Integration of radio frequency identification and building information modelling for decentralised information management

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Abstract

Since 1979, Radio Frequency Identification (RFID) has been used in tracking components on an item level (Sanjiv, 2006). The Facility Management (FM) industry has been slow to adopt RFID technology. Following a comprehensive literature review we discovered RFID to have great potential in the Architecture, Engineering and Construction (AEC) and FM sectors for Decentralised Information Management (DIM). In this paper we propose to use DIM to support the distribution of technical specifications and progress monitoring of maintenance activities such as ambient interaction of maintenance personnel with building components. The Integration of RFID and DIM provides new opportunities for facility maintenance and management. The concept of DIM is to store specific item level information on an RFID device to be constantly available to FM staff in advance of, and during, necessary equipment maintenance, relevant to the RFID device. This leads to a much more advanced level of information management for building inventory elements and components. It also provides useful information concerning inventory locations within a building. From a business point view, data can be easily managed in a cost effective and efficient manner, with particular emphasis on “outsourced” inspection and maintenance activities.

Keywords: CAD, BIM, RFID, decentralised information management, facility management

1 Introduction

Integrating RFID technology and the Building Information Model (BIM) into a single IT solution will vastly improve the ability to monitor building performance and capture information about building facilities for building maintenance activities. As a result, the building owner and facility managers can visualise a facility location in 2D/3D floor plans and analyse their maintenance status. The facility manager can then assign maintenance tasks to onsite work crews who carry out maintenance activities. Few studies can be found in facility and equipment management. Legner and Thiesse applied RFID technology to maintenance activities in Frankfurt Airport. They integrated RFID and mobile applications with its asset management systems. Ergen et al. overcame difficulties encountered in traditional facility maintenance using RFID.

This paper proposes a new approach which distinguishes different RFID technologies by storing technical information and maintenance data onto active RFID tags and uses unique tag IDs, stored on passive tags, to retrieve relevant information from a central database. This paper also proposes a new methodology for information management by jointly using RFID and the BIM. This paper first introduces RFID technology and BIM. It then discusses the integration of RFID data with BIM,
allowing synchronised and homogeneous information management. DIM’s support of “outsourced” inspection, maintenance scenarios and contributions to improving new management scenarios in building operations is also discussed.

2 RFID and BIM to support Facility Maintenance

The aim of this research is to improve facility maintenance strategies by providing a better orientation within a building environment. Therefore, the use of a mobile RFID reader for maintenance support is proposed in this paper.

The proposed approach envisages that work crew will use a mobile device that will include building and routing information. This information and data is imported from the BIM on to mobile devices, such as a PDA, as proposed by Rueppel (Rueppel et al., 2008).

It is agreed that RFID technology can provide an opportunity to meet the current needs of unique identification of facility components, and provide links to accurately store the maintenance history of building components, and access information related to components within a facility in real-time (Ergen et al., 2007).

RFID is a robust technology with great potential in a wide variety of applications. Its most common use can be seen in the automatic data collection and identification domain. Specific data can be written to and read from small electronic devices called RFID transponders through an RFID interrogator using radio waves at a specific radio frequency. The tags are attached to physical objects which are required to be identified or tracked (Cong et al., 2009).

BIM is the process of generating and managing building data (e.g. building structure, materials) during the life cycle of a building (Lee et al., 2006). Typically it uses three-dimensional, dynamic building modelling software to increase productivity in building design and construction. It is a mature digital framework that models building components and their relationships.

RFID-Based Building Maintenance System

Within the facilities management sector, we envisage to develop algorithms and methods for DIM using RFID technology, such as;

- Development of a web-based FM system for centralised database management.
- Integrating RFID technology with mobile devices to increase the efficiency of facilities inspection and maintenance data collection.
- Provide wireless communication between management offices and facility sites.

For an integration scenario of RFID with BIM, there are two main users: facility managers and work crews, each playing a different role in order to achieve automated facility/inventory management. A facility manager usually uses a centralized database, distributes maintenance and inspection tasks, and assigns these tasks to work crews for renovation and repair. The work crews receive their tasks’ details through mobile devices. These mobile devices are equipped with mobile RFID readers to locate a specific building component requiring maintenance or repair (Figure 1). Different building components have their own unique tags and IDs.
Decentralised Information Management (DIM)

In large facility management projects, there are numerous components, suppliers, and inventory items that require monitoring, maintenance, repair and/or replacement (Cong et al., 2009). The main focus is to use a DIM approach by placing RFID tags on inventory items and building components. With this approach, technical specifications and progress monitoring of maintenance activities are stored into a remote database which can retrieve IDs stored on RFID tags. In this way, building element and component information is distributed and decentralized throughout a building at the individual level of elements. Using the DIM methodology presents advantages for data storage, easy data accessibility and retrieval of technical documentation and performance data that allow work crews to make timely decisions with efficient recovery and response mechanisms.

3.1 Information Management

As with the DIM approach, building component information needs to be distributed onto RFID tags. Considering the memory limitations of a tag (especially in the case of passive RFID tags), we need to associate information with a unique tag ID (UID). This information is related to individual building components and elements, and need to be managed by a central database. Important data associated with one component is proposed as follows;

- Inventory Name: The ID name of an item to which a tag is attached.
- Manufacturing ID: Manufacturer details of the relevant item.
- Specification/Type ID: The specification of an item including model/serial number.
- Installation Date: Timestamp indicating when item was installed.
- Sensor Reading (optional): RFID tags can be combined with sensor technologies which have the ability to measure physical and chemical properties of building equipment and surrounding environmental parameters (e.g. temperature, humidity, and CO₂ level).
- Building Name ID: The ID name of the building to which an item is located.
- Actor/Person ID: Details of the person in charge for item maintenance activities.

Using IDs is more efficient and secure. An application of using IDs is to use the IFC root ID and then decode this into a BIM.

This tag information (excluding sensor readings) will consume approximately 470 bytes of tag memory space. Active tags, such as I-Q 32, have a total memory capacity of 32000 bytes. Active tags have the capability to store sensed data locally.
Figure 2 illustrates an onsite crew member checking the maintenance status of an “Intelligent Radiator”. The “Intelligent Radiator” has many features such as integrated fan units and additional thermostats which require additional attention of work crews. Crews can use a PDA with a built-in RFID reader to collect technical information from the active tag that is attached to the radiator and hence, carry out maintenance activities on the relevant radiator.

After maintenance activities have been carried out, the updated decentralised information (technical information and maintenance data) remain on the active tag. Using wireless technology, the central database is updated with maintenance history and future planning information relevant to the specific tag ID.

### 3.2 Information Objects

A facility manager assigns a maintenance task to the on-site work crew. The central database is used to retrieve tag IDs for relevant building components associated with the maintenance task. For example a task ID (TA00002001) has been assigned to work crew associated with a specific RFID ID (T01110001231) and task description. The work crew member will immediately be able to review all relevant information regarding the inventory item, such as inventory name (radiator), manufacturer (Dahua Co., Ltd.), specification (M302-231), user name (Mr. Zixiang Cong), location (ERI Building). On closer inspection of the RFID_Information table, RFID_ID is the primary key and Building_Name and User_Name are foreign keys, which link to Building_Information and User table, to detail the building address (Lee Road, Cork, Ireland), floor (Lower Ground Floor), room (LG04) etc, and also detail the user name (Mr. Zxiang Cong) with office location (CEE building) and contact details. The information provided can be further distilled down to a level incorporating the BIM where items are described as being part of, for example, a building’s heating, HVAC, or solar systems. The simplified database schema used is represented below using UML class diagrams (see Figure 3).
DIM can improve the efficiency of outsourced inspection and maintenance scenarios. Our research investigates the optional support of active RFID sensors and how to make RFID technology work more effectively for different stakeholders. In addition to this, our research will analyse the impact of having large quantities of sensors within a defined building space (zone). Finally, we work on a methodology that assists in determining the optimal radio wave propagation.

4 Prototypical Implementations

Students and researchers of the Chair of Information Technology in Architecture, Engineering, and Construction at University College Cork (Ireland) have successfully developed solutions to test the different types of RFID tags for FM activities with emphasis on inspection and renovation.

Table 1 shows the RFID deployment for FM activities using active and passive UHF and HF tags. For renovation and repair scenarios, active UHF-tags have been used, specifically for the case of repairing and maintaining HVAC equipment. For inventory management purposes, passive UHF-tags have been deployed.

Table 1. Deployment of RFID tags.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Activity</th>
<th>IT-Equipment</th>
<th>Additional Equipment Required</th>
</tr>
</thead>
</table>
| 1 | Work crew repairs HVAC equipment (Renovation & Repair task):  
• Place active UHF-tags on HVAC system.  
• Repair HVAC equipment where necessary.  
• Retrieve technical information relevant to HVAC equipment. | Active UHF-tags with sensors (Identec Solution).  
Panasonic Laptop.  
I-card 3 reader (Identec Solution).  
PDA with RFID-reader | Wi-Fi Environment.  
Window-CE Development Tools.  
mEnable Software |
| 2 | Office Staff track inventory items and building components in buildings. (Inventory Management task):  
• Place passive UHF-tags on inventory items (e.g. PC, Laptop and Chair etc.).  
• Staff use RFID cards for access control. | Passive UHF-tags.  
Panasonic Laptop.  
RFID reader antennas.  
Gate Reader & Desktop, PC | Java Developer  
Oracle Database |
For renovation and repair purposes, we have deployed RFID tags on building HVAC system components such as radiators, fans and pumps. RFID hardware and associated software were utilized and connected to a database.

When work crew place active UHF tags on a HVAC system, they can retrieve technical data relevant to the sensed equipment and make effective decisions to carry out a maintenance task. The location of the tag is documented in the relevant floor plan of a BIM through IFC root or building ID and can be displayed on mobile devices. This is a more effective method to locate building components by having “decentralised” building information available for maintenance crews (see Figure 4).

For inventory management purposes, our research focused on tracking inventory items with the aim of reducing equipment stock, reducing FM staff activities and resultant costs (staff hours). The tags used to implement this scenario were passive UHF tags (Tag-it UHF tags, manufactured by Texas Instruments).

<table>
<thead>
<tr>
<th>Tag ID</th>
<th>Floor Plan</th>
<th>RFID Deployment in Building</th>
<th>Major activities</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>active UHF-Tags with sensors</td>
<td>Renovation &amp; Repair</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>passive UHF-Tags</td>
<td>Inventory Management</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Characteristics of Tags and Locations

Decentralised information was loaded onto active tags using a mobile reader operated by site staff and relevant information was retrieved from a central database by using the unique tag ID from passive tags.

Figure 5 describes the field test performed in UCC’s Department of Civil and Environmental Engineering building. Selected components of the HVAC-system, the lighting system and control components of the Building Management System (BMS) were equipped with RFID tags. Within a fixed area, the approximate location of the item is calculated using a digital floor plan. Submission of data through a specific sequence of tags provides information on the movement of staff. Maintenance activities can be monitored as they occur. For example, by detecting RFID tags in read-range zones, we can determine the approximate position of maintenance crew. From Figure 5, tags 1, 2 and 3 have been detected by a mobile RFID reader. According to the location of these tags, we can estimate the approximate position of maintenance crews. This functionality enables us to deliver technical documentation such as performance history data in a context sensitive way to maintenance staff.
Conclusion and Future work

This paper has illustrated the abilities, use, and possible integration methodologies of RFID with the BIM for decentralised information management of building facilities. Basic scenarios were developed and the DIM approach was followed for carrying out different maintenance activities. Based on our prototypical implementations we performed our tests in two rooms in the Civil and Environmental Engineering building, UCC. For future work it is recommended that appropriate methods and techniques be further developed and analysed on a larger scale with emphasis on using UCC MEngSc students as test personnel allowing for tests to support the whole building scenario.

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References

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