

# GIB 2

# **RFID Low Cost Book Tracking System**

CSE Final Year Project

## **Final Report**

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**GIB2**

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## Abstract

Books tracking and organizing have always been handled by Barcode systems. Major problem is that these systems cannot provide any real time location. In a library system, only a rough tracking location is provided according to where a book should be allocated ideally. A book is not likely to be found if it is misplaced accidentally. It is also the reason large scale reorganization is performed regularly in any well-organized library. Long term running cost is another issue for such systems because each book needs to be scanned and inserted in designated areas manually.

In this project we have developed an automated Book Tracking Prototype using RFID that can provide real time information of books. The hardware RFID system consists of passive tags and 4 RFID readers. This project improved a typical RSSI-based trilateral localization algorithm for calculating location with RSSI data. The new algorithm used the idea of Shadow overlapping, in which could compensate insufficient accuracy in low cost RFID readers. Data preprocessing to further reduce hardware inaccuracy was also introduced. Mobile and Desktop applications were also developed. Users can access book locations remotely using the apps. This prototype provides a cheap alternative to existing Book Tracking systems in Library with low long-term running cost.

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# 1. Introduction

## 1.1 Overview

Barcode system is widely used not just in book tracking systems, but also in places like offices or medical facilities [1]. Barcode systems cannot provide any real-time location of books and are often costly to operate in the long run because the manager need to scan the labels manually. Automation and real-time location are often demanded in tracking systems nowadays. Using barcode for book tracking is no longer the most economical solution to library systems.

A better low-cost alternative is available for book tracking and tracing as Radio-Frequency Identification (RFID) technology [2] is becoming affordable. RFID systems can provide real-time location and organize items within a designated area without the need for manual inserting/scanning [2]. There are 2 types of tags - Active and Passive. Both can offer location information. While active tags regularly send signals (RF) to the reader, they are expensive compared to the passive ones. Passive tags only react when there's a signal request from the reader. However, it's cheaper to operate, considering a large number of tags is needed in a book tracking system. Frequency range affects the detection range between tags and readers. In general, readers with higher frequency have better detection range but also more expensive. [3]

Our project aimed at providing a feasible automatic book managing solution to client users. The designed system is targeted for indoor areas. Users can easily access location information by Mobile and Desktop apps.

This project focused on developing an RFID- tracking prototype for a relatively small-scaled area. This system, however, has the potential to be scaled up for book tracking or complement the current system in the library.

## 1.2 Objectives

The project was divided into three main parts: (1) RFID tracking system, (2) Website application that allowed access to book tracking system and related information, and (3) Mobile application that supports the Android platform.

RFID systems consisted of 3 main components: readers, tags and data processing systems. [4] Each RFID reader module was embedded with a WIFI module and microcontroller. A passive RFID tag was attached to each book. Readers could automatically identify and track tags within the reading range upon request. Collected data was stored in the database through the WIFI module.

Book information was accessible through website and mobile apps. Users could borrow and return books by apps as well.

## 1.3 Literature Review

### 1.3.1 Different existing Tracking technologies

There are different existing tracking technologies apart from RFID. However, they all tended to exhibit constraints which fail to be a low-cost, efficient tracking system.

The Global Positioning System (GPS) has been extensively used to identify the location of people, vehicles, and objects. This technology is useful in tracking and localization in large areas. It is excellent for users to navigate on roads and neighborhoods. However, GPS is not a suitable technology for this project because it is expensive. GPS work great in a large-scale environment to provide approximate location coordinate, but it cannot provide a precise location in a small-scale environment. Furthermore, some places do not have good GPS signals [3]. GPS is also often inaccurate for tracking in small areas compared to RFID technology.

Another existing option for asset tracking is Bluetooth Low-Energy Tracking Technology (BLE) [4]. This technology carries out tracking by using battery-powered tags to emit their unique identifier continuously to readers. This technology is not considered in the project because BLE tags have a much higher cost and shorter lifetime compared to passive RFID tags.

The WIFI Real-Time Location System (RTLS) is another widely used asset tracking technology. In the system, the tags attached on objects transmit WIFI signals to multiple access points throughout the area by tags, and the location of the tags are calculated by differential-time-of-arrival and signal strength. The system provides precise results for tracking. However, the system is not used in this project because the system requires an infrastructure that supports time-of-arrival (TOA) algorithms, which will pose a huge location constraint for our project [5].

### **1.3.2 Current existed book tracking system**

This paper illustrated an existing Book Tracking System with passive RFID technology [6]. The borrow-return system of the system is simple and practical. It sends a mobile message to the user whenever the user borrows books or return books. However, the location of the required books is not clearly shown in the graphical user interface. Improvements can be made by showing the accurate location of the book on a map in user interface.

### **1.3.3 Other similar tracking system with the use of RFID technology**

A paper illustrates a student final year project design with the use of RFID for a learning factory at low cost. The project design is quite like the final product we hope to achieve, and hence there is a lot of ideas that can be considered as reference for this project.

All RFID systems consider the main 3 components: tags, readers and data processing system. [7] Tags are divided into active and passive tags. The main difference is that active tags can actively send out Radio Frequency signal to communicate with RFID reader. In the paper also addressed that frequency range affects the detection range between tags and reader. Higher frequency often results in better detection range. [8]

For this project, since our prototype will work on a relatively small-scale environment, a low frequency range system will be used. And for the same reason, passive tags are enough in this project.

The low tracking system used in the system will make use of the Master-Slave concept. [7] Each RFID reader is connected to a microcontroller. Several microcontrollers are connected to a central database. The system can distribute workload to less powerful microcontrollers that can significantly reduce process time and workload on a single computer. This technique is important in achieving a low tracking system, and especially when extending this tracking system to a larger scale for future development.

### **1.3.4 Enhance reading range in RFID system**

The RFID technology is a solution for developing a low-cost tracking system. However, the current existing RFID tracking systems still have several challenges. The reading range of tags is one of the major challenges in the RFID system.

Due to the physical limitation of passive tags, it is more efficient to enhance the RFID system by using a higher gain reader antenna. Gain is usually increased by increasing the size of an array or multiple layers with air gaps [9]. Researchers have suggested that a flat reflect-array has been applied to the frequency higher than 10 GHz, but their design required a structure size is 40 cm x 1 m x 6.15 cm, which is too large to propose in the indoor environment such as office and library [10]. Another existing approach is to enhance the reading range of tags, the study illustrated that the bit error rate (BER) of the reader should be minimized for a given reader transmit power, the tag BER of readers are directly related to the "distance" of the reflection coefficient [11].

As a result, this project would like to enhance the reading range by focusing on three categories by increasing the number of RFID antennas, the number of RFID readers and improving BER at the RFID reader [11,12].

This project will make use of RFID technology to build an embedded system. Considering the scale of our prototype, passive tags, and shorter frequency will be used in the project. The embedded system will work with android apps and desktop application for more practical and user-friendly features.

## 2. Design

### 2.1 System Overview

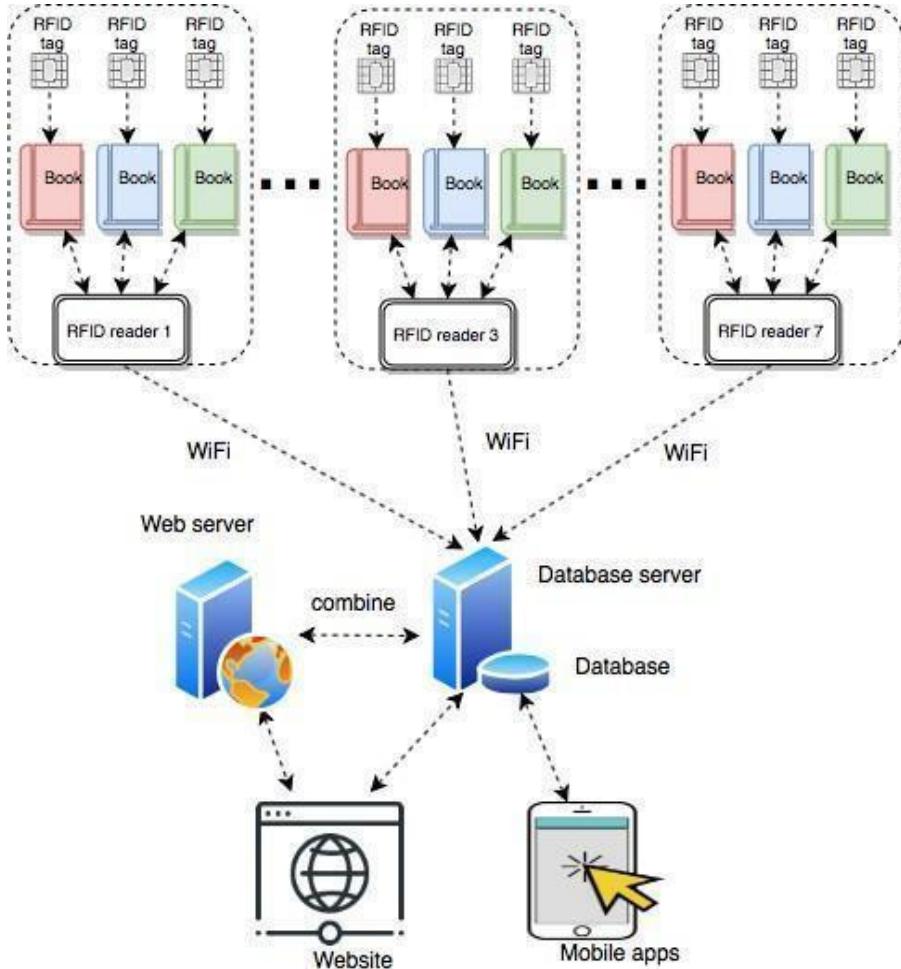


Figure 1. Overview of prototype design

The figure above showed different parts of our project, how they were connected and designed. For the overall picture of the design, it included RFID tags, RFID readers, Server, Website and Mobile Application. RFID tags store the book location and information. RFID readers were responsible for receiving/reading the tag data. After setting the reader to be the client (service requesters), the reader could automatically transfer data through the WIFI module(embedded). Of course, there needed to be an API to receive data transmission via TCP / IP method and saved it to the database. The book tracking and management system based on our database.

Server and database were set up to collect and organize data from RFID readers. Website and Mobile Application provided a user-friendly interface to track books. Users could utilize the above platforms to get relevant information such as the location of a specific book and book information.

## 2.2 Hardware Design

All books must be steadily identified and tracked. Radio Frequency Identification (RFID) Technology was the best choice for our project. It is a wireless communication technology, which utilizes electromagnetic fields.

### RFID reader



Figure 2. Reader with embedded WIFI module

Multiple readers were needed in this prototype. Our plan was to build a relatively small prototype rather than a production-scale product. Reader models with shorter reading distance were used instead in order to reduce production cost.

## RFID tag

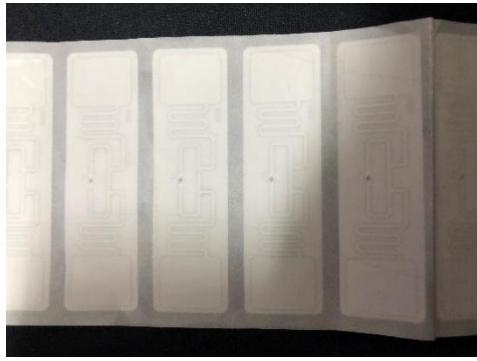


Figure 3. The Passive RFID Tags

RFID tags are small, flat devices that can provide a unique set of identification code and a small amount of memory storage space. For data transmission, it utilizes radio waves to communicate with the RFID reader.

There are mainly two types of RFID tags, i.e. active and passive. Active tags are battery-powered and have a longer reading range but are often quite big. The passive tags, although with no internal power source, are cheaper than the active ones and shape is like stickers. Passive RFID tags were good enough for our current prototype for its low cost and size. UHF RFID tag was used.

## RFID Tracking system setup

When RFID readers sent a radio frequency signal to tags, a response signal were returned by tags. RFID reader had an embedded Wi-Fi module. Therefore, the data was able to transfer to the server through WIFI. To receive data, we developed an API over TCP/IP interface. Tags were stuck at the back of books for book tracking and allows connections to physical space.

## 2.3 Software Design

### 2.3.1 Algorithm for location calculation

A reader can only send RSSI that indicates how close a tag is. However, it is not the location yet. An algorithm was needed to process 4 RSSI data from 4 readers respectively to calculate a tag location. Also, since the readers were not accurate enough so that results in fluctuation of data even a tag did not change location. A data processing procedure was needed to compensate for possible errors. The tracking system at the end still maintained a relatively good tracking function while maintaining low cost.

### 2.3.2 Server

A channel was needed to communicate with the database after receiving RSSI values from the RFID setup. Servers played an important role as a medium of network. They were responsible for processing requests as well as providing services within regional networks and to other regional networks.

Database Server and Web Server were used to operate the database and website, respectively. Database Server was a channel that allowed users to obtain database data. Web Server was responsible for storing, processing, delivering web pages to clients and handling network requests over HTTP.

Nowadays, these two servers were usually combined into one, and this project intended to combine them as well.

### 2.3.3 Database

Database was used throughout the project. It allows data sharing across platforms (RFID readers, Web and Mobile Apps). Users could read or modify the database through Website or Mobile Apps based on their permission level.

MySQL was used to build the database because of its flexibility and open-source features. These characteristics allowed us to fully customize and add unique requirements to the database server during development.

### 2.3.4 Desktop Application - Website

A combination of Ajax, HTML, CSS, PHP, jQuery, and JavaScript were used for front-end development to create user interfaces. For Backend, a convenient and suitable MVC architecture software is necessary. Both Drupal and Laravel can be a good choice. However, Laravel was chosen instead for our website framework structure because it is more flexible than Drupal. This is a free open source framework. Although it does not include a developer-oriented GUI like Drupal (e.g. constructing queries and designing static APIs), all models, views, and controllers are easier to be customized.

For website debugging, a local host was used to run the server, and web browsers can display content and assist for debugging. Mobile version used Google Chrome extension-Mobile Browser Emulator for debugging.

### 2.3.5 Mobile Application

A Mobile Application that worked well on mobile devices was another important part to enhance users' experience in this project. In this project, only Android Apps would be developed. IOS version was not considered in the initial planning because the review process of Apple Store was

too complicated and time-consuming.

Android Studio was the main development tool for the apps, and Java Language were used. APK files would be downloaded directly to Android devices for checking real-time functionalities. Built-in Emulator in Android Studio has been used for testing and debugging.

## 2.4 Data Model Design

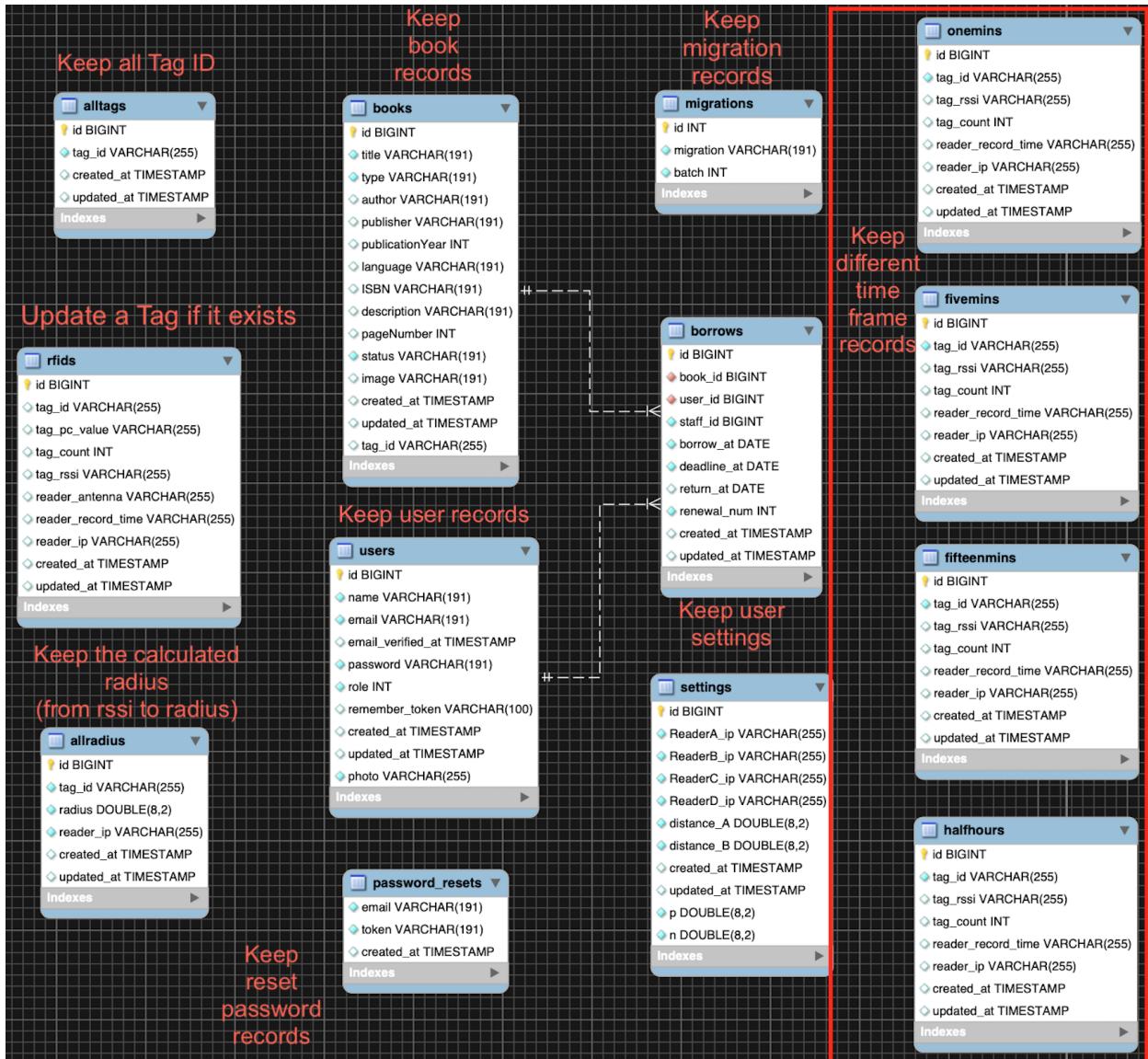


Figure 4. Design Overview of data model

The data model had changed a lot during the development process. For instance, some tables were created to store the raw data from RFID readers within a time frame such as 1 minute, 5 minutes, and 30 minutes. If the system was in the tracking state, the "rfids" table continued to update the passive label data (if it already exists) instead of inserting new row data. The "settings" table stored the reader's IP address, the reader's setting distance, the reader's Tx power, and the path loss index. Users can update these data to make the system more flexible. The "allradius" table stored the radii converted from rssi values obtained from different reader ips. The "alltags" table retained all registered rfid passive tags that the system was using.

## 2.5 Web View Page Design

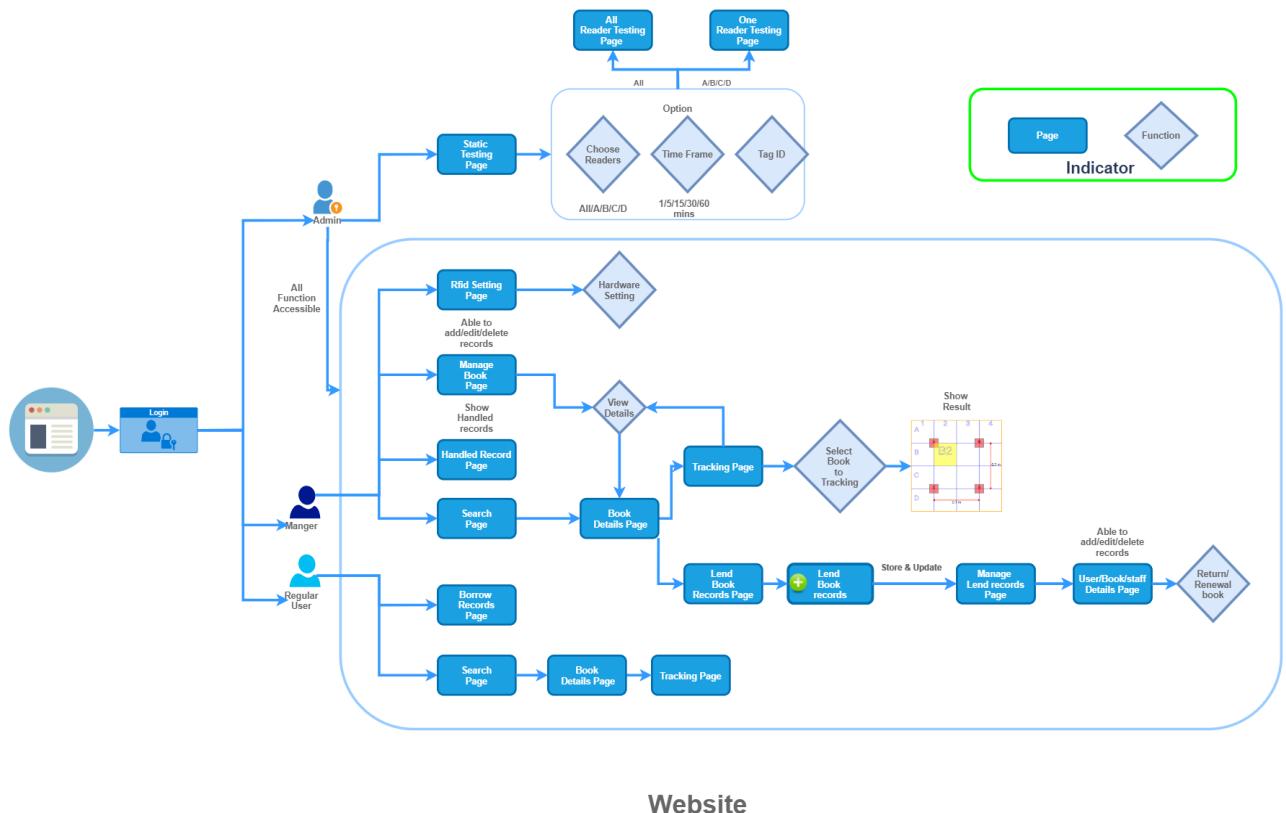


Figure 5. Website view page hierarchy diagram

The figure above illustrated the structure of the entire website, more details were included in the implementation section.

## 2.6 Mobile Application View Page Design

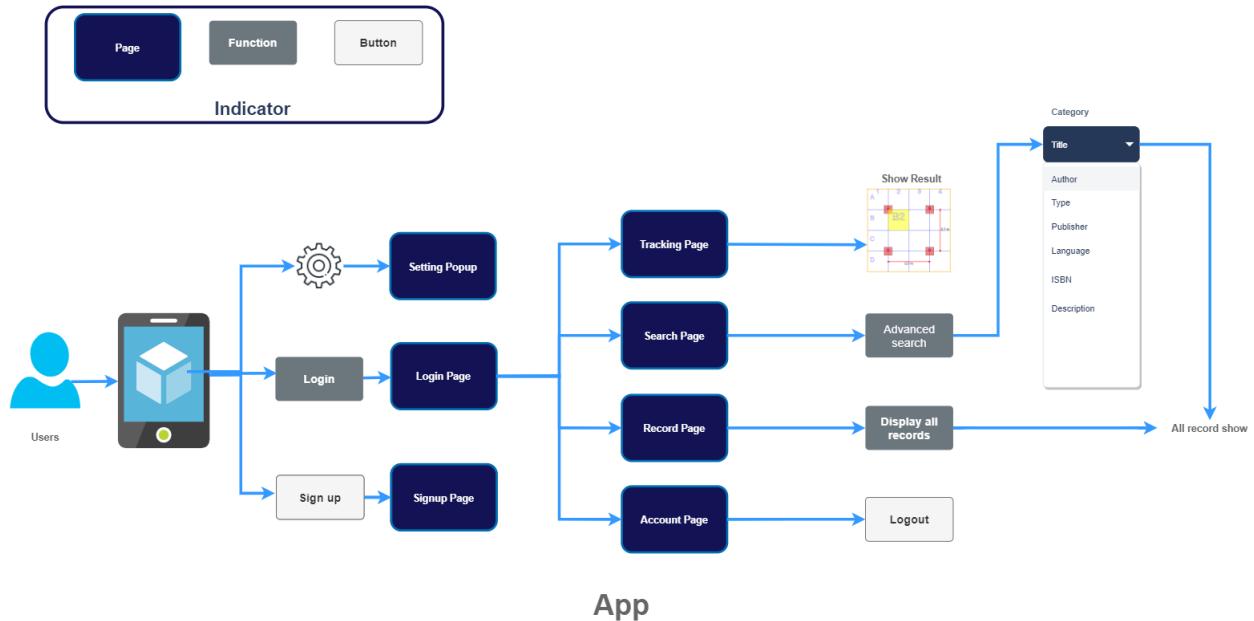


Figure 6. Mobile apps view page hierarchy diagram

The figure above illustrated the structure and layout of the entire application, and more details were included in the implementation section.

### 3. Implementation

#### 3.1 Tools used Overview

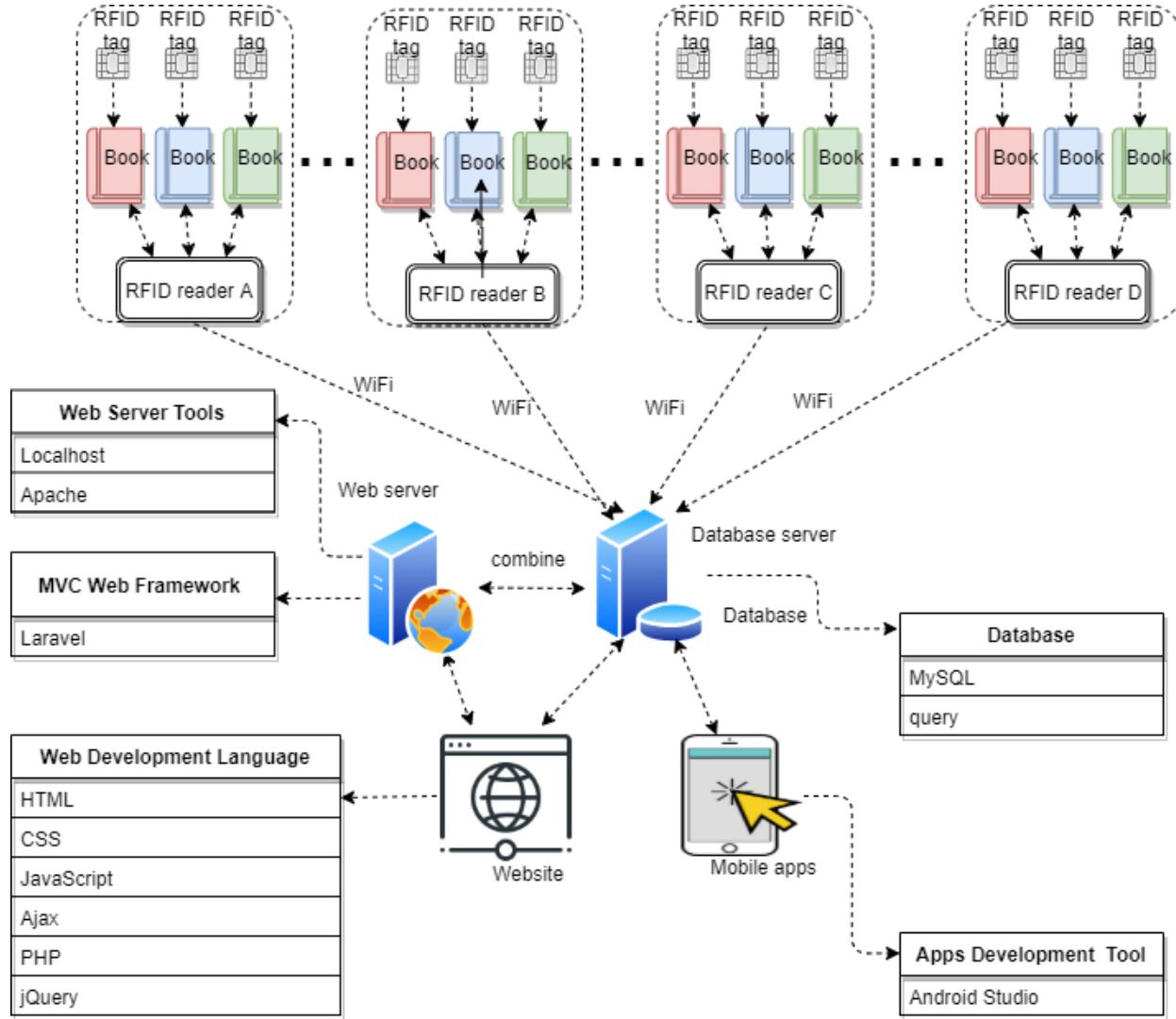


Figure 7. The whole picture of implementation with tools

The figure above described the overview of the systems and tools used at each stage. 4 readers were used and recorded each of their IP in the database. The RSSI value received then passes to pc localhost Server. Our group modified the C# application (from the buyer) to pass data and receive data in our web server. RSSI value was then stored in the database.

### 3.2 RFID hardware Implementation & Setup

The RFID reader was embedded with a WIFI module, and an RFID tag was attached to each book. The database recorded the unique tag id (EPC data) of each book. The readers were set to send out RSSI once per second. Readers sent RSSI data to the server and database via WIFI. Configuration was needed for all the connections and ports settings such as power, net port, IP address, WIFI and RFID reader connection.

#### Idea for System Set-up

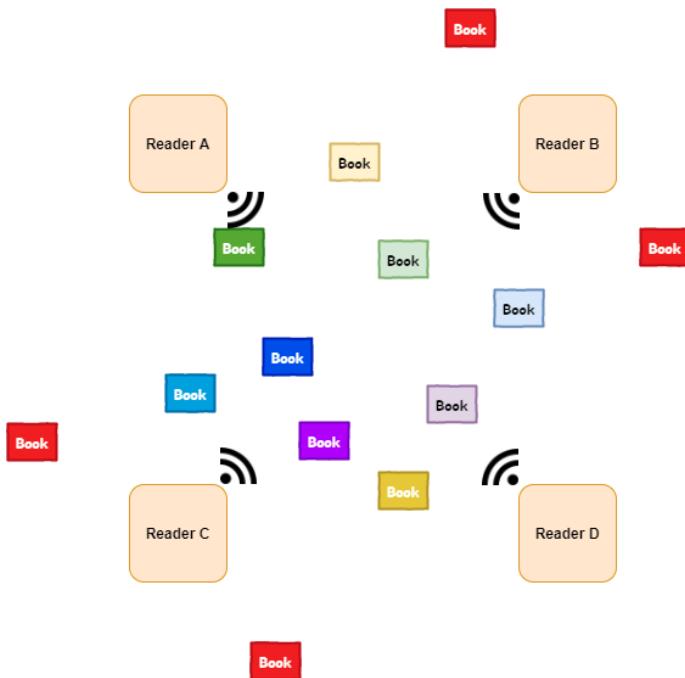


Figure 8. Final hardware setup design

Readers are placed in 4 corners forming a rectangular network. All books inside can be detected. If a tag is out of range, the reader may not detect the tag.

## Actual Implementation



Figure 9. Hardware Testing

The tested reader range was 0-0.5m. Each reader is 0.7 m from another. The setup above allows stable connection between localhost and readers with the Wi-Fi module.

Next steps include writing data to the server. The idea is to transfer raw data from the RFID readers to our server, and then receive the data with an API and save it to our database.

An algorithm was needed to transform RSSI values to location coordinates. Calculation process was discussed in the next session.

### 3.3 Location Calculation Process

RSSI data obtained from the four readers passed through a tracking algorithm to get the locations of books. A simple data processing was performed before using the Localization Algorithm to compensate hardware insufficiency.

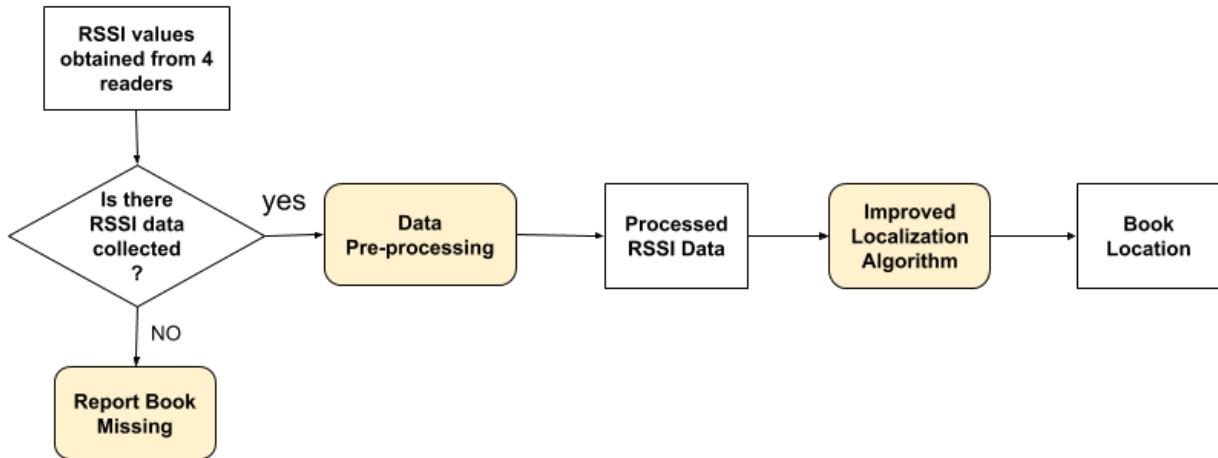


Figure 10. Idea of handling RSSI value in hardware set-up

#### Step 1: RSSI Data Collection

For each tag, RSSI values were collected from 4 readers for a 5-minute time frame and stored in the database. An RFID reader would send RSSI data once per second. Ideally, 300 RSSI data was collected per tag per reader during the 5-minute time frame. Total of 1200 RSSI data was used for preprocessing in a 5 min time frame. When no RSSI value was updated one tag, a book was reported missing. The database would reset every 5 minutes.

#### Step 2: Data Pre-processing

RSSI fluctuated even with no change in location. The fluctuation can result in errors in our RSSI - based localization algorithm. Therefore, it is essential to process our data before putting them in

our algorithm. In real life, our readers do not read any RSSI value in each second, which makes data pre-processing an even more important step before putting the RSSI value in the algorithm.

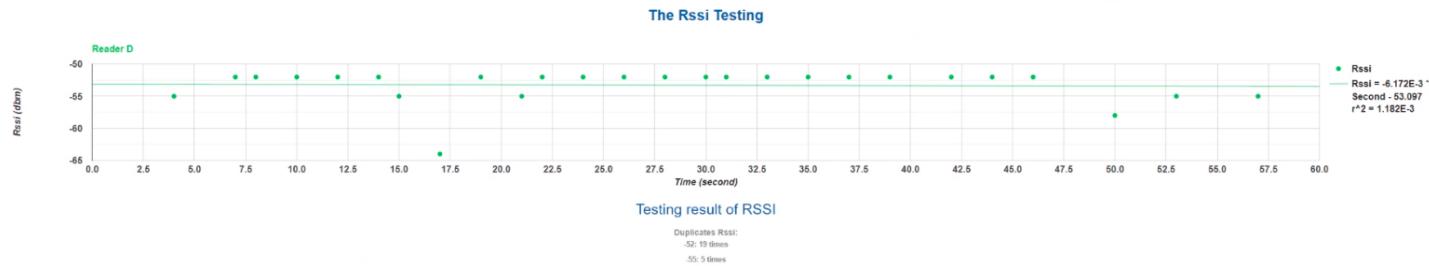


Figure 11. Linear Regression using 1 min Timeframe

The idea is obtaining the expected RSSI value by setting the Timeframe to 5 min. We have tested with other Timeframes and turns out 5 minutes one is the best. Details can be found in the **Testing Part**.

RSSI values often ranged from -65 to -50 in our experimental setup. The figure above shows a graph obtained by performing linear regression with an RSSI dataset from Reader D in 1 min Timeframe. This step was repeated four times to generate a regression line for each dataset.

### **Step 3: Processed RSSI Data**

The  $\beta$  Intercept from each generated linear regression was chosen as the RSSI value representing each reader, i.e. 4 RSSI value in total. These 4 values were then passed to the Localization algorithm to calculate the actual location of book tags.

#### How to get the one RSSI data

During data preprocessing, we were able to identify some RSSI values that may cause errors in the tracking algorithm. As the test result of preprocessing, we chose the intercept of linear regression instead of the median, mode and mean. Although we found that the mean of the original data can be used as an indicator for our tracking algorithm, the larger the data set, the higher the RSSI Values such as the maximum and minimum values continue to increase, and the mean would be affected. Therefore, the mean cannot be used as a reference for our tracking algorithm. Also, the "trilateral positioning algorithm" or other algorithms requires stability, and the accuracy value

becomes variable. However, in this example, the RSSI value is changing, which indicates that we must perform data processing to find better reliable variables. As a result, the understanding of linear regression becomes the best solution to convert the final RSSI value into a radius to calibrate the distance. In other words, this is a round radius, and the centre point is the RFID reader. However, after much testing, from our observation perspective, due to the source of the RSSI value from the reader, the value when the intercept was converted to the radius was still not accurate enough to find the intersection of the circles.

## **Step 4: Localization Algorithm**

1st attempt: **Trilateral Localization Algorithm**

idea:

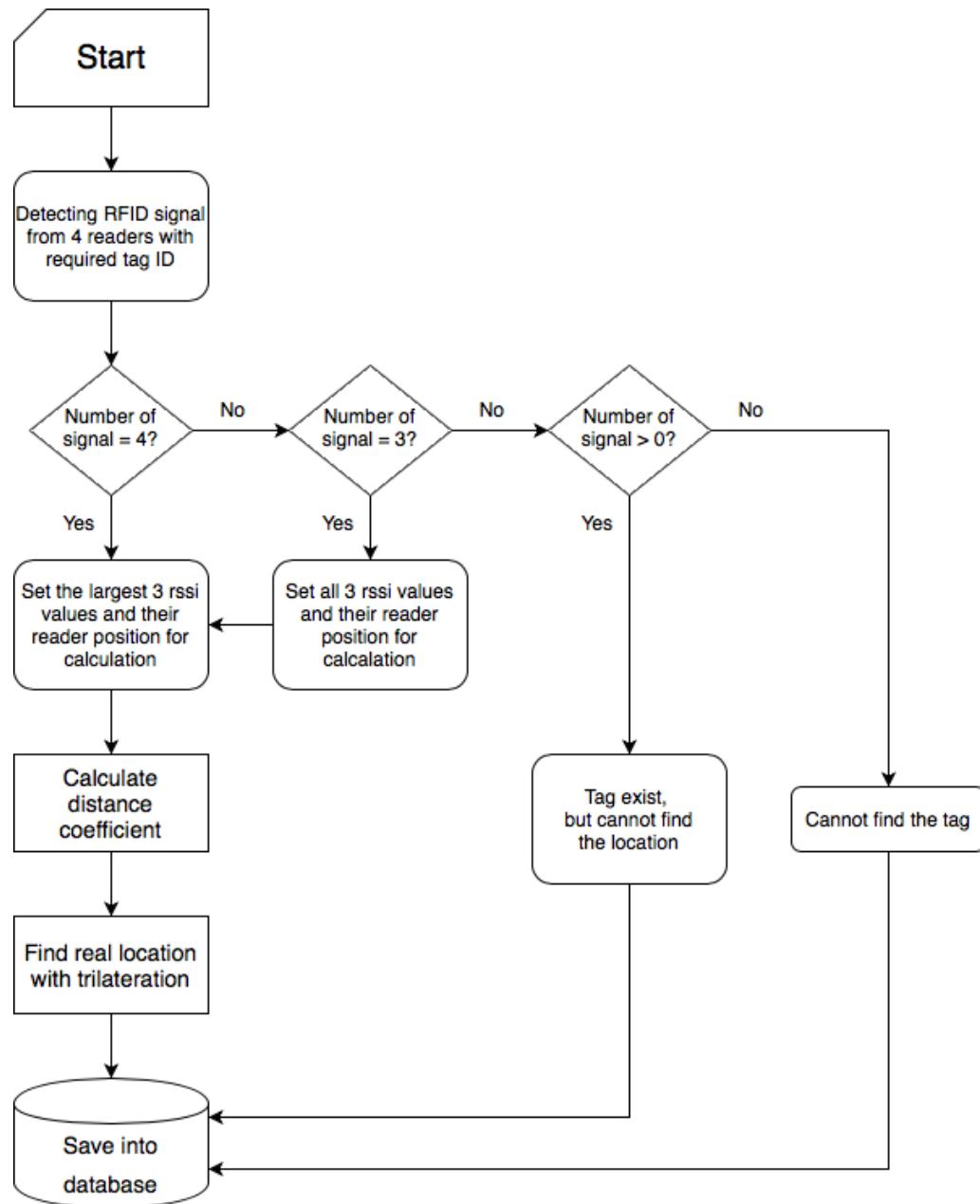


Figure 12. Algorithm Flowchart

### **1. Transfer RSSI values to distance**

When the RFID reader detects the tag, the reader will get a data, which is Received Signal Strength Indicator (RSSI). In our algorithm, it would base on this signal strength to calculate a distance between the RFID reader and the tag.

$R_i$  – Distance between reader and the tag (in meter)

RSSI – The RSSI value read by the reader

P – Tx Power (Usually ranges between -59 to -65)

N – Path loss exponent

$$R_i = 10^{\left(\frac{P-RSSI}{10 \cdot N}\right)}$$

## 2. Find real location with trilateration

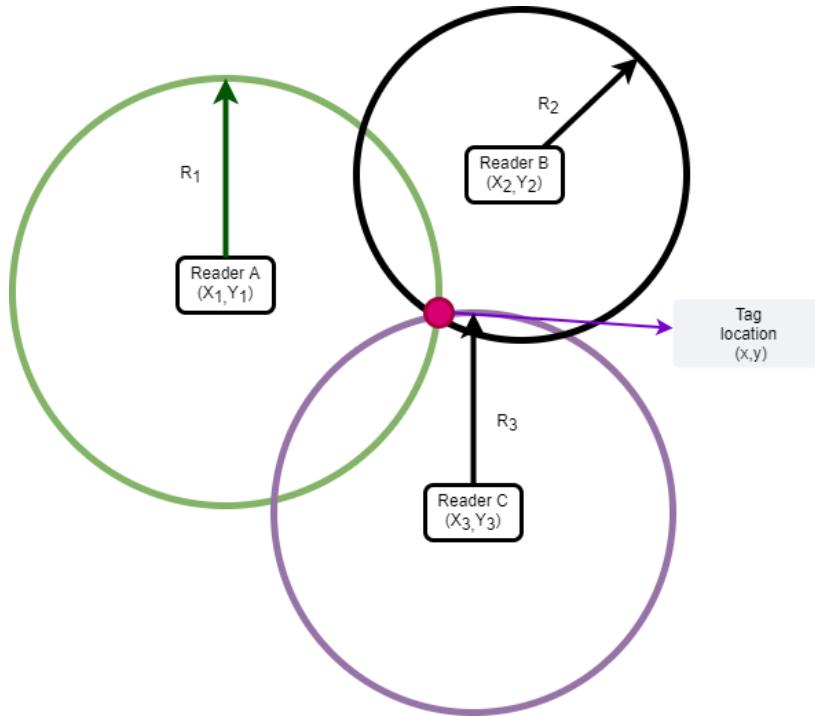


Figure 13. Trilateration Algorithm Diagram

$R_1, R_2, R_3$ : The distance between the RFID reader and the Tag (in meter). Therefore,

$$R_1, R_2, R_3 = 10^{\left(\frac{P-RSSI}{10 \cdot N}\right)}$$

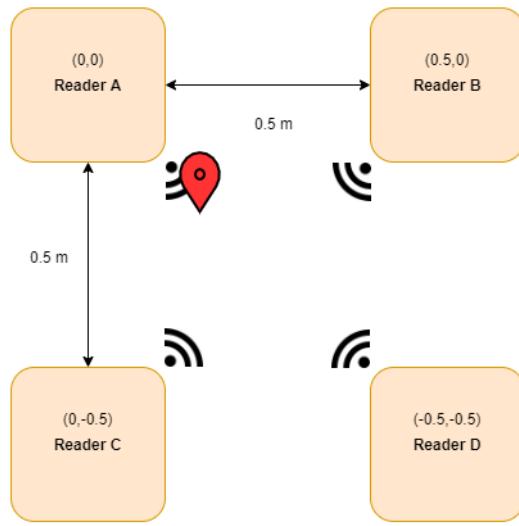


Figure 14. Reader and Tag instance diagram

E.g. When the coordinate of Reader A is (0,0).

If the distance between Reader A and Reader B is 0.5m.

The coordinate of Reader B is (0.5, 0).

The coordinate of Reader C is (0, -0.5).

The coordinate of Reader D is (-0.5, -0.5).

The intersection point of the three circles is the location of the tag. The circle radius will adjust when the distance between the readers and the tag are changed.

**The equation of the circles:**

$$(x - x_1)^2 + (y - y_1)^2 = R_1^2$$

$$(x - x_2)^2 + (y - y_2)^2 = R_2^2$$

$$(x - x_3)^2 + (y - y_3)^2 = R_3^2$$

**x and y values are the location of the tags.**

## Problem Discovered:

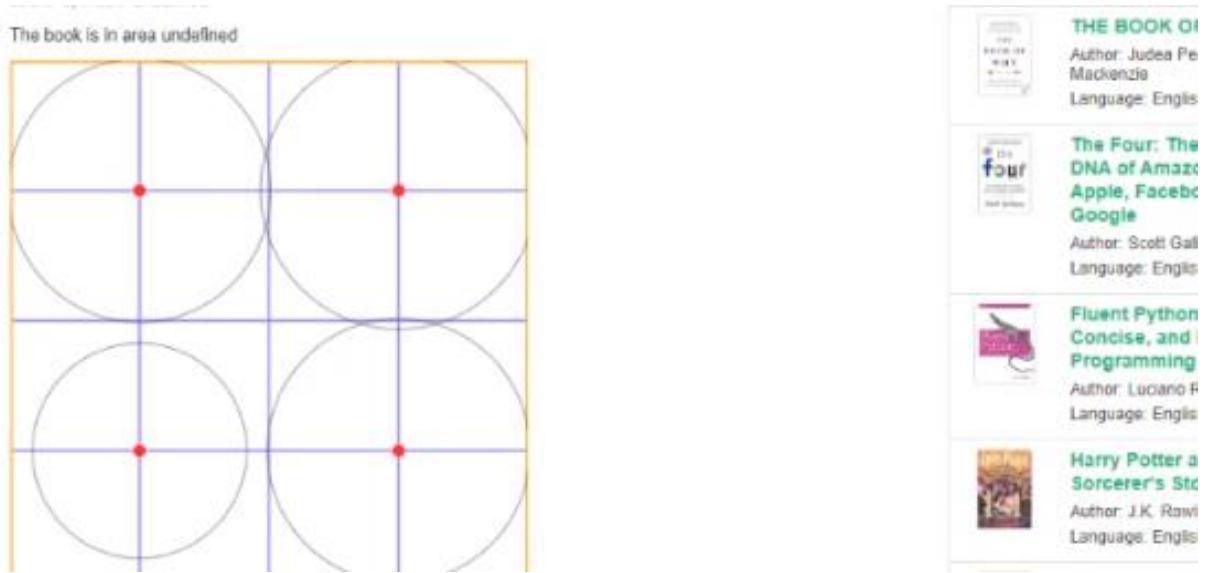


Figure 15. Problem with no area with 3 circles overlapping

As we experimented with getting data from RFID readers, we soon discovered that in many cases, no 3 circles were overlapping. The result would mean that the typical approach for RFID tracking did not work in our setup. A possible reason was that the RFID readers were not stable enough.

Since a trilateral localization algorithm is only a mathematic theory, it requires precise raw variable data. The testing results showed that it is impossible to receive precise data based on our low-cost hardware. Therefore, we had made some changes to the algorithm to enhance accuracy.

## 2nd attempt: Increase Accuracy - Shadow Overlap Method

**Idea:**

### 1. Draw simulation diagram

After receiving the raw data(the width, the height, the distance between the required tag and the readers), it would draw a Scalable Vector Graphic (SVG). First, locate each reader on the scale. Then, draw a width stroke circle with half-opacity. The width of stroke is the error boundary. This method aims to make up for the lack of hardware.

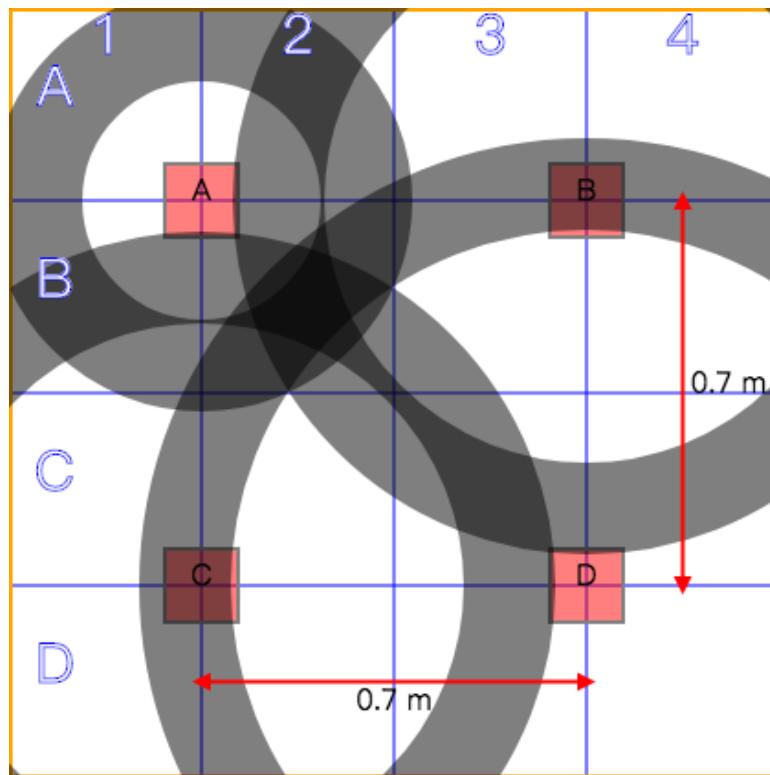


Figure 16. Simulation Diagram Example

### 2. Find location based on opacity

Referring to the picture above, we found that the more circle borders overlap, the higher opacity the overlapping positions. It could determine the location by detecting the opacity of each pixel, then analyzing which area contains the most overlapped borders.

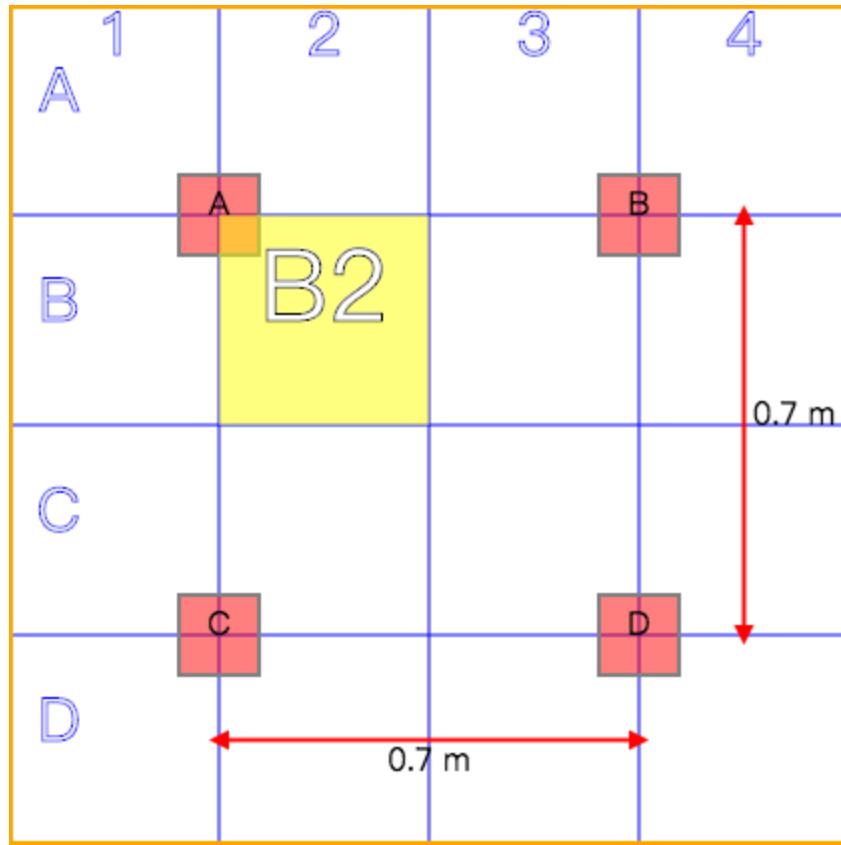


Figure 17. Track Book Result Diagram Example

#### **Tracking and mapping function on Desktop and Mobile Applications:**

This is an extension function of tracking location algorithms. A tracking location button in the applications to allow users to visualize the book location. Approximate book location can be seen on the visualized map.

### 3.4 Server

```
^C
[tonywanMacBook:bookTracking tonywan$ php artisan serve --host 192.168.1.108 --port 8050
[Laravel development server started: http://192.168.1.108:8050]
[Wed Apr 29 12:52:57 2020] PHP 7.4.4 Development Server (http://192.168.1.108:8050) started
[Wed Apr 29 12:53:02 2020] 192.168.1.137:52143 Accepted
[Wed Apr 29 12:53:02 2020] 192.168.1.137:52143 Closing
[Wed Apr 29 12:53:02 2020] 192.168.1.137:52144 Accepted
[Wed Apr 29 12:53:02 2020] 192.168.1.137:52144 [200]: GET /js/app.js
[Wed Apr 29 12:53:02 2020] 192.168.1.137:52149 Accepted
[Wed Apr 29 12:53:02 2020] 192.168.1.137:52149 Closing
[Wed Apr 29 12:53:02 2020] 192.168.1.137:52153 Accepted
[Wed Apr 29 12:53:02 2020] 192.168.1.137:52153 [200]: GET /js/book_manage.js
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52153 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52154 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52155 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52154 [200]: GET /js/user_manage.js
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52157 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52156 [200]: GET /js/book_track.js
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52156 [200]: GET /js/borrow.js
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52158 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52154 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52156 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52156 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52156 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52157 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52159 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52156 [200]: GET /storage/avatar1_small.jpg
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52160 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52159 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52156 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52160 [200]: GET /storage/uploads/QjKTBLbm1YpSHRJwnv6LqHWigAdtYA9NBRTGDr.jpeg
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52159 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52160 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52160 [200]: GET /storage/uploads/QHs2h2tR32XjbdE8Yq3IKg10tfjdrM2BXBNXjbLL.jpeg
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52160 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52163 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52164 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52163 [200]: GET /storage/uploads/7dyAevJh7xe50Ew4rlmsbczLpcTiVQ5GaVZ8dZe.jpeg
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52162 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52164 [200]: GET /storage/uploads/y5B0yEHk0fNKAMDKU060LJDosEUN3C4E8vDCFPcb.jpeg
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52162 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52165 Accepted
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52163 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52164 Closing
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52165 [200]: GET /storage/uploads/zu1Y0xmoMxpkw3YIxyrjiZH83rbjVoFxz0kTZii.jpeg
[Wed Apr 29 12:53:03 2020] 192.168.1.137:52165 Closing
[Wed Apr 29 12:53:05 2020] 192.168.1.137:52168 Accepted
[Wed Apr 29 12:53:05 2020] 192.168.1.137:52168 Closing
[Wed Apr 29 12:53:05 2020] 192.168.1.137:52169 Accepted
[Wed Apr 29 12:53:05 2020] 192.168.1.137:52169 Closing
[Wed Apr 29 12:53:05 2020] 192.168.1.137:52171 Accepted
[Wed Apr 29 12:53:05 2020] 192.168.1.137:52171 Closing
```

Figure 18. Server

Localhost was used as the server. It was easier for debugging and testing. Since the nature of our project requires a lot of data entry, servers on campus could quickly treat those as DDOS attacks.

### 3.5 Database

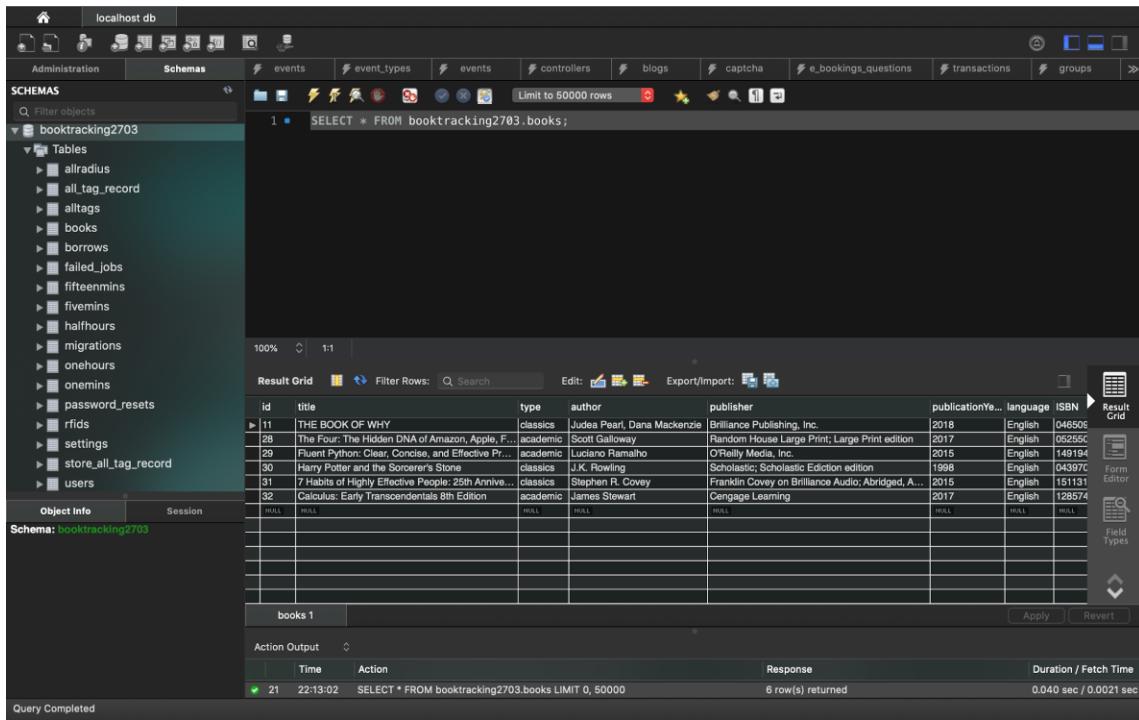


Figure 19. Databases record checking

### 3.6 Mobile Application

Mobile Application Overview:

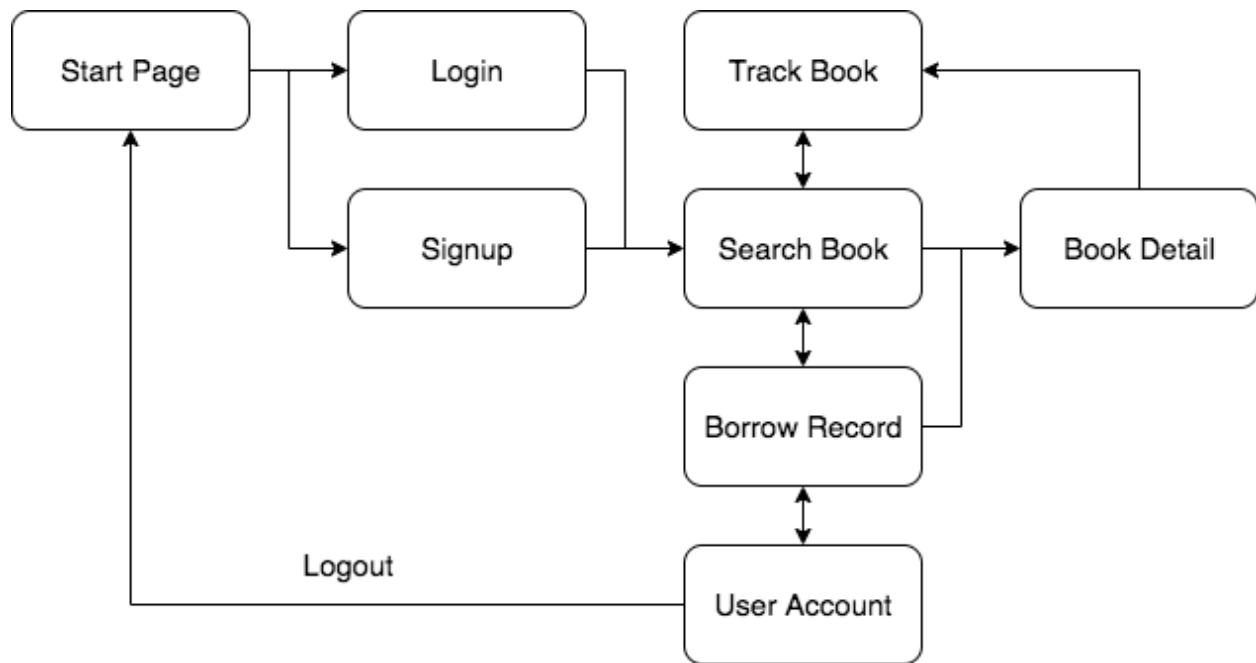


Figure 20. Mobile Application activities relationship diagram

The purpose of developing mobile phone applications is to facilitate users to use, hoping to provide them with good user experience. We considered that some functions in web pages were not suitable for being placed in the app now. For example, admin management in the app is inconvenient and error-prone. So, this app target user group was normal users and developed user-level functions.

Start Page	Login Page	Sign Up Page
------------	------------	--------------

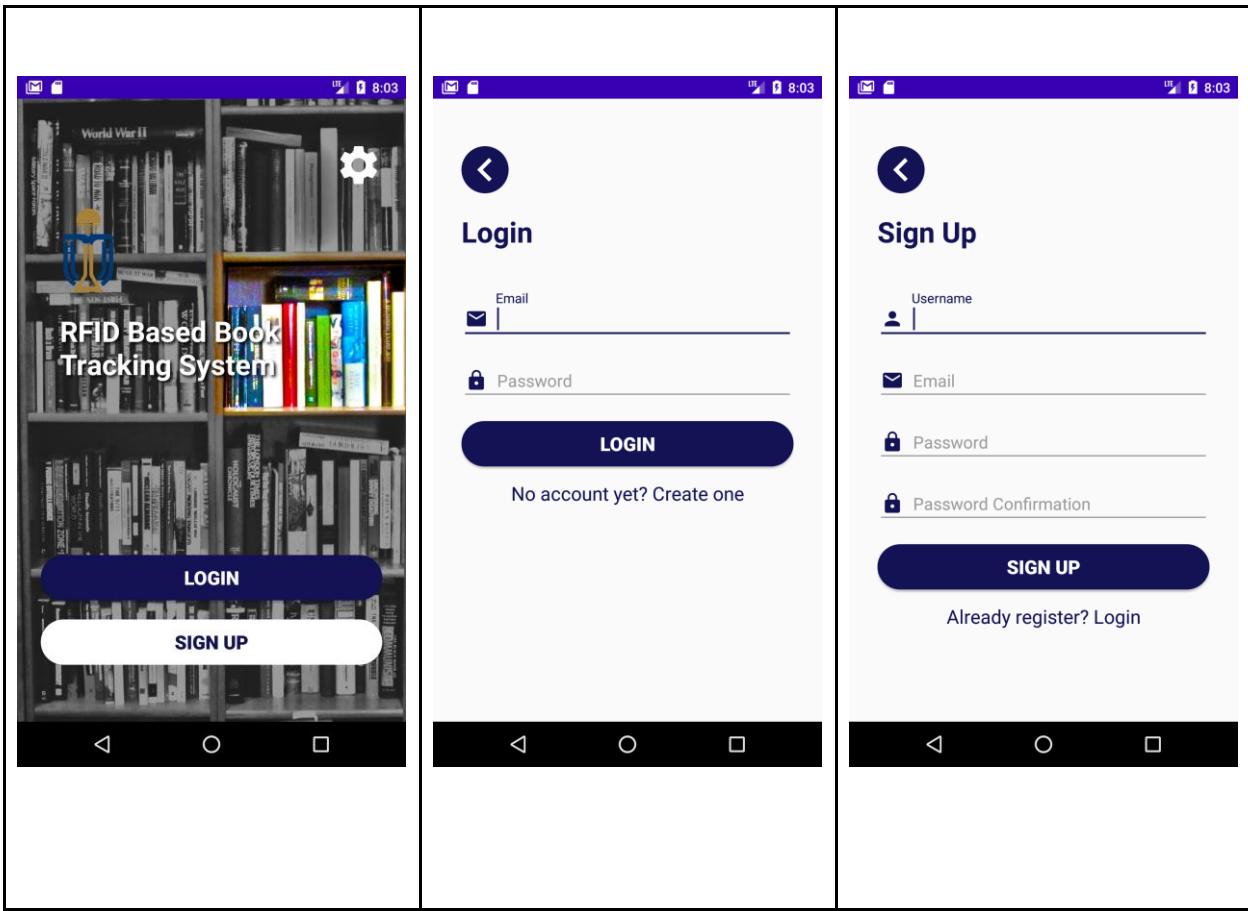


Figure 21. App Layout Before Login

## Start Page

Click the setting button in the top-right corner for configuring the network.

The other two buttons below can redirect to login and signup page respectively.

## Login Page

Login through API with validation.

Click the login button to validate. If success, go to search page.

## Sign Up Page

Signup through API with validation.

Click the button after filling the form, if the validation is successful, go to search page.

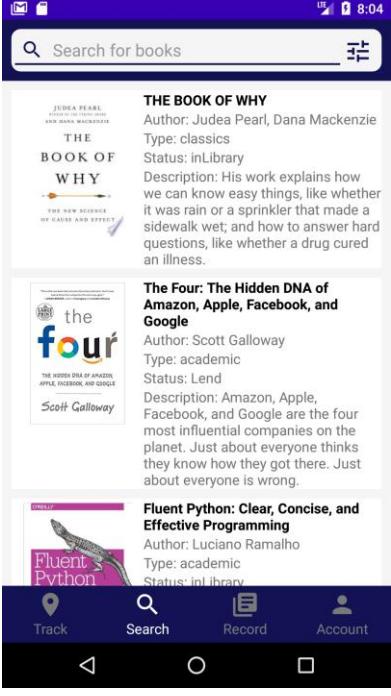
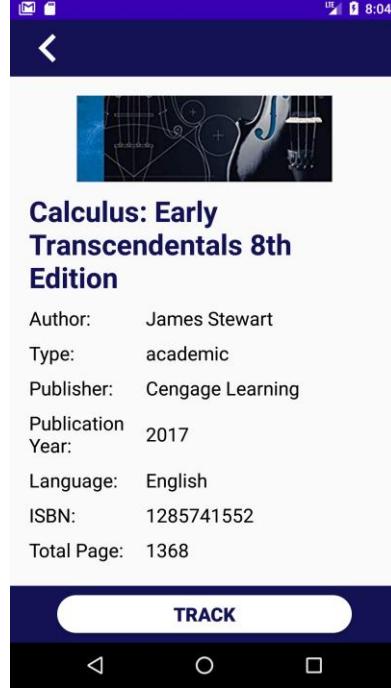
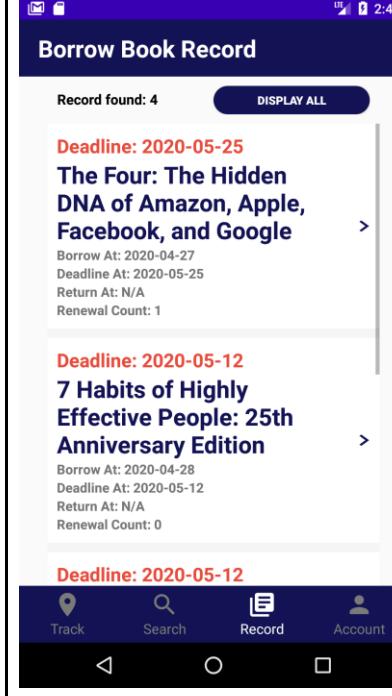
Search Page	Book Detail Page	Borrow Record Page
<p>If the user has already logged in, it will redirect to this page.</p> <p>This page is mainly for search books purposes.</p> <p>Click the filter button can do advanced searching.</p> 	<p>Main purpose of this page is to show more detailed information about the book.</p> <p>Click the track button below can go to the track page and track this book directly.</p> 	<p>This page is to show the borrowed records of the current user.</p> <p>Press the “Display all” button can show all the records included the returned book record.</p> 

Figure 22. App Layout After Login

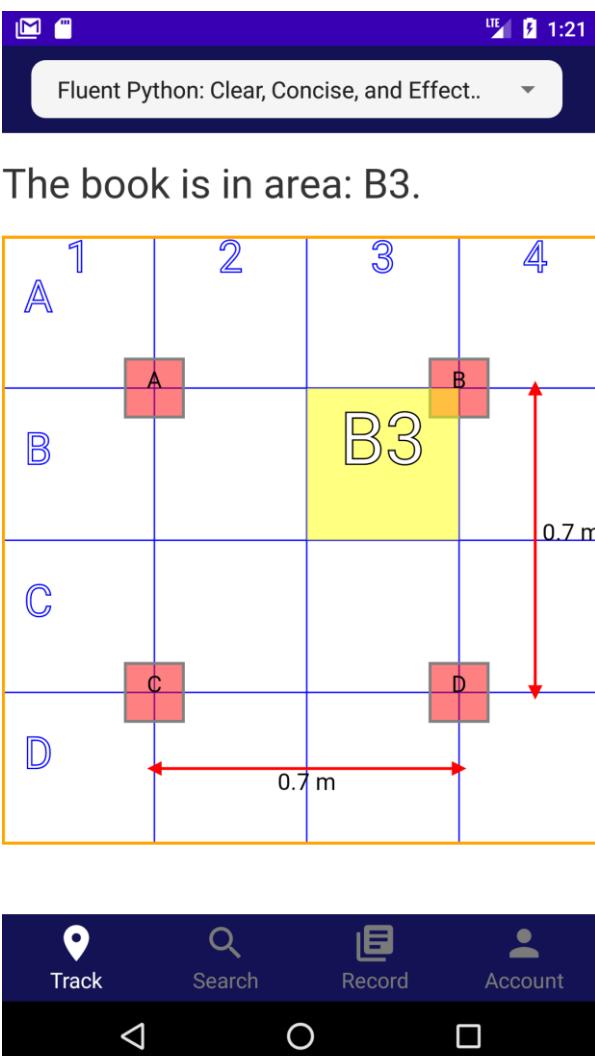
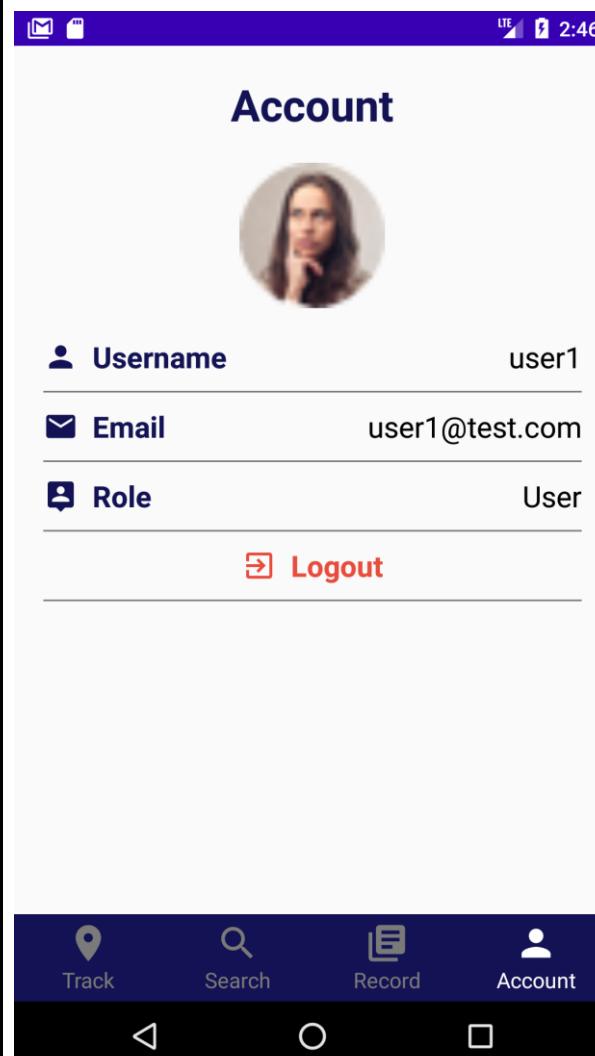
Track Book Page	Account Page
<p>The page is for tracking the book.</p> <p>Select the book that you want to track for, then a diagram will be displayed and show out the book is within which area.</p>  <p>The book is in area: B3.</p> <p>Fluent Python: Clear, Concise, and Effect..</p>	<p>This user account page shows the user information.</p> <p>Press the Logout text, then the app will redirect to the start page.</p> 

Figure 23. App Layout of Track and Account

### 3.7 Website

Our current Webpage address is <http://143.89.130.156/>. The site includes Login, registration system, as well as Book management system.

Our website established a 3-level user right (regular users, managers, admin) with the access right below respectively:

#### Functionalities:

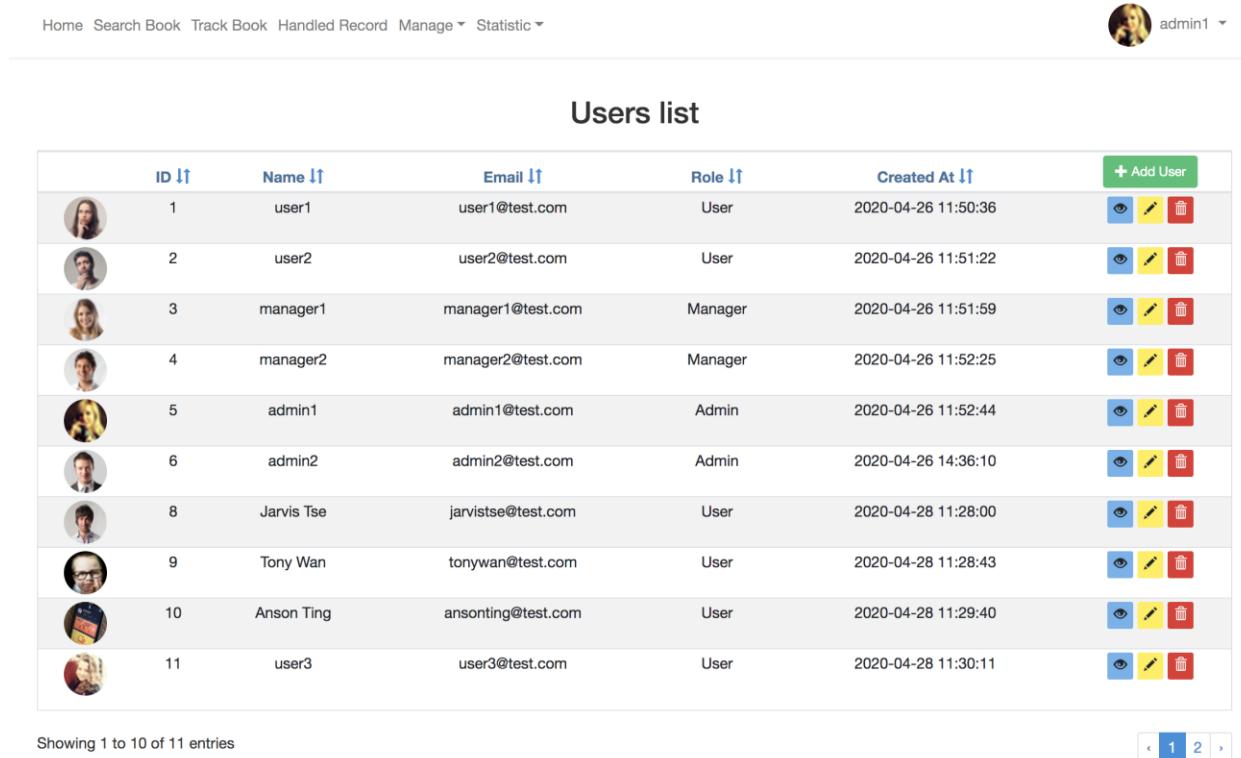
Blue-eye button: View the user/book details

Yellow-pen button: Edit user/book information

Red-trash-can button: Delete the user/book

#### Admin Access Only:

##### 1. Manage user page



ID ↑	Name ↑	Email ↑	Role ↑	Created At ↑	+ Add User
1	user1	user1@test.com	User	2020-04-26 11:50:36	 
2	user2	user2@test.com	User	2020-04-26 11:51:22	 
3	manager1	manager1@test.com	Manager	2020-04-26 11:51:59	 
4	manager2	manager2@test.com	Manager	2020-04-26 11:52:25	 
5	admin1	admin1@test.com	Admin	2020-04-26 11:52:44	 
6	admin2	admin2@test.com	Admin	2020-04-26 14:36:10	 
8	Jarvis Tse	jarvistse@test.com	User	2020-04-28 11:28:00	 
9	Tony Wan	tonywan@test.com	User	2020-04-28 11:28:43	 
10	Anson Ting	ansonting@test.com	User	2020-04-28 11:29:40	 
11	user3	user3@test.com	User	2020-04-28 11:30:11	 

Showing 1 to 10 of 11 entries

< 1 2 >

Figure 24. Manage user page

2. Add new user after clicking the add button

Add User

Name

Email

Password

Confirm Password

Role

User

Photo

選擇檔案 未選擇任何檔案

+ Save User Close

Figure 25. Manage user page

3. Edit user information

Edit User

ID

1

Name

user1

Email

user1@test.com

Role

User

Re-upload Photo

選擇檔案 未選擇任何檔案

Edit close

Figure 26. Edit user information

**Manager and admin access only:**

**1. Manage book page**

The screenshot shows a 'Books list' page with a table of five books. The columns are: ID, Cover, Title, Tag ID, Author, Publisher, Status, and Actions. The books listed are:

ID	Cover	Title	Tag ID	Author	Publisher	Status	Actions
1		THE BOOK OF WHY	E2 00 00 19 66 0E 00 51 70 1A ED	Judea Pearl, Dana Mackenzie	Brilliance Publishing, Inc.	Lend	
2		The Four: The Hidden DNA of Amazon, Apple, Facebook, and Google	E2 00 00 19 66 0E 00 68 75 8E 7D	Scott Galloway	Random House Large Print; Large Print edition	Lend	
3		Fluent Python: Clear, Concise, and Effective Programming	E2 00 00 19 66 0E 49 6E 6E 80 11	Luciano Ramalho	O'Reilly Media, Inc.	inLibrary	
4		Harry Potter and the Sorcerer's Stone	E2 00 00 19 66 0E 00 23 64 74 7A	J.K. Rowling	Scholastic; Scholastic Edition edition	inLibrary	
5		7 Habits of Highly Effective People: 25th Anniversary Edition	E2 00 00 19 66 0E 00 94 E4 88 64	Stephen R. Covey	Franklin Covey on Brilliance Audio; Abridged, Anniversary edition	inLibrary	

Showing 1 to 5 of 12 entries

Figure 27. Manage book page

**1.** Edit book after clicking the pen button

The screenshot shows the 'Edit Book' dialog box. It contains the following fields:

- ID: 11
- Tag ID: E2 00 00 19 66 0E 00 51 10 70 1A ED
- Title: THE BOOK OF WHY
- Author: Judea Pearl, Dana Mackenzie
- Publisher: Brilliance Publishing, Inc.
- Publication Year: 2018
- Language: English
- ISBN: 0465097601
- Page Number: 432
- Type: Classics
- Status: Lend
- Description: His work explains how we can know easy things, like whether it was rain or a sprinkler that made a sidewalk wet; and how to answer hard questions, like whether a drug cured an illness.
- Re-upload Image: Choose file | No file chosen

At the bottom right are 'Save' and 'Close' buttons.

Figure 28. Edit Book

**2.** Add a new book after click add book button

The screenshot shows the 'Add Book' dialog box. It contains the following fields:

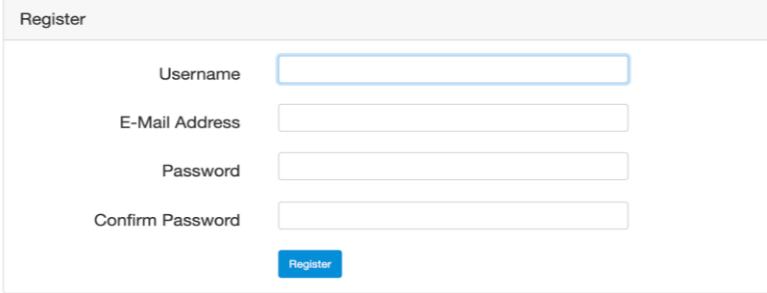
- Tag ID: (empty)
- Title: (empty)
- Author: (empty)
- Publisher: (empty)
- Publication Year: (empty)
- Language: (empty)
- ISBN: (empty)
- Page Number: (empty)
- Type: -- Please Select --
- Status: In Library
- Description: (empty)
- Image: Choose file | No file chosen

At the bottom right are '+ Save Book' and 'Close' buttons.

Figure 29. Manage book page

## All User

### 1. Register Page

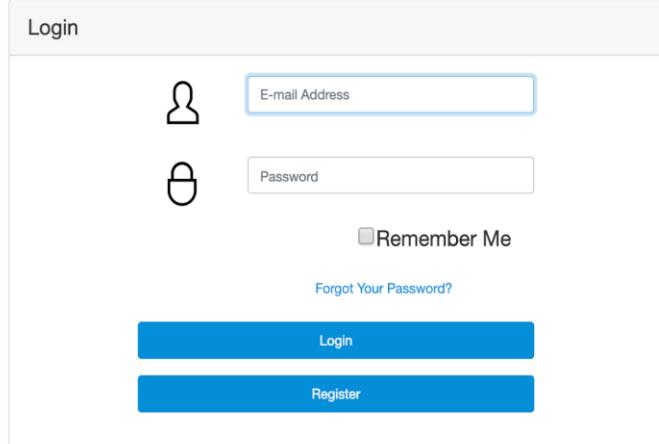


The image shows a 'Register' form. At the top right are 'Login' and 'Register' links. The form itself has a light gray header labeled 'Register'. It contains four input fields: 'Username' (with a blue outline), 'E-Mail Address', 'Password', and 'Confirm Password'. Below these is a blue 'Register' button.

Figure 30. Register

Regular users can sign up for an account to use book tracking and management features. User information is saved to the database, and only administrators can manage users.

### 2. Login Page



The image shows a 'Login' form. At the top right are 'Login' and 'Register' links. The form has a light gray header labeled 'Login'. It features two input fields: 'E-mail Address' (with a blue outline) and 'Password'. To the left of each field is a small icon: a person for the email address and a lock for the password. Below the fields is a 'Remember Me' checkbox followed by the text 'Forgot Your Password?'. At the bottom are two large blue buttons: a blue 'Login' button on the left and a white 'Register' button on the right.

Figure 31. Login

If the user has previously registered, they can log in to our system. Otherwise, can register a new account by pressing the "Register" button.

### 3. Book Searching Page

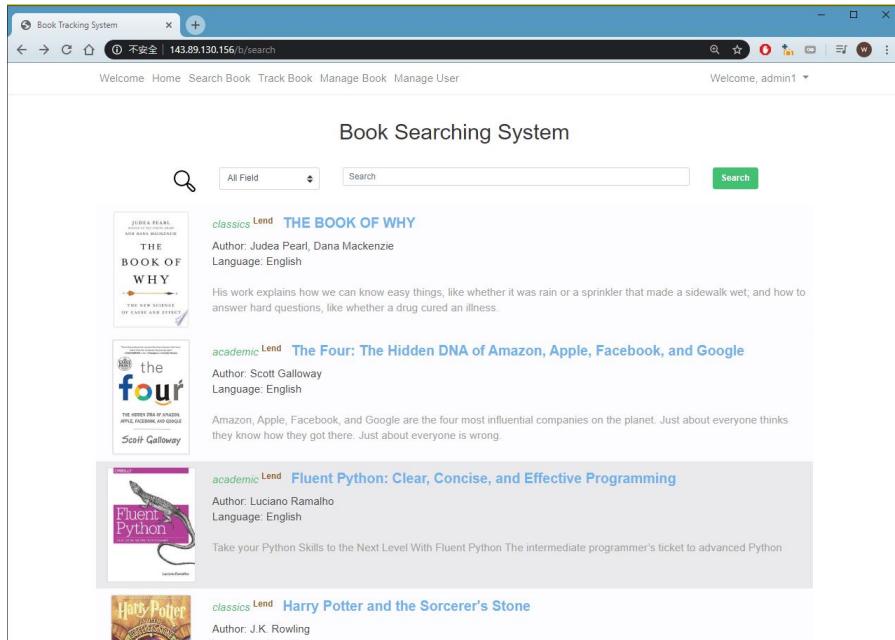


Figure 32. Book Search

Users can search for books by keywords like author, publication year, etc. Search engine will show the book cover, current status, book type, title, author, language and description.

#### 4. Book Details Page

The screenshot shows a web-based library system interface. At the top, there is a navigation bar with links for Home, Search Book, Track Book, Handled Record, Manage, Statistic, and a user account section for 'Welcome, admin1'. The main content area is titled 'Book Information'.

**Book Details:**

**Title:** The Four: The Hidden DNA of Amazon, Apple, Facebook, and Google

**Author:** Scott Galloway

**Publisher:** Random House Large Print; Large Print edition

**Language:** English

**Page Number:** 442

**Description:** Amazon, Apple, Facebook, and Google are the four most influential companies on the planet. Just about everyone thinks they know how they got there. Just about everyone is wrong.

**Tracking and Borrowing:**

On the left side, there is a large image of the book cover for 'The Four'. On the right side, there are two icons: a location pin labeled 'inLibrary' and a book icon. Below these icons, there are several data fields with their corresponding values.

Tag ID:	Type:
E2 00 00 1D 30 10 01 34 23 70 66 1F	academic
Author:	Publisher:
Scott Galloway	Random House Large Print; Large Print edition
Publication Year:	Language:
2017	English
ISBN:	Page Number:
0525501223	442

Figure 33. Book Details

Users can view book details such as title, author, publisher, year of publication, language, ISBN. On this page. Users can track the location of a book or borrow it by pressing an icon. On the left-hand side is the tracking button, and on the right side is the book borrowing button. At the top of the tracking button, the status of the book would be shown, for example, the book is in the library, lent or lost.

## 5. Track Book Page

The screenshot shows a user interface for tracking books. At the top, there is a navigation bar with links: Home, Search Book, Track Book, Handled Record, Manage, Statistic, and a user profile icon labeled "admin1".

The main content area displays a book's details:

- Calculus: Early Transcendentals 8th Edition**
- Tag ID: E2 00 00 19 66 0E 00 51 70 1A ED
- A message: "This book is in area B2"

Below this is a grid-based map of an area. The grid is 4 columns wide and 4 rows high, labeled A-D on the vertical axis and 1-4 on the horizontal axis. A red square at position A1 is labeled "A". A yellow shaded rectangular area covers positions B1 through B4, labeled "B2". Red squares at positions B2 and C4 are labeled "B" and "D" respectively. A red double-headed arrow between the vertical lines of B2 and C4 is labeled "0.7 m". A red double-headed arrow between the horizontal lines of B2 and D is also labeled "0.7 m".

To the right of the map is a list of books:

Harry Potter and the Sorcerer's Stone Author: J.K. Rowling Language: English
7 Habits of Highly Effective People: 25th Anniversary Edition Author: Stephen R. Covey Language: English
Calculus: Early Transcendentals 8th Edition Author: James Stewart Language: English
The Gift of Anger: And Other Lessons from My Grandfather Mahatma Gandhi Author: Arun Gandhi Language: English
One Thousand and One Nights: A Retelling Author: Hanan al-Shaykh Language: English
In Order to Live: A North Korean Girl's Journey to Freedom

Figure 34. Book Track

Users can view the position of the book on this page. The red label displayed on the map is the current book position, which is also in red on the right book list. Users can view the book information by clicking the blue-eye button.

# 4. Testing

## 4.1 Location Algorithm

When our group started experimenting with the readers, it became clear to us that there were two main problems with the readers: (1) fluctuating RSSI value even a tag did not change location (2) the RFID readers didn't update an RSSI value per second as the intended set-up.

These two issues can significantly reduce the reliability of our tracking system.

Therefore, we developed a complementing method: to collect data within a specific time frame and pass those data for linear regression. We then used the line to find one representative RSSI value from each reader. This method works because books tend to stay in the same place.

The question came to which time frame was the best. We tested five-time frame settings: 1 minute, 5 minutes, 15 minutes. 30 minutes.



Figure 35. Setting timeframe

We tested the frame setup for five times respectively. Then we plotted those data in a graph and performed linear regression.



Figure 36. Test result Display

The computer-generated data and graphs above were for different time frame settings. We tested different settings for one day. In the end, 5 minutes time frame model worked the best. So, we decided to use this time frame as our setup.

#### 4.2 Software Testing Criteria

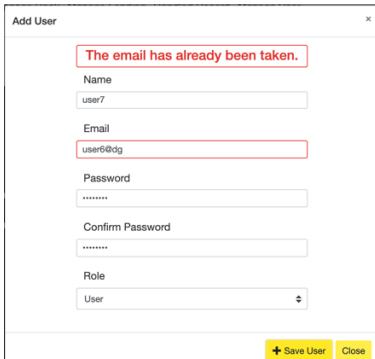
Tests would mainly focus on the accuracy of the tracking result, the consistency of databases, the website and the mobile application. The testing procedure of the application should mainly focus on the following areas:

- Correctly receive the RSSI value from the RFID reader
- Correctly calculate and show the location of the RFID tags
- Able to update the tracking data in the database
- Able to add and delete accounts in an administrator account
- Able to track the book locations in an administrator account
- Able to add and manage books in a manager account
- Able to borrow and return books in a user account

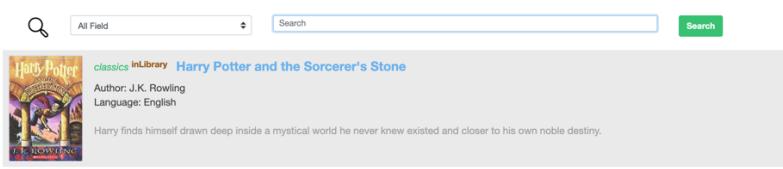
The following test cases would be tested in both the web application and the mobile application. The test cases are mainly on functionality testing.

## Functionality Testing

### Test Case 1

Purpose	User Registration
Validity	Valid
Test Value(s)	Typing same username that register before
Expected Result	Unable to register and log-in, shows “the email has already been taken” 

### Test Case 2

Purpose	Searching books by keywords
Validity	Valid
Test Value(s)	“Harry Potter”, “success”, “English”, “Chinese”, “紅樓夢”
Expected Result	Shows the expected book 

### Test Case 3

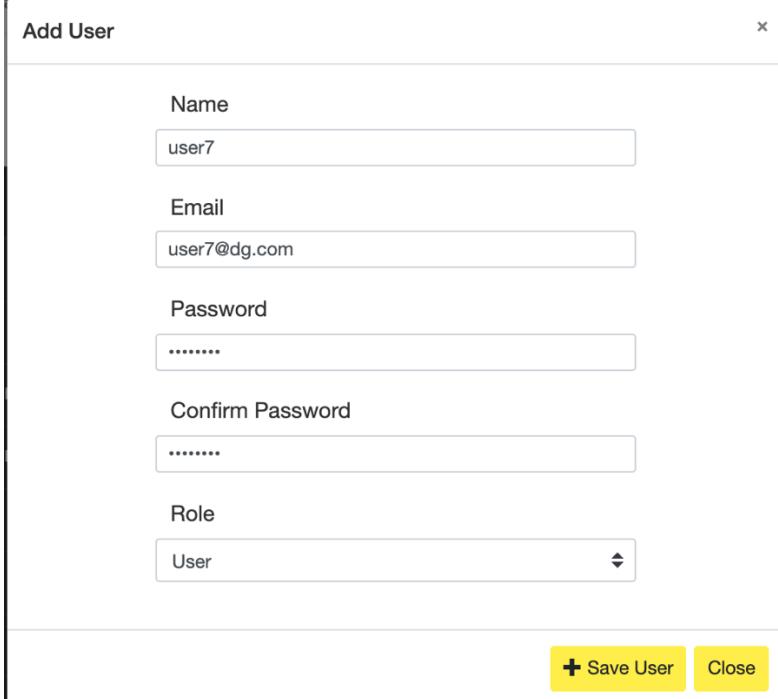
Purpose	Add new books – admin & manager account						
Validity	Valid						
Test Value(s)	Add the book “Harry Potter” to the system						
Expected Result	<p>The system adds the book correctly in the database, user accounts cannot add new books</p> <p>Title Harry Potter and the Sorcerer's Stone</p> <p>Author J.K. Rowling</p> <p>Publisher Scholastic; Scholastic Ediction edition</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">Publication Year 1998</td> <td style="width: 50%;">Language English</td> </tr> <tr> <td>ISBN 0439708184</td> <td>Page Number 309</td> </tr> <tr> <td>Type Classics</td> <td>Status In Library</td> </tr> </table> <p>Description Harry finds himself drawn deep inside a mystical world he never knew existed and closer to his own noble destiny.</p>	Publication Year 1998	Language English	ISBN 0439708184	Page Number 309	Type Classics	Status In Library
Publication Year 1998	Language English						
ISBN 0439708184	Page Number 309						
Type Classics	Status In Library						

### Test Case 4

Purpose	Delete new books – admin & manager account
Validity	Valid
Test Value(s)	Delete the book “Harry Potter” to the system
Expected Result	<p>The system deletes the book correctly in the database, user accounts cannot delete new books</p> <p>Delete Book <span style="float: right;">×</span></p> <p>Are you sure to delete Harry Potter and the Sorcerer's Stone?</p> <p style="text-align: right;"><span style="background-color: red; color: white; padding: 5px 10px; border-radius: 5px;">Delete</span> <span style="background-color: yellow; color: black; padding: 5px 10px; border-radius: 5px;">close</span></p>

### Test Case 5

Purpose	Add new accounts – admin account
Validity	Valid
Test Value(s)	Add a new user account to the system

Expected Result	The system adds the user account correctly in the database, the added user account is able to login 
-----------------	---

#### Test Case 6

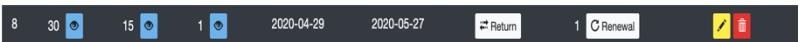
Purpose	Delete accounts – admin account
Validity	Valid
Test Value(s)	Delete a user account in the system
Expected Result	The system deletes the user account correctly in the database, the deleted user account is unable to login 

#### Test Case 7

Purpose	Borrow books – user account
Validity	Valid
Test Value(s)	User account 1 try to borrow the book "Harry Potter"
Expected Result	User account 1 borrow the book "Harry Potter" successfully, the status of the book "Harry Potter" turns from "In library" to "Lend", the return deadline is two weeks later the borrow

	<p>date</p> <div style="border: 1px solid #ccc; padding: 10px;"> <p><b>Create Record</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">Book ID</td> <td style="width: 50%;">Book Title</td> </tr> <tr> <td>30</td> <td>Harry Potter and the Sorcerer's S</td> </tr> <tr> <td>User ID</td> <td>User Name</td> </tr> <tr> <td>15</td> <td>user7</td> </tr> <tr> <td>Borrow At</td> <td></td> </tr> <tr> <td colspan="2">2020-04-29 <input type="button" value="Calendar"/></td> </tr> <tr> <td>Deadline At</td> <td></td> </tr> <tr> <td colspan="2">2020-05-13 <input type="button" value="Calendar"/></td> </tr> <tr> <td colspan="2" style="text-align: right;"> <input type="button" value="Submit"/> <input type="button" value="Close"/> </td> </tr> </table> </div>	Book ID	Book Title	30	Harry Potter and the Sorcerer's S	User ID	User Name	15	user7	Borrow At		2020-04-29 <input type="button" value="Calendar"/>		Deadline At		2020-05-13 <input type="button" value="Calendar"/>		<input type="button" value="Submit"/> <input type="button" value="Close"/>	
Book ID	Book Title																		
30	Harry Potter and the Sorcerer's S																		
User ID	User Name																		
15	user7																		
Borrow At																			
2020-04-29 <input type="button" value="Calendar"/>																			
Deadline At																			
2020-05-13 <input type="button" value="Calendar"/>																			
<input type="button" value="Submit"/> <input type="button" value="Close"/>																			

#### Test Case 8

Purpose	Renew books – user account
Validity	Valid
Test Value(s)	User account 1 try to renew the book “Harry Potter”
Expected Result	User account 1 renew the book “Harry Potter” successfully, the return deadline changes to two weeks later the original return deadline 

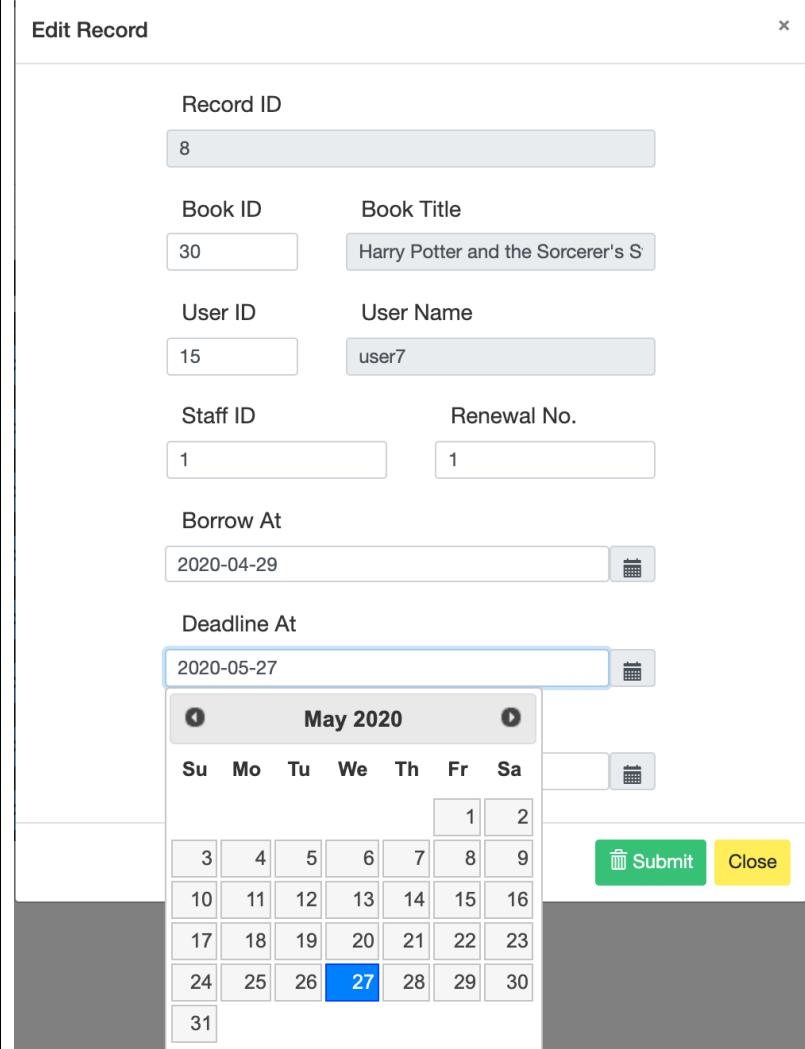
#### Test Case 9

Purpose	Return books – user account
Validity	Valid
Test Value(s)	User account 1 try to return the book “Harry Potter”
Expected Result	User account 1 return the book “Harry Potter” successfully, the status of the book “Harry Potter” turns from “Lend” to “In

library"	<div style="border: 1px solid #ccc; padding: 5px;"> <p style="margin: 0;">Return Book <span style="float: right;">x</span></p> <table border="1" style="width: 100%; border-collapse: collapse; font-size: 0.9em;"> <tr><td>Borrow ID</td><td>8</td></tr> <tr><td>Book ID</td><td>30</td></tr> <tr><td>Book Name</td><td>Harry Potter and the Sorcerer's Stone</td></tr> <tr><td>User ID</td><td>15</td></tr> <tr><td>User Name</td><td>user7</td></tr> <tr><td>Borrow At</td><td>2020-04-29</td></tr> <tr><td>Deadline At</td><td>2020-05-27</td></tr> <tr><td>Return At</td><td>2020-04-29</td></tr> <tr><td>Renewal No.</td><td>1</td></tr> </table> <div style="text-align: right; margin-top: 10px;"> <span style="background-color: green; color: white; padding: 5px 10px; border-radius: 5px; border: none; cursor: pointer; font-weight: bold;">✓ Confirm</span> <span style="background-color: yellow; color: black; padding: 5px 10px; border-radius: 5px; border: none; cursor: pointer; font-weight: bold;">Close</span> </div> </div>	Borrow ID	8	Book ID	30	Book Name	Harry Potter and the Sorcerer's Stone	User ID	15	User Name	user7	Borrow At	2020-04-29	Deadline At	2020-05-27	Return At	2020-04-29	Renewal No.	1
Borrow ID	8																		
Book ID	30																		
Book Name	Harry Potter and the Sorcerer's Stone																		
User ID	15																		
User Name	user7																		
Borrow At	2020-04-29																		
Deadline At	2020-05-27																		
Return At	2020-04-29																		
Renewal No.	1																		

#### Test Case 10

Purpose	Update loan record – admin account
Validity	Valid
Test Value(s)	Change the return deadline and the renewal number of the borrowed book “Harry Potter”

Expected Result	<p>The return deadline and the renewal number change correctly in the database</p> 
-----------------	--

#### Test Case 11

Purpose	Show handled record
Validity	Valid
Test Value(s)	User account 1 borrow the book "Harry Potter", renew it two times, then return the book
Expected Result	The handled record page shows the correct record of the user's borrow activity

8 Harry Potter and the Sorcerer's Stone      2020-04-29      2020-05-27      Not Yet Returned      1

#### Test Case 12

Purpose	Compatibility Testing - Synchronization
Validity	Valid
Test Value(s)	Login to user account 1 using two mobile phones / web browser, then use one mobile phone to borrow the book "Harry Potter"

Expected Result	The borrow record is shown on both mobile phones / web browser after refreshing
-----------------	---

## 5. Evaluation

The objective of the project is to develop a low-cost RFID tracking system. Website application that allows access to the book tracking system and related information is designed to support all permit levels. A Mobile application that runs on Android is developed for normal users.

Objectives of this project are achieved. The RFID tracking system works well with other Website and Mobile Applications we developed for this system. Data Flow and Communication is smooth across platforms. There were four main aspects to evaluate our RFID tracking prototype:

### 1. Reliability

When a reader detects a tag, the reader can automatically transfer RSSI data through the WIFI module. An API to receive data transmission via TCP / IP method is working well and allows saving data back to the database. The RFID readers can steadily update tags RSSI value at a rate of 1/s. The recorded RSSI value is saved to the database for location calculation. Website and Mobile Applications both can access database data smoothly without problems. Connections with servers were also ensured that both Android apps and Websites can connect servers normally.

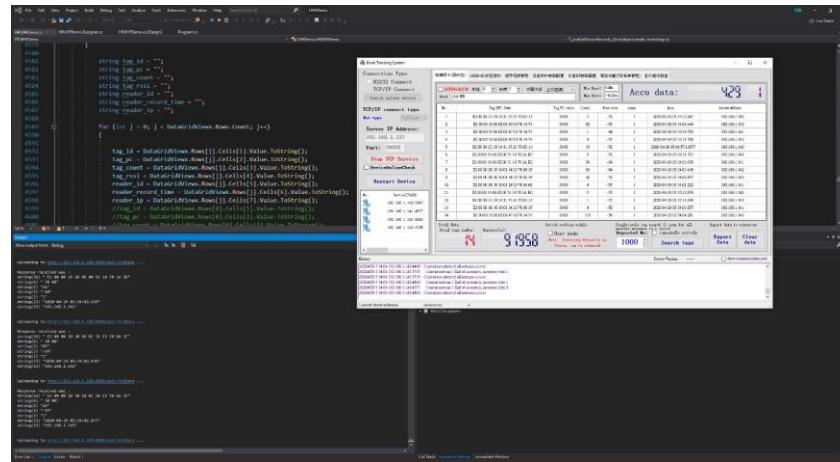


Figure 37. Data Flow

## 2. Comparison with other similar projects

The final product was compared with other similar proposed prototypes in the market such as RFID tracking systems and Indoor Localization setup. Details can be found in section 1.3 Literature Review.

## 3. User interface

Website and Apps applications were developed in addition to the hardware setup. The purpose is to enhance users experience so the user interfaces were carefully designed. Both User interfaces were neat and simple to use. For the Android Apps, we targeted only Users permit levels. Only the most basic functions e.g. tracking books and reviewing own borrow records etc. are there. As for the website, it supported all permit levels and with more functions. Admin and Managers can manage users and process book borrowing requests.

## 6.Discussion

Most of the proposed functionalities were achieved. Mobile and Website work well in the prototype. An improved location tracking algorithm was modified based on the traditional trilateral localization algorithm.

The main reason we needed to modify the typical algorithm is the limitation of our hardware. We only had very little time to purchase our main hardware requirement - RFID readers due to the epidemic this year. The readers turned out do not have the accuracy we predicted. As a result, using the original algorithm, some books cannot be tracked because no intersection point can be drawn. We therefore adapted and improvised a new algorithm by calculating the color intensity of the calculated area, which in our case works with the system and we can almost track all the books within the designated area. There are several ways to increase the accuracy by reducing tracking error and enlarge maximum read range of RFID readers respectively.

- ❖ Frequency gain of RFID readers can be made possible by having large reader size, but it is inconvenient and costly. Therefore, this project does not employ those methods for now. But it is a possible method to improve the tracking accuracy.
  
- ❖ Active tags provide a better accuracy compared with passive tags, but the cost is also much higher. Considering the demand of this project (Low-cost and small-scale device), passive tags should be sufficient for this project. We indeed checked for the possibility of active tags, but they were not compatible with our readers. Active tags may be considered in future development when the design is scaled up to be used in larger area e.g. Library.

## 7.Conclusion

### **Summary of Work**

The development of the Low-cost RFID book tracking prototype was a success overall. The objectives were mostly achieved. Platforms with user friendly interface complement the hardware set-up.

### **Major Technical accomplishments:**

- ❖ Set up RFID readers and ensure reliable detection with tags
- ❖ Pre-process RSSI data with linear regression to increase accuracy
- ❖ Improve typical Trilateral Algorithm to better suit our hardware setup
- ❖ Set up Servers and ensure smooth communications across platforms
- ❖ User friendly GUI

In this project, we successfully accomplish the main features of our design. It is a low running cost, automated system that can provide a relative reliable tracking for users.

### **Future Research Direction**

To enhance accuracy of the hardware setup, decreasing tracking errors and increasing RFID readers maximum reading range by simply increasing the number of antennas can improve workable reading range of the RFID readers, and the accuracy of the book tracking. Future development should also involve a study with active tags. We attempted to do so but due to lack of hardware supply was not feasible. To track books in multiple bookshelves in an area, further study on applying Trilateral Localization in 3-dimensional is also recommended.

## 8.References

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## **Appendix A: Meeting Minutes**

### **Minutes of the 1st Project Meeting**

Date: June 4, 2019

Time: 11:00 am HK time

Place: HKUST campus

Present: Claudia, Tony, Jarvis, Anson, Professor Gibson

Absent: None

Recorder: Claudia

#### 1. Approval of minutes

N/A

#### 2. Report on progress

2.1 All members discussed the design and implementation details of the project.

2.2 Professor Gibson explained the idea and purpose of the project clearly.

2.3 All members briefly discussed the distribution of work.

#### 3. Discussion items

3.1 The idea and purpose of the project

3.2 The distribution of work for the project

3.3 The design and implementation details of the project

#### 4. Goals for the coming week

4.1 Research on the project

#### 5. Meeting adjournment and next meeting

The next meeting is on August 4.

## **Minutes of the 2nd Project Meeting**

Date: August 4, 2019

Time: 4:00 pm HK time

Place: Skype (Online Meeting)

Present: Claudia, Tony, Jarvis, Anson Absent: None

Recorder: Claudia

### 1. Approval of minutes

The minutes of the last meeting were approved without amendment.

### 2. Report on progress

2.1 All team members have read the requirement of the coming proposal report.

2.2 All members have read related research paper and technology that we need for the project.

### 3. Discussion items

3.1. The outline of the proposal project

3.2 internal deadline for the group and division of work

### 4. Goals for the coming week

4.1. Find the related study papers

### 5. Meeting adjournment and next meeting

The next meeting is on August 10, next Saturday

## **Minutes of the 3rd Project Meeting**

Date: August 10, 2019

Time: 2:00 pm HK time

Place: Skype (Online Meeting)

Present: Claudia, Tony, Jarvis

Absent: Anson

Recorder: Claudia

### **1. Approval of minutes**

The minutes of the last meeting were approved without amendment.

### **2. Report on progress**

2.1 All members have read related research paper and technology that we need for the project.

2.2 All members have discussed the choice of framework we use for the computer system.

2.3 All members have been distributed the part of writing the Proposal Report.

### **3. Discussion items**

3.1. The framework of the computer system

3.2 The distribution of the work of the Proposal Report

### **4. Goals for the coming week**

4.1. Write the Proposal Report.

### **5. Meeting adjournment and next meeting**

The next meeting will be a group meeting with advisor at the end of August. Time and Venue will be further informed after confirming with Advisor

## **Minutes of the 4th Project Meeting**

Date: September 10, 2019

Time: 11:00 am HK time

Place: Gibson office (Online Meeting)

Present: Gibson, Claudia, Tony, Jarvis, Anson

Absent: None

Recorder: Tony

### 1. Approval of minutes

The minutes of the last meeting were approved without amendment.

### 2. Report on progress

2.1 All members have done the assigned parts.

2.3 All members have been distributed the part of writing the Proposal Report.

### 3. Discussion items

3.1. The improvement of the Proposal Report

3.2 Details of the development progress

### 4. Goals for the coming week

4.1. Finish the Proposal Report.

### 5. Meeting adjournment and next meeting

The next meeting will be an online group meeting on 15th September.

## **Minutes of the 5th Project Meeting**

Date: September 15, 2019

Time: 3:00 pm HK time

Place: Skype (Online Meeting)

Present: Claudia, Tony, Jarvis, Anson

Absent: None

Recorder: Claudia

### 1. Approval of minutes

The minutes of the last meeting were approved without amendment.

### 2. Report on progress

#### 2.1 Completion of Literature Review and Design Part of the project

### 3. Discussion items

#### 3.1. Work Progress on the Draft Proposal report

#### 3.2 Confirm hardware items to buy

### 4. Goals for the coming week

#### 4.1. Feedback and finalize the proposal report

### 5. Meeting adjournment and next meeting

The next meeting will be next Tuesday 17th September 2019 together with Project Supervisor (Gibson Lam). It will take place at 12pm in the office of supervisor.

## **Minutes of the 6th Project Meeting**

Date: Feb 14, 2020

Time: 13:00 HK time

Present: Claudia, Tony, Jarvis, Anson, Professor Gibson

Absent: None

Recorder: Anson

### 1. Approval of minutes

N/A

### 2. Report on progress

2.1 All members discussed the design details of the Mobile App and Web App

2.2 Professor Gibson explained the implementation approach of the software clearly.

2.3 All members briefly discussed the problems and solutions of the project.

### 3. Discussion items

3.1 The design and implementation details of the Web and Mobile App of the system

3.2 The solution to the shortage of RFID readers

3.3 The structure of the Progress Report

### 4. Goals for the coming week

4.1 Implementation of Web App

### 5. Meeting adjournment and next meeting

The next meeting is on Feb 20.

## **Minutes of the 7th Project Meeting**

Date: Feb 20, 2020

Time: 13:00 HK time

Present: Claudia, Tony, Jarvis, Anson, Professor Gibson

Absent: None

Recorder: Anson

### 1. Approval of minutes

The minutes of the last meeting were approved without amendment.

### 2. Report on progress

2.1 Professor Gibson explained the implementation approach of the hardware clearly.

2.2 All members briefly discussed the problems and solutions of the project.

### 3. Discussion items

3.1 The design and implementation details of the RFID readers of the system

3.2 The details of the built Web prototype

3.3 The details of the Progress Report

### 4. Goals for the coming week

4.1 Implementation on Hardware

### 5. Meeting adjournment and the next meeting

The next meeting is on Feb 21.

## **Minutes of the 8th Project Meeting**

Date: Feb 21, 2020

Time: 14:00 HK time

Present: Claudia, Tony, Jarvis, Anson, Professor Noor

Absent: None

Recorder: Anson

### 1. Approval of minutes

The minutes of the last meeting were approved without amendment.

### 2. Report on progress

2.1 Professor Noor explained the approach of writing the Progress report effectively and clearly.

2.2 All members briefly discussed the problems and solutions of the project.

### 3. Discussion items

3.1 The approach of writing the Progress report

3.2 The weaknesses of the previous Proposal report

### 4. Goals for the coming week

4.1 Write the Progress report

## **Minutes of the 9th Project Meeting**

Date: 9 April, 2020

Time: 3:00 pm HK time

Place: Zoom meeting

Present: Claudia, Tony, Jarvis, Anson

Absent: None

Recorder: Tony

### **1. Approval of minutes**

N/A

### **2. Report on progress**

2.1 All members discussed the overall progress of the project.

2.3 All members briefly discussed the work of the Progress report

### **3. Discussion items**

3.1. The purchase of the RFID readers and the RFID tags

3.2. The planning and the work distribution of the Progress report

### **4. Goals for the coming week**

4.1. Write the Progress report

### **5. Meeting adjournment and next meeting**

The next meeting is on April 22 with Professor Noor.

## **Minutes of the 10th Project Meeting**

Date: 16 April, 2020

Time: 3:00 pm HK time

Place: Zoom meeting

Present: Claudia, Tony, Jarvis, Anson

Absent: None

Recorder: Tony

### **1. Approval of minutes**

N/A

### **2. Report on progress**

2.1 All members discussed the overall progress of the project.

2.3 All members briefly discussed the work of the Final report.

### **3. Discussion items**

3.1. The current progress of the project

3.2. The planning and the work distribution of the Final report

### **4. Goals for the coming week**

4.1. Set up and test the tracking system

### **5. Meeting adjournment and next meeting**

The next meeting is on April 22 with Professor Noor.

## **Minutes of the 11tst Project Meeting**

Date: 23 April, 2020

Time: 3:00 pm HK time

Place: Zoom meeting

Present: Claudia, Tony, Jarvis, Anson, Professor Noor Liza

Absent: None

Recorder: Tony

### **1. Approval of minutes**

N/A

### **2. Report on progress**

2.1 All members discussed the overall implementation details and difficulties of the project.

2.2 Professor Noor explained the problems of the Progress report.

2.3 All members briefly discussed the work of the Final report.

### **3. Discussion items**

3.1. The problems of the Progress report.

3.2. The planning and the improvements of the Final report

### **4. Goals for the coming week**

4.1. Plan and write the Final report

### **5. Meeting adjournment and next meeting**

The next meeting is on April 24 with Professor Gibson Lam.

## **Minutes of the 12nd Project Meeting**

Date: 24 April, 2020

Time: 2:00 pm HK time

Place: Zoom meeting

Present: Claudia, Tony, Jarvis, Anson, Professor Gibson

Absent: None

Recorder: Tony

### **1. Approval of minutes**

N/A

### **2. Report on progress**

2.1 All members discussed the progress and implementation difficulties and of the project.

2.2 Professor Gibson commented on our current progress of work.

### **3. Discussion items**

3.1. The progress of the project

3.2. The accuracy of the tracking result.

3.3. The further improvements of the project

### **4. Goals for the coming week**

4.1. Plan and write the Final report

### **5. Meeting adjournment and next meeting**

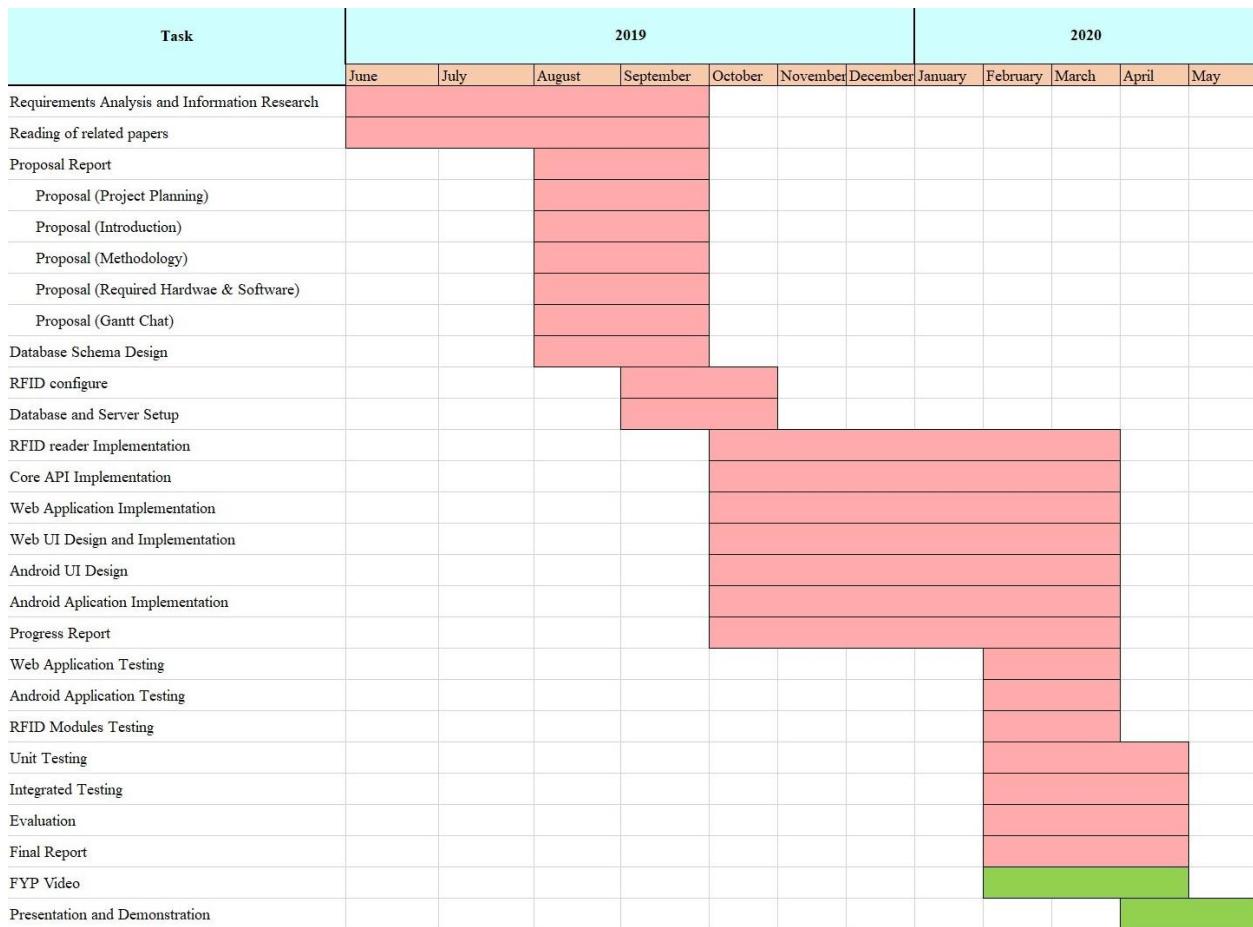
N/A

## Appendix B: Project Planning

### Division of Work

Task	Tony wan	Jaryas Tsc	Claudia Lo	Anson Ding
Requirements Analysis and Information Research	L	A	A	A
Reading of related papers	A	A	A	L
Proposal Report	L	A	A	A
Database Schema Design	A	L	A	A
RFID configure	A	L	A	A
Database and Server Setup	L	A	A	A
RFID reader Implementation	A	L	A	A
Core API Implementation	A	A	A	L
Web Application Implementation	A	L	A	A
Web UI Design and Implementation	L	A	A	A
Android UI Design	A	A	A	L
Android Application Implementation	A	A	L	A
Progress Report	A	A	L	A
Web Application Testing	L	A	A	A
Android Application Testing	A	A	A	L
RFID Modules Testing	L	A	A	A
Unit Testing	A	L	A	A
Integrated Testing	A	L	A	A
User Acceptance Testing	A	A	L	A
Evaluation	A	A	A	L
Poster Design	A	A	L	A
Final Report	A	A	L	A
Presentation and Demonstration	L	A	A	A
L = Leader , A = Assistant				

## Gantt Chart



## **Appendix C: Hardware and Software Requirements**

The following table shows the hardware and software that are required in the testing and implementation stage.

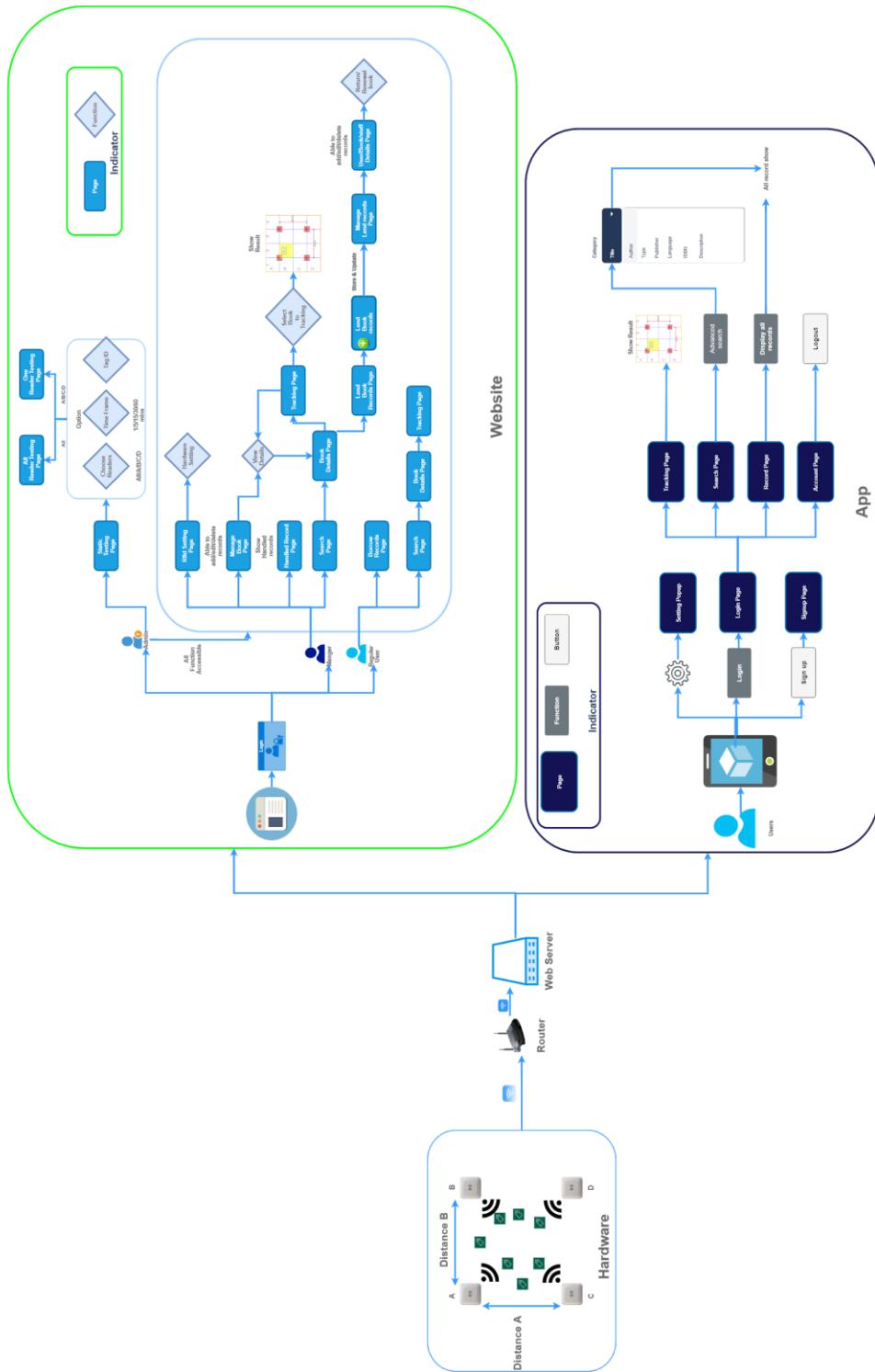
### **Hardware**

<b>Hardware</b>	<b>Quantity</b>	<b>Specification</b>
Rfid Passive Tags	17	Included id (Hex formal)
Rfid Active Tags	3	Embed, and required battery and special RFID readers
Rfid reader	4	Can connect to Wi-Fi, but first-time configuration can only though USB or LAN.
MacBook Pro (2014)	1	Mac OS X 10.15.4  2.6 GHz Dual-Core Intel Core i5, 8GB RAM, 256GB SSD
Desktop PC	1	Window 10  Intel core i7-8700, 3.20GHz
adapter	3	2A current, 2-Pin Plug to 3-Pin Plug

## Software

Software	Usage
HTML 5 with CSS3	Designing and Constructing the interface
JavaScript 6	Web page design
PHP 7.4.4	Constructing Controller, model
Laravel 6.15.1	MVC
Ajax 2.1.3	Post data
jQuery	Constructing function
MySQL 8.0.19	Manipulating the database
Adobe Photoshop	Designing button, background, layout, image
Composer 1.9.2	Install components
Scalable vector graph (SVG)	Draw some diagrams

## Appendix D: Whole System diagram



## Appendix E: Testing Rssi Accuracy

Book ID 30

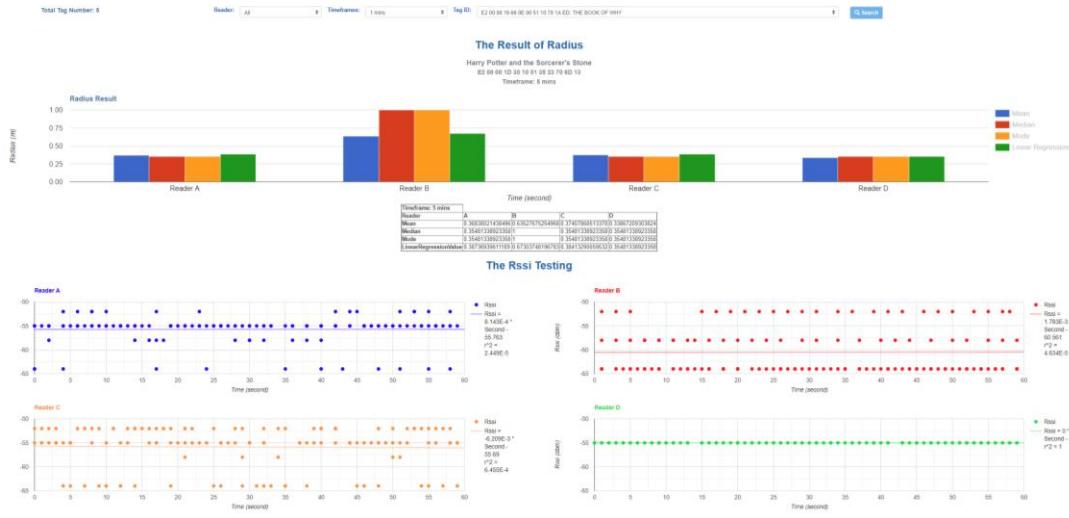
E2 00 00 1D 30 10 01 35 23 70 6D 13

Read distance

Reader	A	B	C	D
Distance (m)	0.28	0.51	0.32	0.64



Timeframe: 1 mins				
Reader	A	B	C	D
Mean	0.2581693979023	0.5199959965335	0.2804895377121	0.2754228703338
Median	0.3548133892335	0.5011872336272	0.3548133892335	0.3548133892335
Mode	0.3548133892335	0.5011872336272	0.2511886431509	0.3548133892335
LinearRegressionValue	0.3397262467411	0.6620894763321	0.3959760205369	0.3548133892335



Timeframe: 5 mins					
Reader	A	B	C	D	
Mean	0.36838021438496	0.63527675254968	0.37407868513378	0.33867209303824	
Median	0.35481338923358	1	0.35481338923358	0.35481338923358	
Mode	0.35481338923358	1	0.35481338923358	0.35481338923358	
LinearRegressionValue	0.38736939611189	0.67303748196783	0.38413290059532	0.35481338923358	

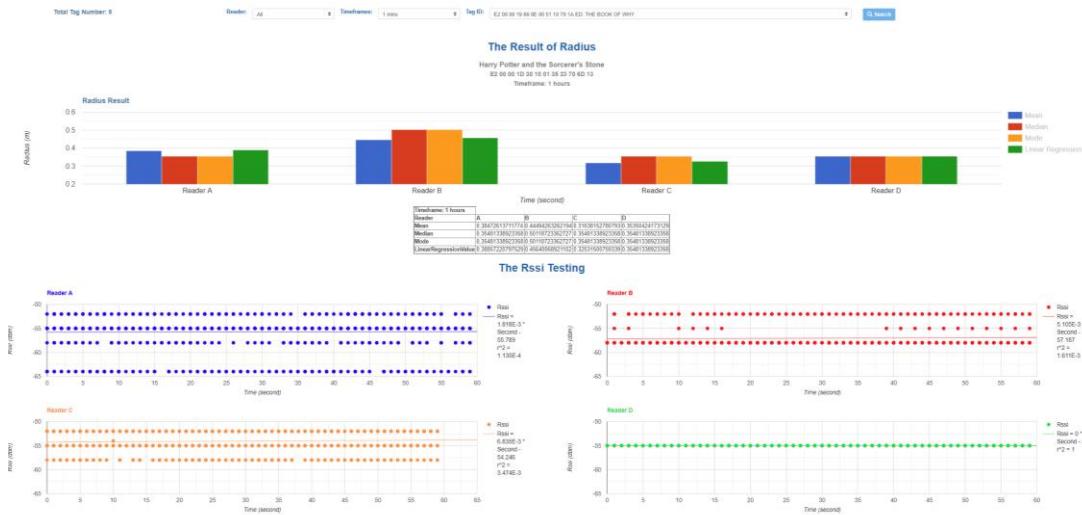


**Timeframe: 15 mins**

Reader	A	B	C	D
Mean	0.37724761780071	0.86247952186414	0.38389889977994	0.34942782737496
Median	0.35481338923358	0.35481338923351	0.35481338923358	0.35481338923358
Mode	0.35481338923358	0.35481338923351	0.35481338923358	0.35481338923358
LinearRegressionValue	0.39973062001235	0.88137116824667	0.38424116510574	0.35481338923358


**Timeframe: 30 mins**

Reader	A	B	C	D
Mean	0.37519786205819	0.71774349833652	0.40006464909083	0.352164489798
Median	0.35481338923358	0.35481338923351	0.35481338923358	0.35481338923358
Mode	0.35481338923358	0.35481338923351	0.25118864315096	0.35481338923358
LinearRegressionValue	0.38335670215843	0.73596683379439	0.41972454934089	0.35481338923358



### Timeframe: 1 hours

Reader	A	B	C	D
Mean	0.38472613711774	0.44494263262194	0.31638152780793	0.35350424173129
Median	0.35481338923358	0.50118723362727	0.35481338923358	0.35481338923358
Mode	0.35481338923358	0.50118723362727	0.35481338923358	0.35481338923358
LinearRegressionValue	0.38857220797529	0.45640068921102	0.32531500759339	0.35481338923358

### Book id 31

E2 00 00 19 66 0E 00 49 10 70 14 74

Reader	A	B	C	D
Distance (m)	0.45	0.56	0.23	0.45



### Timeframe: 1 mins

Reader	A	B	C	D
Mean	null	null	0.52983169062837	0.3981071705535
Median	null	null	1	0.50118723362727
Mode	null	null	1	0.50118723362727
LinearRegressionValue	null	null	0.73043170696916	0.50118723362727



### Timeframe: 5 mins

Reader	A	B	C	D
Mean	null	null	0.67025665492514	0.47800520328496
Median	null	null	1	0.50118723362727
Mode	null	null	1	0.50118723362727

<b>LinearRegressionValue</b>	null	null	0.75511418436521	0.50118723362727
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**Timeframe: 15 mins**

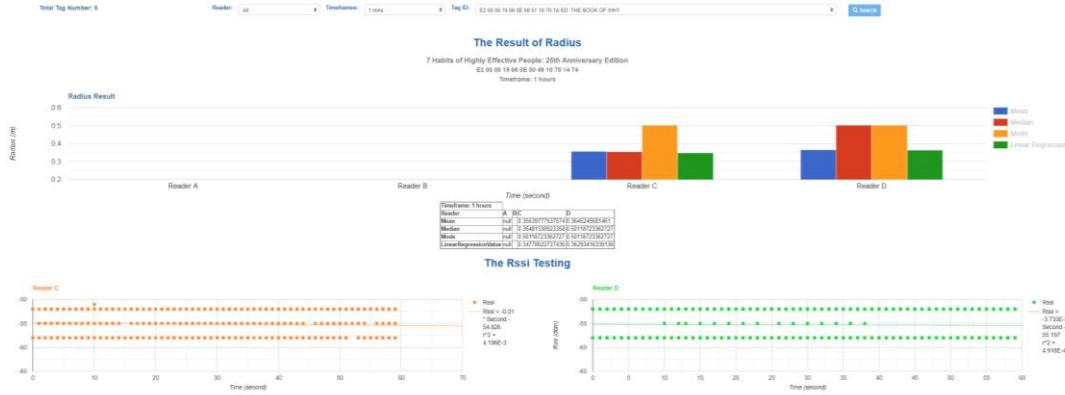
Reader	A	B	C	D
<b>Mean</b>	null	null	0.7075521485924	0.69429796721647
<b>Median</b>	null	null	1	0.50118723362727
<b>Mode</b>	null	null	1	0.50118723362727
<b>LinearRegressionValue</b>	null	null	0.73063510758011	0.70620304976152



**Timeframe: 30 mins**

Reader	A	B	C	D
<b>Mean</b>	null	null	0.68856567316621	0.76084210213961

<b>Median</b>	null	null	1	1
<b>Mode</b>	null	null	1	1
<b>LinearRegressionValue</b>	null	null	0.67646078554392	0.78048017120152

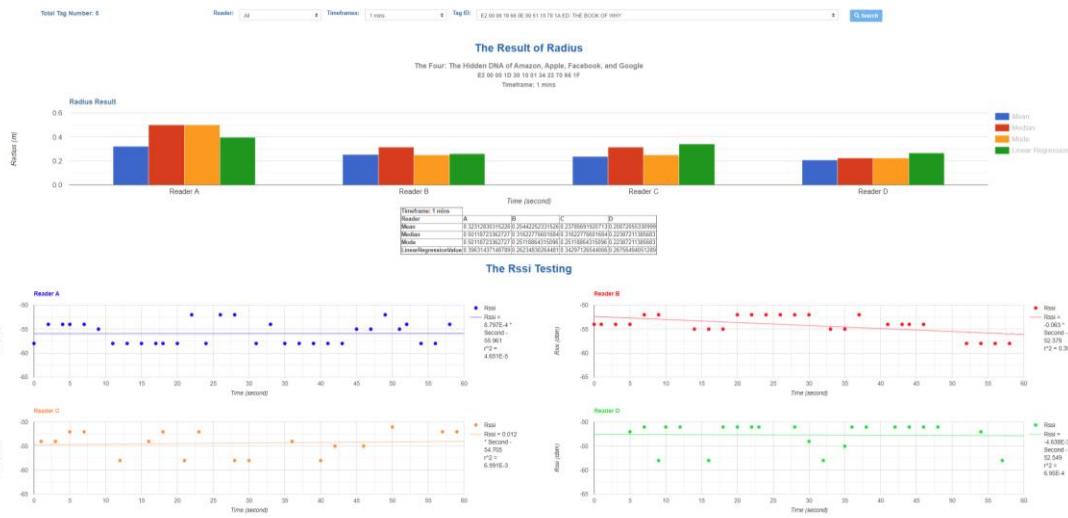


Timeframe: 1 hours					
Reader	A	B	C	D	
<b>Mean</b>	null	null	0.35675199647316	0.36420561192882	
<b>Median</b>	null	null	0.35481338923358	0.50118723362727	
<b>Mode</b>	null	null	0.50118723362727	0.50118723362727	
<b>LinearRegressionValue</b>	null	null	0.34951365069456	0.36266986819075	

E2 00 00 1D 30 10 01 34 23 70 66 1F

### Real world distance

Reader	A	B	C	D
<b>Distance (m)</b>	0.38	0.38	0.38	0.38



### Timeframe: 1 mins

Reader	A	B	C	D
Mean	0.3231283031522	0.2544225233152	0.2378569192071	0.2087205533099
Median	0.5011872336272	0.3162277660168	0.3162277660168	0.2238721138568
Mode	0.5011872336272	0.2511886431509	0.2511886431509	0.2238721138568
LinearRegressionValue	0.3963143714878	0.2623483026448	0.3429712654406	0.2675649405128



Timeframe: 5 mins				
Reader	A	B	C	D
Mean	0.3174539039546 6	0.2898645612882 6	0.3035993832383 1	0.3059096804329 3
Median	0.3162277660168 4	0.3162277660168 4	0.3162277660168 4	0.3548133892335 8
Mode	0.2511886431509 6	0.2511886431509 6	0.2511886431509 6	0.3548133892335 8
LinearRegressionValue	0.3267786940982 5	0.2627205471418 9	0.3333615520462 6	0.3232421959460 4



Timeframe: 15 mins				
Reader	A	B	C	D
Mean	0.4121975313067 8	0.4385685356320 1	0.5093804274539 9	0.4508069577564 6
Median	0.3548133892335 8	0.3162277660168 4	0.5011872336272 7	0.5011872336272 7
Mode	0.3162277660168 4	0.2511886431509 6	0.5011872336272 7	0.5011872336272 1
LinearRegressionValue	0.4411942598385 5	0.4513893107060 7	0.5282099131007 7	0.4782933470668 3



### Timeframe: 30 mins

Reader	A	B	C	D
Mean	0.4134181590101	0.4302979947721	0.5326679901076	0.4609085286174
Median	0.3548133892335	0.3162277660168	0.5011872336272	0.5011872336272
Mode	0.3162277660168	0.2511886431509	0.5011872336272	0.1
LinearRegressionValue	0.4265406774683	0.4521242335604	0.5682157506648	0.4852350671051



### Timeframe: 1 hours

Reader	A	B	C	D
Mean	0.43444325538619	0.31998486298248	0.33819459827879	0.33509926653677
Median	0.35481338923358	0.25118864315096	0.35481338923358	0.35481338923358
Mode	0.25118864315096	0.25118864315096	0.25118864315096	0.50118723362727
LinearRegressionValue	0.45114509057743	0.30389677391317	0.34130063048304	0.33795375667116

E2 00 00 19 66 0E 00 47 10 70 14 73

## Real world distance:

Reader	A	B	C	D
Distance (m)	0.62	0.42	0.45	0.23



Timeframe: 1 mins		A	B	C	D
Reader		A	B	C	D
Mean	null	0.20574691560478	0.20323570109362	0.2351952635071	
Median	null	0.25118864315096	0.25118864315096	0.35481338923358	

<b>Mode</b>	null	0.25118864315096	0.25118864315096	0.50118723362727
<b>LinearRegressionValue</b>	null	0.25118864315096	0.2485718823129	0.3212949087505



**Timeframe: 5 mins**

Reader	A	B	C	D
<b>Mean</b>	null	0.31910424696756	0.27312637228008	0.34646165244298
<b>Median</b>	null	0.35481338923358	0.25118864315096	0.35481338923358
<b>Mode</b>	null	0.25118864315096	0.25118864315096	0.50118723362727
<b>LinearRegressionValue</b>	null	0.36333094167045	0.27738115429235	0.34630084632007



Timeframe: 15 mins				
Reader	A	B	C	D
Mean	0.35231393782382	0.29785164294297	0.34592156395897	0.31860366989425
Median	0.31622776601684	0.25118864315096	0.35481338923358	0.31622776601684
Mode	0.50118723362727	0.25118864315096	0.50118723362727	0.50118723362727
LinearRegressionValue	0.36477560941707	0.26643685495546	0.34886092767416	0.32153821869823



Timeframe: 30 mins				
Reader	A	B	C	D
Mean	null	0.33984031717752	0.28027050042766	0.37794250963904
Median	null	0.35481338923358	0.25118864315096	0.50118723362727
Mode	null	0.25118864315096	0.25118864315096	0.50118723362727
LinearRegressionValue	null	0.35936645655696	0.27397858046821	0.36358698650956

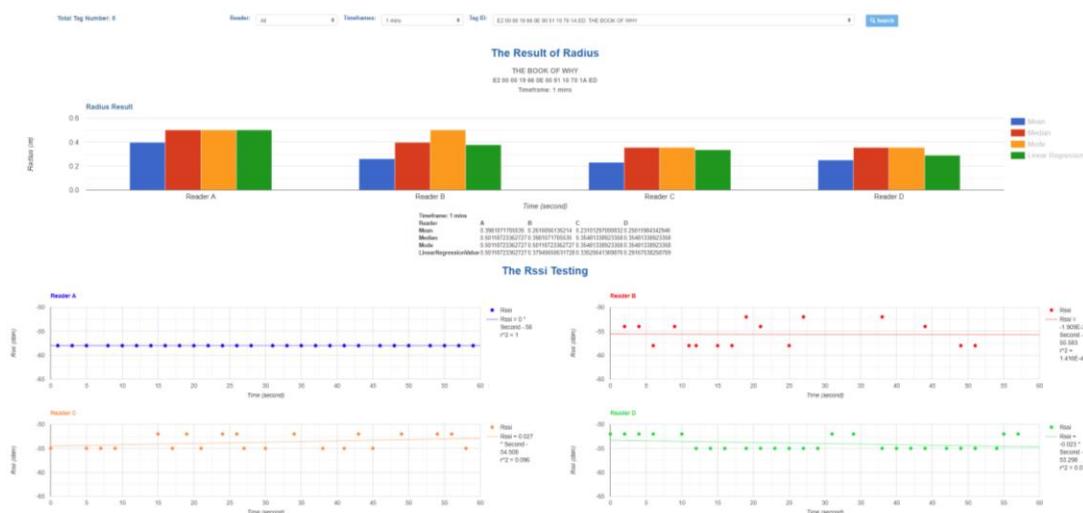


Timeframe: 1 hours				
Reader	A	B	C	D
Mean	null	0.33390360128249	0.28995741379081	0.3805740953431
Median	null	0.25118864315096	0.25118864315096	0.50118723362727
Mode	null	0.25118864315096	0.25118864315096	0.50118723362727
LinearRegressionValue	null	0.35576508896902	0.28606582986176	0.37612434535535

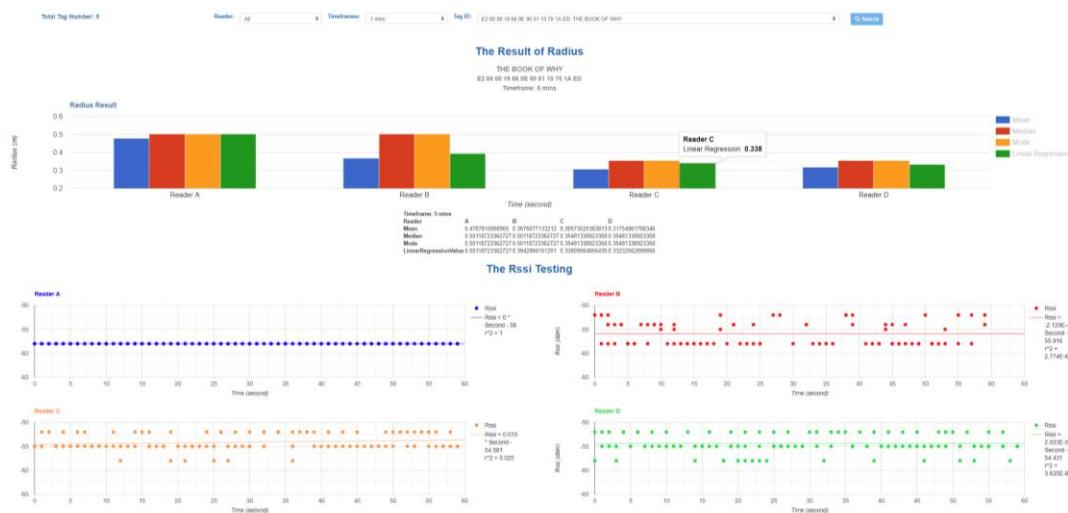
E2 00 00 19 66 0E 00 51 10 70 1A ED

0.3 0.3 0.51 0.58

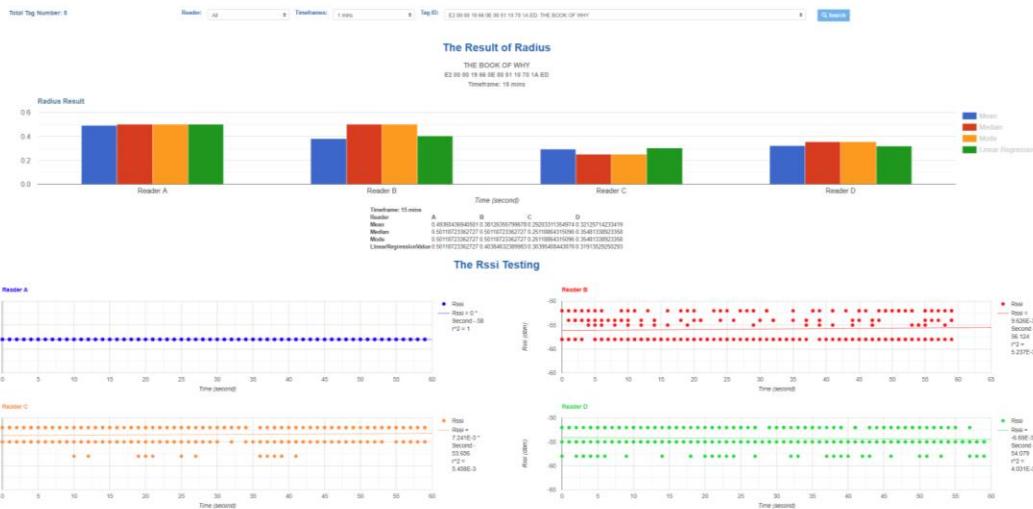
Reader	A	B	C	D
Distance(m)	0.3	0.51	0.3	0.58



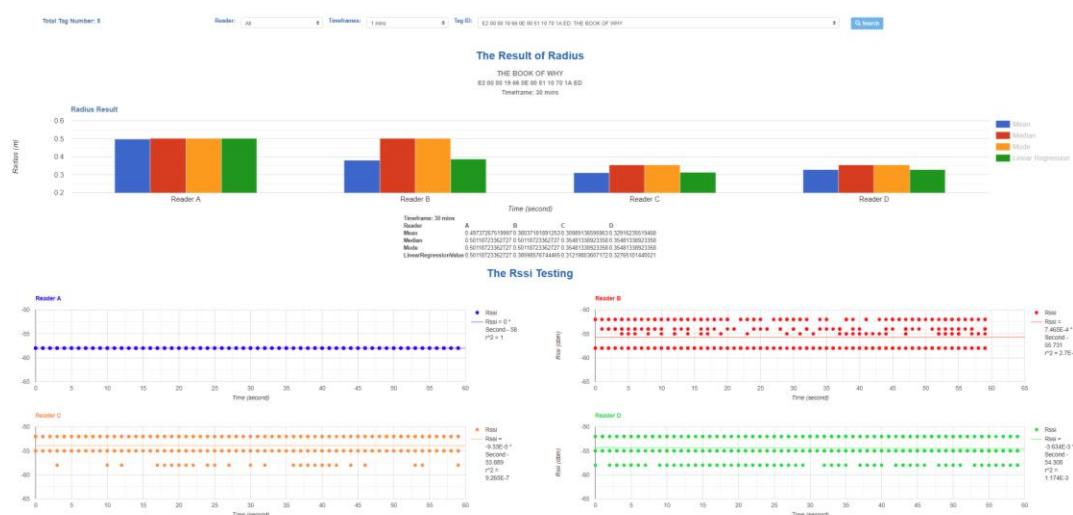
Timeframe: 1 mins				
Reader	A	B	C	D
Mean	0.3981071705535	0.2616056135214	0.2310129700083	0.2501198434294
Median	0.5011872336272	0.3981071705535	0.3548133892335	0.3548133892335
Mode	0.5011872336272	0.5011872336272	0.3548133892335	0.3548133892335
LinearRegressionValue	0.5011872336272	0.3794565063172	0.3352564136987	0.2916753825876
	7	8	6	9



Timeframe: 5 mins				
Reader	A	B	C	D
Mean	0.4787810868905	0.3676077133212	0.3057302038381	0.3175496176834
Median	0.5011872336272	0.5011872336272	0.3548133892335	0.3548133892335
Mode	0.5011872336272	0.5011872336272	0.3548133892335	0.3548133892335
LinearRegressionValue	0.5011872336272	0.3942894151201	0.3380956485643	0.3323256289985
	7	5	5	6



Timeframe: 15 mins				
Reader	A	B	C	D
Mean	0.4936043694050 1	0.3812635579967 8	0.2920331135497 4	0.3212571423341 9
Median	0.5011872336272 7	0.5011872336272 7	0.2511886431509 6	0.3548133892335 8
Mode	0.5011872336272 7	0.5011872336272 7	0.2511886431509 6	0.3548133892335 8
LinearRegressionValue	0.5011872336272 7	0.4038463238998 3	0.3039540844307 6	0.3191352925029 3



Timeframe: 30 mins				
Reader	A	B	C	D
Mean	0.4973726751999 7	0.3803718189125 3	0.3098913659596 3	0.3291623551946 8
Median	0.5011872336272 7	0.5011872336272 7	0.3548133892335 8	0.3548133892335 8
Mode	0.5011872336272 7	0.5011872336272 7	0.3548133892335 8	0.3548133892335 8
LinearRegressionValue	0.5011872336272 7	0.3859857674446 5	0.3121980360717 2	0.3276510144002 1



Timeframe: 1 hours				
Reader	A	B	C	D
Mean	0.4972621070245 3	0.3832644284568 2	0.3171911079801	0.3346251161881
Median	0.5011872336272 7	0.5011872336272 7	0.3548133892335 8	0.3548133892335 8
Mode	0.5011872336272 7	0.5011872336272 7	0.3548133892335 8	0.3548133892335 8
LinearRegressionValue	0.4988914743578 3	0.3850720075977 2	0.3192774296848 8	0.3351596632136 5