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APPLICATIONS OF RFID AND MOBILE TECHNOLOGY IN TRACKING OF EQUIPMENT FOR MAINTENANCE IN THE MINING INDUSTRY

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ABSTRACT: Supply Chain Management (SCM) is a crucial factor in reducing the down time in equipment maintenance in the mining industry. The paper describes a tracking and verification system using Radio Frequency Identification (RFID) and mobile RFID technology developed for an SME in the UK to monitor the assembly of parts for a manufacturing company. The system uses low cost passive tags (costing few cents) to provide information in real time using TCP/IP protocol which is internet compatible and can be viewed anywhere in the organisation worldwide to provide more effective management control. The RFID technology and mobile RFID equipment is able to operate in a manufacturing and fabrication 'metal environment' with read/write distances of up to 6m. The information can be linked to a CAD system and/or Witness Quick 3D to provide visualisation and simulation of the shop floor in terms of equipment and personnel movement. This information can also be linked to digital imagery and used to provide evidence and visualisation for agile management systems in mining machinery workshops and stores.

INTRODUCTION

Radio Frequency Identification (RFID) is an automatic identification technology which has received attention recently because of its potential in asset tracking and logistics support. It is widely thought that RFID technology is causing a revolution in Supply Chain Management (SCM) by providing a substitute for barcodes. The rapid development of RFID technology actually provides business operations with a chance to gain competitive advantage, particularly for SME's (Small or Medium Enterprise) involved in SCM operations, along with its potential for tracking equipment in maintenance operations.

RFID technology offers an efficient means of logistic management especially for agile and lean management. The concept of lean production, originally derived originally from Toyota Production Systems, means eliminating any waste of resources or effort in the system, for example using less of everything, including human effort, manufacturing space, investment in tools and engineering time to develop new products (Womack et al., 1990). Lean management is linked to the concept of "zero inventory" and the Just In Time (JIT) approach (Fan *et al.*, 2007). The concept was promoted by the Laccoca Institute of Lehigh University in 1991 and is based on the idea of "flexible manufacturing systems" (Fan *et al.*, 2007). Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace (Naylor *et al.*, 1999). In fact, lean and agile management share a common objective: to meet customer demands at the least total cost (Goldsby *et al.*, 2006).

This paper describes the application of RFID technology in SCM and the concept of agile management in a manufacturing SME in the UK to monitor the assembly of components. The design of an RFID system is discussed and the performance of two main types of tags used in RFID technological systems is examined and tested. The results presented demonstrate the feasibility of using RFID technology in supporting agile management systems. This technology can be used to monitor and track equipment in engineering workshops used in the mining industry.

RFID IN LOGISTIC MANAGEMENT

There are many ways to use RFID technology for logistic management, but the basic idea is to track and mark the container (usually this is a pallet or container) rather than tracking each product component which may cause extra cost and other issues, for example metal components may block the signal resulting in failure to track the components' movement.

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The application of RFID technology is restricted by many factors, such as the physical environment, production workflow and the financial investment available to the company. The case study was conducted at a company through collaboration arrangements. The company is involved in the fabrication and manufacture of metal assembles for numerous customers. Its environment and complex workflow represent a typical manufacturing SME which would benefit from the use of emerging RFID and mobile technology.

Challenging issues in the SME case study company

The case study company is a fabrication/manufacturing firm that provides metal manufacturing and assembly services, including metal cutting, machining, drilling, fabrication, welding and also uses sub-contractors if any 'powered' or 'paint coating' is required for the finished product before dispatch from their premises to the customer. The large fabrication service offered by the company results in diverse workflows and each individual order is usually specific to that customer, resulting in complex work schedules.

The company's final product usually contains several components that typically have diverse workflow systems. The company has a relatively large factory with several workshops and its current *Manufacturing Resource Planning (MRP)* system is not effective in providing timely information on the work process, job progress and particularly in locating components. This sometimes results in components going missing when they are needed and the staff must spend unproductive time either locating or re-producing the component. The company has realised that its employees spend too much time locating components, which has a negative impact on efficiency and performance, and has resulted in a financial impact on the company.

Consequently there is an urgent need for a practical system to solve these issues, and RFID technology can provide a suitable solution. However, all the products produced by the company are metal components, which affect the propagation of radio waves used by this technology. This paper discusses and describes the experiment for evaluating the feasibility of using RFID technology in this manufacturing environment.

Design of the RFID Technology for Tracking and Monitoring

The manufacturing company uses wooden pallets as temporary containers to hold the components and semi-finished products as they are used and/or fabricated and moved around their workshops. The basic idea of the application is to use passive RFID tags attached to the individual pallets to track the movement of the pallets and indicate the logistics of products movement and storage within the company via 'choke points' also referred to as 'gates' or 'doors'.

The RFID passive tags could be affected by the metal environment of the manufacturing facilities, and must be carefully attached to the pallets. Figure 1 illustrates the attachment of the tag to the corner of the pallet in order to try and avoid interference from the metal products which ideally need to be placed in the centre of the pallet.

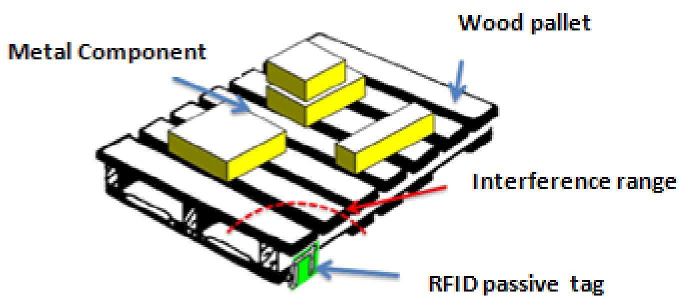

Figure 1 - RFID tag location and arrangement in relation to the pallet

In addition, each pallet could have more than one tag either to reduce erroneous readings and/or be used to represent different product components on the same pallet as illustrated in Figure 2. For example, the tags shown in the illustration on the same pallet can have different ID's but be linked to the same product in the database so that once a tag on the pallet is read electronically, the information on its location and contents can identify where the pallet is located in the workshop and/or warehouse facilities.

Figure 2 - Multiple RFID tags attached to a pallet

In order to receive the tag's signal, and therefore the location of each pallet, each gate or door in the plant has to be installed with an antenna and corresponding reader as shown in Figure 3. The tags will then be captured as they pass a gate and the pallet location can then be determined in relation to the layout of the workshop. Figure 3 gives an example: - the pallet moves through a gate entry (in this case the punch machine room), and as only this gate has captured the tags (reading distance on a passive can be attenuated between 0.2 to 6m), the location of the pallet must be the punch machine room. In addition, the tags can also be scanned by handheld devices such as specially adapted mobile phones (which are ubiquitously carried by individuals) and this provides more flexibility in monitoring and controlling the tags, for example when checking information or updating/ modifying records.

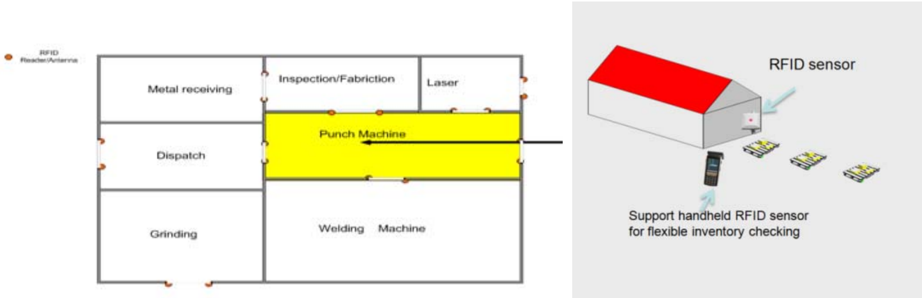

Figure 3 - Read/Antenna gate installed in the workshop

If a longer read-range of the tags is required, then an active RFID tag can be used. Active tags are usually more expensive costing approximately A$ 8 each (depending on scale of purchase) compared to the passive tags which only cost a few cents. However, if the pallet is dispatched to the customer or supplier together with the product the tags can be removed from the pallet and reused. This would only need to be considered when using active tags because of their higher cost. The tags removed from the pallet can be assigned a new ID for a new workflow. The performance of passive and active tags will be discussed later in the paper.

The application of RFID technology can be based on TCP/IP network protocol; a popular network protocol, used with WIFI, Local Network, and the Internet. This means it can provide long-distance monitoring and control from any place in the world providing there is Internet access; another benefit is that the system can be easily linked with the WIFI network and supports wireless control (Zhang *et al.*, 2009a; Zhang *et al.*, 2009b).

The information can be linked to a CAD system and/or Witness Quick 3D (Lanner, 2010) to provide visualisation and simulation of the shop floor in terms of equipment and personnel movement to provide agile management concepts. The data from the RFID equipment can be adapted and used in simulation software such as Witness to identify and determine on-line 'bottle necks' in the workflow, as illustrated in Figure 4 showing that the simulation can be represented in an initiative 3D format for visualisation purposes (Zheng *et al.*, 2007b).

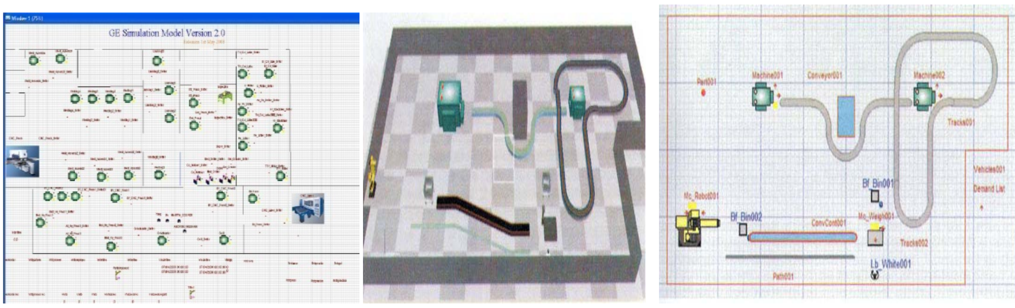

Figure 4 - Simulation and witness quick 3D application

(ZHENG ET AL., 2007A; ZHENG ET AL., 2007B)

RFID EXPERIMENTS IN THE MANUFACTURING COMPANY

In order to determine the 'field' performance of RFID technology in a complicated environment a number of experiments were undertaken in the case study engineering company using RFID technology. The case study company premises comprise a turn of the century 'type' building with heavy gauge structural support stanchions and reinforced flooring containing a large metal fabrication environment with numerous workshops: the worst case scenario for interference when using RFID technology. The first aim of the experiment was to determine the communication range in the factory, which is full of metal sub assembles and heavy manufacturing equipment. The second aim was to set up a RFID embedded door/gate to test the feasibility of recording the movements of pallets in the factory.

Equipment

In this experiment, the performance of both the passive RFID and active RFID was tested. The passive equipment was an ALR-8800 Reader with two circuit antennas from Alien Technology, and the Active equipment was a 217002 Reader with built-in antenna from GAO RFID Inc.

ALR-8800 is a UHF reader and operates in the 865.7-867.5 MHz range, following the EPC G2/C1 RFID standards. The reader supports two communication interfaces: RS-232 for serial connection and RJ-45 for TCP/IP communication. The system configuration needs at least two external antennas for reading: one is for sending the power to the tag, and the other for receiving the signal. In this experiment, one reader with four antennas was used to build the two gates. The RFID equipment with its antenna is shown in Figure 5. The tags used in this experiment were AL=964x, which is the best performing tag that could provide about an 8-9 meter communication range (based on previous laboratory testing).

Figure 5 - Passive RFID equipment with corresponding antennas

The active equipment was from GAO RFID Inc: operates in the 2.45 GHz and applies an 802.11b wireless communication standard (WIFI). It also has two communication interfaces, either RJ-45 or a WIFI interface which can wirelessly communicate to the computer.

Testing procedure and results

The aim was to test the readability of the passive tag (worst case scenario) when attached to a metal skip, and the result shows that it supports up to a 6 meter read range in open areas as shown in Figure 6. The tag was attached to the top of the skip, which was filled with metal 'off cuts'. The tag was kept 2 cm from the skip and the RFID antenna was moved as far as possible from the tag to determine the maximum read range.

To test a more complex environment the tags were attached to a wooden pallet which was full of metal sub assembles. In this situation, the communication range was dramatically affected, but there was still a practical read communication range of 1.5-2 meters. This result proves that passive RFID technology can track components in a factory environment, particularly metal sub assembles used in maintenance workshops etc. The passive tags used in the tests could provide sufficient communication range for the internal logistic management purpose of tracking and monitoring and could give longer distances in open work areas. The experimental details are shown in Figure 6.

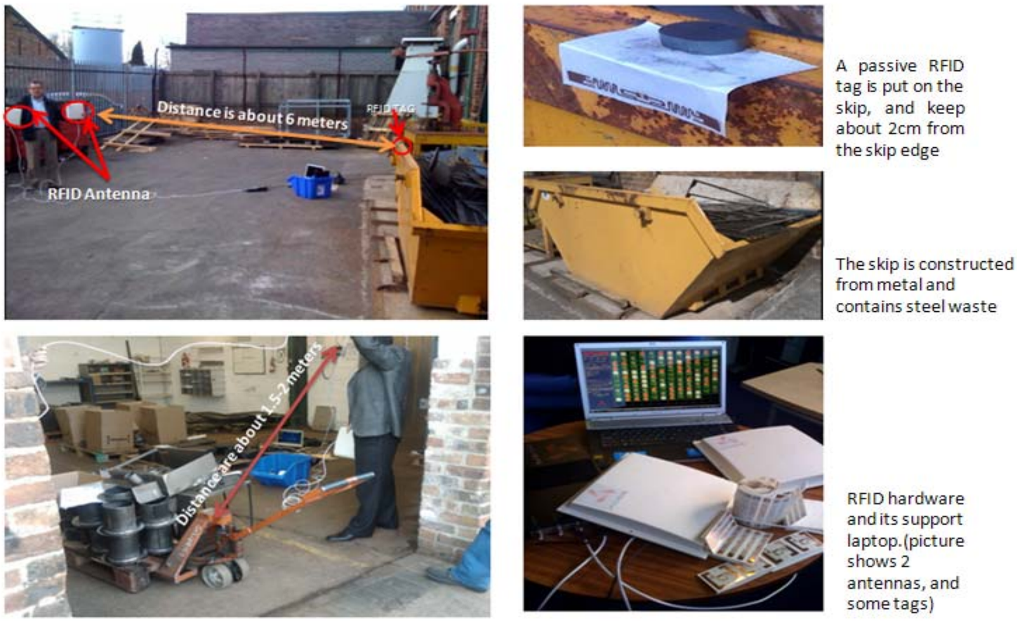

Figure 6 - Communication range testing for passive RFID equipment.

The testing for active tags was a simpler procedure because of its longer communication range and signal penetrability. Even when the tags were fully covered by metal components, the equipment could still read the tag at a distance of more than 10 meters because of the stronger signal strength and wider frequency band. In this test, the reader was fixed and the tag was moved further away until the signal was lost: testing was then repeated 5 times. Figure 7 shows that the final result was about 35 meters a much better result than the passive tags.

The second test was to evaluate the tracking and monitoring function of RFID systems. For this purpose, a software application has been developed for monitoring and automatically generating the database records when movement of the tags is detected at the gates.

Figure 8 shows the four antennas working as two pairs to simulate two gates in the manufacturing company. A pallet with metal sub assemblies is the tracking target and five tags are laid on the metal components. The target pallet is moved by a trolley and navigated though the two gates and then brought back through the gates.

Figure 7 – Communication testing for active RFID equipment

Figure 8 - Scenario for testing two gates or 'choke points' in the factory

During the movement of the pallet, the system picks up the tags four times, and generates three records which are shown in Figure 9. In the demonstration the antennas are numbered to represent the location, and because only two antennas receive signals (the other two are for sending the signal), the locations are respectively marked as "0" and "2". For ease of understanding, the records of one tag (ID "BEEF0007") are shown in Figure 9. The first records indicate that the tag is first captured by the antenna in location 0, therefore, the *Last location column* is marked "N/A", and the second location shows the same tag picked up by the antenna in location 2, which means that the target pallet has moved to location 2. Then, the pallet is moved back and picked up by the same antenna, but no records are generated. The third record shows that the pallet has been moved back to the starting position which is location 0. This scenario demonstrates that RFID technology can work in the manufacturing company to provide management information for tracking and monitoring. More importantly it shows that it can work in one of the worst case environments (regarding RFID interference) as previously outlined, and therefore undoubtedly can work in any similar manufacturing and maintenance company.

The experimentation in the manufacturing company shows the feasibility of using RFID for tracking and monitoring via gates or choke points to provide logistical management information which could help improve efficiency and performance and solve some of the issues related to the case study. In addition, the reader and IT equipment in this experiment are linked by WIFI interface, i.e. are wireless providing more flexible control and deployment for users in the company.

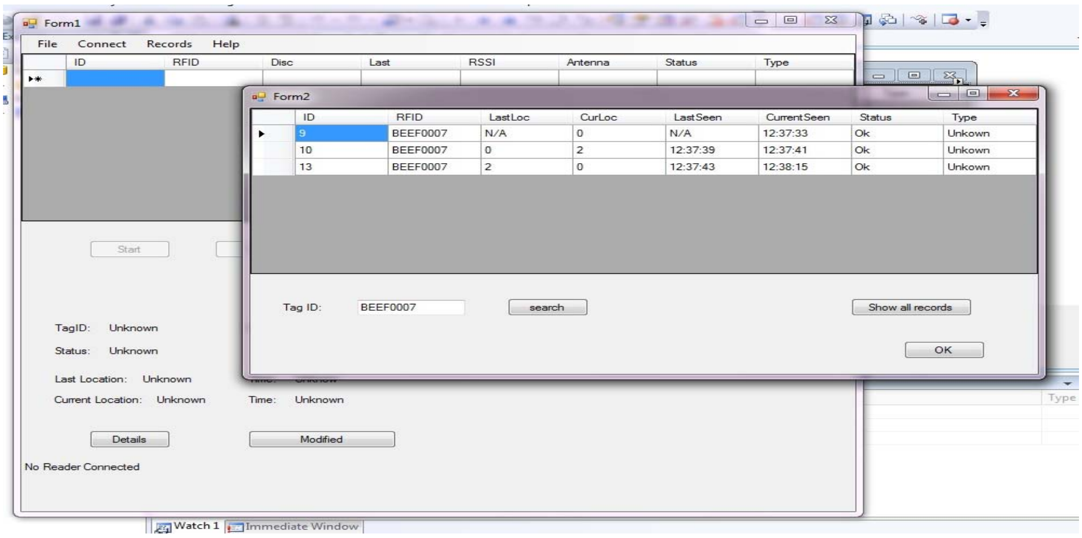

Figure 9 - The Database Results for the scenario testing two gates or choke points

DISCUSSION OF RFID TECHNOLOGY AND SOFTWARE DEVELOPMENT

RFID is an automatic identification technology that allows a small radio device attached to an item to carry an identity of that item (Glover *et al.*, 2006). An RFID system has at least has three components: the reader, tags and middleware. Its working procedure can be briefly outlined as: the reader under the control of the middleware transmits adequate energy through the antennas to power up the tags and communicate with the tag to request and receive the identifier (Landt, 2005; Lehpamer, 2008). As an emerging technology receiving continual attention, many different types of RFID tags and associated technology have been developed. In general the tags are usually classified into passive RFID and active RFID (Landt, 2005), and in the experiments outlined in the paper, both of them are tested in an industrial environment.

The ALIEN equipment used in the experiments is a passive system which follows the EPC standards, from the EPCglobe (Electronic Product Code globe) organization which promotes the concept "Internet of Things", which means an open and shared infrastructures for auto-identifiable networked objects (Roussos, 2008). A passive tag devices has no power supply built into the tag and only works when it is inductively powered by the antenna, which allows it to transmit its information back to the reader. The power from the reader/antenna is usually limited and consequently the communication range of a passive system is shorter than the active system, and is dependent on the output power of the antenna. The communication range of passive RFID has increased dramatically in recent years, and can provide up to 5-10 meters, which is sufficient for practical logistic tracking, compared to a few years ago, when item level tracking was less than 1 meter.

The RFID equipment from GAO RFID is an active system, and the experiment outlined in the paper demonstrates that it provides about a 35 meter communication range in the metal environment of the case study company, previous tests have shown that in open areas, the equipment operates up to a range of 50 meters. An active system usually has an on-board power source, typically a battery and performs a specialized task (Behera *et al.*, 2008). This structure has some advantages in terms of functionality and capability but drawbacks in terms of its cost and maintenance aspects. For example, the simplest tag from GAO RFID inc. costs about A$ 8, and only has a battery life of 3 years.

Figure 10 outlines two aspects firstly the conventional information in terms of tracking and monitoring of components within the manufacturing and workshops zone and secondly that this information can be used to provide knowledge management by using data mining techniques and simulation to provide potential competitive advantage. The latter is of particular importance to an SME in terms of reducing production costs linked with agile management concepts to improve performance.

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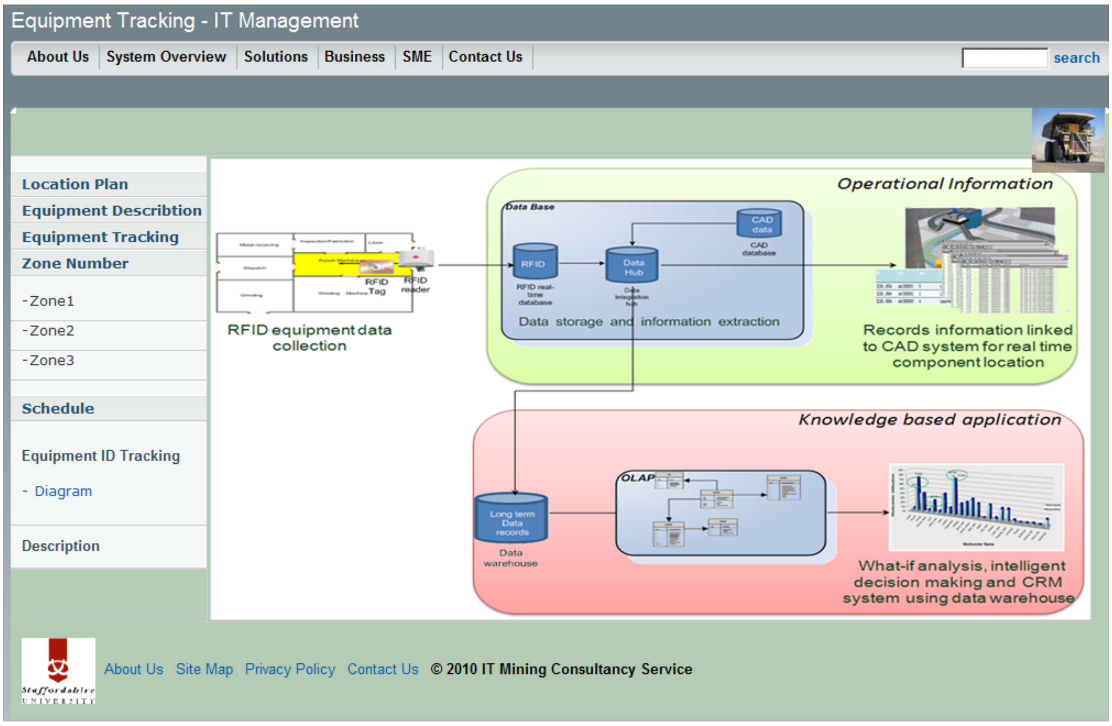

Figure 10 - Data process and knowledge representation

The data transmitted from the RFID equipment will be stored in a database and the records of logistic movement will be extracted from the information and stored in a central database. The CAD system can be linked to the database to provide additional information either from real time monitoring and/or data analysis. The information can be directly used to monitoring the movements of assets or products and help to realize lean manufacture, such as JIT methods. Alternatively knowledge management systems can be developed and the data updated to a data warehouse; the information stored can then be used for data mining purposes to improve the company's performance. For example, the information can be used to support knowledge management systems, including an intelligent decision-making system or other knowledge-based system to optimize the work process. This is extremely important particularly for an SME in terms of reducing production costs linked with simulation-based management concepts to improve performance (Yu *et al.*, 2002; Zheng *et al.*, 2007a)

CONCLUSIONS

This paper describes the emerging technology of RFID used in SCM in order to reduce waiting time and improve performance of the workflow. A tracking and monitoring system is described which was developed for an SME in the UK to monitor the assembly of components for a large excavating manufacturer. The system designed uses RFID technology to acquire information to track and monitor products which can be linked to a CAD system and/or Witness Quick 3D to provide visualisation and simulation of the shop floor in terms of equipment and personnel movement. Serial experiments were undertaken to evaluate the design of the system for both passive and active RFID systems. The tests show the feasibility of RFID technology and mobile RFID equipment, which be operated in a manufacturing and fabrication 'metal environment' with read/write distances of up to 6m. In addition, a brief discussion of RFID technology is introduced in order to compare the two types of RFID tags and associated equipment. The tags can also be scanned by handheld devices such as specially adapted mobile phones which these days are ubiquitously carried by individuals, and can provide more flexibility in monitoring and controlling the tags, such as in checking information or updating/ modifying records.

Application of RFID technology is more complex than widely imagined. It requires the correct specification and customisation to be set up and aligned to the business application in terms of the readers, antenna, middleware and software for individual applications. The requirements for technical advice at the feasibility and implementation stages are crucial to the success of the application. This technology would provide useful applications to mining machinery workshops and stores in terms of both tracking and monitoring and also in cost accountancy in relation to reliability of modular components and usage requirements.

Currently work is being developed in the application of RFID and mobile technology to support several business applications including asset and document tracking in a hospital complex, application in the hospitality industry, construction waste recycling and medical waste tracking and verification systems using customised hardware and purpose-developed software systems.

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REFERENCES

Behera S and Maity C, 2008. Active RFID tag in Real Time Location System, *Systems, Signals and Devices*:

Fan Q, Xu X and Gong Z, 2007. Research on Lean, Agile and Leagile Supply Chain, *Wireless Communications, Networking and Mobile Computing 2007*. pp.4902-4905, 21-25

Glover B and Bhatt H, 2006. RFID Essentials. O'Reilly, USA. ISBN : 0-596-00944-5

Goldsby T J, Griffis S E and Roath A S, 2006. Modeling Lean, Agile, and Leagile Supply Chain Strategies. *Journal of Business Logistics*

Landt J, 2005. The History of RFID. *Potentials, IEEE* 24(4): 8-11

Lanner. 2010. WITNESS website. http://www.lanner.com/, cited Jan/2010

Lehpamer H, 2008. *RFID Design Principles*. Artech House: Norwood, MA ; London

Naylor J B, Naim M M and Dany B, 1999. Leagility: integrating the Lean and Agile Manufacturing Paradigm in the Total Supply Chain. *International Journal of Production Economics*

Roussos G, 2008. *Networked RFID : systems, software and services*. Springer: London

Womack J, David P, Jones T, Roos D. 1990. The Machine That Changed the World: New York: Macmillan

Yu H, Lloyd S and Rigas D, 2002. Petri net Modelling and Witness Simulation of Manufacturing Systems, *Third World Manufacturing Congress*. ISBN:3-906454-28-2.: New York. USA

Zhang L, Atkins A S and Yu H, 2009a. A Survey on Chinese Medical Waste Disposal System and Proposed RFID Tracking System, *SKIMA (International Conference of Software, Knowledge and Information on Management Applications)*. October: Morocco pp: 343-349 ISBN: 9781851432516

Zhang L, Zheng X, Choosri N, Yu H and Atkins A S, 2009b. Applications of RFID in Indoor Navigation for the Visually Impaired, *15th International Conference on Automation & Computing*. September: Luton, UK pp: 148-153, ISBN: 978-0-9555293-4-4

Zheng X, Yu H and Atkins A S, 2007a. Inventory Management Simulation using a Novel Replenishment Algorithm, *IEEE ICNSC*. London pp 35-361 ISBN 1-4244-1076-2

Zheng X, Yu H and Atkins A S, 2007b. A Transferring Approach - From a Witness model to a Petri net, *the 13th International Conference on Automation and Computing*: England pp 23-236.