RFID, Web-Based, and Artificial Intelligence Integration in Facilities Management

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Abstract –

Radio Frequency Identification (RFID) technology has become one of the most important technologies for improving management efficiency. This study enhances facilities maintenance by integrating RFID, web-based, and artificial intelligence techniques. A data management module is developed first to collect facilities maintenance data. A statistical module is established to graphically display the collected data. A prediction module is developed using fuzzy neural networks to periodically maintain the facilities. These three modules are integrated into a web-based intelligent RFID facilities management system. The applicability of applying RFID technology to facilities maintenance is studied using environmental challenges. This research validates the developed system's performance using a real case. Experimental results show that RFID technology is appropriate for the practical maintenance environment. The proposed RFID system can improve facilities management efficiency, data transfer, data quality, malfunction prevention, service process time and planning.

Keywords –

Facilities Management; Radio Frequency Identification (RFID) Technology; Web-Based System; Artificial Intelligence

1 Introduction

The facility operating condition directly affects occupant satisfaction. However, facilities functions deteriorate with time. A well-tuned maintenance program is required to extend the service life of constructed facilities [1,2]. Facility functions and their equipment depend on continuous maintenance to maintain normal functions. Assigning an ID to each facility and apparatus is the regular way to manage facilities. Bar codes seem to be the most frequently used system for acquiring the information. However, bar codes printed on paper are easily broken. In addition, obstacles between the bar code and laser scanner can interrupt optical communications. These problems limit the efficiency in facilities maintenance [3,4].

Radio Frequency Identification (RFID) technology is characterized by repetitive read/rewrite, non-contact access to multiple tags. This technology has become one of the most important management systems in recent decades [5,6]. Numerous studies can be found in facilities management. Cardellino and Finch [7] surveyed innovations in facilities management and pinpointed that RFID is a promising information technology (IT) in the field. Wing [8] investigated RFID technology applications in construction and facilities management. Legner and Thiesse [9] applied the same technology to maintenance at Frankfurt Airport. They integrated RFID with a mobile application into its asset management systems. Ergen et al. [10] overcame difficulties encountered in facilities maintenance using RFID technology. Limitations in data transfer between maintenance workers were improved by this work. Although previous studies explored the promise of applying RFID technology to facilities maintenance, a comprehensive system integrating the required management technologies has rarely been discussed. How does the RFID technology work with the practical maintenance environment? In addition, tremendous maintenance data are collected and created while implementing maintenance jobs. How are the collected records analyzed through the assistance of RFID technology has rarely been fully addressed [11].

The primary objective of this study is to enhance facilities management efficiency by integrating RFID, web-based, and artificial intelligence. RFID technology is investigated first. Three modules: data management, statistical, and prediction modules are established according to the facilities management needs. To understand the performance in a practical maintenance environment, experiments were conducted with RFID devices using environmental challenges. Finally, the proposed system efficiency is examined using an actual building case. Application results and conclusions are documented in this paper.

2 RFID TECHNOLOGY AND FUZZY NEURAL NETWORKS

2.1 Radio frequency identification technology

RFID technology is a wireless sensor technology first proposed by Stockman in 1948 [12] that fulfills the need to identify useful applications for ‘‘reflected-power communications.’’ One of the first large-scale commercial uses was documented in the 1990s in electronic toll collection on US highways in Texas, Oklahoma, and Georgia [13]. Since then, RFID has been used across multiple industries and continued to advance in functionality and capability. Today RFID is a generic term for technologies that use radio waves to automatically identify people or objects.

A typical RFID system is shown in Figure 1. In the figure, radio signals are emitted by the transceiver through the antenna. A transponder (RF tag) is activated and the data on it are read and written by the requested signals sent from the antenna. The RF tag transfers data according to requests sent from the transceiver. The transceiver is responsible for acquiring the data when the transponder returns signals. The data can consequently be transferred to any computer system for processing [14,15].

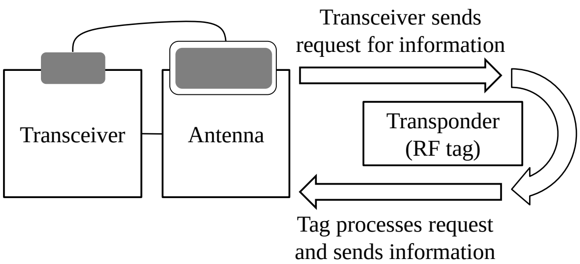

Figure 1. Schema of typical RFID system

2.2 Fuzzy Neural Networks

Fuzzy logic systems (FLSs) simulate the high level human decision making process, which models imprecise modes of reasoning to make rational decisions in an uncertain and imprecise environment. In general, FLSs contains four major components: fuzzifier, inference engine, rule base and defuzzifier [16], as shown in Figure 2. In spite of FLSs advantages over traditional approaches, it is not easy to acquire appropriate and complete fuzzy rules in applications (Maier et al., 2000). Artificial Neural networks are treated as complementary techniques to overcome this difficulty [17].

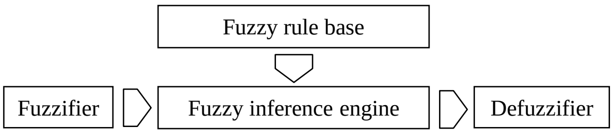

Figure 2. Control blocks of fuzzy logic system

Artificial neural networks are massively parallel distributed processors made up of simple processing units (neurons), which perform computations and store information [18]. Human brain modeling functions provide an alternative approach to conventional methods. A typical multi-layer feed forward network, as shown in Figure 3, consists of three types of layers: input layer, hidden layers and an output layer. Combining fuzzy logic and neural networks into an integrated model is a promising path towards the development of intelligent models capable of capturing qualities characterizing the human brain [19].

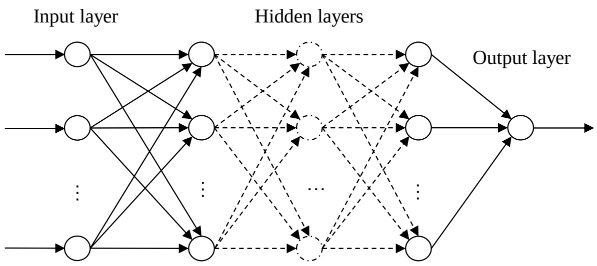

Figure 3. Multi-layer feed forward networks

3 RESEARCH METHODOLOGY

The web-based intelligent RFID facilities maintenance system development could be divided into three steps. First, hardware and software requirements are identified. System architecture is then elaborated. The web-based system uses application software that can be executed through the Internet on web pages. The conceptual architecture of the facilities maintenance system consists of three tiers, namely: storage, application logic and presentation. The storage tier is used for storing system data such as basic facilities information, maintenance history, seller information, etc. The application logic involves system modules and database connections. The presentation tier is used to interact with the application logic layer. Finally, the facilities maintenance system is constructed. The RFID facilities maintenance system includes three modules, i.e. data management module, statistical module and prediction module. The data management module is designed for users to manipulate data stored in the system database. The statistical module is established to help users understand the data distribution and properties. A prediction module is developed to estimate malfunctions before the next maintenance.

4 WEB-BASED RFID FACILITIES MANAGEMENT SYSTEM

4.1 Hardware and Software

Facilities operating conditions refer to functions provided by facilities themselves and their apparatuses. Therefore, facilities maintenance discussed in this study includes facilities and apparatuses. Portable RFID devices (reader/writer) are adapted to conform to the mobile requirement. RFID devices are chosen by considering the weight, transmit power, size, interface, price, and frequency range. Ensyc RFID Block shown in Figure 4 is thus selected. Gen 2 RFID tag displayed in Figure 4 on Ensyc RFID Block is selected with corresponding communication protocol.

To allow multiple users to use the system, a web-based application is planned. ASP.NET is chosen as the development platform. Microsoft ASP.NET can integrate the selected RFID hardware with web application. It supports browsers in executing on various kinds of platforms including the personal computer, cell phone, personal digital assistant (PDA), Palm, etc. Users can manipulate these systems using all kinds of hardware and software platforms.

Figure 4. Selected RFID hardware and Gen 2 RFID tag

4.2 Data Management Module

Maintenance jobs are executed by staff that carry tablet PCs with portable RFID devices. Facilities and equipment are identified by the RFID device attached to the tablet PC. As shown in Figure 5, maintenance data were entered into the system using the web-based RFID system through a wireless Internet connection. The numbers of facilities and equipment may increase day by day. The developed web-based RFID management system connected to a single database through the Internet enables multiple users to implement maintenance work at the same time.

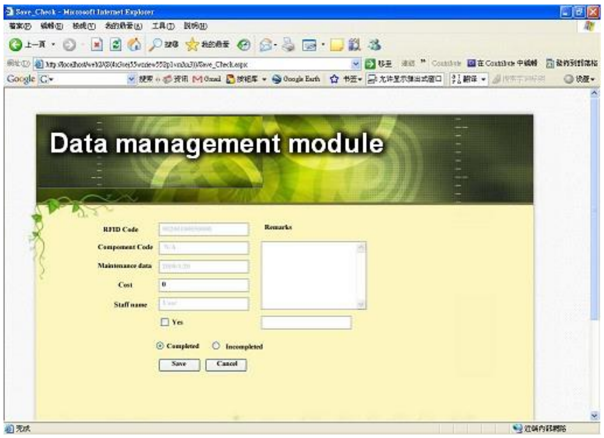

Figure 5. Data management module

4.3 Statistical Module

The proposed system updates the database in real time, which avoids data re-typing, duplicate maintenance and missing maintenance activities. Data stored in the database can be analyzed using statistical graphs from anywhere at any time with up-to-date distributions. A graph summarizing the purchasing cost is shown in Figure 6.

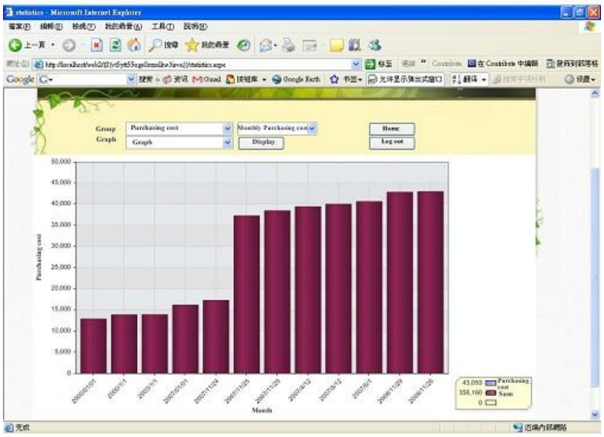

Figure 6. Statistical module

4.4 Prediction Module

In addition to periodically maintaining facilities, the proposed system actively forecasts the possible lifetime of components through maintenance records, as shown in Figure 7. Users can establish a forecast for a specific facility and modify the project with corresponding requirements. Facilities functions can therefore be ensured before the next maintenance.

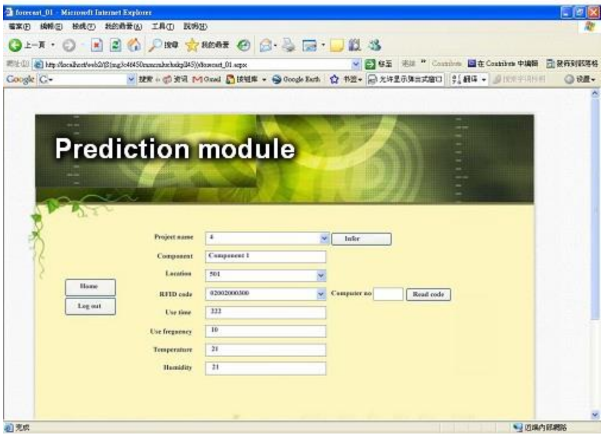

Figure 7. Prediction module

A fuzzy neural network is employed to develop a prediction model to overcome the difficulties faced in component lifetime evaluation. In this module fuzzy logic is used to represent the uncertain information and execute approximate reasoning. An artificial neural network is used for representing fuzzy rules. Complex relationships between inputs (influencing factors) and output (component lifetime) mappings are identified through learning algorithms. The fuzzy neural network architecture used in the prediction module comprised of four layers, as shown in Figure 8. The first layer is an input layer that receives the input data features and distributes them to the next layer (fuzzification layer). The fuzzification layer converts crisp inputs into fuzzy values using membership functions. Neurons at the intermediate layer process the fan-in signals and then perform an activation function. The output layer processes the fan-in signals and produces outputs. Because the prediction module infers a single result (component lifetime), the layer has one neuron.

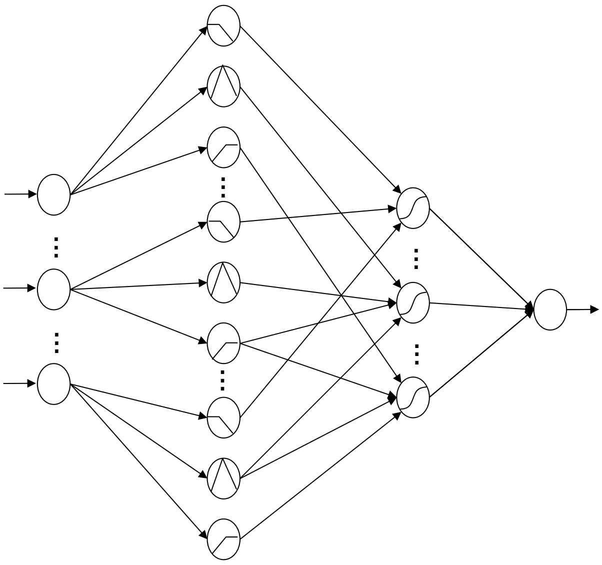

Figure 8. Fuzzy neural network architecture

5 EXPERIMENTS

The effective ranges of RFID devices are influenced by environmental factors [11,20]. To understand the environmental impacts on RFID devices, practical conditions encountered in facilities maintenance were provided. Nearby appliances, metallic equipment and dust conditions were thus tested. The experimental results are depicted in Table 1. The effective range of the selected RFID device is 10 cm.

Table 1 Effective range under normal conditions

Distance (cm)	Successful times	Unsuccessful times
8	5	0
9	5	0
10	5	0
11	0	5
12	0	5

RFID tags could be covered with dust over a short time span. To understand the impact of dust on the effective range, grime conditions were conducted. Table 2 demonstrates the experiment results. Dust and grime have little effect on the effective RFID tag range.

Table 2 Effective ranges under grime conditions

Distance (cm)	Successful times	Unsuccessful times
7	5	0
8	5	0
9	5	0
10	0	5

Facilities and equipment frequently consist of metal parts. Because metal reflects radio signals, it has been considered as the most challenging issue for RFID applications. This experiment examined how metal influences the effective range. Table 3 shows experimental results. Placing the RFID tag directly onto a metal surface is inappropriate.

Table 3 Effective ranges under metal conditions

Distance (cm)	Successful times	Unsuccessful times
0	0	5
1	3	2
2	5	0
3	5	0

Radio communications are influenced by nearby radio signals. Electrical equipment emits electromagnetic waves that affect radio communications. Consequently, the effect of electrical appliances on RFID signals was examined. A Personal Computer, regarded as one of the most popular electrical apparatuses, was used in this experiment. The experimental results summarized in Table 4 show that a minimum distance of 3 cm is required to avoid the impact from the electromagnetic waves emitted by electrical appliances like PCs.

Table 4 Effective ranges nearby running appliance

Distance (cm)	Successful times	Unsuccessful times
0	0	5
1	0	5
2	0	5
3	5	0
4	5	0
5	5	0

6 CASE STUDY

The performance of the developed web-based intelligent RFID maintenance system was examined using a building located in Taipei City, Taiwan. The structure was built in 2007 and designed for material experiments. The facilities defined in the study include the facilities and the related installed equipment. More than 12 kinds of laboratories were used involving valuable experimental instruments such as a universal testing machine, electron microscope, e-beam, spin coater, differential thermal analyzer, rapid thermal annealing machine, etc.

Maintenance jobs were executed by laboratory staff that carry tablet PCs with portable RFID devices. Facilities and equipment were identified by the RFID device attached to the tablet PC. The numbers of facilities and equipment in the study case increased day by day. The developed web-based intelligent RFID system connected to a single database through the Internet enables multiple users to implement maintenance work at the same time. In addition, to periodically maintain facilities, the proposed system actively forecast the possible lifetime of components through maintenance records. Users can establish a forecast for a specific facility and modify the project with corresponding requirements. Facilities functions can therefore be ensured before the next maintenance.

7 CONCLUSIONS

This paper presented a web-based RFID facilities management system. Three modules including data management, statistical, and prediction modules were established. A tablet PC attached with a portable RFID device was used to implement maintenance jobs. RFID performance was examined to verify the proposed system applicability in a practical environment.

This study integrated RFID technology with the Internet and a management information system to develop a web-based intelligent RFID facilities management system. The proposed system could automatically identify facility IDs, thus avoids typos and saves operational time. Unlike conventional barcode systems, data stored in RFID tags can easily be modified. In addition, RFID tags have been proven practical challenging conditions.

The developed web-based system can be implemented from anywhere, at any time under any platform with wire or wireless Internet connections. This characteristic enhances facilities management efficiency. The statistical module provides users with the opportunity to monitor facilities status using graphs. Maintenance data can thus be visualized. The developed prediction module enables users to predict the lifetime of a facility component using a fuzzy neural network. Timely inspection, repair, or replacement according to inference results can reduce malfunctions and unexpected breakdowns.

ACKNOWLEDGEMENTS

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References

[1] Ko, C. H., Pan, N. F., and Chiou, C. C. Web-Based

Radio Frequency Identification Facility Management Systems. *Structure and Infrastructure Engineering*, 9(5):465-480, 2013.

[2] Barco, A. L. Budgeting for facility repair and maintenance. *Journal of Management in Engineering*, 10(4): 28-34, 1994.

[3] Ko, C. H. RFID-based building maintenance system. *Automation in Construction*, 18(3):275-284, 2009.

[4] Djerdjouri, M. Assessing and benchmarking maintenance performance in a manufacturing facility: A data envelopment analysis approach, *INFOR*, 43(2):121-133, 2005.

[5] Ko, C. H. 3D-Web-GIS RFID Location Sensing System for Construction Objects. *The Scientific World Journal*, 2013, Article ID 217972, 8 pages, 2013.

[6] Ngai, E. and Riggins, F. RFID: Technology, applications, and impact on business operations. *International Journal of Production Economics*, 112(2):507-509, 2008.

[7] Cardellino, P. and Finch, E. Mapping IT innovation in Facilities Management. *Electronic Journal of Information Technology in Construction*, 11:673-684, 2006.

[8] Wing, R. RFID applications in construction and facilities management. *Electronic Journal of Information Technology in Construction*. 11711-721, 2006.

[9] Legner, C. and Thiesse, F. RFID-based maintenance at Frankfurt airport, *IEEE Pervasive Computing*, 5(1):34-39, 2006.

[10] Ergen, E., Akinci, B., East, B., and Kirby, F. Tracking components and maintenance history within a facility utilizing radio frequency identification technology, *Journal of Computing in Civil Engineering*, ASCE, 21(1):11-20, 2007.

[11] Ko, C. H. Accessibility of Radio Frequency Identification Technology in Facilities Maintenance. *Journal of Engineering, Project, and Production Management*, 7(1):45-53, 2017.

[12] Stockman, H. Communication by Means of Reflected Power. *Proceedings of the Institute of Radio Engineers*, 36(10):1196-1204, 1948.

[13] Association for Automation Identification and Data Capture Technologies (AIM), Shrouds of Time: The History of RFID, 2002. On-line: http://www.aimglobal.org, Accessed: 30/03/2017.

[14] Ko, C. H. RFID 3D location sensing algorithms. *Automation in Construction*, 19(5):588-595, 2010.

[15] Domdouzis, K., Kumar, B., and Anumba, C. Radio-Frequency Identification (RFID) applications: A brief introduction, *Advanced Engineering Informatics*, 21(4):350-355, 2007.

[16] Oysal, Y., Becerikli, Y., and Konar, A. F. Modified descend curvature based fixed form fuzzy optimal control of nonlinear dynamical systems. *Computers and Chemical Engineering*, 30(5):878-888, 2006.

[17] Ko, C. H. and Cheng, M. Y. Dynamic prediction of project success using artificial intelligence. *Journal of Construction Engineering and Management*, ASCE, 133(4):316-324, 2007.

[18] Haykin, S. *Neural Networks and Learning Machines*, Pearson, New York, 2008.

[19] Keller, J. M., Liu, D., Fogel, D. B. Fundamentals of Computational Intelligence: Neural Networks, Fuzzy Systems, and Evolutionary Computation, John Wiley & Sons, New Jersey, 2016.

[20] Ko, C. H. Integrating RFID, Web-Based Technology, and Artificial Intelligence in Engineering Management. *Scientia Iranica*, 22(2): 299-312, 2015.