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Position and Orientation Detection of Stored Object Using RFID Tags

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Abstract

Radio Frequency Identification (RFID) technology already plays a major role in many areas. One of the applications is for object detection. RFID is used for effective object's identification. A good example is object detection at storage management system. It is applicable to the environment where people easily forget the places of the stored object. In the other hand, the automatic object detection will be useful for disabled people like blind person such that they need information before pick up and store object while doing their daily life activities. As a solution of these problems, this study is proposed in order to assist the disabled people by develop an intelligent storage system which has database to store and inform the position and orientation of object stored using the idea of 'Intelligent Space'. In this article, the methodology and experiment validation to determine the position and orientation of object storage will be presented. The system consists of object storage, object shelves, RFID reader, and RFID tags. RFID tags are attached to the object storage. Meanwhile, RFID reader is at fixed position and detects tags' data to obtain the coordinates of stored object. The information represent the coordinate of stored object is located as well as how the object is oriented. The orientation provides useful information to the intelligent storage system which the user may know whether the object is placed in upside down position or otherwise.

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Keywords: Radio Frequency Identification (RFID), storage management system, object orientation, human robot interaction

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1. Introduction

In recent years, because of its ubiquity, radio frequency identification (RFID) technology has becoming the hotspot in the field of object location. RFID systems use radio transmissions to send energy to a tag which, in turn, emits a unique identification code back to a reader linked to an information management system. Moreover, the idea of employing RFID technology for detecting tagged objects on surfaces such as shelves or tables has been investigated for many years now and has reached a certain level of maturity. In retailing, for example, there are already existing solutions available that keep track of goods placed on shelves in real-time such as for replenishment and storage management.

Previous study developed database of information mainly in the home environment using the idea of "Intelligent Space". Intelligent Space extends possibility of home service robot. Main application services are searching and automatic object restoring. The proposed system consists of object case or box, RFID reader, RFID tag, and Arduino board. RFID tag is attached to the object case cover. RFID reader detects tag data and gets information of the stored object box with interfacing of Arduino to software. The receiving information from tags contains box coordinate and indicate the right or wrong of each object's position and orientation through different code. In these studies, the variety of positions and orientations of object stored is limited and they do not consider reliability of RFID tag reading. However, people put on variety of things in object case on shelf, positions and orientation of the stored object's boxes or cases are irregular. So, the information of positions and orientations is significant in order to keep the object's case on shelf in a correct position. In the other hand, it will be easy for robot to grip the box within right position and orientation.

2. Development of Object's Storage Management System

The managing system such as server stores and informs the place of the stored things by using the idea of "Intelligent Space". Home service robot is able to use this system for getting information of stored things and bring them to the user. The system consists of drawer case, RFID tag, tag antenna and tag reader. RFID tag is attached to the stored things. Tag antenna reads RFID tag data and gets information of the objects [1].

In this system, reliability of RFID tag reading is especially important. However, the stored objects in the storage area are varied and the positions and orientations of the attached RFID tags are different according to the posture and the shape of the stored objects. It is necessary to be read RFID tags of various positions and orientations in this system [2]. Basically, hardware used consists of RFID reader, RFID tag attached as object ID in order to identify object position. The software of Arduino IDE is applied where the Arduino board also is used in hardware together with RFID sensor. Furthermore, the database is the central unit for collecting and processing the data. The database is processing manually in Excel. Figure 1 shows the system flowchart of object's storage management system.

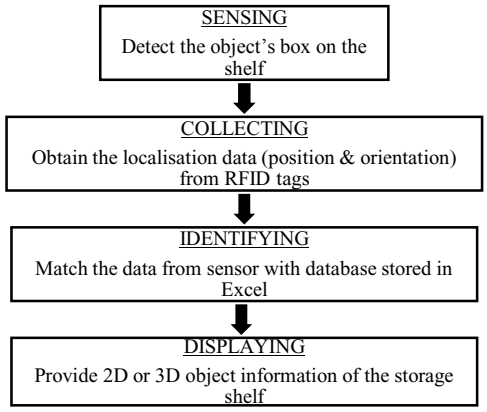

Fig. 1. System Flowchart.

2.1. RFID system components

The RFID system mainly includes three parts, there are reader, antenna, and RFID tag. Because of the uniqueness of the RFID tag, the reader can locate and track the object once it is attached with an RFID tag. Passive tags are used to attach on the object because they are much cheaper, long lived, lightweight and have a smaller foot print. The reader can communicated with host computer through RFID tag reader RS232.

2.2. RFID tags and reader

RFID Reader also known as a Proximity Coupling device (PCD) read a data through the tag antenna at a certain frequency. In case of passive tag then reader generate a radio signal so that passive tag can energized and transmit a signal that can read by the reader. The reader translates the received information and passed to the forwarded system through wired or wireless. A single reader can read the data from multiple frequency based tags. RFID tag known as a proximity integrated circuit card can be powered by actively or passively. RFID tags also known as transponder and one transponder consist of antenna, microchip and battery. Antenna size and form is dependent on the frequency that used by the tag. Active tag can work in absence of reader and records the sensor reading or perform their calculation. Passive tags can operate in presence of reader only [3]. The purpose of microchip is to store the Unique Identification (ID) of each object. The range of RFID tags depends on their frequency. These frequency ranges of low frequency, high frequency and ultra-high frequency are 30-500 KHz , 10-15 MHz and 2.4- 2.5 GHz respectively..

2.3. Liquid crystal display (LCD)

The main purpose of LCD in this proposed design is to display the information like status, coordinate, and welcome message that is stored on the software when tag is read by the reader. The configuration of the LCD used is 16×2.

2.4. Real time clock

The real-time clock (RTC) is a device incorporates a battery input, and maintains accurate timekeeping when main power to the device is interrupted. The RTC maintains seconds, minutes, hours, day, date, month, and year information. The date at the end of the month is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with an active-low AM/PM indicator [4]. The information is displayed in software when the tag's ID detected by reader.

2.5. Arduino board

Arduino Uno board is basically a microcontroller board based on the ATmega328. The function of microcontroller is significant because it can control the process like blinking light, speaker, microphones, sensors, motors and solenoids [5]. Arduino board offers one critical advantage: the open source philosophy for both hardware and software, which capitalizes on the massive non-expert community that has flourished around the Arduino concept [6]. This controller operates between 1.8V to 5.5 volts. In addition, the controller is interfaced with LCD and buzzer, and RTC using various ports. For RFID system that using Arduino board as the platform, IDE software is a need. IDE is a software that be used to program the Arduino boards for certain functions such as to make the LCD displays the object box information.

2.6. Microsoft excel

The database is stored in Excel. The data stored are coordinate in 3D, name of box and object box number, actual coordinate of position and orientation of the object box. The database also collects and processes detected object data manually. The analysis is carried out such as accuracy in sensor data from the database.

3. Methodology

In this proposed system, the experiment approach is used to develop object's storage management system. Ability of RFID tag detection rate is the most important thing and it is necessary to read RFID tags of various positions and orientations, because the object box stored on the shelf is varied and the positions and orientations of the attached RFID tags are in different coordinate according to the object box edge point.

The experimental procedures covers the use of an Arduino Uno board, RFID reader, and RFID tags attached to box cover on shelf for the experiment and the IDE software to obtain the data that been collected from the experiments. Figure 2 shows the hardware components used in this experiments.

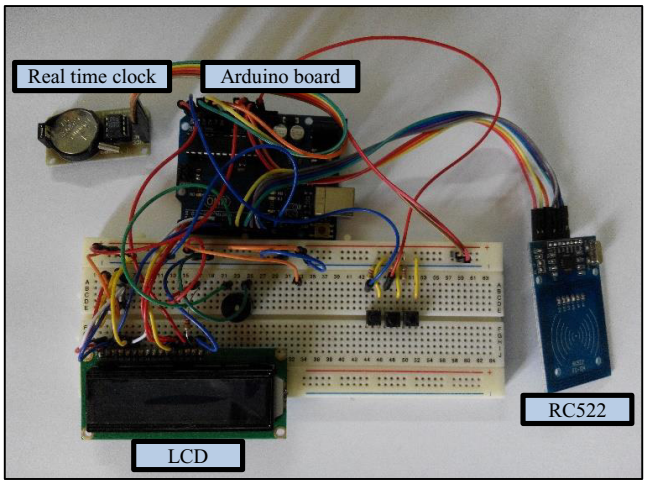

Fig. 2. RFID based system components.

All of the apparatus that been used for the experiments such as RFID reader, Arduino Uno board, RTC timestamp and LCD display can be easily purchased in the market. The data for this experiment is analyzed using Excel manually.

3.1. Experimental procedures

The basic principle of this project started with the RFID reader detecting the box on the shelf. Experiment conducted, the reader is static and mounted at shelf on the object's box. The reader obtained the position and orientation data as well as timestamp from tag's ID. Data obtained is forwarded to Excel and compared with database as reference for the analysis. The Arduino IDE software shows the data signal and object's coordinate is presented in 2D information. Figure 3 shows the experiment environment for this research. The method used to obtain the information from sensor for both position and orientation is determined by the object and shelf coordinates. The coordinates is defined in X and Y axis and 2D coordinates is the dimension of top view for shelf number 1. The RC522 is located on box 1 position and coordinate is defined as (5,0) in shelf 1 as in figure 4. The RC522 is parallel to reference coordinate for box 1. The reference coordinate box 1 is (5,0), box 2 is (25,0) and box 3 is (50,0) as shown in figure 5. The tags are located in the object storage. The coordinate data is stored in each tag, and the tags are mounted at edge of the box. All the coordinates stored in tags represents the dimension of the box. There are 6 tags mounted in box 1 and 4 tags in box 2. Figure 6 shows the coordinates of each boxes and shelf 1.

The coordinate is significant in order to determine and identifying 2D object′s box size. The experiment is carried out for object localization with respect to several cases as follows:

Fig. 3. Experiment area.

A. Position

Case 1: Empty position. There no box detected at box 1 position.
Case 2: Correct position. The box 1 at its position.
Case 3: Wrong position. Box 2 located on box 1 position.

B. Orientation

Case 1: Correct orientation. Similar to position case 1.
Case 2: Wrong orientation. Box 1 in upside down oriented.
Case 3: Wrong orientation. Box 1 in horizontally oriented.
Case 4: Wrong orientation. Box 1 in diagonally oriented.
Case 5: Wrong orientation. Box 1 in half oriented.

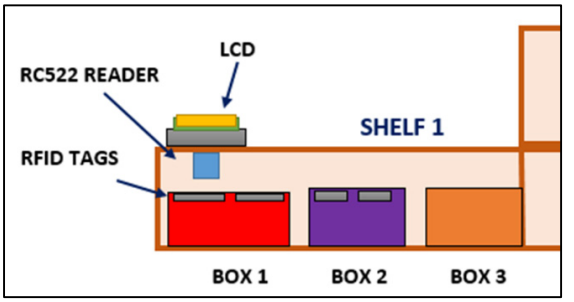

Fig. 4. Front view of storage shelves layout and boxes arrangement in 2D.

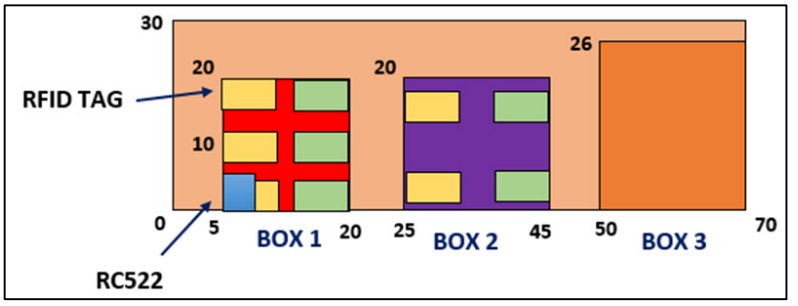

Fig. 5. Reference coordinates for each box.

Fig. 6. The dimension coordinates in each tags mounted.

3.2. Detection range

Detection range of a RFID reader plays a big role in defining tools box location and orientation on the shelf. As the system is developed using passive RFID tag, the average scanning system theoretically is 4 cm of distance. The limitation of RC522 detection range is 4 cm as stated in the catalogue. Experiment was done and the result shows that the reader will only detect object storage which is the nearest and perpendicular to the reader location. In the experiment, the box is able to be detected by RC522, the test for localization and tags distribution were conducted. Then, the analysis also carried out. The RC522 has successful identified and determined box position and orientation. So, the 4 cm distance will allow a sufficient range in order to help the blind people to find the object stored and at the same time it also allows the action of pick up box. Figure 7 shows the experiment conducted to calibrate the detection range of RFID sensor.

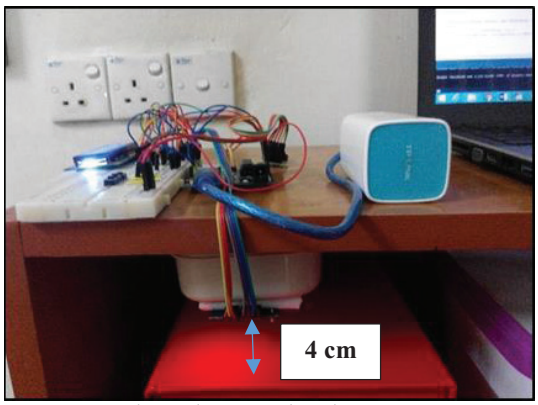

Fig. 7. The RC522 detection range.

4. Result and Discussion

4.1. Position result

Based on the position experiment, when the object storage located on shelf, there are three cases could be detected. The box might be located in correct or wrong condition and no box located on shelf 1. The RC522 is static and parallel to box 1, the box 1 is detected as at right position due to same coordinate with RC522 is (5,0), while the rest will be detected as wrong position. In addition, if there is no box located parallel to RC522, the results will be no detection. The LCD signal displayed the information about coordinate from tags and specified whether the box is located in right or wrong position on shelf 1. Meanwhile, the buzzer gives the signal with single beep for right position and double beep signal for wrong position. The information also displayed on the serial monitor in Arduino IDE with the timestamp data. The collected information from IDE is manually export to excel to match with the

database. The coordinates in database were identified and 2D sketch is carried out and visualized on how the box position is located on shelf.

4.2. Orientation result

The experiment for wrong orientation is classified into 4 types: box 1 in upside-down, horizontally, diagonal and half position oriented. Compared to position case, the wrong orientation occurred when the box is located in correct position but a bit changes in accuracy of box oriented. The correct orientation detected if RC522 reads coordinates (5,0) only, while the rest, it assumed as wrong orientation. When box 1 is located, the RC522 detected coordinate (20,20). Thus, it defined as wrong orientation, due to different coordinate's detection. Then, signal in LCD is displayed status of box oriented. The information of this case is stored in IDE and collected to excel. The 2D result is identified to determine the correct orientation for each stored object. Also, the buzzer gives the double beep signal to acknowledge the user about stored object is placed in wrong orientation. Table 1 illustrates the orientation result for each case.

Table 1. Orientation experiment results

Orientation	**Trial 1**	**Trial 2**	**Trial 3**	**Average**
Desired	Correct	Correct	Correct	Correct
Upside down	Wrong	Wrong	Wrong	Wrong
Horizontal	Wrong	Wrong	Wrong	Wrong
Diagonal	Correct	Wrong	Wrong	Wrong
Half	Correct	Wrong	Wrong	Wrong

4.3. RFID tags distribution on the object

Based on the experiments, number of tags attached to the object's case is analyzed. The 8 tags mounted shows better result to detect the box position and orientation compared to 6 tags. All box surfaces should be covered by RFID tags to identify the position of box and orientation. The 8 tags are sufficient to cover box 1 surface as shown in figure 8. The detection of box orientation is more accurate because if object is in wrong orientation even in range of 1 cm, the box could be detected by RC522. Summary of the analysis for 6 tags and 8 tags is presented in table 2.

Table2. Differences between 6 and 8 tags used.

6 TAGS	**8 TAGS**
Not all surfaces covered by RFID tag	All surfaces covered by RFID tag
Some coordinates of surface could not be detected	All coordinates could be detected by reader
Able to determine position of object box, orientation result is inaccurate.	Able to determine and identify box position and orientation accurately
Capability reader detect some coordinates	Capability reader detect all coordinates and more effectives

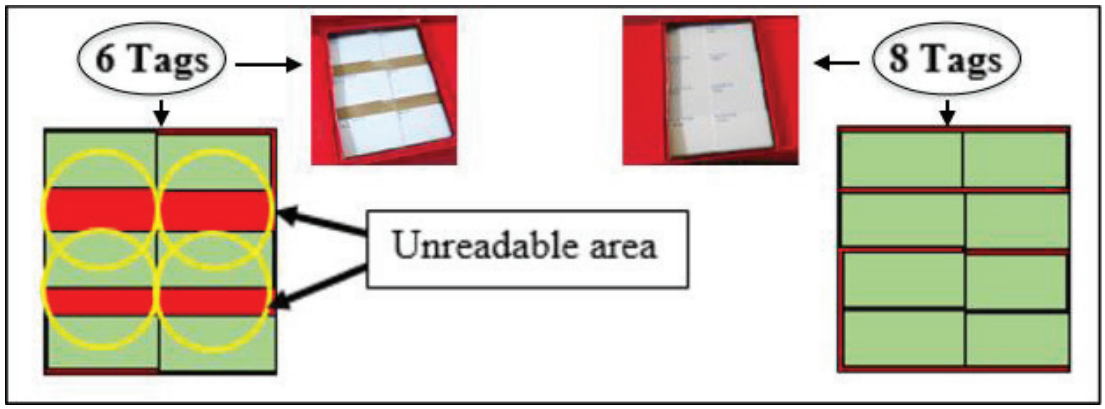

Fig. 8. Experiment conducted for 6 tags versus 8 tags attached to Box 1.

5. Conclusion

RFID based technology definitely has increased effectiveness and improved efficiency for storage management system. Arduino platform system becomes faster in response to collect information data.

In this study, the objects storage management system is practical to apply within RFID technology. The automatic storage system can be applied for some applications such as home service robot and in assisting blind people to get information before pick up object or locating object at the shelf. Besides, the system may monitor the localization of objects thus help the user to retrieve back the information when they forget.

In this system, shelf is used to store object's box that embedded several RFID tags onto it. RFID reader is attached at shelf above box 1 to set the global reference coordinate. Information of stored objects has to be read reliably. All the RFID tags are successfully detected by reader RC522. Moreover, the position and orientation also can be identified through coordinates reading. The information obtained is provided with 2D and transform into 3D. The result shows that the storage system is effective with greater number of RFID tags are mounted. The unreadable area of RFID tag is identified for fewer number of tags used. Therefore, if many tags are used, the accuracy and effectiveness of object detection will be increased.

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