RELIABILITY TEST OF RFID TECHNOLOGY IN TOOL TRACKING

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ABSTRACT : RFID technology offers the possibility that tools and valuable supplies tagged with RFID devices could be tacked down automatically. Such automated tool tracking has the potential to reduce theft, identify underutilized tools to be relocated, insure that crafts have access to the appropriate tools as needed, and reduce overhead labor cost of managing tools. Although other industries have been busy to enhance their supply chain management using RFID technology, construction professionals may be wondering whether it works reliably in construction jobsites as well. This paper presents a field test conducted to determine the reliability of RFID technology in identifying tools in the field storage box. The test indicated that RFID technology is reliable in inventorying tools in field storage.

Key words : RFID, Tool Management

1. INTRODUCTION

Many construction companies have used barcode based tool tracking systems to expedite the tool issue and receipt process and eliminate manual data entry. Although the barcode based tool tracking systems were a significant improvement over manual tool system data entry, the barcode process is still subject to some error and requires a dedicated room attendant for issue and receipt. Recently, the utilization of Radio Frequency Identification (RFID) technology has been suggested in order to make up for the week points in the current tool tracking systems.

RFID is a generic term that is used to describe a system that transmits the identity of an object or person wirelessly using radio waves. A typical RFID tag consists of a microchip attached to a radio antenna. The chip can store as much as 2 kilobytes of data [1]. For example, information about a product or shipment including date of manufacture, destination, and sell-by date can be written to a tag. In more sophisticated applications, some tags can incorporate sensors, data storage, and even processors that enable them to collect, store, and interpret additional information (e.g. temperature, location, etc.) about the object. The data stored on an RFID tag can be retrieved by the reader that has one or more antennas to emit radio waves and receive signals back from the tag. The reader then passes the information in digital form to a computer system.

The ability of RFID technology to identify multiple tags in a short time is expected to replace barcode systems in many industry applications. Because no line of sight is required between the reader and the tag, unattended reading stations can be set up to identify objects regardless of their orientation to the reader. Simultaneous processing, automatic unattended reading, and the ability to store and process information locally are the main performance characteristics that set RFID apart from bar code.

Manufacturing, logistics, and retail industries already have started utilizing RFID technology to expedite their material handling processes. A white paper produced by the Construction Industry Institute (CII) in 2002 proposed that RFID technology would improve the material handling process by eliminating manual data entry and by facilitating automated solutions [2]. Recent research conducted in conjunction with FIATECH Smart Chips project concluded that RFID technology has the potential to both improve the efficiency and the accuracy of current material tracking processes, and eventually could enable a more complete automation of these processes [3].

The current trend in utilizing RFID technology has inspired some construction companies to challenge a fully automated unmanned tool tracking system. One may speculate though whether the RFID reader would identify tools reliably no matter how many tools are being tracked at once. This paper presents an experiment conducted to answer this question.

2. TOOL MANAGEMENT

The principal control process for tool management on a construction site is the issue and receipt of tools from and back into a central tool storage area. The second important process supporting management of tools and valuable supplies is to conduct periodic inventories of tools and supplies issued in the field, as well as those remaining in the tool room. The objectives of these tool management processes are to: 1) insure that appropriate types and quantities are available when needed by crafts, 2) manage inventories to insure that tools and supplies are used

productively and not idle for unreasonable periods of time, and 3) reduce loss or theft of tools and supplies by assigning worker responsibility to specific items.

Currently, tool management systems rely on manual identification or barcodes to identify tools when they are issued, received, or inventoried at the tool room. Whenever workers need a new tool, they are supposed to go to the tool counter and tell the tool room attendant what they need. The tool room attendant then locates the requested tool, and records the tool ID and employee ID in the tool management book or the computer application such as Tool Management System (TMS). Once this information is registered, the tool is released to the craft.

Tools issued from the tool room usually are stored in field storage boxes that are distributed at convenient locations around the construction site. Field storage boxes give crews easy and timely access to the tools they need without having to go back and forth to a tool room each time a tool is needed. Typically, each field storage box is assigned to a specific crew. In theory, tools kept in a given storage box are the responsibility of the leader of the crew using the storage box, and the crew leader controls access to the storage box. In practice, access to storage boxes is not controlled during work hours, because crew leaders want workers to have timely access to the tools they need and do not stop working to receive tools.

During the course of a project, inventories are often taken to account for both those tools stored in the field storage boxes and those remaining in the tool room. These inventories are normally be made in order to insure sufficient tools are available to begin new phases of a project or to account for specific tools needed for completion of particular phases. Occasionally, inventories are prompted by recognition of shortages of particular tools, which ends up discouraging loss or theft of valuable tools. Inventory check also helps to identify unused tools and get them sent to other area or projects.

These inventories are labor intensive, time consuming, and error prone. Typically, workers will take paper inventory lists into the field and check off those tools they find. An accurate inventory of specific tools requires that the worker clearly identify each tool he or she finds. Identification is based on reading an ID number marked or etched onto the tool. Where barcodes are used and in good condition, the specific ID can be positively and accurately recorded with a handheld reader. This process is also subject to error, since a tool must be located (often in a field storage box with many other tools) before it can be recorded, there is a good chance that tools will be missed. In addition, those tools that are found may be easily misidentified or incorrectly recorded, even in barcode systems where the barcode is subject to marking or damage in the course of construction work.

RFID technology opens the possibility that tools and valuable supplies tagged with RFID devices could be issued and received from storage without intervention or help from a tool storage attendant. RFID tagged tools issued from central storage and kept in distributed field storage boxes could be automatically inventoried as required.

For automated tool issue and receipt, workers with RF or 'smart card' identification would be able to enter a secure, unmanned tool storage area through a portal system designed to read the worker ID and permit access to pre-authorized workers. After the worker selects the necessary tool(s), he would carry the tools through the portal system exit, and the system would automatically record his exit and the ID(s) of the tools he is carrying. The transaction is automatically recorded in the tool management system. The same process would be done in reverse as tools are returned to the central storage area.

For automated inventory of tools kept in field storage boxes, an RFID reader in the box would be prompted to read all of the tags inside the box. The list of tool IDs collected by the reader is then wirelessly communicated to the tool management system. The tool management system could then be inquired as to the tools that were not being used (i.e. rarely or never removed from the boxes) or tools that were not in the boxes when they should have been (e.g. at the end of a crew's shift).

These automated systems could reduce overhead labor and human error in managing tools and supplies. Craft productivity is increased by insuring that the appropriate tool is available and idle tools are identified and removed from the location. Most significantly, real-time inventory of tools on site can help better manage tool inventory by 1) reducing opportunities for theft, 2) identifying tools that are not used so they can be retrieved and used elsewhere, and 3) insuring that crafts have access to the appropriate tools called for in their work plans.

3. FIELD TEST DESIGN

RF signals bounce off metal and are absorbed by water at ultra-high frequencies, which makes tracking metal products or those with high water content problematic [4]. Construction professionals who are interested in utilizing RFID technology for tool management may be wondering whether RFID tags especially attached on metal tools would be well detected. Another concern is the location of tags on the tool. Some researchers doubt that RFID tags may not be well detected if they are attached on the deep corner of the tool and stored in the field storage box made of metal. Can tools with RFID tags attached be identified reliably even in the field storage box made of metal? In order to answer this question we conducted a field test.

The field test was designed to determine how reliably we can identify tools in a metal storage box using RFID technology. We speculated that the RFID tags may not be well detected if various tools, especially made of metal or containing liquid material, are piled up in the metal storage box. To verify our speculation, an experiment similar to a hide and seek game was designed. We located a metal tool storage box (Figure 1) and installed an RFID reader in the box. The eLink Receiver (Figure 2) of eXI Wireless in Richmond, British Columbia was employed as reader. Seven various tools were then selected and RFID tags (Figure 3) were attached to them as shown in Figure 4. We used active tags provided by eXI Wireless. The tag size is 4.8cm by 2.4cm by 0.9cm and it weighs 13g. Tags were set to transmit the RF signal of 433.92 MHz every minute.

Figure 1. Tool Storage Box

Figure 2. RFID Receiver

Figure 3. Active RFID Tag

Figure 4. RFID Tag attached on a tool

Three experiment participants were recruited and instructed to pile up these seven tools in the storage box with other tools that no RFID tags were attached to. While piling up the tools, they were specifically instructed to cover up the RFID tags with any tools that would hinder the RF signal from traveling to the reader as shown in Figure 5.

Figure 5. Tools piled up in the storage box

Once experiment participants finished piling up the tools in the storage box, we ran the RFID reader and counted the number of tags identified within two minutes. Tools then were rearranged again for another round. This experiment was conducted 30 times.

4. FIELD TEST RESULT

Out of 30 trials, the RFID reader successfully identified all seven tags 26 times within in 2 minutes. For 4 times though, it identified only six tags. Overall, the RFID reader missed 4 tools out of 210 tools engaged in the test. Interestingly, the tool shown in Figure 6 kept missing for three times.

Figure 6. Tool missed for 3 times

We noticed that this tool was made of metal and the RFID tag was attached in the deep corner of the tool as shown in Figure 6. We speculated that the material of the tool and the tag position might contribute to hindering the RF signal from getting detected by the reader successfully.

This test was implemented with the storage box lid opened. However, when the reader tried to identify tags one more time with the lid closed, all seven tools were identified successfully within 2 minutes. We assumed that the RF signal was less dispersed and kept bouncing back and forth inside the storage box when the lid was closed, which ended up providing the RFID reader with higher chances to detect the RF signal. The result of the field test is presented in the Table 1.

Table 1. Tool identification result

Tasks	Lid Opened	Lid Closed
Number of successful identification of all tools within 2 minutes	26	30
Total number of tools (out of 210 tools) successfully identified in the gangbox	206	210

6. CONCLUSION

Many construction professionals, knowledgeable in tool management issues, expect that RFID technology might have the potential to dramatically improve tool management processes using automated systems that provide accurate and timely information about the status of tools on a construction site. These improved processes would also likely lead to significant savings in tool management. However, one may concern about the reliability of RFID technology in terms of identifying tools especially on construction sites.

The purpose of the field test presented in this paper was to determine whether RFID technology would reliably track tools when RFID tags were attached to them. Specifically, we sought to determine the reliability of RFID technology in identifying tools in a field storage box.

The prototype RFID system, fabricated for the test, worked reliably, considering that it was implemented with minimal time and adjustment, and it had never been tested previously. In the field test, for 26 times out of 30 trials, it successfully identified all seven tools in the storage box within two minutes. For the other 4 times, it missed just one tool in each trial. We believe that our test provided empirical evidence to support the technical reliability of RFID technology in tool tracking. It appears that technical issues encountered during the tests (e.g. occasionally missed tags) could be resolved with relatively little additional system development.

However, some technical issues will need to be investigated before this application of RFID technology can be deployed commercially. These include:

1) How can tags are attached to the wide variety of tools used on a typical construction project? Attachment would need to be secure and safe.

2) How long can tags last? Tags must withstand the rough treatment typical of construction tool usage.

3) Additional application would be needed to effectively utilize RFID technology for tool management. For example, the storage box inventory application would require wireless communication between storage boxes and data collection point(s) across a construction site.

The first two issues above could best be resolved by tool manufacturers incorporating RFID technology into tools at the factory. Some manufacturers are beginning to incorporate RFID technology in limited applications. Necessary supporting systems for wireless storage box inventory are becoming more common as more and more projects implement wireless LAN to support technical and management communications and data sharing on site. The third issue will require a widespread industry consensus on specific standards.

It should be noted that while the test reported here was encouraging with respect to the technical potential of RFID in tool management, we did not attempt to quantify economic cost or benefit of a commercial application. The economic feasibility of such an application would depend on a number of factors such as: 1) specific beneficial impact to a particular organization 2) cost of the technology, and 3) cost of implementation (e.g. training, system integration, etc.).

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REFERENCES

[1] RFID Journal, "What is RFID?", Web Document (http://www.rfidjournal.com/article/articleview/1339/1/129/), 2005.

[2] CII, *RFID in the Construction Industry*, 2002.

[3] Song, J. et al., "Using RFID to Track Fabricated Pipe - Field Trials and Potential Benefit Assessment", *FIATECH Smart Chips Project Report*, 2004.

[4] RFID Journal, “Frequently Asked Questions”, Web Document (http://www.rfidjournal.com/faq/18), 2005.