AC 2008-1817: INTEGRATED AUTO-ID TECHNOLOGY FOR MULTI-DISCIPLINARY UNDERGRADUATE STUDIES (I-ATMUS)

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Integrated Auto-ID Technology for Multidisciplinary Undergraduate Studies (I-ATMUS)

Abstract

Automated Identification (AutoID) and Radio Frequency Identification (RFID) technologies are unique in that their research and development are led by industry rather than academy. Therefore, there is a large knowledge gap between the best practices in industry and theoretical academic work, which should be bridged by the future engineers that are acquainted with such technologies. In order to fill that gap and fulfill the industrial manpower needs, the number of such individuals is to be increased. That can be achieved by developing next-generation laboratory learning environments, which provide hands-on experience for on-campus and off-campus students. For this reason, user-friendly, web-based applications are built as a way to give access to off-site students. A laboratory motorized hardware system is assembled in order to provide RFID technology testing setups. The overall environment is empowered by a programming language that yields remote agent control, RFID data acquisition, and abstract computations. Furthermore, the website contains online teaching modules for AutoID technologies and their application areas. The result of such an implementation is a powerful educational tool that is utilized to support innovative curriculum activities and provide hands-on laboratory experiments to on-campus and off-campus students. This project not only increases the understanding of AutoID technologies and their applications, but also improves students' attitudes about engineering education and enhances their confidence towards the targeted technologies. Partial support for this work was provided by the NSF CCLI program.

Introduction

The Auto-ID and RFID technologies are becoming more popular than ever while being led by industry rather than academia. As a result, a gap between the corporate practices and theoretical work has been formed. This caused a lack of potential experts in such emerging fields within the market of qualified personnel. The number of engineering students who are acquainted with the target technologies is to be raised to fulfill the manpower demand of the industry. That can be achieved through a next-generation learning environment that can provide remote hands-on laboratory experimentation setups, in addition to on-site setups.

Furthermore, recent research has shown that students learn and retain information best through interactive examples and experiments[2,3,4]. With the increase in use of technology and the internet, many researchers in all fields are focused on creating web-based laboratories to enhance students' learning, thus students are able to study and learn anywhere and anytime[1,5,6]. Another benefit of online virtual laboratories is that researchers are able to stimulate the interest of students with new teaching techniques provided by the web[7].

This paper presents the idea of building an RFID learning environment that includes a remotely controlled online RFID laboratory. Specifically, a brief introduction to the RFID technology is given, the concept of hardware and software support of the online RFID learning lab-environment is discussed, and the way of integrating RFID in the remotely controlled system is explained. The laboratory is developed to assist the teaching, training, and research of RFID technology as a response to the growing need for RFID experts who can help companies deploy and utilize the technology in a variety of applications. Moreover, test sites in the laboratory are developed in such a way to have the ability to mimic typical RFID applications and distantly available for the users who don't have access to RFID hardware.

RFID Technology

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 most likely converted into meaningful numbers and patterns.

This system can be extended with a set of middleware devices, a variety of software applications, a network of readers, and a powerful database management system (DBMS) to facilitate data acquisition and management.

With its capability of storing a descent 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. RFID however can identify each entity uniquely since tags contain room for extra data that represent the item's ID. While this emerging technology is being used in inventory control and tracking merchandize throughout the supply chain, it can also prove itself useful in other fields such as healthcare, security, and asset management. In the future, RFID will probably be used to compute the price sum of a supermarket cart of items just by passing it from a gate; for that reason, it is compulsory to have a 100% read rate, which is not attained currently. On the other hand, universities began embracing the RFID technology after some corporations have showed interest in testing and developing its equipment and started sponsoring research programs. RFID users basically need to assess the capability of such a technology, which depends on:

- the quality of the RFID reads
- the reliability of tags and readers in different environments
- the impact of electromagnetic wave interference
- the effect of changing distances or angles between readers and tags

Therefore, the existence of RFID laboratories is very important to providing testing results and conclusions as well as improving the RFID materials. Furthermore, it gives the involved individuals hands-on experience making them potential RFID experts.

Building a Lab Learning Environment for RFID

RFID is a new technology that is still not very accessible to the public. Also, it is not a technology that can be learned, mastered, and improved just by reading. Hands-on experiments are one very important component of teaching and promoting RFID, and using web technology to provide such commodity is one step to the future. The idea is to build a website that gives access to an RFID laboratory environment where experiments can be performed online, and therefore, can be carried out from anywhere in the world since the internet is ubiquitous nowadays.

Beside the basic RFID components (readers, tags, and databases), an RFID learning environment contains robots, motors, or even toys that allow moving RFID tags and antennas with different degrees of freedom such as rotations, translations, or combinations of both. A user in this atmosphere can configure the setup of each device, start reading the surrounding RFID tags (which might be in motion), then do his/her data analysis and provide conclusions. Not only that, but this learning environment can be enhanced with a programming language that facilitates hardware control and data acquisition for advanced users.

This paper discusses another important aspect of building such an environment, which is the architecture that lies under the hardware and software systems. This point is important because it can affect the complexity of updating or upgrading the overall system in the future. For that reason, we start with a basic but reliable core structure that controls a motor, and then we extend it to form an advanced online-controllable system.

1. Core System Structure

Building a system infrastructure from scratch might involve talking about some details. What is important to know is that a simple motor has three states: turn clockwise, turn counterclockwise, and idle. These states can be obtained by constructing a circuit that uses relays to switch on/off the right motion. Also, the signals that turn a relay on/off can be imported from a computer and controlled with a software interface.

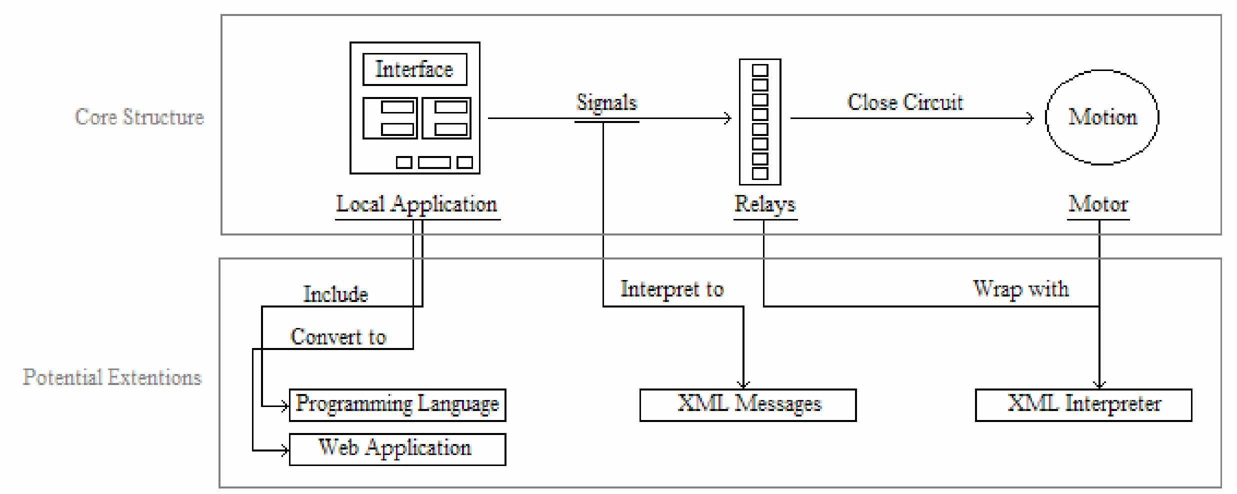

Figure 1 Core framework of system

The core structure of our basic system design therefore includes merely a software application and a robot (or simply a number of relays and motors). Upon a click of a button, the application sends signals through a computer port (such as the parallel port) and causes the relays to open or close, leading the robot to move or stop. The core framework of system is given in Figure 1.

Now, imagine that you can sit down at a computer, turn on our software application, and start playing with a little robot. Also imagine that you play with this system long enough that you become an acquainted user who craves for more control. Would not it be desirable to be able to program the robot according to a designed scenario or an inspired choreography? Would not it be even more useful to be able to do all this from any place in the world?

We hence explore the following system extensions (also showed in the figure above):

1. integrate a programming language to allow the user to program the behavior of a device
2. Embed the control interface on a web page for online access
3. Encapsulate a group of interrelated objects into one entity. For instance, relays and motors can be grouped together to make a robot that behaves independently of other external devices. This leads to a flexible system that is easy to upgrade.

2. *Extended System Structure*

As mentioned before, the first extension applied to the system is the integration of a programming language. The reason behind such decision is because programming languages hide powerful computational and logical potentials, which have to be learned and explored by the user himself/herself. In the target system, the programming language can be used to program hardware scenarios, retrieve data from databases, obtain variable values at different time instants, debug programs, perform arithmetic operations, and simply solve problems. Also, a programming language can be built to fit a certain community of coders. For instance, if the users of the target system are mere people whose purpose is to learn and obtain RFID hands-on experience, instead of software engineers, then it is desirable to construct a programming language that hides the technical details and is easy to use for the public.

The second extension is to make the lab environment accessible through the ubiquitous internet. That is done by embedding the software application that controls the lab equipment on a webpage. A website is to contain this page as well as other relevant pages that can facilitate the use of the programming language and learn RFID better. While creative methods can be used to display the knowledge and convey it online, the website can be organized in a fashion that walks the individual from a beginner level to an RFID expert level. Furthermore, besides articles about the RFID technology and the programming language tutorials, teaching modules can be added to the website to teach the different uses and applications of this technology in the real world. Such applications include supply chain, logistics, material handling, production planning, and automated manufacturing.

The final extension touches upon the infrastructure of the lab environment and targets grouping interrelated components to make one independent device, which we name "an agent." Building an agent means not only gathering the dependent entities, but also constructing a software application that accepts messages from the outside world and translates them into messages or actions that the group understands. For example, in the previously discussed core structure, instead of directly sending signals from the software interface to the motors, the application would send a message (we choose XML as an encoding language for messages) to the interpreter; then the interpreter takes care of sending the appropriate signals to the appropriate components in general, or motors in this particular case. As an outsider to the system, one can see that an XML message, which resulted from a click of a button from the software interface, was interpreted as an agent (or motor) motion. If this strategy is followed, then integrating other independent agents in the system will be an easy and rapid task in the future, reducing by that the maintenance and upgrade costs.

Finally, the set of extensions discussed in this section can be summarized in the following figure:

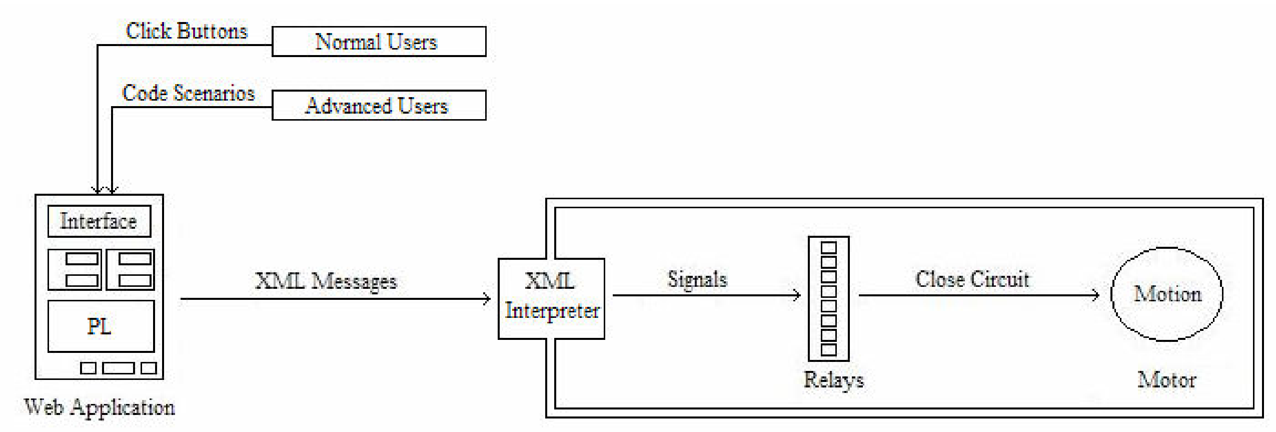

Figure 2 The structure of the extended system

Notice that, even though it is not mentioned in the figure, the agent involved in the illustration is formed from the XML interpreter, the relays, and the motor.

Integrating RFID

By this time, the reader should be familiar with the idea of controlling devices over the internet. The next step is to integrate the RFID technology in the remotely controlled system. That is done by attaching RFID antennas to motors to obtain the desired rotation or translation. Also, movable tags are easy to make since they are considerably light. They can be placed on boxes or items that slide on a conveyor belt or simply stuck on a displacing toy such as a car or a train.

On the other hand, the RFID reader is to be linked to its database and ready to be controlled through a software interface. For the user's convenience, it is preferable to have such interface integrated in the website from which the hardware devices (motors, robots, toys, agents…) are controlled. This website should also include a mechanism that allows querying the RFID database and acquiring the read data.

One final important component is the presence of a good quality web-camera that prompts the user to view and zoom on a specific part of the laboratory. Such device helps the RFID learner in many ways such as obtain a visual of the laboratory and the RFID equipment, control the hardware with ease, and take snapshots of the lab view for future documentation.

If we assume that these steps are implemented, now a user can access the website from a web-browser, open a lab view streamed by the web-camera, zoom on the target devices, move them according to the desired test setup, acquire the reads, and finally export the data to a file for future analysis. This is as far as the RFID testing and the hands-on experiments are concerned. For other aspects of learning about RFID, the learner can explore the teaching modules of the website, read the articles and responses on the discussion-boards, and even post detailed questions for more clarification.

Summary

This paper introduces the concept of developing an RFID learning environment supported by a system that can be controlled through the web technology. Learning RFID can be carried out by exploring teaching modules on a constructed website and by remotely performing hands-on experiments that involve RFID equipment. Such experiments can be done online thanks to a suggested laboratory hardware structure that allows users to control devices through a software interface with clicks of buttons. The system is also enhanced with a programming language that yields users to code hardware motion scenarios as well as perform computational and logical tasks. Finally, the website includes a query mechanism that allows the RFID read data acquisition. The result of our effort is a learning environment that benefits any individual from any part of the world who is interested in learning the emerging technology of RFID, to obtain the knowledge and hands-on experience about RFID as well as test the performance of the RFID equipment and come to technical conclusions.

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