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RFID-based conveyor belt for improve warehouse operations

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Abstract

The Government of the Republic of Indonesia is currently focusing on building logistics infrastructure to facilitate the distribution of logistics to all regions in Indonesia. The Distribution of logistics to each area requires an electronically connected warehouse so that information about goods in the warehouse can be monitored continuously. There are some problems with one of the logistics companies because the existing warehouse management technology is not sufficient enough, so the complex warehouse functions do not become dynamic. One of the solutions to solve the problem need to use RFID technology, conveyor belt, and robotic arm by using an Arduino microcontroller. This research uses Design Science Research Methodology which focuses on developing and improving the model performance of a system and using the prototyping model for system development. The test results state that the built system works well because it could lift, identify and sort goods by type. So, this research could answer the problem that happened at the warehouse.

Keywords*: conveyor belt, design science research, logistics, RFID, warehouse*

1. Introduction

The Government of the Republic of Indonesia is currently focusing on building logistics infrastructure to facilitate the distribution of logistics to all regions in Indonesia. Logistics is a framework and planning orientation to create a plan for the flow of goods and information across the enterprise [1]. Logistics costs contribute a big part of the total production costs, and therefore the amount spent on logistics becomes an essential factor of firm's competitiveness [2]. Logistics performance is critical to the economic growth and competitiveness of a country and has a global measurement called Logistics Performance Index (LPI). The value of LPI determines by the professional survey results in the field of logistics [3]. The results of LPI 2016 point to Germany as the best-performing country, with a LPI score of 4.23 and Syria as the lowest-rated country, with a score of 1.60 [4]. Indonesia's LPI dropped from 53rd with a score of 3.08 to 63rd with a score of 2.98 [5]. Five critical assessments from the World Bank, Indonesia's three evaluation parameters declined compared to 2014, on infrastructure, customs processes, and logistics competencies [6]. Therefore, Logistic business actors need innovation to provide their best services to consumers, one of them by controlling the movement of goods in the warehouse.

A warehouse should be view as a buffer in supply chains and as a temporary place to store inventory and play an essential role to reduce variations in supply and demand [7]. In every process in the warehouse requires a system that can control all the operations that are in it, this is called Warehouse Management System (WMS) [8]. The primary purpose of WMS is to control the movement and storage of goods in a warehouse [9]. Logistics problem has always faced with uncertainty and risk due to their uncertain nature [10], the development of an efficient logistics system is a challenge faced by logistics companies in Indonesia [11]. One of the factors is because Indonesia has more than 17.000 islands spread over a territory from west to east with the total coastal line of 81.000 km [12]. Therefore, it is necessary to build a warehouse network that is connected electronically so that information about goods in the warehouse can monitor continuously. According to a report in 2014, there were 60 Third-Party Logistics (3PL) companies and about 4200 transporter and expedition companies operating in Indonesia [13]. Logistics companies certainly have warehouses because it has a significant

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effect on the company if they do not have it, the production of any goods will be difficult to control. There are some problems with one of the logistics companies because the existing warehouse management technology is not sufficient enough, so the complex warehouse functions do not become dynamic. The warehouse management process is difficult to lift, identify and sort goods by type so that the goods can stored in the wrong place.

One of the solutions to solve the problem need to use Radio Frequency Identification (RFID) technology, conveyor belt, and robotic arm by using an Arduino microcontroller. RFID is a technology with objectives to unique identification of objects, enable the non-contact and automatic using radio waves [14]. The function of a conveyor belt is to carry goods from one point to the end point with regularly and to sort goods by type using servo motors and at the final process the goods lifted using the robotic arm. Arduino is a user-friendly open-source platform based on a simple microcontroller board [15]. So, the design and implementation of RFID-based conveyor belt on WMS using Arduino microcontroller can provide benefits and convenience for logistics companies.

2. Related Work

A warehouse is a highly dynamic environment with different numbers of goods going in and out every day [16]. The primary purpose of WMS is to control all processes in the supply chain [17]. Information distortion on the supply chain is one of the significant problems in creating supply chain inefficiencies [18]. Data warehouse (DW) define as a subject-oriented, stable, integrated and variation data which sets along with time to support companies [19] and to run an entire business in a company requires resources that focus on information technology investment planning [20]. Automated warehouse refers to a dozen or even dozens of shelves used to carry on goods storage, with the corresponding material handling equipment for cargo inbound and outbound warehouse operations [21], and several kinds of sensors are necessary to collect much different information around the warehouse [22]. Comprehensive automatization based on warehouse management can decrease the leaks in the control of entering the warehouse, out of the warehouse, and inventory [23]. The cost saving by implementing RFID in a warehouse depends [24]. RFID is a simple, highly secured, cost-effective, used widely [25], as communication between a reader and a tag, and replacing barcode technology [26]. RFID reader is the circuit which generates a 125KHZ magnetic signal [27]. RFID technology recently maturated and improved by computational RFID tags with sensors and had some of the critical aspects [28]. The filter is implemented on all data to produce one feature on each data by calculating the standard mean of each signal [29]. The Arduino Uno is a microcontroller board grounded on the ATmega328 (datasheet) [30], open source, user-friendly platform for hardware and software prototyping [31].

Qualitative research often concerned with the development of a profound understanding rather than a broad understanding [32]. It also will design a study, collect data, analyze data and interpret data same as a quantitative researcher does [33]. However, qualitative research demands that researchers follow specific procedures and document the research process in detail [34]. The design of Information systems (IS) that apply contemporary methodologies can provide new knowledge that could enhance the design of particular IS artifact [35]. Design Science Research (DSR) in relation to other IS research paradigms with a long history [36]. In DSR, an error is a finding that a new artifact works when in fact the artifact does not work [37]. DSR methodology includes six stages is identify a problem & motivate, define objectives of research, design and development of solutions, building simulation/demonstration, testing, and conclusion [8]. A DSR process results in several artifacts, which are methods, constructs, models, or instantiations [38]. The SDLC is a framework that the software development group follows in every software organization [39]. It consists of several steps that are planning, analysis, design, implementation, testing, and maintenance [40]. The Waterfall, rapid prototyping, incremental, spiral, rapid application development (RAD), rational unified process (RUP) and agile software development are few to mention as successful SDLC models [41]. A prototype model is a system development which does not require freezing the requirements [42]. The advantages of the prototyping model are users actively involved in the development, missing functionalities identified early, and errors are detected much earlier [43]. Block diagrams represent components of the transfer function of control subsystems [44].

The impact of RFID technology, conveyor belt, and a robotic arm will have a significant effect on the warehouse. Moreover, it will modernize the current working process and increase productivity in the warehouse. The purpose of this research is to design and implementation of RFID-based conveyor belt on WMS, to speed up the process in the warehouse. The scope of this research is the design of a series of systems using Arduino Uno microcontroller and designed for a box-shaped object with a maximum size of length=6 cm, width=5 cm, Height=4 cm with a maximum weight of 100 grams. The data is stored in MySQL database management system and integrated with API in Web Service [45]. This research uses Design Science Research Methodology (DSRM) and using the prototyping model for system development.

3. Research Method

Figure 1 follows the six stages of classical DSRM that focuses on problem-solving and system development [46]. As can be seen from the picture, the first stage identifies the problems that occurred in the warehouse and we found the problem in one of the warehouses that are in the current process is still difficult to distinguish the type of goods. The purpose and benefits of this research are to simplify the process of selecting goods with the design and implementation of RFID-based conveyor belt on WMS, so the complex warehouse functions become dynamic. The design of solution is made to facilitate us to make an overview of the design and implementation of RFID-based conveyor belt on WMS. Based on the design, the demonstration was built with the aim of testing the developed system to see the suitability of the model with expectations to be achieved. After the demonstration is completed, the test results state that the built system works well because it could lift, identify and sort goods by type. Finally, the author will provide suggestions that can be considered by the logistics company, such as if the design and implementation of this system will be developed in the future.

Figure 2 illustrates the circuit design of RFID-based conveyor belt controlled by Arduino Uno R3 microcontroller. The connected components are RFID reader, buzzer, RGB LED, I2C module, LCD, and servo motors. There are additional components such as the Ethernet Shield used to connect Arduino with the database server. The RFID used in this system is RFID RC522 which designed with relatively low cost and an antenna works in the small frequency band, so RFID tag can only be read with positioned in parallel with RFID reader with a range about 5 cm. There are supporting components in the design of the RFID-based conveyor belt circuit. But this component is not connected directly with Arduino microcontroller; it is DC motor. The DC motor with a speed of 100 rpm is supplied with an external power supply used to rotate the conveyor belt so that it can turn at a constant speed. There is also a robotic arm that is driven by four servo motors; another Arduino microcontroller controls this component. In the robot arm is applied ultrasonic sensors to measure the distance of goods. So, the goods lifted when the range is close to the robotic arm.

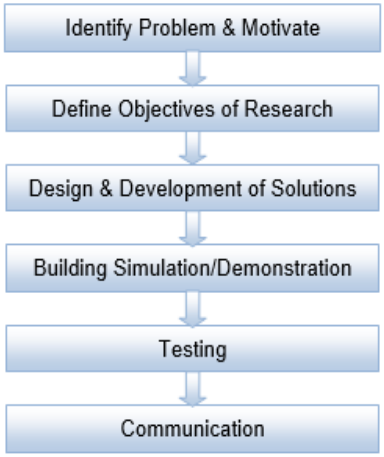

Figure 1. Flowchart of research methodology

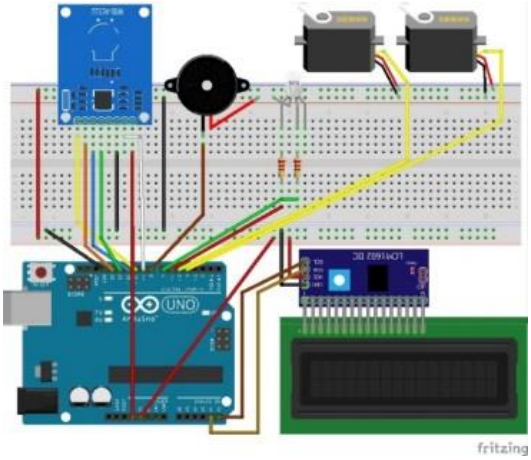

Figure 2. The circuit design of RFID-based conveyor belt

4. Results and Analysis

The functionality test has been performed to verify that the system functions are running as expected. Several experiments have completed, and the results of the tests observed and analyzed by the authors.

4.1. Tests

Figure 3 shows the prototype RFID-based conveyor belt to performed tests, and an Arduino Uno R3 microcontroller controls it. In the first process, the goods placed on the conveyor belt, and it carried over the RFID reader. Then the RFID reader identified the type of goods based on the information of the RFID tag by adjusting the data on the database. After identification is completed, the buzzer emitted a sound, while RGB LED and LCD will inform the result of the identification type of goods. If it is unidentified, the RGB LED will be red, whereas if it is identified the RGB LED will be blue and the LCD will display output the type of goods. After that, the servo motor serves as a selector to direct the goods to storage. At the final process when the goods arrive at the storage, the goods lifted using the robotic arm.

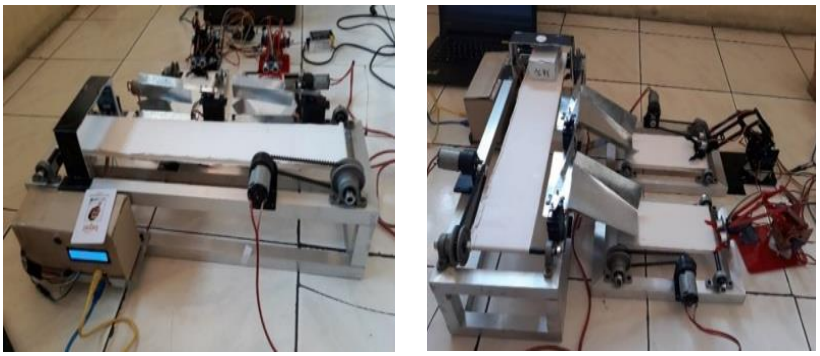

Figure 3. Prototype RFID-based conveyor belt

4.2. Results

Table 1 shows the results of identification of the type of goods displayed by the LCD. The system test was conducted for five experiments, and the types of goods were categorized into three types: type A, type B and unidentified. The results of all system tests with various types of goods are declared successful, and each test is carried out in about 20 seconds.

Table 2 shows the cost of the components used in the design of this system is expressed in Indonesian currency (IDR). The prices shown are the average prices obtained from different local suppliers and online stores. Explanations of other components are pipes, aluminum, bolts, nuts, bearings, pulleys, small wooden stick, gears and small analog electronic elements such as a breadboard, resistors, and jumpers.

Table 1. System Test Results

Type of goods	Process time (seconds)	Result
Type A	18.05	Success
Type B	23.84	Success
Type A	18.68	Success
Type B	23.89	Success
Unidentified	21.87	Success

Table 2. Component Costs

Component	# Units	Cost (IDR)
Arduino Uno R3	2	250,000.00
Ethernet Shield	1	115,000.00
RFID RC522	1	30,000.00
Piezo Buzzer 5V	1	10,000.00
RGB LED	1	15,000.00
Servo Motor MG996R	2	100,000.00
I2C Module	1	20,000.00
LCD 16x2	1	30,000.00
DC Motor 30V 100 RPM	3	255,000.00
Power Supply 24 V 2 A Switching	1	100,000.00
Power Supply 5 V 3 A Switching	1	40,000.00
MeArm V0.4 + Micro Servo SG90	2	500,000.00
Ultrasonic Sensor HC-SR04	2	40,000.00
Other Components	1	350,000.00
Total	-	1,855,000.00

4.3. Discussions

The RFID-based conveyor belt on WMS will make the warehouse become dynamic and information about the goods can be monitored continuously. Moreover, it will modernize the current working process and increase productivity in the warehouse. RFID technology is the answer to various weaknesses that are owned by barcode technology, because it can only be identified by bringing the barcode closer to the reader, and also because the barcode has very limited data storage capacity and cannot be reprogrammed. However, the RFID frequency can be interrupted by the frequency of other equipment, so the chip will respond to that frequency. RFID readers are also difficult to identify RFID tags if the LAN network is not connected. Alternatives are needed to improve system performance in the process of selecting goods.

4.4. Recommendations

There are several recommendations to be proposed for the development of design in this research. Based on the test results required the development of a prototype conveyor belt to meet the standards to be a tool that is ready for use. It takes some other components so that the conveyor belt performance can be better in the future and it is necessary to measure the performance of the conveyor belt, RFID, and other components.

5. Conclusion

After the development of RFID-based conveyor belt on WMS, it can conclude that the analysis has been able to answer the purpose of this research. This system can make the warehouse become dynamic and connected electronically, so the information in the warehouse can be monitored continuously. The system could sort goods running on the conveyor belt according to the information on the RFID tag and use the servo motor as a selector to direct the goods to their storage. This system is one of the solutions to modernize the current working process and increases warehouse productivity with good integration.

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