Automatic Identification/RFID Course and Equipment for Teaching and Research

by

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Abstract: With the increasing implementation of radio frequency identification (RFID) in the supply chain, engineering technology and industrial technology degree programs should incorporate or begin to incorporate course work in automatic identification (AutoID) and RFID. Although there appears to be some information for these topic areas, there is no ready and clearly identified data about what AutoID and RFID equipment is both reasonable to purchase for schools and appropriate for teaching and research. In addition, there is little information about possible texts and virtually nothing about suggested teaching methods. Further, although not strictly identified as an AutoID technology, the tracking of assets with Global Position System (GPS) technology is an integral part of the supply chain. There is little about how to teach it or what equipment could be used to give students real-world or near real-world experience. Research into these technologies at the undergraduate and graduate levels could be possible with the appropriate choice of lab equipment, even with a limited budget.

This paper offers suggestions on an undergraduate/graduate course outline to teach the topic areas identified. Included are suggested texts, media presentation methods, and other teaching information. A suggested list of equipment for teaching lab activities and a list of ideas for undergraduate and graduate research using the equipment are provided.

I. Introduction

Teaching AutoID can be difficult, which is not unusual for evolving technologies. Although barcoding, which is part of the general field of AutoID, has been in existence for more than 60 years, RFID, the newest form of AutoID, is changing the supply chain scene. RFID's influence is significant because of its adoption by organizations such as Wal-Mart, the Department of Defense, the U.S. pharmaceutical industry, and the U.S. automotive industry.

RFID is rapidly being implemented into the global supply chain. Millions and millions of RFID tags attached to products are being read daily and their data stored in databases. New ways to use RFID tags are being developed almost overnight.

Programs in engineering technology and industrial technology need to be incorporating course work in AutoID and RFID so that students will be aware of this ubiquitous supply chain technology. Although there appears to be information for these topic areas, there is no readily and clearly identified information on several issues in teaching AutoID and RFID, such as the following:

1) Equipment that would be reasonable for schools to purchase
2) Equipment that would be appropriate for teaching and research
3) Appropriate texts
4) Suggested teaching methods

Further, although not often strictly identified as an AutoID technology, tracking assets with GPS technology should be included in an AutoID course. GPS tracking technology is an integral part of supply chain tracking, but there is very little information about how to teach it or what equipment could be used to give students real-world or near real-world experiences. Research areas at the undergraduate and graduate levels are possible in RFID with the appropriate choice of lab equipment identified for teaching AutoID and RFID, even within a limited budget.

This paper focuses specifically on AutoID technologies for the supply chain that would be appropriate for teaching and research, especially on a typical school budget.

II. Course Outline/Teaching Topics

For the purposes of this paper, the field of AutoID will be broken into the three general areas of barcoding, RFID, and GPS tracking, which are integral to the supply chain. Tables 1a and 1b contain an outline of a possible AutoID/RFID course covering the three general areas in a 15-week semester format. The study topics in each section of the outline provide a list of specific concepts to be taught. The activities and labs are examples that relate to the study topics. The teaching resources and evaluations are correlated primarily to the study topics.

The study topics in the Overview and Barcoding section of Table 1a give an overview of the field of AutoID as well as specifics of barcoding. Security technologies such as biometrics and smart cards are included in this overview. The teaching resources identified are examples of what is available.

The Automatic Identification and Data Capture Technical Institute (AIDCTI) at Ohio University [1] offer's a weeklong workshop on most facets of the general field of AutoID. PowerPoint presentations by experts during the institute and hands-on laboratories comprise the weeklong event.

The GPS tracking section in Table 1a focuses on six technologies that relate to the tracking of objects and people using GPS and related technologies. The six technologies range from hardware and software to systems. Web resources are used exclusively here.

The study topics in Table 1b involve all aspects of RFID—especially middleware—that are necessary to capture the data contained on an RFID tag. Once again, the teaching resources identified are selected examples of what is available.

Table 1a: Example AutoID/RFID Course Outline (part 1)

Overview and Barcoding 4 Weeks	Study Topics: • Overview of AIDC • Data Carriers and Data Structures • AIDC Standards • Bar Coding • Printing Barcodes • Scanning Concepts: Theory, Types, Performance, and Applications • Types of Codes, Symbology, Information Content, Errors • Machine Vision Barcode Reading • Smart Cards • Biometrics • RFID Introduction Teaching Resources: • *The AutoID Book* [2] with modified AIDCTI PowerPoints	Example Activities and Labs: • Create a poster of examples of each type of barcode. • Create a survey or test in Excel or Word using a barcode reader as the input device. • Explore linear and matrix barcodes using a machine vision camera. • Create linear and matrix barcodes using a dedicated barcode printer. • Explore an equipment inventory database system using a computer-based barcode scanner. Evaluation(s): • First test including terminology
GPS Tracking 5 Weeks	Study Topics: • Automatic Identification Systems (AIS) • Automatic Vehicle Location (AVL) • Automatic Position Reporting System (APRS) • Geographical Information System (GIS) • Global Positioning System (GPS) • Real Time Locating Systems	Example Activities and Labs: • Explore using a GPS receiver for position location. • Create a GPS tracking base station setup using APRS software. • Explore using a one-way tracker with GPS attached. • Explore using a two-way tracker with GPS attached. • Explore using a two-way tracker with messaging system and GPS

	(RTLS) • Vehicle Tracking System (VTS) Teaching Resources: • Web pages • APRS PowerPoints	attached. Evaluation(s): • Second test including terminology

Table 1b: Example AutoID/RFID Course Outline (part 2)

RFID 6 Weeks	Study Guide: • Intro to RFID • RFID Architecture • Tags • Tag Protocols • Readers and Printers • Reader Protocols • RFID Middleware • RFID Information Service • Manageability • Privacy and Security • Future of RFID Teaching Resources: • *RFID Essentials* [3] with modified AIDCTI PowerPoints • YouTube videos	Example Activities and Labs: • Explore using LF RFID tags and readers. • Explore using HF RFID tags and readers. • Explore using UHF RFID tags and readers. • Explore creating RFID tags using an RFID printer. • Explore middleware needed for RFID. • Explore slap and ship operations. • Explore RFID door locks and access. • Explore implementing RFID in ASRS. • Explore implementing an RFID smart shelf system. • Explore implementing RFID in warehouse. Evaluation(s): • Final test including terminology • Graduate student research projects

III. Textbooks and Presentation Materials

A key question when creating a course is "What textbook should be used?" First, there are numerous texts about the field of AutoID. However, many have old publication dates. Also, since some aspects of AutoID, such as RFID, are in flux, this quickly outdates textbooks. This does not mean that a text would not be useful as an overview even when it is does not have the latest publication date.

Second, large amounts of information on the field of AutoID are not in printed textbooks but are available online through the Internet. Some of it is good, and some is bad.

Third, there is at least one special organization that provides training in the general field of AutoID. It is the AIDCTI in the Russ College of Engineering and Technology at Ohio University [1]. PowerPoint presentations at the AIDCTI by experts provide up-to-date information in the general AutoID field.

The question, then, is which of these should be used. One obvious answer is to use all of them if possible. This is the pattern that is proposed in this paper.

The teaching resources identified in Tables 1a and 1b include AIDCTI PowerPoint presentations with modifications, which would supplement a textbook. This appears to work quite well, since the textbook provides an overview of basic AutoID information, and the presentations provide up-to-date information and allow for a choice of topics according to what needs to be presented. They also allow for the incorporation of special technologies such as biometrics, smart cards, and others.

The Overview and Barcoding section of Table 1a shows that AIDCTI presentations with modifications are used with the textbook *The AutoID Book* [2].

The Teaching Resources in the GPS Tracking section of Table 1a identifies the use of Web resources, since there is no appropriate text for this area. Bob Bruninga, the author of the Automatic Position Reporting System (APRS) concept and software, has an APRS PowerPoint presentation [4] that describes GPS tracking from a practical standpoint. This presentation with modifications provides an overview of GPS tracking.

The RFID section in Table 1b shows that AIDCTI presentations with modifications are used as supplements to a more detailed text, *RFID Essentials* [3]. This text includes coverage of middleware topics, which are critical in RFID.

Two other possible RFID teaching resources are the following:

1. Ranky [5] CD/DVD of RFID materials created from Internet resources
2. Berisso [6], Director of the AIDCTI, uses *RFID for Dummies* [7] to give an overview of the RFID field.

Videos are a teaching method that can be used effectively to give students a dynamic way of seeing a concept in action. The YouTube Web service [8] has a large number of RFID

videos. Reviewing the videos resulted in 165 useable videos, organized into the categories and subcategories shown in Table 2. These videos are posted on the course Web site.

Table 2: YouTube RFID Video Categories

- Entertainment
  - Coffee cup display
  - Creating music
  - Others
- Future Uses of RFID
  - Smart homes
- Middleware for RFID
- RFID Applications
  - Door locks
  - Libraries
  - Material handling
  - Parking
  - Retail stores and supermarkets
  - Smart card
  - Warehousing
- RFID Technology Overview and Explanation
  - Implantable tags
  - Privacy issues
- University of Nebraska Lincoln RFID Laboratory
- Crazy RFID videos that don't fit anywhere else
  - Mark of the devil
  - Political comments

These videos can be used in several ways. One initial way is to give an introduction to RFID using the classic IBM video of a man shopping in a RFID-enabled supermarket [9]**.** This video was shown during the first week of class and immediately captured students' interest and sparked comments and discussions about the class, RFID, and projects.

The YouTube Web site can also be used as a place to post videos of student projects. Not only does this provide students with an interesting way of demonstrating their projects, but it is also a form of advertisement of the university, the department, and the course. Students appear to enjoy the idea.

IV. Equipment for Labs

There are many types of AutoID and RFID equipment. Some are complex and expensive, ranging from thousands to tens of thousands of dollars, while others are simple and well under $100. Table 3 shows a list of equipment based upon the teaching topics identified Tables 1a and 1b.

Table 3: List of Equipment for AutoID/RFID Course

Barcoding equipment

- Symbol LS2208 laser barcode scanner
- Intermec 700 wireless color computer
- Zebra R2844-Z printer
- Symbol DS6708 2D barcode scanner or Cognex DVT535 machine vision camera

GPS tracking equipment

- Kenwood FT-1802M mobile transceiver
- Astron SL-15R 12 amp DC power supply
- MFJ VHF mobile antenna
- Kantronics KPC3+ terminal node controller
- Kenwood TH-D7A (G) handheld APRS transceiver
- Garmin Etrex GPS receiver
- WinAPRS GIS software
- Tiger maps

RFID equipment

- Dynasys LF/HF evaluation kit RFID reader/writer
- Sirit Infinity 210 UHF reader/writer
- Jett RFID+ HF handheld reader/writer
- Phidgets LF RFID reader
- Parallax LF RFID reader

Barcoding Equipment

The Symbol LS2208 is a high-quality laser handheld scanner that is inexpensive and can be used to demonstrate the usefulness of linear barcodes. The first lab identified in the Overview and Barcoding section of Table 1a has students learning how to program the scanner, especially control codes, and then creating a survey or test in Word or Excel that has the answers encoded in linear barcoding format. This lab could be extended to have the students create an attendance roster on which they scan their absence or presence in class.

If additional funds are available, the Intermec 700 Wireless Color Computer can provide additional experiences beyond the LS2208 scanner. The Intermec 700 is a wireless-based scanner that can be integrated into an Ethernetwork to store barcoded information in a server database. Creating an equipment inventory system using the Intermec is a possible lab activity, as shown in Table 1a.

Printing linear barcodes is fairly easy. Most any type of printer with the appropriate barcode generating software can print barcodes. There are a number of free and shareware programs available for printing linear barcodes. One popular commercial software package is BarTender by Seagull Software [10].

If additional funding is available, a small printer just for barcode printing and encoding RFID tags gives students experience with these types of printers. The Zebra R2844-Z printer is a compact printer that is used quite often in commercial applications. It is possible to connect this printer to an Ethernetwork with added equipment. As shown in Table 1a, a lab activity to print linear and matrix barcodes representing different types of products would be instructive for students.

Reading two-dimensional matrix barcodes requires a different type of scanner. The Symbol DS6708 2D Digital Barcode Scanner is a high-quality scanner for matrix code reading. Since matrix codes can contain more data, an activity that involves creating such codes to represent complex products would also be instructive as a lab activity.

If additional funding is available, a machine vision camera, such as the Cognex DVT535, can be substituted for the DS6708. The Cognex Intellect software for the camera supports reading one- and two-dimensional barcodes. An additional advantage of a machine vision camera is that is has other capabilities that are useful in detecting product failures, inspection, and related activities. This is useful with automated systems, especially those involving robots.

GPS Tracking Equipment

AutoID textbooks do not usually include GPS tracking even though GPS is becoming an integral part of the supply chain and AutoID in general. Commercial supply chain GPS tracking equipment is expensive and is not open to general use. This makes it hard to include hands-on GPS tracking in AutoID courses.

However, amateur radio service experimenters (also called ham operators) have developed their own GPS tracking system that tracks vehicles, people, hurricanes, and many other types of items. The system is called the Automatic Position Reporting System (APRS), developed by Robert Bruninga [2]. This is a free technology for any licensed ham operator to use. The operator only needs to provide his or her own equipment and software. Commercial GPS vehicle tracking uses equipment and software that is similar to the types used in APRS. One of the main differences exists in the frequency of operation.

APRS uses digital technology through packet radio. Location data from a GPS receiver is converted to a packet of bits, which is converted into a stream of sounds in a RF modem. These sounds are then sent through a frequency modulated (FM) high-powered wireless radio transmitter. The packet sounds are received by a FM receiver, which converts the packet sounds back into a digital bit stream and through another RF modem. The bit stream is processed and displayed on Geographical Information System (GIS) type map-based software with a database. A wireless network of APRS digital repeaters covers most of the United States, much like the cellular telephone system. As mobile stations travel, their packet signals are picked up by the digital repeaters and re-sent. Through a pathing system somewhat similar to the Internet, the packets can travel from their beginning location to a desired ending location, which is then displayed on the APRS GIS type display.

Since high-powered wireless radio transmitters are used in APRS, a Federal Communication Commission (FCC) Amateur Radio Service license is required. Ham radio groups periodically administer license testing locally, which consists of a written test. The license cost is minimal and would be relatively easy for technology or engineering students and faculty to pass.

Ham radio operators have included the Internet in their APRS operations. They have connected the wireless radio packet signals into special servers called IGates. APRS is now a worldwide GPS tracking system. The Internet connection also includes SATGates, which connect packet signals originating to and from satellites and the International Space Station (ISS).

Table 3 shows the equipment needed to implement APRS as the GPS tracking system. This equipment allows the setup of a base station with GIS software and a mobile station placed in the vehicle to be tracked. Figure 1 shows the WinAPRS GIS software map display.

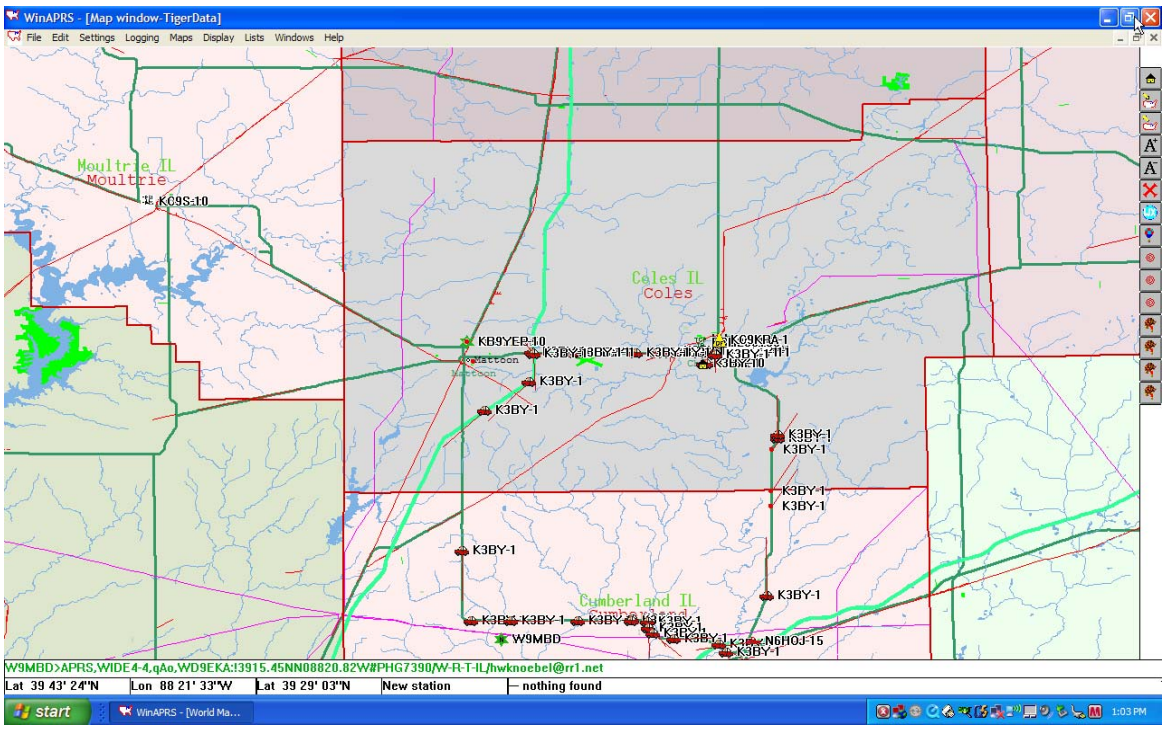

Figure 1: GPS Track in WinAPRS

There are several GIS type software packages for APRS, which can be found on the APRS Web site [2]. The figure above illustrates how WinAPRS displays the GPS track of the author's personal vehicle (K3BY-1) during a test drive loop of about 40 miles.

As listed in the GPS Tracking section of Table 1a, setting up and exploring the characteristics of the vehicle tracking system and the APRS software would be an initial activity. Other activities could involve having students learn how to access and use the APRS Internet Service [11] and an online finder database called FindU [12].

RFID

The equipment listed in Table 3 supports the three most popular RFID tag radio frequencies of LF (low frequency), HF (high frequency), and UHF (ultrahigh frequency). The tag is the device that contains information on a microchip about a specific object and sends that information to a reader whenever the reader wirelessly interrogates it.

The Dynasys/RFIDUSA [13] dual band RFID reader/writer is a self-contained unit that can program (write) and read both LF and HF tags. The unit comes with software and a selection of sample tags. Students can use this to complete the first two labs identified in Table 1b.

The Sirit Infinity 210 UHF reader/writer is an industrial-grade RFID reader/writer. The reader includes an internal high-gain antenna integral to the unit as well as demonstration

software and tags. Students can use the Infinity 210 to explore a production tracking system or a library book tracking system.

In addition, the internal antenna can be disconnected, and a separate external antenna can be connected. This means that students could experiment with antenna designs to increase, for example, the read distance for different tracking systems.

Besides experience with RFID reader/writers, exposure to an industrial grade RFID printer is necessary for students to develop experience. The Zebra R2844-Z printer, identified above as a barcode printer, is a dual-purpose printer. It can program HF RFID tags as well as print plain text on the tag or even a barcode. With this printer, students can experiment with a slap-and-ship type operation among other activities.

Working with a high-end handheld RFID reader/writer is another activity for students to experience. The 2 Technologies Jett RFID+ HF handheld uses the Windows CE .NET operating system. This handheld is a state-of-the-art RFID reader, which can read and write HF tags. This reader/writer could be used to develop an inventory system, a product tracking system, or even a library book tracking system.

A most important part of RFID is the creation of the middleware needed between the reader/writer and the host computer with its database. This most crucial part of an RFID system requires students to have programming experience.

The PhidgetsRFID [14] and Parallax RFID reader [15] in Table 3 are each well under $100. Although these readers are hobbyist oriented, they can bring interesting experiences to a class. A number of these readers can be purchased cheaply so that each student can experiment with a RFID reader individually.

In his book *RFID Toys*, Amal Graafstra [16] describes a number of easy-to-build RFID-enabled projects. Some of the projects from this book have been used as class RFID experiments. Of course, these projects could be modified to create new types of experiments.

V. Research Possibilities

Graduate and undergraduate research opportunities are possible with the equipment identified in Table 3. Some selected graduate and undergraduate RFID research topics are shown in Table 4.

Table 4: Selected RFID Research Topics

Graduate

- Development of middleware needed to support RFID reader/writers
- Exploring use and behavior of RFID in a warehousing environment
- Tracking people or things inside of a building using RFID
- Exploring seamless transition between GPS tracking and RFID tracking
- Locating the exact position of a RFID tag in a warehouse without prior knowledge of its location

Undergraduate

- Exploring working issues of different frequency RFID tags in a production work cell
- Exploring automated library book checkout system
- Exploring library book inventory system using inexpensive RFID tags and readers
- Exploring using RFID tags in an automatic storage and retrieval system (ASRS)

The Sirit Infinity 210 UHF reader/writer and the Jett RFID+ are especially suitable for research because they are industrial grade. However, meaningful research could be done with the other equipment.

Note that the inexpensive RFID readers could be used to develop a low-cost library book inventory system. Of course, there are many more possibilities for research, depending upon the equipment available, student interest, and faculty research interests.

VI. Summary Comments

We have tried to offer suggestions to help those who teach or want to teach AutoID, RFID and GPS tracking. Of course, teaching is a process that evolves over time. The techniques, ideas, and equipment discussed in this paper hopefully can provide a starting point. The majority of the equipment identified can be purchased for well under $10,000. The equipment identified can support a class size of 10 to 12 students working in teams of 3 or 4 and using a rotation method. It provides exposure to the majority of AutoID equipment and uses.

We hope the information in this paper will be of use to all who have an interest in AutoID, RFID, and GPS tracking.

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