Development and Testing of an RFID-based Cutting Tools Tracking Application

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Abstract

Recently one of the important concerns for manufacturing industry has been improving the return on investment. With the introduction of RFID technology, industry is hopeful of providing visibility to assets, supplies and personnel, and improves the operations. Using RFID-based asset tracking and more precisely tool tracking, machine shops can introduce automated management and maintenance achieving near real-time location, reduce shrinkage and monitor tool condition.

The current research project presents an interactive application capable of tracking the tools, managing their maintenance by following up their effective usage automatically and organizing their storage and utilization.

Introduction

Competitiveness is obviously necessary for industrial production. In order to keep abreast, manufacturers continually have to improve efficiency. There are many ways to do so. One of latest methods is to integrate an RFID-based asset tracking system in the manufacturing facilities.

Study of RFID-based tool tracking in machine shops is the focus of research in this work. Among the existing automation systems many asset tracking programs already exist but they often use bar-codes which do not allow to process more than one item at a time. Only a few of them manage tool tracking and most of the time they do not deal with tool maintenance.

In order to meet manufacturing requirements, a cutting tools tracking system was created. Prior to describing the developed system, its implementation and the tests conducted in simulation exercises, a brief description of RFID technology, Asset Tracking and .NET Framework is provided in the following sections.

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1 Background

1.1 RFID Technology

Radio Frequency Identification (RFID) is an identification technology which consists in setting up communication between a tag which is in the interrogation zone and one or more antennas connected to a reader. There are other identification technologies which are quite popular in industry such as:

- Magnetic stripes for credit cards, smart cards, security gates keys
- Bar-codes for goods tracking in stores and inventory systems

However, compared to the bar-code technology, RFID is much more efficient. Bar codes only allow scanning one item at a time and require ‘line-of-sight’, whereas RFID can deal with multiple tags even when the tags are not in the line-of-sight. In many instances, human intervention is no longer required, and the transactions can be automated.

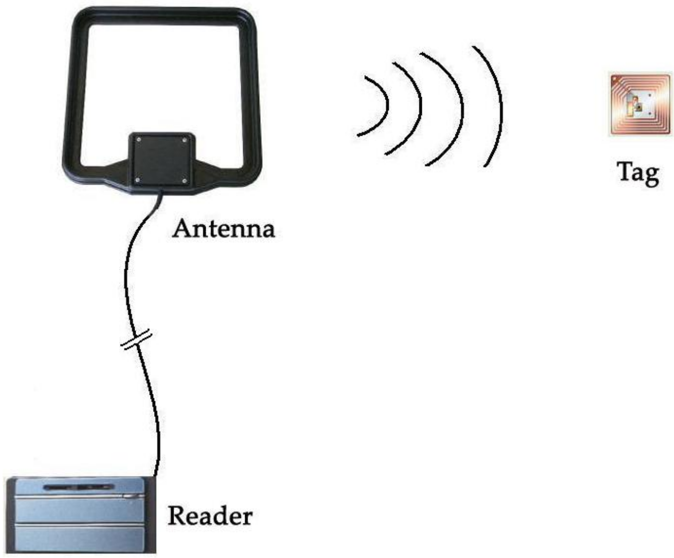

Figure 1: Typical RFID System

1.2 Asset Tracking

Asset tracking refers to fixed assets, which are items purchased for long-term use and that are evaluated by different metrics leading to measurable return on investment.

In order to know exactly which assets they own and to manage it efficiently, companies use asset tracking systems. This kind of system enables continuous as well as discrete industries to keep track of what equipment they have, where it is located, who is using it, when it was checked out. This may involve machines, computers, printers or copying machines, office equipment, tools, pallets, etc.

When using such systems, companies can reduce loss and prevent pilferage, better manage equipment maintenance, and this information is easily accessible on computers or portable devices and is provided in the form of customizable and printable reports.

Some of the existing asset tracking systems use RFID, the others generally use barcodes [4] [5]. Today manufacturing companies must have a lean supply chain in order to compete in the market. Eliminating waste is a top priority and using asset tracking as a full-fledged supply chain tool seems to be something incontrovertible.

1.5 The System: AssetTrack

The goal of this project is to check the feasibility of using RFID technology in tracking and tracing of cutting tools in a typical manufacturing shop floor. The scope covers providing unique identity to the cutting tools and complete transactions with minimal user interactions during activities such as assigning locations to tools, borrowings, returns, monitoring cutting times, and inventory audits.

The RFID technology used is high frequency, operating at 13.56 MHz, conforming to ISO 15693 protocol, and with read/write capability.


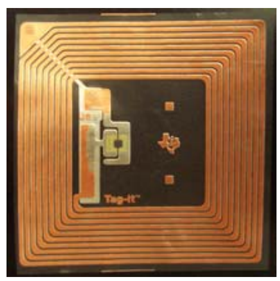

Figure 2:
Texas Instrument T01A 13.56MHz antenna and STU650A reader with TI Tag-IT HF passive tags (source: UCLA-WINMEC, RFID lab)

2 Programming approach

2.1 Objectives of the system

Manage a set of cutting tools used in a machine shop: have their location, features, utilization and maintenance state recorded and available at anytime for consultations in real time.

2.2 Step 1: Creating the database

To store the cutting tools' information, the first thing to do was create the Access database. To support the stated objective of the system the database was created with four tables: Locations, Cutting Tools, Check-in/Check-out and Utilization.

2.3 Step 2: Keyboard interface

Once the database was designed the user interface (UI) was programmed. In the first stage the UI was implemented as a simple interface only allowing simple keyboard entries so it was easy to test the scope and interface of the database, as well as the interactions between the different functions of the asset tracking application.

At the end of this phase, the program enabled manual data entries and the overall architecture of the program was finalized regarding the following modules:

- Administration: The user can add, modify, delete a tool or allocate a tool to a particular store, modify or delete this allocation
- Check in / Check out: The Checking-in and Checking-out times are recorded as well as the operator's name and the name of the project.
- Report: The user can know which tool is IN or OUT, each tool details and usage history.

The system also supports many logical and security functions like the checking of the existence of the tool we want to modify, delete or relocate in the database or the checking of the availability of the tool when we want to check it out. Most of the exceptions are handled through intelligent messages, so that the user understands the status of the application.

2.4 Step 3: Integrating the RFID readers

The RFID reader driver was interfaced with the system and the data was generated and transmitted through the RFID driver. The driver is a component of the WinRFID middleware and handles the communication and data protocols between the reader and the tags. To begin with the system features were tested with handling a single tag at a time.

2.5 Step 4: Replacing simple entries by multiple entries

One of the distinguishing features of this asset tracking application is the fact that tools are not scanned one by one but in lots on account of RFID. After the successful testing of the system with single tag processing, the system was modified to handle multiple tags at a time.

2.6 Step 5: Add a reading station for use at the Machine-Tool

A second application was created to simulate a reading station which would be placed on or near the machine tool which would record the time the tool is put on the spindle / turret and the time it's taken out.

This module writes the start and end cutting-times to the tool tag. During the tool check-in the difference in cutting-time start and end is computed by reading the time data from the tag and the cutting time for a particular operation by the tool is calculated.

Cumulatively adding the cutting times when the tool is returned, the tool maintenance module monitors the cutting life of the tool against a preset tool life assigned to the tool. The application tells the user when a tool has to be maintained by preventing the operator from checking it out when it needs maintained- sharpening, or replace the tool bits.

2.7 Step 6: Inventory Module

Sometimes we need to know what are the features of a particular tool. To do so, an inventory module has been added to the system. Anybody can take an inventory of the tools used in the machine shop by scanning them with a portable device. The data base is accessed directly from this device.

3. Detailed Description of the Tool Store Reading

The system's user interface had to be user-friendly, and respond to a machine shop objectives regarding cutting tools maintenance. For each case the reading of the tool ID tags is done automatically when the tool is in the vicinity of the reader. From this page the user has access to four sub-menus as follows:

3.1 Administration Menu

This menu infers directly on the data base contents.
If the tool already exists in the data base, a message appears after the "Add this tool" button is clicked. In each case, if the tool doesn't exist an appropriate message is flashed. For instance, if the user wants to modify an allocation, the tool must have been allocated at least once.

3.2 Report Menu:

In this menu the user can observe which tool is stored, which tool has been borrowed, when, by whom, for which project, and its current location. For each scanned tool, the user can know all the features, the tool usage history as well as its time left before maintenance. This information comes directly from the data base.

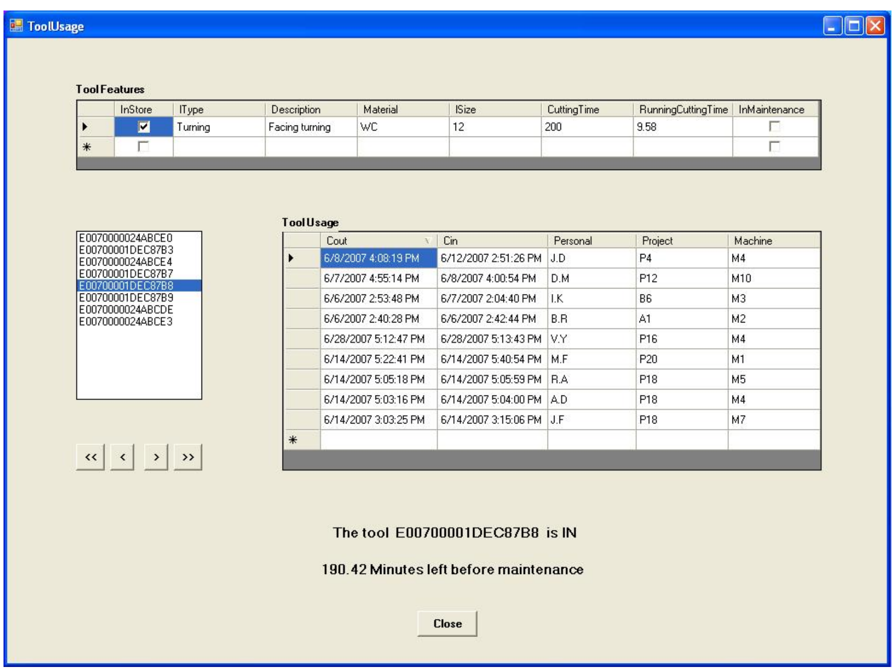

Figure 3: The tool usage history is displayed for all the selected tools.

3.3 Check-in / Check-out Menu

This menu consists in supervising the borrowing of a tool and its return at the end of the cutting operation. For the Check-out and for the Check-in as well, the tool ID tags are read like in tool usage.

CHECK-OUT Function:

The Tool ID is pre-entered on the form which the operator as to fill for each tool he wants to borrow. If for some reason the tool is already out, a message is displayed to warn him. At the end of this operation, the data base is updated and the new checking out is recorded.

CHECK-IN Function:

For the Check-In function, all the IDs of the tools returning to the store are scanned as well as the cutting start and end times. At the end of this operation, the data base is updated: the new checking in is recorded and the cutting times are calculated to appear in the tool usage function.

3.4 Inventory Menu

Each time a tool tag is read, a new line appears on the screen. When all the tools have been scanned, a search function is enabled and the tool features can be sorted and displayed depending on this sorting.
For all the tools that are scanned but don't belong to the tool store the system manages, a message is displayed showing the tool IDs.

4. About the Reading Station at the Machine Tool

The beginning of cutting operations time and the end of cutting time have to match the exact cutting times, which means that a second reader must be made available on or near the machine tool. The start time is written when the tool is put on the chuck, the end time is written when it's removed.

5. Integration and Tests for the Machine Shop

5.1 Tags

Tests were conducted in the RFID@WINMEC lab, using turning tools from the UCLA machine-shop.

The main goal was to answer the following questions:

- Can the tag be read when attached on the tool?
- How will the orientation of the tool with the tag on the reading stage affect readability?
- How many tags can be read at a time?

Figure 4: Tags attached to tools and antenna

5.2 Store Reader

One antenna was used for these tests but the tags can not always be read immediately because of their orientation. Best readability was observed when the plane of the tag is parallel to the plane of the antenna. To achieve this care should be taken to properly orient the tags.
One solution to this issue could be suggested: if two antennas can be used which are mutually perpendicular to each other, then there might be more freedom in orienting the tags with higher probability of reading them.

5.3 Machine Tool Reader

The same setup as above was used for this test too. The writing of time data to the tag was challenging. The tag being attached to metal and the number of blocks of data to be written impacted successful writing to the tag. A little experimentation was required to find the best data size to be written successfully in one cycle as well as controlling the writing thread. It was found that smaller the data size written to the tag in a cycle more successful it was to complete the write operation. Also the writing thread was put in sleep mode (add latency to the execution logic) for the reader to complete the write operation.

5.4 Observations

Considering the tests that have been conducted, the following questions would arise:

Ease of handling and using the system?
What kind of access to the data should be provided to the operators?
How many management stations would be required in a typical manufacturing setup?
How should these stations be integrated?

These tests were conducted in the RFID@WINMEC lab. To ascertain its performance it needs to be tested in a real machine shop.

Conclusion

This research project presents a representative study to demonstrate how RFID can bring benefits and how it can improve data collection and automating activities in a machine shop. Tests were conducted regarding identifying the tagged tools, reading and writing data to the tags attached to tools, and demonstrated the potential of integrating the RFID-based system in the machine shop workflow. In the future, the system can be improved by using the latest generation tags which are small in size as compared to the size of the tags used in this project which are too large to be used in actual situation.

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Biographies

Dr. Rajit Gadh is a Professor at the Henry Samueli School of Engineering and Applied Science at UCLA, and he is the Founder and Director of the Wireless Internet for Mobile Enterprise Consortium or WINMEC(http://winmec.ucla.edu) of which major companies including Hewlett Packard, Hughes Network Systems, Intel, Intelleflex, ISBM-Italy, Lucent Technologies, Microsoft, Mobio, Motorola, Qualcomm, Raytheon, Satayam, Siemens, TCS, Verizon Wireless and others are supporting members.
Dr. Gadh is also Founder and Director of the Wireless Media Lab in UCLA. Dr. Gadh works in the areas of Mobile/Wireless Internet, Wireless Multimedia (http://winmec.ucla.edu/mobime), RFID edge-of-the-network technology, RFID Middleware (WinRFID), RFID-sensor interfaces (ReWINS), wireless enterprise security, within the Wireless Media Lab (http://wireless.ucla.edu/wml). He has over 125 papers in journals, conferences and technical magazines, 3 patents granted and 3 patents in application.

He has a Doctorate degree from Carnegie Mellon University (CMU), a Masters from Cornell University and a Bachelors degree from IIT Kanpur. He has taught as a visiting researcher at UC Berkeley, has been a Assistant, Associate and Full Professor at University of Wisconsin-Madison, and did his sabbatical as a visiting researcher at Stanford University for a year. He has won several awards from NSF (CAREER award, Research Initiation Award, NSF-Lucent Industry Ecology Award, GOAL-I award), SAE (Ralph Teetor award), IEEE (second best paper, WTS), ASME (Kodak Best Technical Paper award), AT&T (Industrial ecology fellow award), Engineering Education Foundation (Research Initiation Award), etc., and other accolades in his career. He is on the Editorial board of ACM Computers in Entertainment Publication and the CAD Journal. He has lectured and given keynote addresses worldwide in countries such as Belgium, England, France, Germany, Holland, Hong Kong, India, Italy, Japan, Mexico, Singapore, Spain, Taiwan, Thailand, etc.

Dr. Gadh has a strong background in creating technology partnerships with industry. His industrial background started prior to his academic career, when he worked as an engineer and a technology lead for two software startup companies over a period of 4 years (Formtek Inc. and Carnegie Group Inc.). Currently, he serves as advisor to a handful of startups and three venture capitalists. In partnership with his students and researchers, he has co-founded two technology startups, the second one being in wireless media.

Laure Vogel is an undergraduate student at the French Institute for Advanced Mechanics in France. She served an internship for five months as a research visiting student at the RFID Lab in UCLA, working on a RFID and its application to supply chain.

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