

A Framework of Integrating an RFID-enabled Communication System into an Automated Storage and Retrieval Mechanism

Qian Wang, Hongwei Wang, Nick Bennett, Misha Filip

Abstract—A typical automated warehousing system consists of automatic storage and retrieval modules including lifting equipment and powered conveyor systems. These facilities are used to overcome some disadvantages of manually operated warehousing systems which often lead to a high frequency of human errors, high labour costs and low efficiency. The information system integration also plays a key role in speeding up data processing and coordinating inventory control and management in a warehouse. In recent years, it has also been seen a rising trend for online shopping across the UK as well as in many other countries. Suppliers or distributors have therefore been seeking for even more efficient and effective methods of storing and dispatching goods in a way of increasingly centralised distribution centres through which customers place their orders online and goods are dispatched automatically from storage and retrieval areas to collection points where these goods are packed and delivered directly to customers' door steps. In order to achieve this functionality, a novel design of automated warehousing system through an integrated inventory data platform is desired. This paper presents a framework by proposing a novel design of future generation warehousing systems incorporating fast-growing IT applications such as radio frequency identification (RFID), wireless sensors and communication networks.

Keywords—automation, warehouses, RFIDs, inventory, management, systems integration

I. Introduction

Over the past few years, it has been seen a growing trend of online shopping that is likely to gain even greater prominence every day. More and more customers prefer to order their goods that can be found online and these customers also demand a faster delivery of ordered goods to be dispatched directly to their door steps. A study through a literature review suggests that future generation warehouses may be designed and implemented as even more centralised distribution centres in which a novel design of automated storage and retrieval systems are increasingly desirable [1-6]. Current automated warehouses are equipped with expensive mechanical facilities which may include palletising robots, carton flow order picking systems, automated guided vehicles (AGVs), rotary storage cabinets, and automated storage and retrieval systems (AS/RSs). These facilities can partially replace human workers in performing operations of picking an

and placing items; and vertically improving space utilisation of a warehouse. Implementation of IT capabilities has also been seen great improvement opportunities in terms of tighter inventory control, shorter response time and greater variety of SKUs (stock keeping units). These IT capabilities can be implemented using smart-labels such as barcodes, radio frequency identification (RFID) tags and automatic identification (Auto-ID) sensors, together with cable and/or wireless communication networks and integrated warehouse management system (iWMS). Unlike the barcode scanning method, radio frequency identification or RFID technology uses the wireless non-contact radio wave communication mechanism to identify an object attached with an RFID tag that contains up-to-date information of this object. In recent years, there has been a growing interest of applying RFID technologies into logistics and supply chain sectors to improve efficiency of information processing, achieve a better inventory control and a real-time data management, and maximise utilisation of warehouse capacity. In logistics sectors, for instance, RFID tags are widely used for identifying large and heavy items (containers, pallets and heavy components) because of its advantage using the wireless signal transmission method for receiving and updating data from these items. With the RFID solution, inventory can also be tracked more accurately in a simple, timely and more efficient manner leading to a significant reduction of data processing time and labour cost, compared to the barcode method as each barcode has to be scanned individually and it is a labour intensive and time consuming process.

This paper aims to propose and describe a framework of incorporating an RFID-based information management system into a novel design of automated storage and retrieval mechanism. Within such a novel design of storage and retrieval mechanism, an item, which is attached with an RFID tag, can not merely be traced, sorted and inventoried in a real-time control manner; but also the item can be stacked on the storage racks randomly at wherever a place is available for incoming goods, i.e., each item can be distributed from anywhere throughout the system.

II. The RFID System

Figure 1 illustrates a framework of the proposed RFID-enabled inventory control and management system used for a novel design of automated storage and retrieval modular, which is described in section III. A typical RFID system consists of RFID tags, an RFID antenna, and an RFID reader. Each in-store item is attached with an RFID tag that has a unique identification code containing an amount of

Qian Wang*, Hongwei Wang, Nick Bennett, Misha Filip
School of Engineering, University of Portsmouth, UK
(*Corresponding author)

information data that an RFID tag is able to carry, depending on capacity of its embedded chip memory. The usage of RFID tags can be classified as passive RFID tags, active RFID tags, and semi-active RFID tags. A passive RFID tag does not have its own source of power and relies entirely on the readers to activate it. By contrast, an active RFID tag has its own power to actively broadcast data stored on it via an antenna. A semi-active RFID tag is also powered; however, this type of RFID tag is able to turn itself off after being triggered by a given action from an RFID reader. There is a difference in coverage using different types of these RFID tags. An active tag generally has a better coverage but with a higher cost than use of a semi-active tag followed by a passive tag. The RFID system is in a constant communication with the data server that receives and updates information data of each tagged item via a local area network (LAN). The controller shown in Figure 1 is a device that allows a group of readers to communicate with a central computer system (e.g. data server). A centralised platform for handling system data and communication is therefore needed.

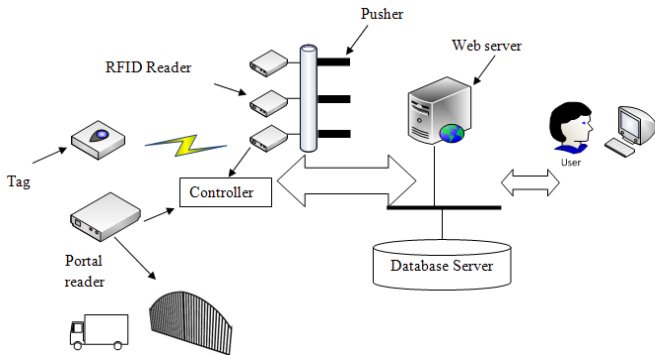


Figure 1. A framework of the RFID-enabled communication system for the proposed warehouse.

Figure 2 illustrates the RFID tagged tote used for the proposed automated warehousing system. Items are pre-loaded onto pallets named totes; totes need not be of identical sizes. If a tote contains different types of items, each item is attached with an RFID tag to indicate its identification only for this item. If a tote contains the same type of items, each item is matched to a unique identifier of that tote with an RFID tag; the item is thereafter tracked and manipulated throughout the system within the tote. Two types of RFID tags (using active and passive RFID readers) can be selected based on criteria of their reading performance tests at different locations and their costs throughout the system.

III. The Novel Design of Automated Storage and Retrieval System

As illustrated in Figure 3, an item enters storage in a tote onto the end of a storage conveyor row. When a specific item is demanded from the store it will be transferred onto the output conveyor from the storage conveyor by a pusher device (tote pusher). The space previously occupied by the tote is

then filled with all succeeding totes moving forward along the storage row; an item's position on a storage row is therefore not fixed in time. Readers mounted on the push-arm identify the tote as required by reading RFID tags via an indoor wireless communication network (iWCNet-IEEE802.11). These data captured by the RFID devices contain information of types, quantities and locations of SKUs (stock keeping units) in the store; and the inventory levels in each rack indicates the availability of space for incoming products. The collected RFID data are stored in a centralised database. Position knowledge of all totes on all storage levels is acknowledged and updated each time a pusher arm traverse a module via an RFID-inventory system illustrated in Figure 1 and 2. The arm's position travelling along the storage row is determined and activated by a modular controller, which receives instructions of mechanical operations from the warehouse control system via the LAN. The control system also maintains up-to-date information of such as what in-store items are and where these items are located in one or more modules of the entire warehouse via the RFID-inventory management system.

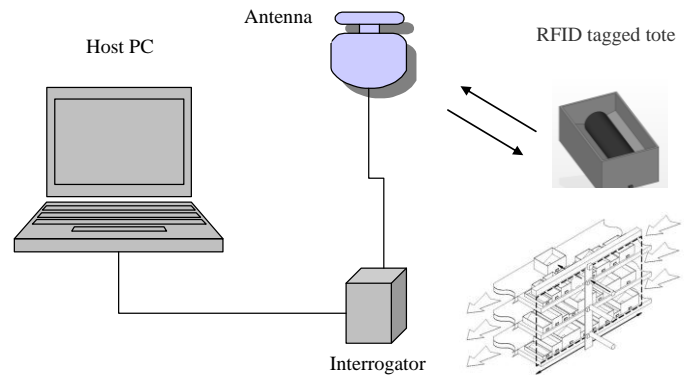


Figure 2. Components of the RFID system.

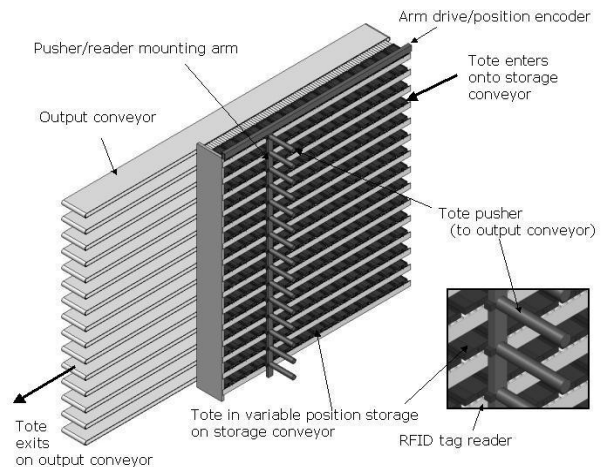


Figure 3. The RFID-enabled storage and retrieval system.

Figure 4 shows a snapshot of simulation model for the system of storage and retrieval racks. One of core elements of the proposed automated warehouse is the storage and retrieval

module, which includes the following components (1) tote boxes to be fed into the cantilever storage rack, (2) slower input belt-driven conveyor system, (3) faster output belt-driven conveyor system, (4) tote pusher horizontal position rail, (5) tote pusher vertical position rail, (6) tote pusher. The storage and retrieval module comprises of two types of powered conveyors aligned next to one another; these are storage conveyors and output conveyors. The entire operation of each type of conveyor is controlled by a PLC (programmable logic controller) that communicates with mounted sensors via the LAN [7].

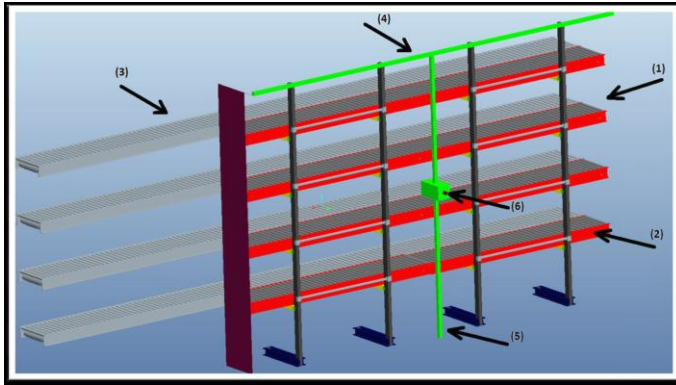


Figure 4. Key components of the storage and retrieval module: (1) tote boxes to be fed into cantilever storage rack (2) slower input belt-driven conveyor system (3) faster output belt-driven conveyor system (4) tote pusher horizontal position rail (5) tote pusher vertical position rail (6) tote pusher.

Figure 5 schematically illustrates an overall layout design in a 3D model of such a distributed warehousing system. The system consists of a series of individual modules in which all levels of output conveyors are interconnected to equal levels of a looped and cross-linked conveyor system, which also includes output spiral conveyors with a number of collection points at where the ordered goods or products will be packed manually and delivered to customers through an logistic service chain. These conveyors, which also act as delivery paths as well as buffers, form the output zone of the warehousing system. Selected items are sequenced and routed by an integrated RFID-guided control system, sensors and PLCs along the delivery path. These items subsequently arrive at an assigned pick location or collecting points for re-packing. The multiplicity of parallel routes ensures that substantive congestion problems should not arise.

Notably through its modular design, the warehouse can be adapted according to specific customer needs. Each module is designed as a standardised element for manufacturing, although single module can be of different size and arrays in a module can be configured in many different ways. The capacity of an overall warehouse can be changed easily by adding or removing modules to accommodate the changing environment of such as different building spaces and layouts as well as changing demand from customers or retailers. The RFID-based control system permits a large number of parallel events to occur at any given time throughout the warehouse. By using RFID tags, SKUs can be distributed randomly at varying locations wherever a place is available for incoming goods as illustrated in Figure 6. A chosen SKU can be released

by the system based on 'being nearest to a collection point and/or a modular arm which is free or adjacent to the chosen SKU's algorithm. This approach will significantly increase the capability, flexibility and responsiveness for the warehousing system to dispatch items.

Intelligent control software is needed to realise the potential offered by this design. Input variables in the control software can be classified into three broad categories, namely application parameters, hardware parameters and software parameters. Application parameters may include such as number of different SKUs handled by the system, storage information of each SKU, number of items per request, number of requests per time unit, and number of concurrent users etc. Hardware-related parameters may include factors such as height and depth of each rack and number of racks per aisle etc. Software parameters may cover scheduling and optimisation algorithms used for job priorities to assign or dispatch items to/from arrays of a storage modular. For achieving this, a material-handling solution should be constructed based on optimal algorithms in order to generate the shortest pick-up sequence and route for the material-handling equipment; this maximises the efficiency and minimises the total material-handling costs in the warehouse.

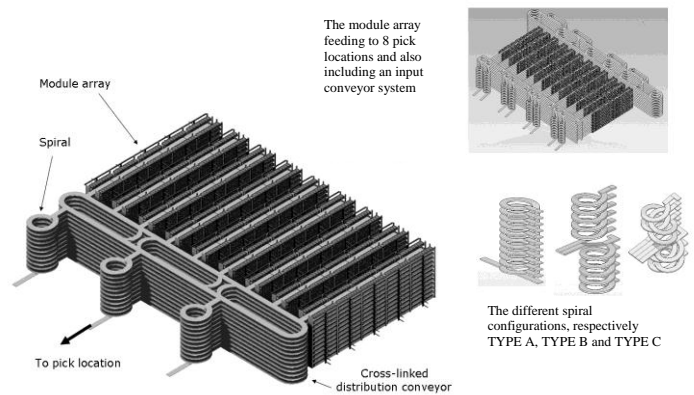


Figure 5. The overall layout of the 3D warehousing system.

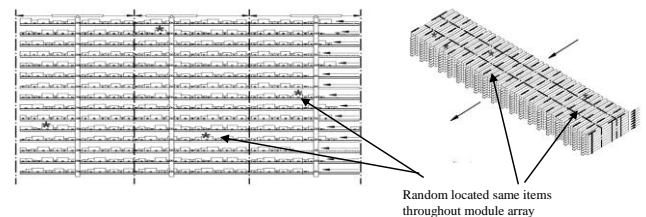


Figure 6. Random locations and even distribution of the same item storage throughout the system.

IV. Conclusions

This is a proposal-based paper which presents a novel concept and design of a new generation automated warehouse



and its capability that the conceptual system may offer. Such a capability can be achieved by integrating fast growing IT applications, such as RFID tags, wireless sensors and networks, into the mechanism of the proposed warehousing system. The operations of such an RFID-based automated warehousing system in a distribution or logistics centre are described in this paper. The paper also presents a framework of a storage and retrieval module, which is named as cantilever storage and retrieval racks. These storage and retrieval racks are designed as a scalable and reconfigurable storage and retrieval mechanism, which is the core element to form the mechanical system for the proposed RFID-enabled automated warehousing system. Moreover, this framework illustrates its capability of integrating inventory data and system information data involved in the proposed design of the next generation automated warehousing systems offering effective control and information management of storing and delivering activities for incoming goods and outgoing SKUs. The preliminary design work also demonstrates the key system components consisting of the proposed RFID-based warehousing systems, which are illustrated in this paper. The system design also incorporates some characteristics of the system reconfigurability and flexibility in order to accommodate a changeable system capacity in terms of storage size and warehouse layout at varying locations of centralised distribution centres. In our future work, a prototyping system with a series of pilot tests through an implementation of hardware components and control software is undergoing.

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References

- [1] Q. Wang, R. McIntosh, and M. Brain, "A new generation automated warehousing capability,," International Journal of Computer Integrated Manufacturing, vol. 23, pp. 565-573, 2010.
- [2] A. Ramduhin, "A generic framework to support the selection of an RFID-based control system with applicatioun to the MRO activities of an aircraft engine manufacture,," Production Planning and Control, vol. 19, pp. 183-196, 2008.
- [3] T. C. Poon, "An RFID case-basd logitics resource management system for managing order-picking operations in warehouse,," Expert Systems with Applications, vol. 36, pp. 8277-8301, 2009.
- [4] C. Conolly, "Warehouse management technologies,," Sensor Review, vol. 28, pp. 108-114.
- [5] P. Baker, and Z. Halim, "An exploration of warehouse automation implementation: cost, service and flexibility issues,," Supply Chain Management, vol. 12, pp. 129-138.
- [6] G. Q. Huang, Y. F. Zhang, and P. Y. Jiang, "RFID-based wireless manufacturing for real-time management of job shop WIP inventories,," International Journal of Advanced Mnaufacturing Technology, vol. 36, pp. 752-764.

- [7] Q. Wang, and J. Y. Tan, "A reconfigurable mechanism of cantilever storage racks,," International Conference on Advanced Material and Manufacturing Science, Beijing China, 2012.

About Author (s):



Dr Qian Wang is a senior lecturer in manufacturing systems and management; he has experience from both industry and academia. When he worked in industry, he was involved in many industrial projects and businesses; some had links with leading international companies. In his own academic research experience, Dr Wang had independently completed a number of research projects with supportive grants over £400,000 before he took the lectureship role. He has broad interests in manufacturing systems design, information systems for manufacturing, logistics and supply chain integration, sustainable manufacturing and lean production, and digital manufacturing.



Dr Hongwei Wang has been researching and lecturing engineering design for six years. His main research interests are in the application of advanced information and computing technologies to specific design issues, which include collaborative simulation, knowledge management, sustainable design and service design. He has taken part in a few research projects and published more than 40 papers.



Professor Nick Bennett is a director of manufacturing research group with broad interests of academic and industrial research activities particularly in engineering manufacture and innovation. He has led many funded research projects through research and knowledge transfer grants and other funding resources.



Dr Misha Filip is Head of School of Engineering. He has research and development experience of digital systems including microprocessor system design and communications hardware in both industry and academia with diverse research projects supported by research grants.