RFID Object Tracking in Civil Engineering: An Academic Literature Review

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Abstract

RFID (Radio Frequency Identification) is a general term for technologies that use radio waves to automatically identify objects or people. Several methods have been proposed for RFID object tracking. This study creates a road map and summarizes the information obtained from RFID object tracking in civil engineering.

This paper considers RFID technology performance in tracking various objects and constructs tracking knowledge based on literature examination that deals with this issue. The literature study time range was limited to 11 years (2000-2010). Various application examples using different RFID technology methods in civil engineering are compared.

Keywords: RFID, GPS, Tracking, Civil Engineering.

Introduction

Radio Frequency Identification (RFID) systems are one of the most anticipated technologies that may transform processes across the engineering and construction industries. Although the RFID potential is real, it does have limitations like any other technology. Without understanding and working with the limitations of RFID, this technology may disappoint many before its true and significant capabilities are realized (Goodrum et al. 2006).

In general, civil engineering is, regardless of the nation it belongs to, advanced or otherwise, of local character bounded to the narrower view of its marketplace, supply chain and technology advancement (Yagi et al. 2005). RFID technology in the manufacturing, retailing, transportation and logistics industries relies on its capability to identify tagged objects without requiring physical contact, line-of-sight, or clean environments. Civil engineering has also explored its potential applications and several pilot tests demonstrated that this technology could be useful in receiving uniquely identified materials at job site laydown yards. The use of RFID technology in construction work processes was also considered for tracking precast concrete components and storing the information associated with them through a supply chain (Song et al. 2007).

This paper presents RFID traceability in civil engineering results derived from an academic literature review (2000-2010). This work shows this technology's use in civil engineering and compares different RFID technology systems.

Recently, more new technologies have been used to simplify, speed, improve quality work and eliminate negative factors in civil engineering. The role of RFID technology should be defined in this industry. This article deals with creating a road map for using RFID technology in tracking objects in civil engineering. It is appropriate to create this

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map because of influencing factors that may affect RFID technology use and subsequent research results in civil engineering

Research methodology

This paper investigates the RFID position paradigm in civil engineering through a literature review. The studied literature was limited to 11 years ranging from 2000 to 2010, due mainly to growing interest and timeliness of this topic.

This research procedure was inspired by an article written by Ngai et al. (2008), who are also trying to show this technology. That article dealt with RFID technology in general. This study, however, focuses on the RFID tracking technology used in civil engineering. This research is based on the examination of various papers, all of which are directly related to RFID technology and its application in construction for monitoring purposes. These papers are the resources most commonly used to acquire information and release new findings. The literature search was conducted using the Science Direct electronic database.

The literature search for suitable documents was based on the awards and combination of chosen terms – RFID, radio frequency identification, tracking, monitoring, location, civil engineering, and construction. The observed results from the search convince that RFID positioning technology is reported only in rare cases. Fewer of papers were related to the construction industry. Therefore, it is necessary to acquaint more people with this technology and try to establish links between researchers and practitioners. This research investigates RFID technology use in civil engineering in terms of cost, accuracy, tracking objects, RFID systems and the environment in which the technology is used.

Localization technologies

Many different technologies and methods can be used to monitor objects and people. One of the main characteristics among these technologies is indoor or outdoor localization. Thus, this study divides the localization technologies into indoor and outdoor uses, explained as follows.

Indoor technologies

Infrared system (IrDA)

This method uses diffuse infrared technology to realize indoor location positioning. The line-of-sight requirement and short-range signal transmission are two major limitations that deteriorate location effectiveness in practice for indoor location sensing (Ni et al. 2004).

IrDA (infrared systems) accuracy is about 5–10 m. Although the system may result in cheap, compact, and low power consumption, there are some shortcomings. For example, the system is sensitive to sunlight, must be in the line-of-sight and the installation and maintenance costs are high at large scale (Tesoriero et al. 2010).

Wi-Fi (802.11.) – based system

The Wi-Fi based system locates and tracks users using a standard 802.11 network adapter. This method measures signal strengths at multiple base stations positioned to provide overlapping coverage in a given area. The system combines empirical measurements and signal propagation modeling in order to determine user location thereby enabling location-aware services and applications (Ni et al. 2004).

Positioning accuracy using WI-FI is about 3–5 m. One of the advantages of this system is that it uses existing IEEE 802.11 infrastructure that results in reduced deployment cost.

However, in a multi-floor, dense indoor environment the system performance decreases because of signal reflections and dynamic network conditions may affect signal readings (Tesoriero et al. 2010).

Bluetooth (IEEE 802.15)

Bluetooth accuracy is about 2–15 m depending on the deployment method and the technique (inquire or communication) employed. One of the most valuable advantages of Bluetooth is the variable read-range. This technology is capable of 1/10/50 m read range, being suitable for proximity techniques to locate objects. The cost of implementation on a small scale is relatively cheap (Tesoriero et al. 2010).

Ultrasonic

The Cricket Location Support System and Active Bat location system are two primary examples that use ultrasonic technology. Normally, these systems use an ultrasound time-of-flight measurement technique to provide location information. Most of them share a significant advantage, which is the overall accuracy (Ni et al. 2004).

RFID

RFID is a general term used to describe a system that transmits the identity (in the form of a unique serial number) of an object wirelessly using radio waves. This is sometimes referred to as contact-less technology. A typical RFID system is made up of three components: tags, readers and the host computer system.

Outdoor technologies

Global Positioning System

The Global Positioning System (GPS) is a satellite-based navigation system that requires 24 orbiting satellites to function. Each of which makes two circuits around the Earth every 24 hours. These satellites transmit three bits of information - the satellites' number, position in space and time the information is sent. These signals are picked up by the GPS receiver, which uses this information to calculate the distance between it and the GPS satellites.

Generally GPS does not work indoors and so while it is the best technology for outdoor tracking. It may be supplemented or replaced by RFID if accurate indoor tracking is required.

RFID Technology

RFID can be viewed as a sister technology to bar code labels which use radio waves instead of light waves to read a tag. A RFID system is comprised of tags (also known as transponders) and a reader that, depending on the configuration, includes an antenna and scanner. The tag contains a small integrated circuit chip and an antenna that is encapsulated inside a protective shell. The reader contains, at a minimum, an antenna and scanner and is used to communicate with the tag. Tags can be categorized as read only or have both read and write capabilities (Jeselskis et al. 2003).
RFID technology can be classified as either a passive or active system.

Application

RFID is an emerging technology that has been successfully used primarily in the areas of logistics, manufacturing, supply chain management, but its range of application extends far beyond these areas. Based on the information, it is presented in several areas of application of this technology, summarized below:

- Automotive
- Animal detection
- Building management
- Healthcare Pharmacy
- Fabric and clothing
- Airlines
- Logistic
- Raw Material Industry
- Civil Engineering
- Manufacturing
- Personal and Asset security
- Museums
- Library
- Food safety warranties

Costs

The cost of RFID technology is based mainly on the type and quantity of selected transponders and transceivers. A major constraint on the widespread use of RFID technologies is the cost of the tags. The most widely used tags are Electronic Article Surveillance (EAS, class 0) tags, which cost between 1 and 6 US cents. Each passive tag (class 1) has some data storage cost, between 5 and 10 US cents each in large quantities (several million). High value items, cartons and pallets are being tagged (class 2–4) and here costs may be up to US$100 per tag. At current prices it is not economical to incorporate tags into every retail item. Prices will fall as manufacturing technologies improve and there is a prediction that 1 trillion tags will be used annually by in 2015. In the last 50 years only one billion RFID passive tags (other than EAS tags) and 500 million active tags have been sold. While RFID technology use is predicted to grow significantly, it may take several years to get to the point where the majority of retail items are tagged (Roberts 2006).

Benefits

Rather than using light to collect or read a number from a bar code, radio waves are used to read a number from the RFID tag. RFID therefore does not need line-of-sight to operate. Using radio means that the tag no longer has to be visible on the object to which it is attached. The tag can be hidden inside the item or box that is to be identified.

Another feature of RFID is the ability to read many tags at once. Data can also be written to the tag, which is a feature not possible with barcode systems. This latter feature has tremendous implications for IT systems and a potential benefit in increased RFID use.

Each technology has several advantages and disadvantages including RFID technology. The advantages of this technology are summarized as follows:

- Non-contact technology
- Tags can be read through a variety of visually and environmentally challenging conditions
- Improved productivity and cost avoidance
- Reduced rework
- Improved utilization of resource
- Tags coupled with sensors can provide important information on the state of the goods

Tracking Methods

This section presents selected tracking methods used in civil engineering to monitor objects. Here are three methods: 1) passive RFID, 2) active RFID and, 3) combination of RFID and GPS. The selection of these methods depends on several factors: indoor or outdoor monitoring, location accuracy, environmental factors, cost and expected results from the method.

In the papers published in the field of civil engineering RFID technology was used for tracking precast concrete components, pipe spools, hand tools (hammer drills, band saws and reciprocating saws), steel components and other items.

Passive RFID Systems

The passive tag is an RFID tag that does not contain a battery. The power is supplied by the reader. When radio waves from the reader are encountered by a passive RFID tag, the coiled antenna within the tag forms a magnetic field. The tag draws power from it, energizing the circuits in the tag. The tag then sends the information encoded in the tag's memory. Passive tags have an unlimited life, are lighter, smaller and cheaper. The trade-off is limited data storage capability, a shorter read range and they require a higher-power reader (Roberts 2006).

Automated materials tracking at civil engineering projects has the potential to both improve project performance and enable effortless derivation of project performance indicators.

Tesoriero et al. (2010) dealt with a cheap and reliable RFID technology to develop a passive RFID-based indoor location system that is able to accurately locate autonomous entities, such as robots and people, within a defined surface. The system architecture is shown in Figure 1. That system has been applied to solve the robot tracking problem. They presented that sensing surfaces are physical surfaces where autonomous entities can be located (i.e. floors, walls and even tables) within a space. A sensing surface is divided into a grid of small squared surfaces or location units.

Sensing surfaces are one of the key elements of the system. They are composed of a grid of RFID passive tags that are hidden below other surfaces. For example, the passive tags can be placed under a fitted carpet or under wallpapers. RFID reader was placed on the robot moving across defined areas.

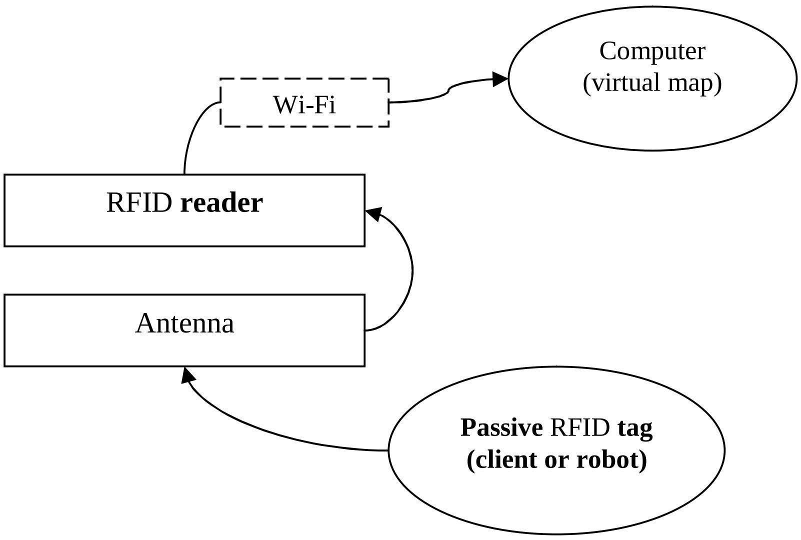

Figure 1. Passive RFID Tracking System

In another case, this technology was used for monitoring the location of materials and components on construction job sites (Song et al. 2006). In both cases, this technology is used only for a short range and the errors in location at longer distances are greater. This is the disadvantage of this method. In civil engineering most situations require a method with greater accuracy over longer range.

Active RFID Systems

An RFID tag is an active tag when it is equipped with a battery that can be used as a partial or complete source of power for the tag's circuitry and antenna. Some active tags contain replaceable batteries for years of use, others are sealed units. Active tags are larger and more expensive than passive tags. Battery use places a limit on the life of the device, although with current battery technology this may be as long as 10 years (Roberts 2006).

The active RFID technology in civil engineering is used to improve the availability of tools and materials. This technology saves time and money.

Active RFID technology is for greater read ranges than passive RFID units. Goodrum et al. (2006) presented results from a research effort that examined a spectrum of RFID systems in the development of tool tracking prototypes for the construction industry. They used an active RFID system for tracking small (hand) tools, which included a corded hammer drill, a portable band saw and a reciprocating saw. This method tested the tags' durability to hot and cold temperatures, outdoor or indoor places, vibration and magnetic interference. The active RFID localization architecture is displayed in Figure 2.

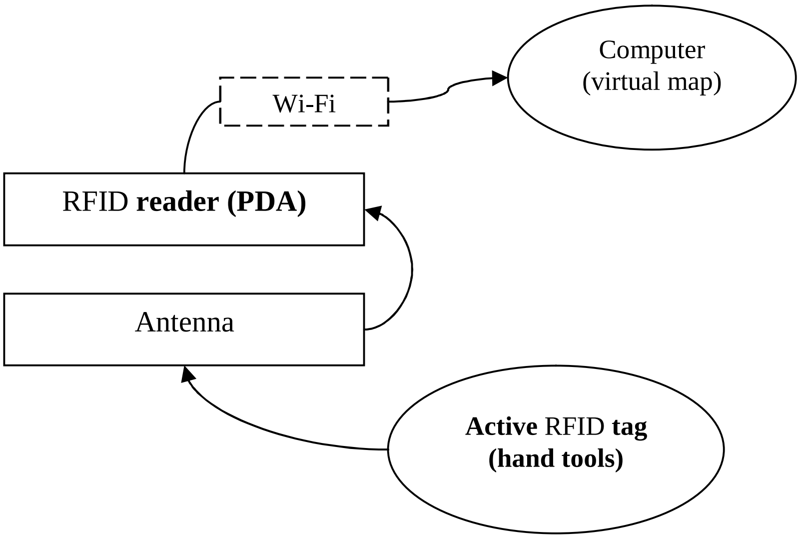

Figure 2. Active RFID Tracking System

Ni et al. (2004) described another indoor tracking method using active RFID technology. The LANDMARC, a location sensing prototype system that uses RFID technology for locating objects inside buildings is discussed in this section. The major advantage using LANDMARC is that it improves the overall accuracy in locating objects utilizing the reference tag concept. Based on their experimental analysis, the active RFID can be regarded as a viable, cost-effective candidate for indoor location sensing.

Combination of RFID and GPS

The combinational use of RFID and GPS in location sensing was mentioned by Ergen et al. (2006) and Torrent and Caldas (2009). The former paper used this method for locating precast concrete components with minimal worker input in the storage yard of a manufacturing plant. Torrent and Caldas (2009) used this concept to quickly locate steel components on large industrial projects. Figure 3 shows the RFID with GPS concept in tracking objects.

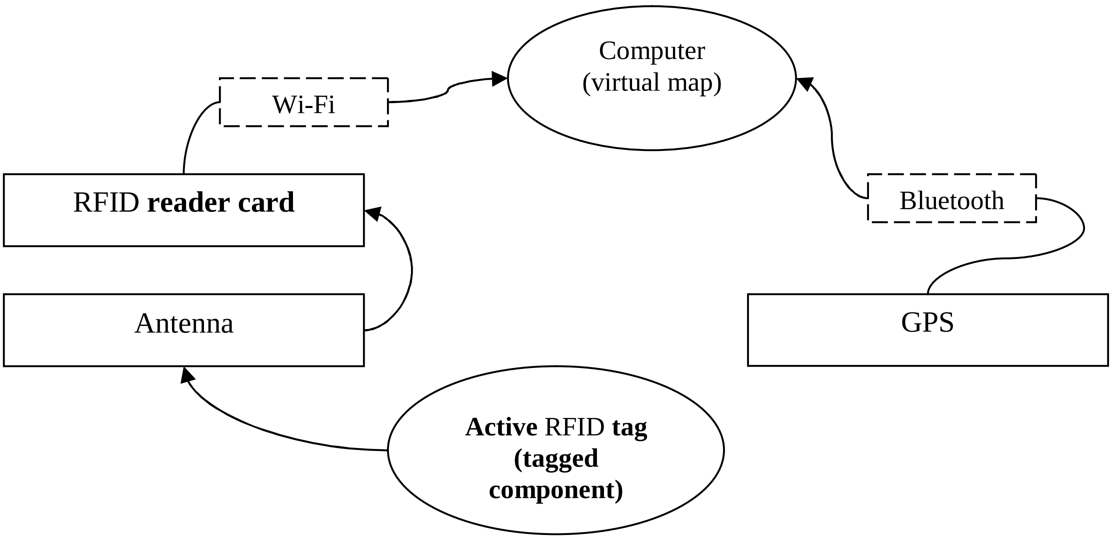

Figure 3. Combination Tracking System

Results from the reviewed papers suggest that engineered components can be automatically identified and located using this method on large industrial projects. The localization approach developed in these two studies can significantly improve manual tracking practices by enabling effortless, quick and reliable localization. This method is particularly beneficial for large industrial projects that need to keep an updated inventory of thousands of items over long periods of time.

Summary

Various methods are useful for tracking different objects. Table 1 summarizes three methods for tracking objects in civil engineering chosen for this paper. It cannot be said which method is the best because success depends on many factors and the method used.

Passive RFID technology should be the cheapest of these methods. This is because of the price of passive tags which is lower than that for active tags. Passive RFID technology is appropriate for indoor applications, while active RFID technology and RFID+GPS technology are appropriate for outdoor applications. The accuracy of these methods is influenced by factors such as the environment, frequency and type of technology. Of the papers studied, a combination of RFID and GPS technology with high accuracy is appropriate for use in civil engineering. In summary, passive RFID technology is useful for tracking tools only over a short range. Active RFID technology and RFID+GPS is useful for tracking materials and components over a long range on civil engineering job sites.

Table 1. Summary of Methods

Method	Passive RFID	Active RFID	RFID + GPS
Tracking object	Components, materials, robot	Hand tools	Precast concrete components
Equipments	Passive tag, PDA with a compact flash passive RFID reader	Active tag, PDA with a PCMCIA card slot	Active tags, antenna, RFID reader, GPS reader and antenna
Localization	Indoor	Outdoor	Outdoor
Range	3-8 cm	10-15 m	15 m (up 100 m)
Using in civil engineering	Tracking objects (tools, materials, components) only for short range	Tracking objects (tools, materials, components) only for longer range	Tracking objects (all components) for long range

Conclusions

This paper reviewed the RFID tracking technologies used in the construction industry. Based on the information on the materials studied, this technology can be used as a tracking system for both indoor and outdoor environments. The experimental results show that this technology still has shortcomings. To improve tracking accuracy and applicability in the construction industry, a combination of RFID with another technology (e.g. GPS) can be considered.

Using RFID tracking technology in civil engineering has many advantages such as: real time monitoring and access to detailed information; reducing manpower and manual data recording and reducing human error in handling repairable parts.

Applying RFID tracking technology to civil engineering is still a new area. In the 2000-2010 timeframe, only few papers described this issue. This article may help develop and increase interest in applying this technology to the construction industry in the future.

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