Framework to Develop the Customized Tool for RFID Experiment

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Abstract

Radio Frequency Identification (RFID) technology has been adopted and widely used in many applications including agriculture, forest industry, hospitals, highway transportation, and manufacturing industry. Due to its advantages such as tracking and real-time monitoring. RFID technology uses the tag to store limited data that can be read by RFID reader through the antenna. Passive RFID technology is commonly used in industry because of no power source requirement on the tag. Most of current RFID manufacturers provide the software that can help user to collect the data and control the reader such as transmission power. The data available from such a software is simple and limited to reading count of Electronic Product Code (EPC) number without the log. However, more factors are involving in RFID communication such as receiving signal strength, user data, and etc., which are not available at the providing default software. Besides the default software, manufacturer also provides several other resources such as modules that can be implemented to collect more data such as receiving signal strength, EPC value, and user data, control the reading rate and transmission power, and create a log. In this paper, we identify the collectable data and adjustable parameters. Then, we investigate the available resources by the manufacturer besides the software and illustrate the developed tool to collect the data such as success rate of EPC and user data readings. Then, we present the experimental setup and the results with various reading distances and angles. We also discuss how it can be implemented in class.

1. Introduction

Recently, Radio Frequency Identification (RFID) has received a great attention and widely adopted and popularly used in many applications such as agriculture, forest industry, hospital, toll way, manufacturing industry, etc. The advantages of RFID usage in those applications are mainly tracking and real-time monitoring [1-3]. The traditional method used in industry was barcode, which has several disadvantages such as line of sight reading, limited data storage, and non-programmability [4]. Instead, RFID uses a tag that communicates with reader using near distance wireless communication. In addition, it can store the data that can be read by RFID reader through its antenna. There are three components in RFID system; one is antenna, another is reader, and the other is a tag or transponder. Two types of tags are available, active and passive. The active tag requires battery powered while the passive tag requires no power source. Because of no power source requirement, passive RFID is commonly used in industry.

In passive tag RFID, the tag uses the electromagnetic energy transmitted from the reader instead, which creates significant interference between readers. Therefore, many literatures focused their study on electromagnetic interference (EMI) [5,6]. However, noise is another important factor in wireless communication, which may impact on the reading rate in RFID, because RFID uses the small range wireless communication to read the transmitted data from the tag. Several researchers focused on investigating its effective range of the readings in different set of testing conditions including conveying belt in the manufacturing process [7,8]. They use the two distance factors to measure and compare the RFID reading in different tag locations. Reading rate in various temperature and distance between tag and reader has been observed in [10].

The reading rate is especially important in manufacturing industry because the higher reading rate can speed up the manufacturing supply chain and improve the productivity. Therefore, most of literatures paid more attention to improve the reading rate and providing application in RFID focuses in reading Electronic Product Code (EPC) and user data with some other features such as transmission power control. However, more useful information is available from RFID. In this paper we introduce how to develop the system to directly interact with RFID and available reading information from RFID.

The rest of the paper is organized as follows. In section 2, we describe the system and experimental setup and define the varying factors with measuring metric. We illustrate and discuss the results in section 3. Then, we present the conclusions in section 4.

2. System and Experimental setup

RFID system requires several equipment and tools besides the reader, antenna, or application. In this section, we introduce and explain how to build the system. Then, we discuss what types of data can be collected from the system and illustrate data collection using the system.

2.1 System requirements

The system needs several equipment and tools with requirements such as PC, Operating System (OS), database, compiler, and etc. In order to retrieve the more detail information in RFID reading, we will have to access the raw reading data from RFID reader. For the direct communication, RFID manufacturer provides the library modules. We implement these communication modules to send the commands and receive the raw data. Most of RFID manufacturer such as GAO and ALIEN provides the communication modules upon request or in their websites in JAVA or C#. These modules allows the direct communication using send and receive function. There are four primitive modules in general, connect, send receive, and disconnect. Connect module initiates and establishes the connection from PC to RFID reader. Send module enables user to send the commands to the reader such as reading and transmission power level. Receive module receives a data from reader to PC. Disconnect module terminates the connection between PC and reader.

The first step to use above modules is a physical connectivity between PC and reader. There are several physical connections are available in most of RFID reader, such as serial port, Ethernet port, Wi-Fi, or Bluetooth. In general, all physical connections work good with most of OS, but some types of RFID reader may need special requirement for certain connection type. For example, UHF RFID reader from GAO requires 32-bits of Windows OS to use the serial port connection. Once the connection is established, it can control the reading time and data collection. The collected data can be stored in log file or database depending on the application. For example, real time monitoring, which uses web-based application, may need to use database.

2.2 System setup and data collection

Now, we describe the system setup for our experiment study. We use the UHF 860-960 MHz Bluetooth USB Handheld Reader/Writer' from GAO RFID. This device is passive and its operating frequency is 860 to 960MHz. At PC, we installed several software to run the application, store the data, analyze and display the result. We used Eclipse to write and run the code, MySQL to store the collected data, Apache HTTP server for web-based application, PHP to write the web-based application. For the physical connection, we use the Bluetooth since the serial connection requires 32-bits of Windows OS. The database to store and analyze the data. All received reading data are stored in database first with several attributes such as reading error, reading time, and etc. In our system, there are 6 data flows, send command, transmit signal, receive signal, receive data, store data, and data query as shown in Figure 1. The stored data in database are used later at the web-based application to analyze and display the data.

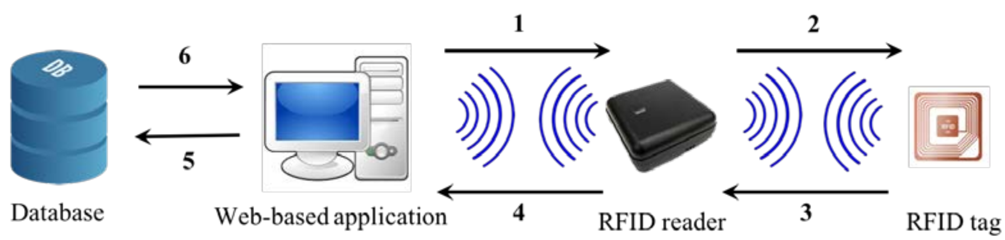


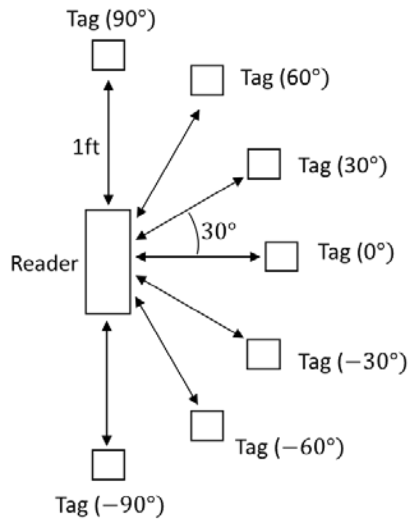
Figure 1. 6 Basic data flows, 1: send command, 2: transmit signal, 3: receive signal, 4: receive data, 5: store data, 6: data query

2.3 Experimental setup and measuring metrics

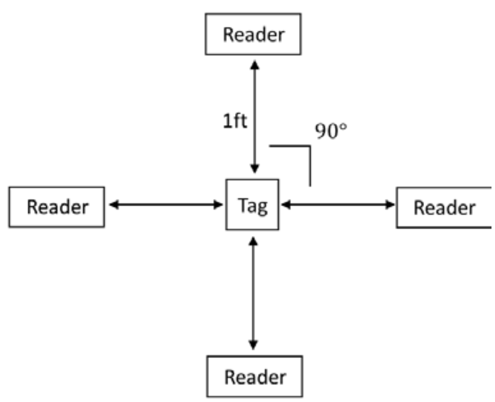
We use above system to examine the success rate for both EPC and user data readings. We schedule the reading interval and measure the success rate of each readings, EPC and user data. According to the manufacturer, RFID reader only displays the correct format of reading. If the reading format is not correct in any case, it would not be included in readings. Therefore, exclusive readings are not included in our success rate measurement. The reading interval is 1 second (i.e., 1 reading per second) and we maintain the same transmission power levels. We vary the distance and angle to collect and compare the success rate. Three experimental setups are selected. First, we varied the distance between tang and reader from 0.5 ft to 5.5 ft with 0.5 ft intervals (i.e., D = {0.5, 1, 1.5, …, 5.5 ft}) as in Figure 2 (a). Second, we varied the tag angle. The reader is placed in center and we place the tag in 7 different angles (i.e., A_T = {-90° to 90°}) as in Figure 2(b). Last, we place the tag in the center and place the reader in 4 different positions (i.e., A_R = {0, 90, 180, 270°}) as in Figure 2(c). When we change the angle of tag or reader, we maintain same distance between tag and reader (i.e., 1ft). In each setup, success rates are computed with 10 sets of 100 readings. One tag is used for the reading test and it checks for an error in each reading. For every 100 readings, the success rate is computed by dividing the number of successful readings by total reading (i.e., 100 for each set). Success Rate (SR) is in equation (1). In each test, we compute three SRs, EPC and user data, EPC only, and user data only. SR in EPC and user data counts successful reading only when both EPC and user data are read without an error.

$$SR = \frac{Reading\ without\ an\ error}{Total\ number\ of\ readings} \quad (1)$$

(a) Experimental setup for various position of tag in distance



(b) Experimental setup for various position of tag in angle



(c) Experimental setup for various position of reader in angle, $A_R = \{0, 90, 180, 270°\}$

Figure 2. Three experimental setups in (a) distance, (b) tag angle, and (c) reader angle.

3. Results and Discussions

In this section, we present our experiment results of success rate in various distances and angles for 10 sets of experiment. In each set, success rate is computed from 100 readings and 10 success rates are averaged in the result.

3.1 Results

Here, we present the success rates for various distances and angles described as in section 2.3. Figure 3 illustrates the success reading rate in 11 different positions of tag from the reader (i.e., D = {0.5, 1, 1.5, …, 5.5 ft}) for three sets of results. The results show that the highest SR for all case is at D = 0.5ft. EPC reading shows highest SR of 97.7%. User data reading reaches highest SR of 95.1% at D = 0.5 and 1ft. The highest SR of EPC and user data pair is 93.9% at D = 0.5ft. The lowest SR for all cases is 0% at D = 4.5ft. However, SR for all cases increases slightly further away than 4.5ft (i.e., averagely 3% at 5ft or 22% at 5.5ft). In overall, EPC only reading shows the highest SR, the second is user data only, and the lowest is a pair of EPC and user data. In addition, SR decreases by the reading distance and SR drops more sharply after 2ft of reading distance.

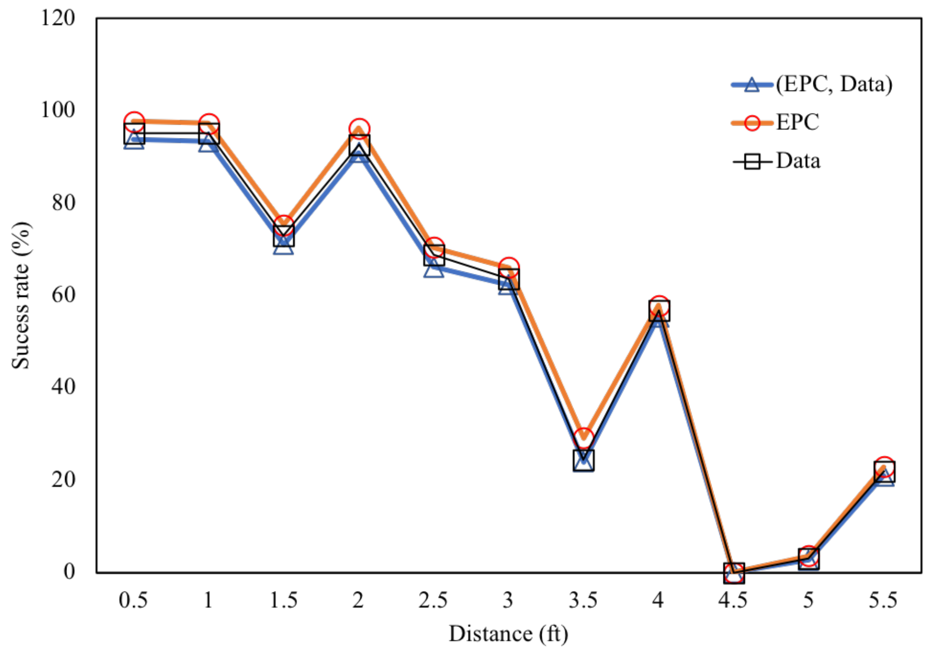


Figure 3. Successful reading rate (SR) in 11 different distance positions of tag from the reader where D = 0.5ft to 5.5ft.

Now, we present the results of success rates (SR) in seven different angles from the reader, A_T = {-90°, -60°, -30°, 0°, 30°, 60°, 90°}, of which results is shown in Figure 4. Overall reading within 30° in both direction shows higher successful reading, higher than 98% for all cases. The highest success rate (SR) is 98.7% at 30° in EPC only reading while the lowest success rate (i.e., 88.9%) is in EPC and user data reading at 90° of angle. The difference between highest and lowest is approximately 6% in all cases. For all angles, success rate of EPC only shows significantly higher than other two cases (i.e., EPC or EPC and user data).

Figure 5 illustrates the success rate in four different positions of reader from the tag. The reader locations are in 0°, 90°, 180°, and 270° from the tag. The highest success rate is 98.1% in EPC only reading at 270° while the lowest is 92.8% in EPC and user data reading at 0°. In all cases, the highest success rate is in 270° position of the reader from the tab. The difference between highest and lowest success rate is approximately 2% overall. Therefore, there is no significant change in success reading rate in all cases for all four positions of reader.

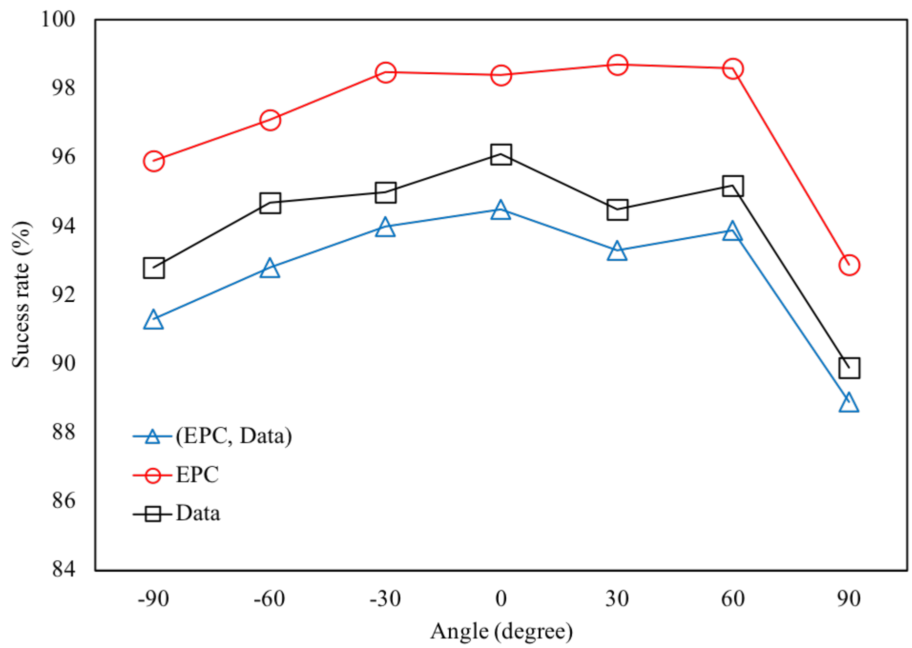


Figure 4. Successful reading rate (SR) in 7 different angle positions of tag from the reader where A_T = {-90°, -60°, -30°, 0°, 30°, 60°, 90°}.

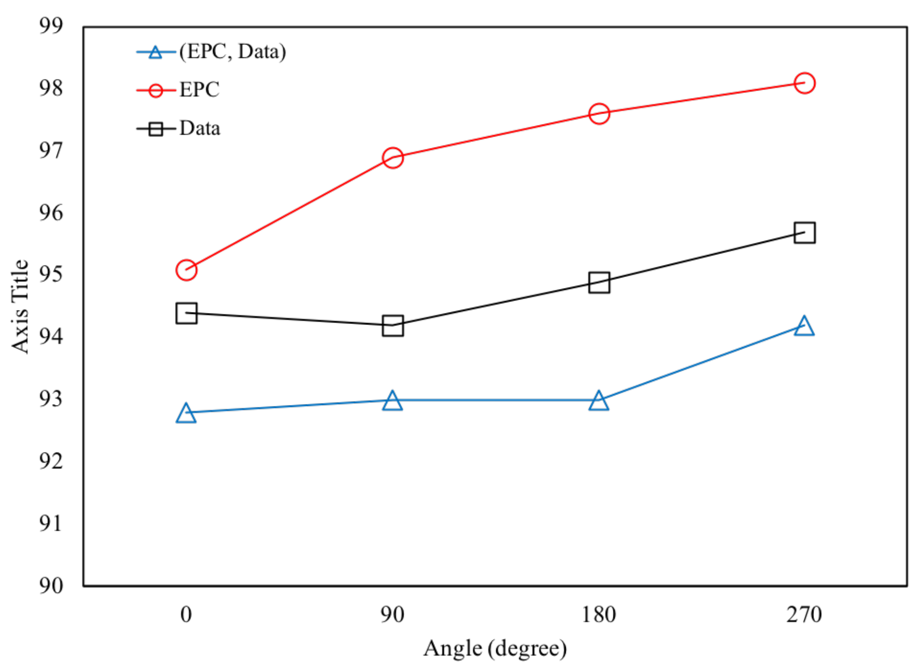


Figure 5. Successful reading rate (SR) in 4 different angle positions of the reader from the tag where $A_R = \{0°, 90°, 180°, 270°\}$.

3.2 Discussions

In our experimental study, we compare the successful reading rate in various tag and reader position in distances and angles. When the tag moves away from the reader, success rate decreases in general. In the range of distance 0.5 to 5.5ft, there are three sudden drops (i.e., 1.5ft, 3.5ft, and 4.5ft) for all three cases. The average drop rates are 22.2%, 38.2%, and 56.7% at 1.5ft, 3.5ft, and 4.5ft respectively. Significant drop occurs at 4.5ft where the success rate is 0%. It implies that error occurs less when the tag is closer to the reader. When the tag is positioned in different angles from the reader, our results shows that the least number of error occurs when the tag is facing within 30° in both direction approximately. When it move away from the center line of the reader, error tends to occur more. Therefore, the tag should be placed close to the center line of the reader for the correct reading. When the reader is located in different position, there is no significant difference. The difference of maximum and minimum success rate is averagely 2%. For three cases of readings (EPC, user data, EPC and user data), EPC only reading shows the highest in all experiment. Our results shows that the error occurs the most in EPC and user data reading.

We compare the success rate with reading rate at room temperature from [10]. It shows that the trend of reading rate by distance does not follow the success rate. This implies that the success rate increases when it reads the tag in slower rate, 1 reading per second in our experiment. There are three sharp dropping in success rate by the distance, however, it decreases more linearly by the distance than the reading rate. Therefore, success rate is more sensitive in the distance than reading rate. The success rate in EPC only is the highest while ECP and user data reading is the lowest in all experiment. In each reading, reader reads the EPC first and then reads the user data. Our results indicates that the more error occurs in user data reading than EPC reading. When it compares with EPC and user data reading, it shows that the error could be occurred either EPC or user data. Error occurrence in user data does not imply the error in EPC reading.

3.3 implementation in classroom

Software provided by manufacturer is usually used by student to measure and collect a data from the experiment. In general, these software have a limited functionality and students have to do an experiment one by one for each test. Therefore, it would be beneficial to student to learn how to interact with hardware and automatic data collection for experiment. There are two-fold in this framework, which can be implemented in class. One is interaction between hardware and software, the other is automation in data collection. In interaction between hardware and software, students will learn how to manipulate the given set of functions provided by manufacturer into the code for the actions for input, output, and actuation of the hardware. In automation, students will learn how to automatically collect and store the data from experiment.

This framework can be split into two parts and used for two labs or one semester project. In first lab, instructor can teach what are the available functions provided by manufacturer and functionality of each function. Then, usage of each function should be taught. In second lab, instructor can introduce how to setup database and write a code to run to collect and store the data. For a semester project, it can be group project and 3-4 students will be appropriate for each group. Instructor can provide with minimum information such as experimental setup, available functions from manufacturer, and etc. There are variable ways to store the data, therefore, it would be better to let student choose the method and compare theirs with others.

4. Conclusions

Passive RFID technology is widely used in many applications due to no power source requirement on the tag and ease of its usage. The tag uses the electromagnetic energy transmitted from the reader. Most of research in RFID focus on reading rate, number of reading per one time unit. However, reading error may occur and it may be included in RFID reading. In this paper, we present how to access the raw data from the reader and analyze them. From the raw data, several types of data is available, EPC, user data, and receiving signal strength. We use EPC and user data to identify the error and compute the success rate to compare in several different experimental setting.

Our results show that the success rate decreases by the distance in general. The error tends to occur more when the tag moves away from the reader. The reading angle within 30° in both direction makes more reliable reading. Comparing EPC, user data, and ECP and user data, EPC reading is more reliable than other two readings. When success rate is compare to the reading rate, success rate, success rate decreases linearly by the distance while the reading rate varies more widely. When the tag is closer to the reader, success rate increase while the reading rate shows significant drop if it is too close (i.e., 1ft). This implies that the slower reading rate in closer distance will help in more reliable reading. Error rate or success rate may be used for distance prediction. The other raw data we can retrieve is receiving signal strength. In general, error rate and receiving signal strength varies with the distance, temperature, and etc. Therefore, the passive RFID could be used for the environment prediction.

For the class implementation, it can be split into two parts such as interaction between hardware and software and automation in data collection. Therefore, it can be used in class as two labs or a semester project.

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