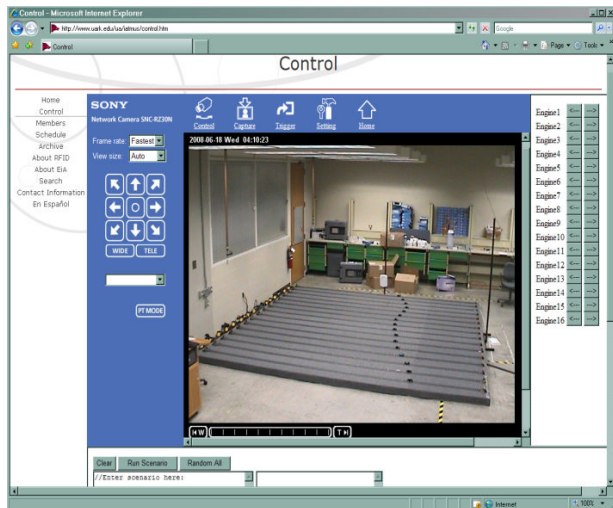


Figure 2: Online view of the developed RFID testing system

The hardware mechanism chosen to be implemented is in the form of a robotic system that has a set of motors and a control unit that cause the RFID tags to move linearly on parallel train-tracks (see Figure 3). For more control power, the tagged trains can be programmed to move according to a certain scenario that is coded in the NBL programming language.

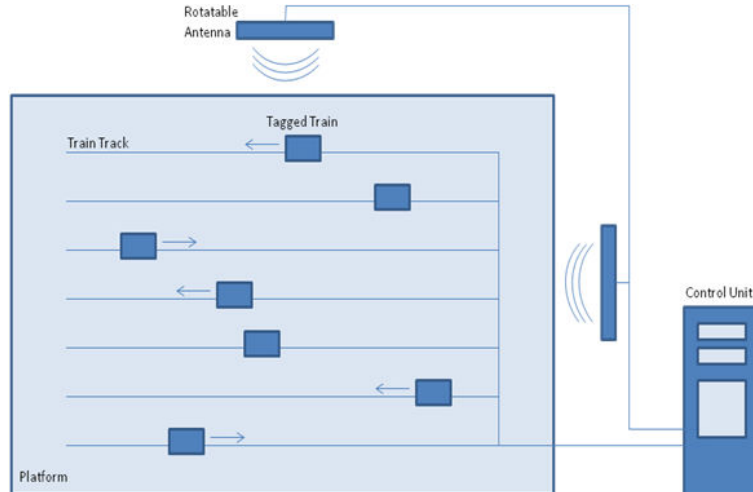


Figure 3: The hardware setup of the RFID testing system

Programmatic Control

NBL is a programming language that was developed specifically for this system to ease the use of hardware while trying to obtain a specific setup (such as the one shown in Figure 4). This system feature allows the significant reduction in mouse-clicks, the omission of tediousness in acquiring specific setups, the construction of complex testing scenarios, and the option of reading RFID tags while in motion. Furthermore, NBL has computation aspects just like other well-known programming languages (e.g. Java[®]); it lets the programmer use arithmetic operators, loops, if-else statements, lists, function-calls, recursion, etc.

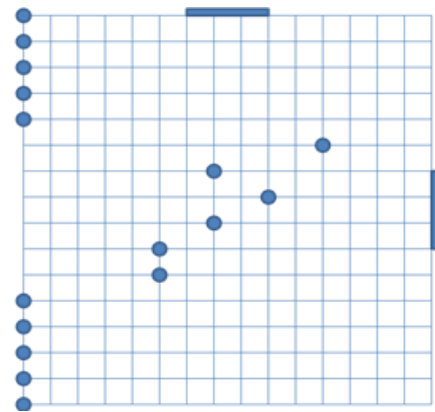


Figure 4: Test-setup of RFID tagged items

Results

Student Assessment

Besides providing users with hands-on experience with RFID, this project is also expected to increase the understanding of the technology and its relevant areas, improve student attitudes about engineering education, and enhance their confidence towards any instructed technology. To prove such usefulness, surveys were used to assess the developed educational tool and its impact on learners, a fact that provides means to receive feedback and improve the learning environment and the operability of its laboratory testing system.

Engineering students in a junior level industrial statistics class indicated that activities that involved using our learning environment improved their confidence in general knowledge about relevant topics:

1. Basic wireless ID applications
2. RFID systems
3. Data acquisition
4. Business benefits through RFID
5. Obstacles to implementation
6. Consumer privacy and security issues
7. Data analysis
8. RFID best practices

Having first arbitrarily assigned numerical values one through five to ordered categories “very unsure” through “very confident,” we report in Table 1 median confidence before and after Phase 1 activities with respect to each of the topics detailed above. Median confidence improved in 6/8 topics, and average median confidence across topics improved greater than 35 percent. The two topics where confidence was not improved was 6) consumer privacy and security issues, and 7) data analysis. Consumer privacy and security were not issues we highlighted, and student self-assessment about data analysis while important was already (pre-module) observed as “confident.”

Table 1: Median student confidence before and after I-ATMUS

Topic	Pre-module	Post-module
1	2	3.5
2	2	3.5
3	3	4
4	3	4
5	2	3.5
6	3	3
7	4	4
8	2	3
Mean of the medians	2.625	3.5625

A more theoretically appropriate treatment of the ordinal data reveals statistically significant differences between pre- and post-module confidence. Results in Table 2 are p values associated with the binary variable that describes whether or not a response is post-module. These binary variables of interest were considered independent variables in proportional hazards models of responses about each topic (controlling for student learning style). We also fit an overall model of confidence as a function of whether or not it was post-module, controlling for learning styles and topic.

Everywhere there was improvement from median pre- to post-module confidence that improvement is significant ($\alpha = 0.05$) with the exception of Topic 4 (business benefits

Table 2: Significance (p value) of module in describing pre- and post-confidence

Topic	$P > z $
1	0.013
2	0.008
3	0.004
4	0.052
5	0.001
6	0.207
7	0.186
8	0.002
Overall	0

through RFID). To summarize student confidence in the following five topics was improved after our module.

- Basic wireless ID applications
- RFID systems
- Data acquisition
- Obstacles to implementation
- RFID best practices

Finally students were asked to indicate how strongly they disagreed or agreed with the following statements (strongly disagree, disagree, neutral, agree, strongly agree).

1. This module helped me learn more about wireless ID technology
2. This module helped me learn more about linear regression
3. I would like to have more modules like this to help me learn
4. This module helped me to visualize RFID systems
5. This module was relevant to my education
6. The content of the module was easy to understand
7. The examples and exercises helped me learn

The median response to each of the seven items was “agree.”

Results Analysis

Results are based on fourteen student responses to the Index of Learning Styles (ILS) Questionnaire (SOLOMAN and FELDER) and our own I-ATMUS Module Questionnaire. Responses were collected before and after activities in which student teams used our learning environment to collect real RFID system data for a larger designed experiment. Teams then estimated, examined for adequacy, and selected linear regression models of the larger RFID system in order to understand read rate variation in terms of angle and distance between tags and antennas. Models also led to discussions about how one could use statistics to understand potential interference among tags. Activities took place in the junior level industrial engineering class called Industrial Statistics. In addition to what has been described, students were trained to use the I-ATMUS technology, and encouraged to browse our website for interesting articles. Three students did not participate fully due to absenteeism. They are not considered in our summary of results.

Students completed the ILS Questionnaire and a Pre-module Questionnaire before the activities, and a Post-module Questionnaire after the activities. Both Module Questionnaires ask students to indicate how confident they are in their knowledge about a number of topics. Students indicate confidence by choosing from five ordered categories: very unsure, unsure, neutral, confident and very confident. The Post-module Questionnaire also asked students to indicate how strongly they disagreed or agreed with seven statements about the module. Students indicated agreement by choosing from five ordered categories: strongly disagree, disagree, neutral, agree and strongly agree.

Results of the ILS Questionnaire describe learning styles across four continua: active versus reflective learners, sensing versus intuitive learners, visual versus verbal learners, and sequential versus global learners. Styles are quantified across each continua on a supposedly interval scale (-11, -9, -7, -5, -3, -1, 1, 3, 5, 7, 9, 11). Find in Table 3 results of our sample ($n = 14$) with respect to learning styles.

Table 3: Industrial Statistics students learning styles

	Reflective	Intuitive	Verbal	Global	
11	0	0	0	0	11
9	0	0	0	0	9
7	1	1	0	2	7
5	2	0	2	0	5
3	2	3	0	0	3
1	3	1	0	1	1
-1	2	0	1	4	-1
-3	0	3	1	4	-3
-5	2	3	2	1	-5
-7	3	1	1	2	-7
-9	1	2	3	0	-9
-11	0	0	4	0	-11
	Active	Sensing	Visual	Sequential	

Conclusions

In this paper, we present a learning environment that enables learners to access technological resources of an RFID laboratory through the Web technology. Such a project has a highly automated testing system and it is easy to use by beginner-level learners. It also has the feature of programmatically control hardware devices in order to develop complex test scenarios rapidly and with less tediousness. Student assessment was performed to measure the impact that this educational tool had on a class of students. Results show that it helped students learn many aspects about RFID technology as well as obtain hands-on experience through conducting testing experiments, collecting data, and analyzing it.

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