WIA3002 ACADEMIC PROJECT II

Faculty of Computer Science and Information Technology

Department of Artificial Intelligence

University of Malaya

WeCare

Indoor Positioning Module

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Besides that, I would like to take the opportunity to thank our collaborator company, MDT Innovations Sdn. Bhd. for trusting us with the project. A special thanks to Mr Chew Hoo Beng, the manager of Research & Development department at the company for the constant assistance and feedback.

Abstract

With the most recent report released by United States Department of Labor, the Census of Fatal Occupational Injuries concludes that the construction industry ranks in the top four industries with the highest rate of fatal injuries [8], while in Malaysia, according a recent report by the Department of Occupational Safety and Health Administration (*OSHA*)[1], the construction industry ranked number one [9]. Among the factors contributing to the high fatality rate are there is no way for a site supervisor to track a worker's location and health status in real-time currently. This project aims to provide that solution to the industry by involving wearable devices to be worn by the worker, and a graphical user interface used by site supervisors to gain insight on the location and health status of the workers.

Indoor positioning has been a hot topic in the industry for some time as it has a lot of potential and needs in the current state of technology. One of the many application is to track people in a building. While plenty of research has been done on the topic, many involve complex hardware requirement to be able to gather sufficient data for processing. In this project, trilateration is put to the test as it requires one of the, if not the least amount of data.

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[1] Malaysia's Department of Occupational Safety and Health Administration (OSHA) is a department under the Ministry of Human Resources, which is responsible for ensuring the safety, health and welfare of people at work as well as protecting the people from safety and health hazards arising from the activity sectors.

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1 Introduction

1.1 Overview

Safety is defined by Oxford Dictionaries as "the condition of being protected from or unlikely to cause danger, risk, or injury". However, it is near impossible to get away from being injured while at work no matter how small the injury might be [7]. According to Census of Fatal Occupational Injuries (CFOI), private construction industry is ranked first in number of fatal injuries, and fourth in fatal injury rates across all industry [8]. In Malaysia, the construction industry is ranked fourth in number of accidents and highest fatal injuries and fatal injury rate [9]. Yet, contractors, especially here in Malaysia, are lack of appropriate approach to comply with the Occupational Safety and Health Administration (OSHA) standard to ensure their worker's safety in the site.

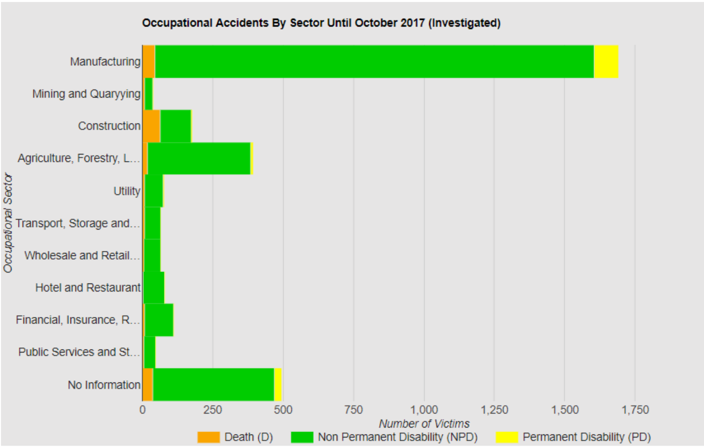


Figure 1 Graph provided by OSHA

Besides that, there is an obvious lack of immediate two-way communication between site supervisors and the workers. This is crucial and felt when there is an accident happen at the construction site. Sometimes, the difference of a few seconds is life or dead matter. Being able to send out SOS signal to site supervisor when accident occurs will enable the supervisor to react faster and more efficient.

In recent years, with the rise of Internet of Things, there have been many new proposed solutions in the market. Among these solutions comes a common theme, to be able to track user location and be able to have a source of health indicator of the user. WeCare is in the vein of this theme. WeCare aims to provide the solution for an organization to monitor the safety of its members or staffs while being a cost-effective and robust system.

1.2 Problem Statements

Construction site workers, especially in Malaysia, usually does not comply to the OSHA standard of equipment requirement. This is very dangerous as it increases the rate of injury significantly. With buildings getting taller and bigger, so do construction sites. Site supervisors are having a hard time to determine where a worker might be at a given time. Thus, it might be hard for the supervisors to react on time when an accident occurs.

Current market trend indicates that the worker health status and location is important to keep track as it provides some indicator to an accident might occur.

1.3 Project Objectives

The main objectives of the project are:

- To be able to monitor the heart conditions of the workers in real time.
- To be able to track the locations of the workers in real time.
- To enable two-way communication between the site supervisors and workers.
-

1.4 Project Module Structure

As an Innovative Product Project Initiative Final Year Project, the project is breakdown into four modules with a team member helming a module each. This paper discussing the indoor positioning module specifically.

1.5 Module Problem Statements

The wearable device that is using for the project provides three important positioning data:

- Global Positioning System (GPS)
- Cellular tower (Cell tower)
- Wi-Fi access points

90% of the time, people tracking happens in indoor environment. Weighted average is a popular technique used for indoor positioning (tracking). However, it is less accurate unless boundary filtering is adopted. Most techniques require information such as angles, time of flight (TOF), Bluetooth or RFID to perform accurate triangulation. However, the wearable device provided have limited info (GPS, base station/cell tower and WiFi). For outdoor positioning, GPS is still state of the art. In the case where GPS is unavailable, the fall back is to obtain cell tower database to do cell tower positioning.

1.6 Module User Requirements

The module-specific user requirements are:

- To be able to provide a usable positioning data in indoor environment
- To provide more than one way for positioning at outdoor environment

1.7 Module Objectives

The module-specific objectives are:

- To develop a framework for indoor positioning using boundary-filtered weighted average technique
- To switch between indoor and outdoor positioning automatically based on data received from wearable device

2 Literature Review

2.1 What is an Indoor Positioning System?

An indoor positioning system (IPS) is a system that only concern about the indoor environment, such as the inside of a building [5]. Dempsey [10] defines it as a system that able to determine the position of something or someone in real-time continuously in a physical space. As such, IPS should be able to work all the time with a reasonable accuracy and delay between each updated position within a specific area.

2.2 Survey of Existing Indoor Positioning Techniques and System

As the IoT industry soars with all the new flashy techs, indoor positioning systems have become increasingly popular over the years. Many of such systems have been implemented in various applications such as asset tracking and inventory management system for huge warehouses where items tend to be misplaced or hard to find. There are several different approaches to indoor positioning system using different technologies in the market, but we will only look into the following few as it is the only available data from the hardware device to be used in the project.

2.2.1 GPS

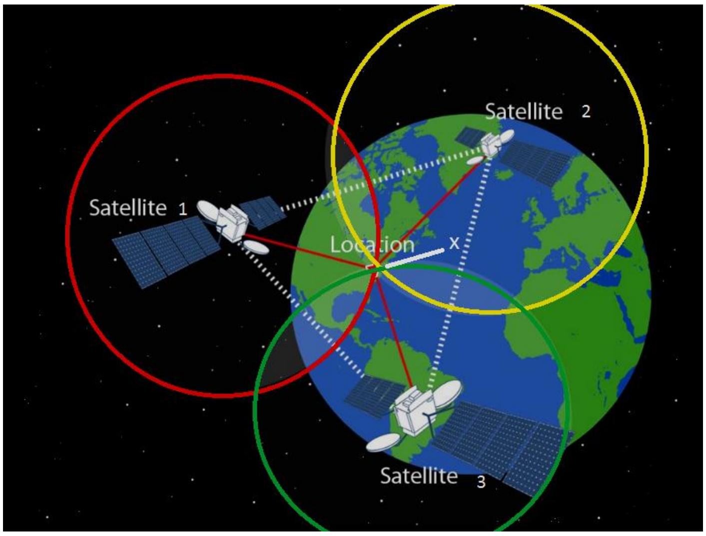


Figure 2 How does GPS work

The most widely used positioning system is the appropriately named Global Positioning System (GPS) developed by United States, and its Russian counterpart, Globalnaya Navigatsionnaya Sputnitkovaya Sistema (GLONASS). As anyone who has ever used Google Map or Waze or Apple Map to navigate through the streets, GPS is an essential, robust and proven system in determining one's location in the globe. It is a satellite-based system, in which the device receiver attempts to connect to at least four satellites to gain an accurate or valid location. However, the coverage of satellite signals dramatically reduces when in indoor environment, and thus its accuracy [1]. This makes it unsuitable for indoor location estimation. To overcome this limitation, SnapTrack, a Qualcomm company, pioneered wireless assisted GPS (A-GPS).

2.2.2 Cellular based

A cell tower, or a Base Transceiver Station (BTS) is a site where antenna and electronic communication equipment are installed, serving as a cell in a cellular network. In layman's term, a cell tower works to receive and transmit radio-frequency signals from a cell phone to another. With the availability of cell tower data, GPS system can get a faster fix on the satellite signals [2], by the means of A-GPS. Cellular based positioning can yield between 50m to 200m of accuracy [3]. The accuracy is generally higher in urban places where there are many cell towers in close proximity of each other [1].

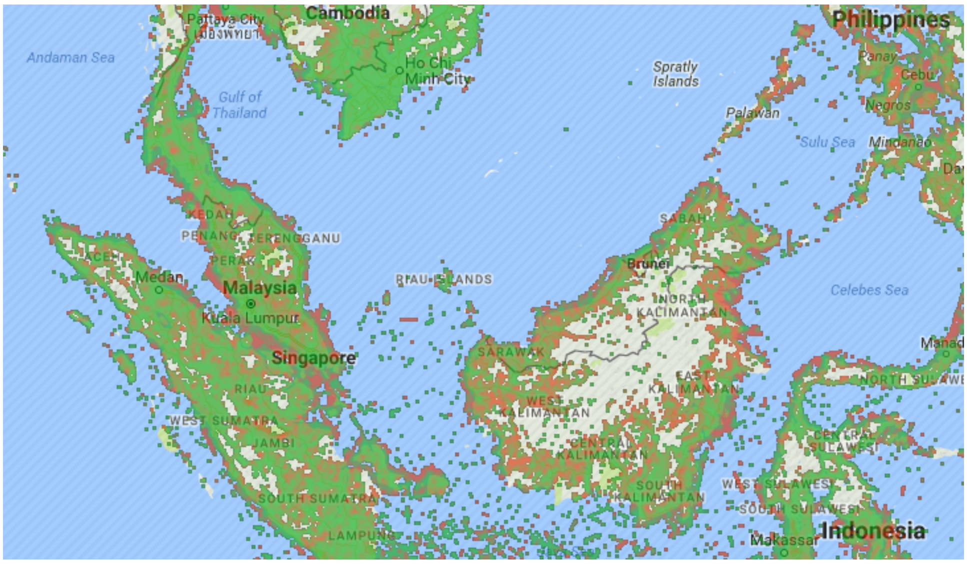


Figure 3 Cell tower coverage of Malaysia taken from OpenSignal.com

2.2.3 WLAN

With the rise of internet connectivity, Wi-Fi access points (AP) began dotting the face of the earth. The idea of positioning using Wi-Fi AP becomes less of an idea, and more of a solution. WLAN based indoor positioning system has a higher accuracy of around 3 to 30 meters [1][5][6]. Microsoft's RADAR is once such system that utilizes WLAN data for positioning, with an accuracy of 2 to 3 meters.

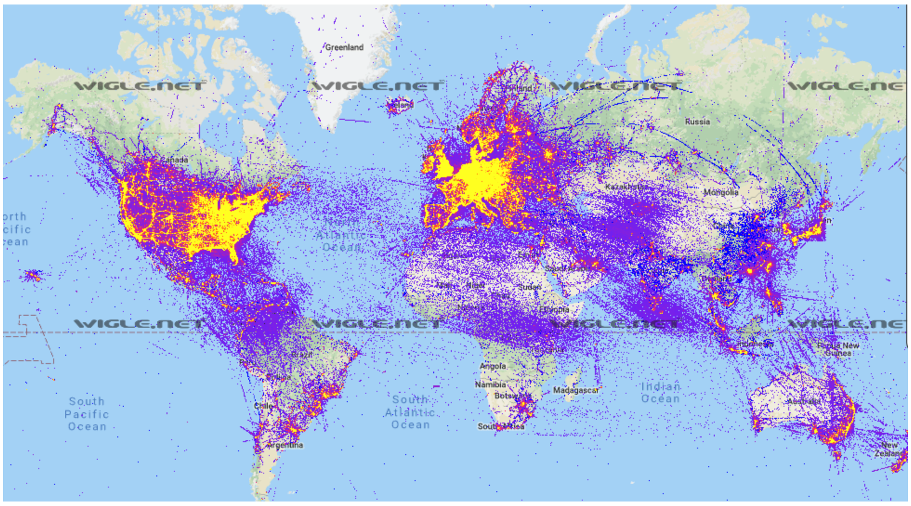


Figure 4 Wi-Fi access points heatmap taken from Wigle.net

2.3 Techniques used by existing system

2.3.1 Triangulation technique

Figure 5 Triangulation example

There are a multitude of positioning algorithm today in practice, with triangulation being the most prominent of all. Triangulation, as the name suggests, is related to trigonometry, basing on the geometric properties of triangles and angles to estimate location. Triangulation can be further derived into two distinct techniques, lateration and angulation [1]. Lateration (trilateration) technique refers to the estimation of location by measuring its distance from multiple reference points. By calculating the intersection point of the RSSI circle around each reference points, the location of a device can be estimated. On the other hand, angulation (triangulation) technique takes into account the angle of relative reference points for more precise estimation while requiring less reference points. However, triangulation comes with a higher cost and more complex hardware requirements.

2.3.2 Fingerprinting technique

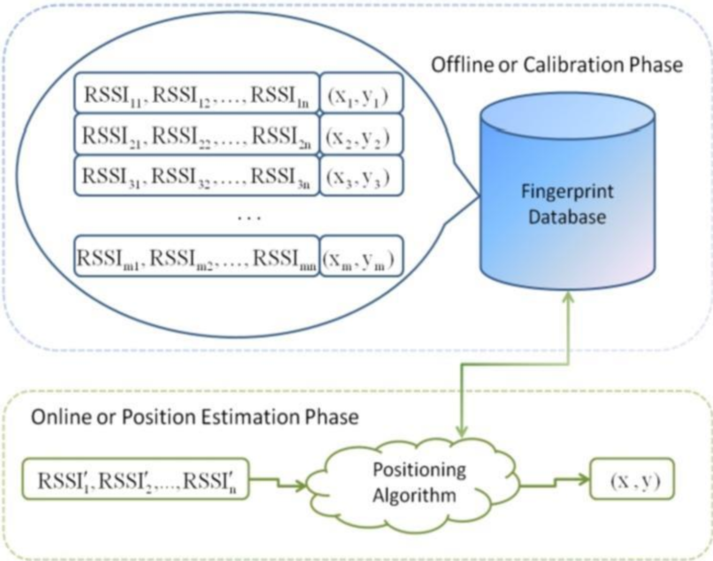


Figure 6 Fingerprinting example

Another positioning algorithm used is the scene analysis technique [1]. Scene analysis is a type of algorithm that builds databases of fingerprints (features) of a scene then subsequently estimates the location of an object by matching the stored fingerprints. There are two stages in location fingerprinting, the offline stage and the online (run-time) stage. During the offline stage, a site survey is performed in the environment to gather location coordinate and its RSSI of nearby cell tower/Wi-Fi AP. The data is then stored in a database as fingerprints. The online stage is simply the running stage where device location is determined based on the fingerprints in the database.

One glaring limitation of such technique is that any changes to the environment will affect the fingerprints in the database [12]. This is due to the fact that the fingerprints are statically stored in database, and RSSI is affected by anything that might block, reflect, diffract or scatter it. Hence, even a simple action of removing a furniture from the room, might affect the fingerprint's accuracy, requiring an update to correct the fingerprint.

3 Research Methodology

The project consists of a wearable device manufactured in China.

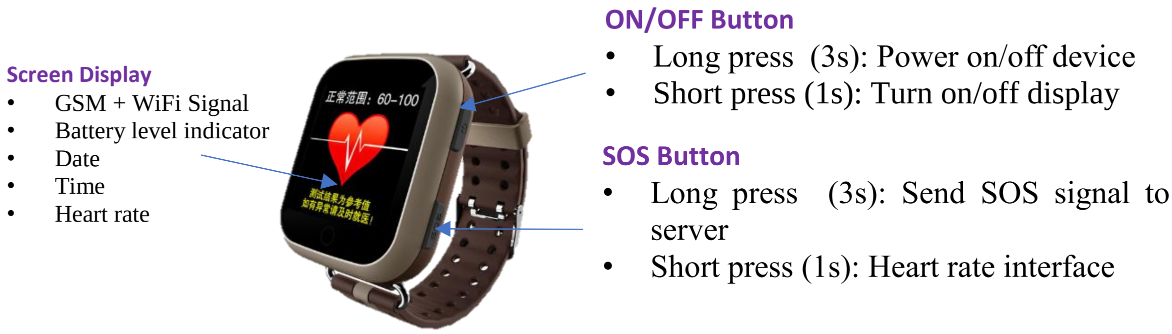


Figure 7 Wearable device functions

The device itself connects to a server TCP socket using mobile SIM data. At a settable period, the device will send a position data packet to the socket connected.

[3G*15052018*00E6*UD2,170118,030135,V,22.570675,N,113.8621067,E,0.00,0.0,0.0,0,82,22,0,0,00000010,1,255,502,16,21091,25021,137,3,mdtresearch@unifibiz,6c:72:20:3d:28:54,-64,GWNET,1c:1d:86:41:11:81,-90,Sunway Pinnacle_Guest,1c:1d:86:41:11:83,-93,12.7]

Figure 8 Raw data packet

For GPS data, as highlighted in red, the data received can be used as it is, given that the device transmit latitude and longitude already. However, for the cell tower data and Wi-Fi access points data, as highlighted in blue and green respectively, some processing of data is needed to extract any meaningful information from it. For cell tower data, data transmitted from the device includes MCC, MNC, cell tower area code, cell tower ID and RSSI for each detected cell tower, whereas for Wi-Fi data, data transmitted from the device includes Service Set Identified (SSID), Basic SSID (BSSID) or MAC address and RSSI for each detected Wi-Fi access points.

After reviewing a few research papers, it is decided that the best way to proceed with the indoor positioning is to use a trilateration algorithm. This is due the device being only able to transmit RSSI data for both cell tower and Wi-Fi.

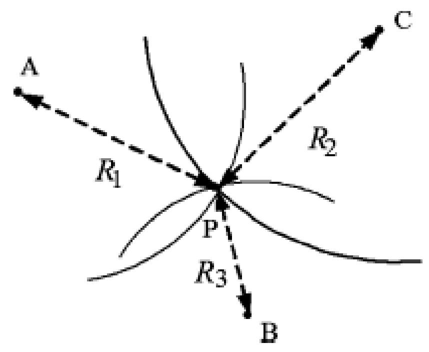


Figure 9 Trilateration

Let the we have 3 points {A, B, C} as input and target being {P} as shown in figure 3.

Using the equation $a^2 + b^2 = c^2$, which is the equation of a right-angle triangle, we get

$$(1)\ c = \sqrt{(a^2 + b^2)}$$

From (1), we can assume that the R of each points as the hypotenuse, we get that

$$(2)\ R = \sqrt{(X - P_x)^2 + \left(Y - P_y\right)^2}$$

And by rearranging we get that

$$(3)\ 0 = (X - P_x)^2 + \left(Y - P_y\right)^2 - R^2$$

From (3), we can apply to the reference points,

$$(4)\ 0 = (A_x - P_x)^2 + \left(A_y - P_y\right)^2 - {R_1}^2$$

$$(5)\ 0 = (B_x - P_x)^2 + \left(B_y - P_y\right)^2 - {R_2}^2$$

$$(6)\ 0 = (C_x - P_x)^2 + \left(C_y - P_y\right)^2 - {R_3}^2$$

By equating the equations (4) and (5), we get

$$(B_x - P_x)^2 + \left(B_y - P_y\right)^2 - {R_2}^2 = (A_x - P_x)^2 + \left(A_y - P_y\right)^2 - {R_1}^2$$

$${A_x}^2 - {B_x}^2 + {A_y}^2 - {B_y}^2 - {R_1}^2 + {R_2}^2 - 2A_xP_x + 2B_xP_x - 2A_yP_y + 2B_yP_y = 0$$

$$(7)\ {A_x}^2 - {B_x}^2 + {A_y}^2 - {B_y}^2 - {R_1}^2 + {R_2}^2 = 2P_x(A_x - B_x) + 2P_y(A_y - B_y)$$

By equating the equations (5) and (6), we get

$$(8)\ {B_x}^2 - {C_x}^2 + {B_y}^2 - {C_y}^2 - {R_2}^2 + {R_3}^2 = 2P_x(B_x - C_x) + 2P_y(B_y - C_y)$$

Since all the values for he equations (7) and (8) is known, except for the only two unknowns $P_x\ and\ P_y$, the equation can be solved by substituting the equations with each other to get the values.

By using the above equations, the coordinate or position of a device can be located [4]. The same algorithm can be used for cell tower positioning and Wi-Fi AP positioning.

For cell tower database, there are a few online sources that can be found. Alexandar Mylnikov's cell tower database is used for the project as the database provided is amalgamation of several online database into one [10]. It contains of more than 60 million rows of data as of now.

id	data_sour	radio_typ	mcc	mnc	lac	cellid	lat	lon	range	created	updated
46086188	-1	WCDM	234	30	1059	203635705	51.15113	-0.13656	85	1428189618	1446459068
46086190	-1	WCDM	234	33	9051	12700787	51.33726	-0.05435	41	1428189618	1446459068
46086234	-1	WCDM	302	490	10500	658581	43.72369	-79.5279	5274	1428189674	1446459068
46086235	-1	WCDM	302	490	11	658581	43.748	-79.5677	1524	1428189675	1446459068
46086236	-1	WCDM	302	490	16010	658581	43.75974	-79.5715	15	1428189675	1446459068
46086238	-1	WCDM	722	7	4455	1553216	-34.4333	-58.794	229	1428189695	1446459068
46086242	-1	WCDM	722	7	4458	1809138	-34.5994	-58.8596	811	1428189699	1446459068
46086243	-1	WCDM	722	7	4458	1809141	-34.5997	-58.8621	579	1428189699	1446459068
46086266	-1	WCDM	222	10	45066	8112783	40.59502	15.68615	921	1428189772	1446459068
46086239	-1	UMTS	722	7	4455	1528525	-34.4334	-58.7939	439	1428189696	1454032759
46086278	-1	WCDM	262	85	31629	21598557	50.93852	7.0077	26	1428189798	1446459068
46086280	-1	WCDM	262	85	31629	21568557	50.93976	7.014544	330	1428189800	1446459068
46086282	-1	LTE	310	410	34573	143350806	33.59888	-117.664	30	1428189821	1446459068
46086448	-1	UMTS	302	220	46007	239713174	46.7245	-76.062	7919	1428190277	1459470982
46086389	-1	WCDM	310	260	52181	222905798	40.7899	-73.9399	788	1428190118	1446459068
46086394	-1	WCDM	310	260	52190	222903411	40.79427	-73.9315	139	1428190120	1446459068
46086395	-1	WCDM	310	260	52181	65619673	40.79508	-73.9301	11	1428190120	1446459068
46086411	-1	LTE	302	720	25050	12820229	45.54411	-73.7635	399	1428190234	1446459068
46086415	-1	LTE	311	480	2170	247351042	61.52685	-144.345	4455	1428190239	1446459068
46086416	-1	LTE	311	480	2170	247351041	61.53898	-144.446	2800	1428190241	1446459068
46086427	-1	LTE	724	10	50117	230656257	-20.8316	-49.3999	829	1428190253	1446459068
46086438	-1	WCDM	302	610	46000	239399244	48.1041	-77.8176	598	1428190274	1446459068

Figure 10 Snippet of the downloaded database

However, the database downloaded is in the format of .csv, hence additional work is required to transform the csv database into a SQL database. The reason for the need of SQL database is that query using SQL is way faster than reading through an entire file. SQLite3 is chosen as the database as it is natively available in PHP and is known for being lightweight.

4 System Design

4.1 System Flow

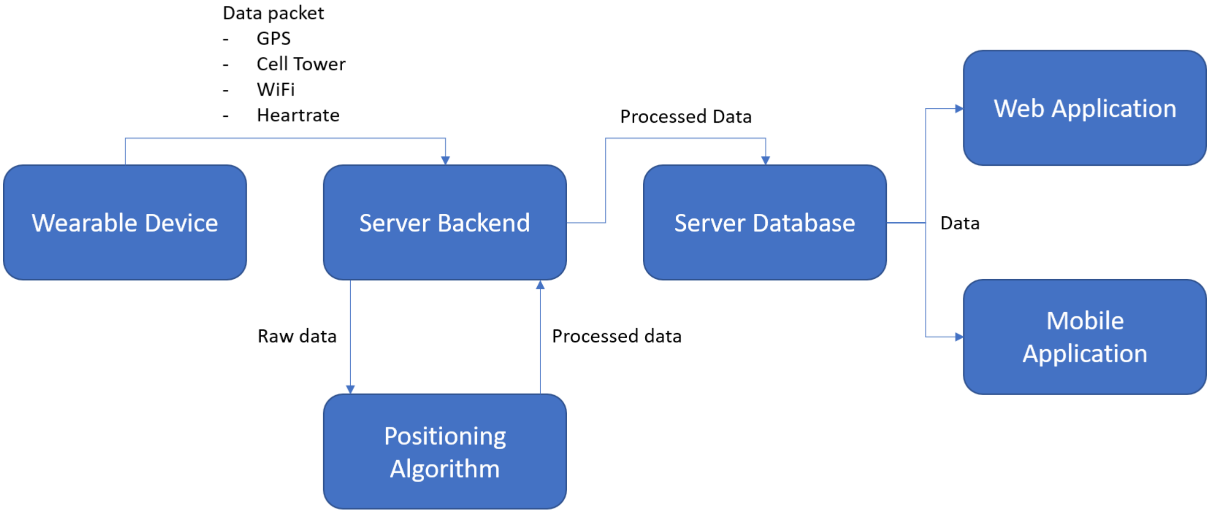


Figure 11 System flow

The system work with a wearable device connected to the server backend. In the server backend, data packets from the device will be interpreted and pass to this module for indoor positioning before injecting into server database. Site supervisor will then access the data from a web application or mobile application.

On this module, the algorithm will coexist with the server backend in the server itself. The algorithm will be run by the server backend when a new data packet is received from a wearable to device to determine its location and then pass back to the server backend to inject into database. This module can be separated into algorithm and database, where the database containing position of cell tower and Wi-Fi will be queried by the algorithm during calculation to output appropriate location.

4.2 Module Flow

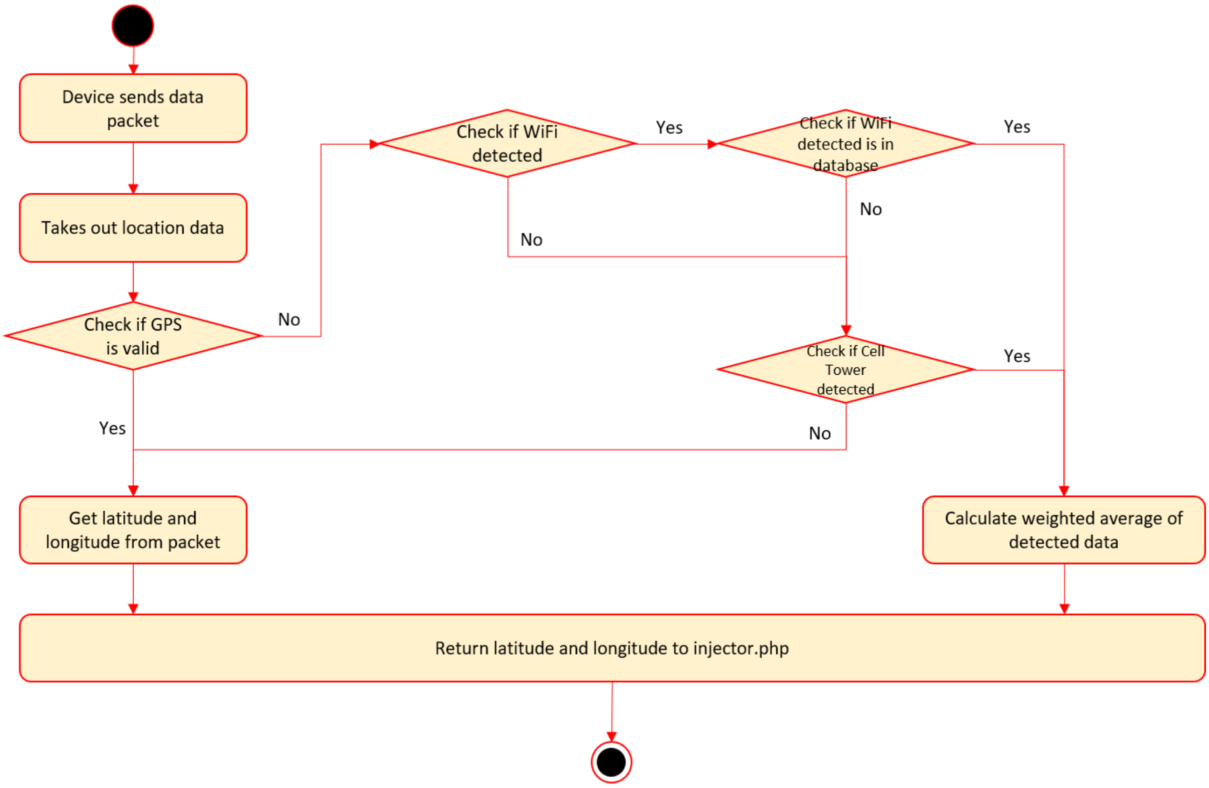


Figure 12 Module flow

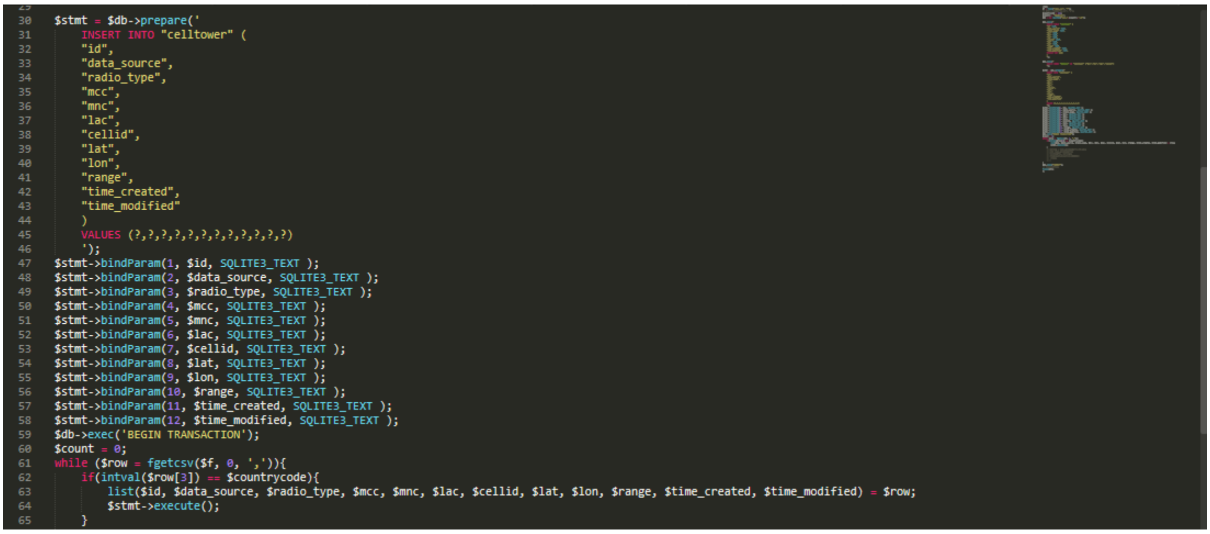
The module begins with the insertion of raw data packet which contains GPS, cell tower and WiFi data. The module will then interpret whether the GPS data is valid or invalid. If valid, the module will then return the GPS data to the server backend. Else, the WiFi data is checked. If WiFi is detected and the MAC address is stored in database, then the module will query the database for location information. Else, the module will fall back to use cell tower data and query database for location information. The location information acquired from either WiFi or cell tower will then be interpreted using weighted average method to get the location of the device. The module ends with returning the location data to server backend.

5 Technical Implementation

The proposed solution is work with the available but limited data gather from the device data packet. Due the severe limitations, trilateration algorithm is the way to go for implementing indoor positioning.

The programming language used for the implementation of the algorithms is PHP. This is to facilitate the integration of modules because that the algorithm is going to be running with the server backend, which is written in PHP.

5.1 Database



```php
$stmt = $db->prepare('
    INSERT INTO "celltower" (
    "id",
    "data_source",
    "radio_type",
    "mcc",
    "mnc",
    "lac",
    "cellid",
    "lat",
    "lon",
    "range",
    "time_created",
    "time_modified"
    )
    VALUES (?,?,?,?,?,?,?,?,?,?,?,?)
    ');
$stmt->bindParam(1, $id, SQLITE3_TEXT );
$stmt->bindParam(2, $data_source, SQLITE3_TEXT );
$stmt->bindParam(3, $radio_type, SQLITE3_TEXT );
$stmt->bindParam(4, $mcc, SQLITE3_TEXT );
$stmt->bindParam(5, $mnc, SQLITE3_TEXT );
$stmt->bindParam(6, $lac, SQLITE3_TEXT );
$stmt->bindParam(7, $cellid, SQLITE3_TEXT );
$stmt->bindParam(8, $lat, SQLITE3_TEXT );
$stmt->bindParam(9, $lon, SQLITE3_TEXT );
$stmt->bindParam(10, $range, SQLITE3_TEXT );
$stmt->bindParam(11, $time_created, SQLITE3_TEXT );
$stmt->bindParam(12, $time_modified, SQLITE3_TEXT );
$db->exec('BEGIN TRANSACTION');
$count = 0;
while ($row = fgetcsv($f, 0, ',')){
    if(intval($row[3]) == $countrycode){
        list($id, $data_source, $radio_type, $mcc, $mnc, $lac, $cellid, $lat, $lon, $range, $time_created, $time_modified) = $row;
        $stmt->execute();
    }
```

Figure 13 Converting CSV to database

Regarding cell tower database, it can be acquired from free online open source, which is roughly 6 to 7 GB worth of data in csv format. SQLite3 database is chosen for the conversion of csv file as it is super lightweight and is readily available as native extension for PHP. Using a database speeds up query time exponentially, from roughly 5 seconds to read the csv file to less than 0.01 second. As for Wi-Fi database, it has to be manually input by user as not all Wi-Fi access points (AP) is stored in open source database.

5.2 Boundary Filtered Weighted Average Method

```
Database info
M1 = X1,Y1
M2 = X2,Y2
M3 = X3,Y3

Let input data be
        [ [ M1, RSSI1 ], [ M2, RSSI2 ], [ M3, RSSI3 ] ]

We calculate the weighted signal for each input data
W1 = RSSI1/ (RSSI1 + RSSI2 + RSSI3)
W2 = RSSI2/ (RSSI1 + RSSI2 + RSSI3)
W3 = RSSI3/ (RSSI1 + RSSI2 + RSSI3)

X = W1*X1 + W2*X2 + W3*X3
Y = W1*Y1 + W2*Y2 + W3*Y3
```

Figure 14 Pseudocode for weighted average

The above pseudocode is regarding to weighted average method. The core idea is to sum the multiplication of the weight, or in this case the relative signal strength (RSS) of the signal, with the location of the origin of the signal, and divide with the sum of the weights.

```php
        //db settings
        $db = new myDB($database.mccToCountry($mcc) .'.db');

        //looping through each dataset
        for($i=0;$i<$data[0];$i++){
             //if $data incompletes
            if(($i*3)+6 > sizeof($data)){
                break;
            }
            $lac = $data[4 + ($i*3)];
            $cellid = $data[5 + ($i*3)];
            $stmt = $db->prepare('
                SELECT * FROM "celltower"
                WHERE
                "mcc" = ?
                AND "mnc" = ?
                AND "lac" = ?
                AND "cellid" = ?
                ');
            $stmt->bindParam(1,$mcc, SQLITE3_TEXT);
            $stmt->bindParam(2,$mnc, SQLITE3_TEXT);
            $stmt->bindParam(3,$lac, SQLITE3_TEXT);
            $stmt->bindParam(4,$cellid, SQLITE3_TEXT);
            $result = $stmt->execute();
```

```php
            $lastarr = array();
            //looping through the returned result
            while($row = $result->fetchArray()){
                $arr = array();
                $arr['lat'] = $row['lat'];
                $arr['lon'] = $row['lon'];
                $arr['sig'] = floatval($data[6 + ($i*3)]);
                $arr['range'] = $row['range'];
                if(!empty($lastarr)){
                    if($lastarr['range']>$arr['range']){
                        $lastarr = $arr;
                    }
                }
                else $lastarr = $arr;
            }
            $signalTotal += floatval($lastarr['sig']);
            $arrT[] = $lastarr;
        }

        for($i=0;$i<sizeof($arrT);$i++){
            $arr = $arrT[$i];
            $signal = floatval($arr['sig']) / $signalTotal;
            $lat += $signal * floatval($arr['lat']);
            $lon += $signal * floatval($arr['lon']);
        }
```

Figure 15 Weighted average translated into PHP code

From the pseudocode, it is implemented using PHP to tally with the server backend. This allows quick deployment to the server without the need to further language translation.

6 Results and Discussion

Several thousands of data packets are gathered from the device from the server backend module logs. The algorithm is tested against the data packets to see if the algorithm works well against the unstable and moving wearable device in a vehicle as well as in indoor environment. The sample data packets are from a device moving from Casa Damansara 1, at SS2/113 to the Faculty of Computer Science and Information Technology (FCSIT) in the University of Malaya.

6.1 Obtaining data

```
[115.164.172.105:5011][3G*8308392955*000B*LK,3080,0,4]
[115.164.172.105:5011][3G*8308392955*009F*UD2,051217,100914,V,3.118407,N,101.6029150,E,0.00,0.0,0.0,0,65
,100,3080,0,00000010,1,0,502,16,21162,24233,133,1,mdtresearch@unifibiz,6c:72:20:3d:28:54,-71,59.5][3G*83
08392955*006A*CONFIG,TY:g601x,UL:10,SY:0,CM:0,W
T:0,HR:1,TB:3,CS:0,PP:0,AB:0,HH:1,TR:0,MO:1,FL:0,VD:0,DD:2,SD:1,XY:0,WF:0]
[115.164.172.105:5011][3G*8308392955*009F*UD2,051217,100925,V,3.118407,N,101.6029150,E,0.00,0.0,0.0,0,65
,100,3080,0,00000010,1,0,502,16,21162,24233,132,1,mdtresearch@unifibiz,6c:72:20:3d:28:54,-69,59.5][3G*83
08392955*0108*UD2,051217,100935,V,3.118407,N,101.6029150,E,0.00,0.0,0.0,0,63,100,3080,0,00000010,1,255,5
02,16,21162,24233,132,4,mdtresearch@unifibiz,6c:72:20:3d:28:54,-71,IntegrationPoint,4:18:d6:82:d5:6f,-95
,IPMalaysiaGuest,6:18:d6:82:d5:6f,-95,GWNET,1c:1d:86:41:11:81,-95,59.5][3G*8308392955*0071*WT,081217,021
031,V,3.118295,N,101.6028400,E,0.00,0.0,0.0,0,75,4,3080,0,00000011,1,0,502,16,21162,14048,136,0,89.5]
[115.164.172.105:5011][3G*8308392955*009F*UD2,051217,100945,V,3.118407,N,101.6029150,E,0.00,0.0,0.0,0,63
,100,3080,0,00000010,1,3,502,16,21162,24233,134,1,mdtresearch@unifibiz,6c:72:20:3d:28:54,-68,59.5][3G*83
08392955*00C5*UD2,051217,100955,V,3.118407,N,101.6029150,E,0.00,0.0,0.0,0,71,100,3080,0,00000010,1,4,502
,16,21162,24233,133,2,mdtresearch@unifibiz,6c:72:20:3d:28:54,-74,IntegrationPoint,4:18:d6:82:d5:6f,-93,5
9.5]
[115.164.172.105:5011][3G*8308392955*00C5*UD2,051217,101005,V,3.118407,N,101.6029150,E,0.00,0.0,0.0,0,71
,100,3080,0,00000010,1,3,502,16,21162,24233,134,2,mdtresearch@unifibiz,6c:72:20:3d:28:54,-77,Integration
Point,4:18:d6:82:d5:6f,-95,59.5]
[115.164.172.105:5011][3G*8308392955*009F*UD2,051217,101015,V,3.118407,N,101.6029150,E,0.00,0.0,0.0,0,53
,100,3080,0,00000010,1,3,502,16,21162,24233,133,1,mdtresearch@unifibiz,6c:72:20:3d:28:54,-68,59.5]
```

Figure 16 Snippet of data samples

After data pre-processing, the cell tower data is extracted for each data packet using the code snippet below.

```python
for line in lines:
    try:
        type = line[0].split('*')[3]
    except:
        continue
    if type == 'UD' or type == 'UD2':
        valid = line[3]
        lat, lng = line[4], line[6]
        gps.append((lat,lng))

        bs_num = int(line[17])
        bs_tower = line[18]
        mcc, mnc = line[19], line[20]
        bs_ = [bs_num, bs_tower]
        if bs_num > 0:
            for i in range(bs_num):
                bs_area = line[21+i*3]
                bs_id = line[22+i*3]
                bs_signal = line[23+i*3]
                bs_.append((mcc,mnc,bs_area,bs_id,bs_signal))
        bs.append(bs_)
```

Figure 17 Code snippet of processing data using Python

```
1,0,502,16,21162,24233,133
1,0,502,16,21162,24233,132
1,3,502,16,21162,24233,134
1,3,502,16,21162,24233,134
1,3,502,16,21162,24233,133
1,3,502,16,21162,24233,133
1,3,502,16,21162,24233,133
6,0,502,16,21163,26482,161,21163,26483,153,21163,26481,149,21163,24323,146,21163,12213,146,21162,140
48,145
6,0,502,16,21163,26482,162,21163,26483,155,21163,26481,150,21163,24323,148,21163,12213,139,21162,140
48,138
6,255,502,16,21163,26482,163,21163,26483,156,21163,26481,144,21163,24323,142,21162,14048,139,21163,1
2213,134
1,255,502,16,21091,25021,134
1,255,502,16,21091,25021,134
1,255,502,16,21091,25021,134
6,255,502,12,2189,28483,145,2023,5013,145,2189,24941,137,2023,5012,137,2023,64532,135,2023,14602,134
6,255,502,12,2189,28483,145,2023,5013,143,2023,5012,138,2189,24941,138,2023,64532,136,2023,14602,135
1,255,502,12,2023,5013,145
1,255,502,12,2023,5013,145
1,255,502,12,2023,5013,145
1,0,502,16,21162,14048,133
1,1,502,16,21162,24233,133
1,4,502,16,21162,24233,133
1,0,502,16,21162,24233,133
1,0,502,16,21162,24233,133
1,4,502,16,21162,24233,130
1,255,502,16,21162,24233,132
1,255,502,19,14702,10558,140
7,255,502,19,14702,10558,141,14702,3496,136,14702,3497,134,14702,3498,131,14702,10556,130,14702,1055
7,130,14702,18832,128
7,255,502,19,14702,10558,141,14702,3496,136,14702,3497,134,14702,3498,131,14702,10556,130,14702,1055
7,130,14702,18832,128
```

Figure 18 Cell tower data extracted

The extracted data is now ready to be use for testing. A total of 2743 data samples are extracted. After running through the algorithm, 2010 coordinates are acquired.

```
3.1275178064885,101.62099358247
3.1311360523907,101.66072510183
3.1300169705402,101.62514965037
3.1299259380508,101.62527037866
3.1274623963874,101.62105866611
3.1275998976974,101.62118214061
3.1317292187895,101.66577916186
3.1244531776847,101.61972114505
3.1401028334867,101.63726899453
3.1287692226087,101.64495111809
3.1307898814504,101.6604167007
3.1386830583794,101.64096270357
3.1384252572706,101.63533237028
3.1308063848141,101.66032307198
3.1766936555324,101.73569434315
3.1268305546447,101.62060102037
3.1289436632189,101.62320149769
3.1601588032028,101.66826942511
3.162941531365,101.64865624506
3.1310067730498,101.62383765432
3.1285864661671,101.62299754772
3.1684207201389,101.67995234145
3.1629811563617,101.64860780256
3.1286923660436,101.6229809438
3.126806370728,101.62056799155
3.1556713960185,101.64327689969
3.1640104507676,101.67375594202
3.1591253628193,101.64573088867
3.1640224033358,101.6739169635
3.1640524544716,101.67382576296
3.1640486032252,101.6739117832
3.1260235489575,101.6230328995
3.1403119063373,101.64470204543
```

Figure 19 Coordinates calculated

6.2 Visualizing data

The coordinates are then plotted on the map using Leaflet, a Javascript library, for visualizing the coordinates.

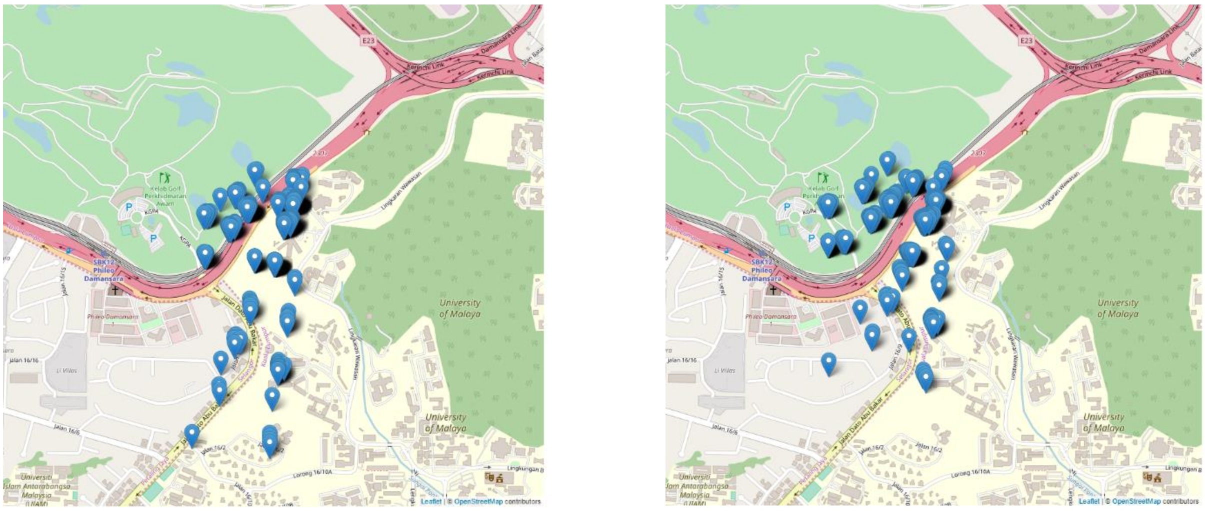


Figure 20 Before and after boundary filtering

From the results above, we can see that the results are more clustered together after doing boundary filtering.

6.3 Comparing results to Mylnikov API and Google API

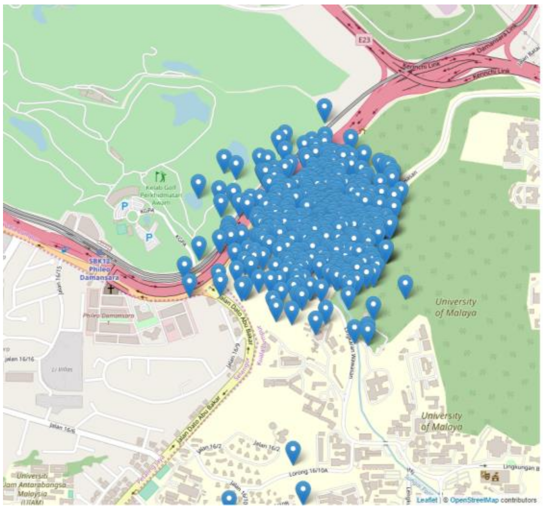


Figure 21 Results from Mylnikov API

From the visualization above, the API provided by Mylnikov, the provider of the cellular tower database we are using is not as accurate as the one developed. The data points are spread around instead of clustered together.

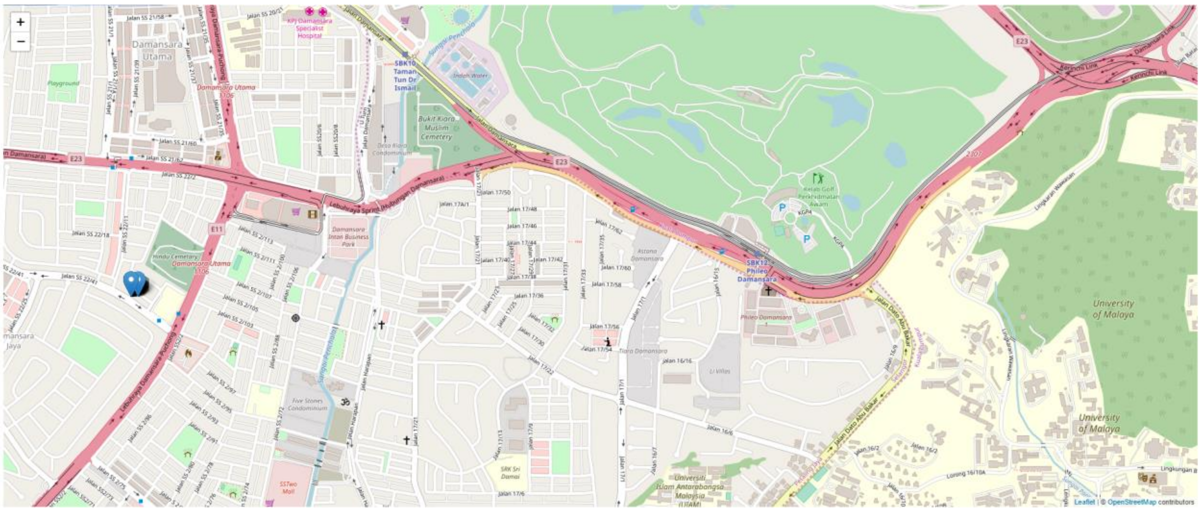


Figure 22 Result from Google API

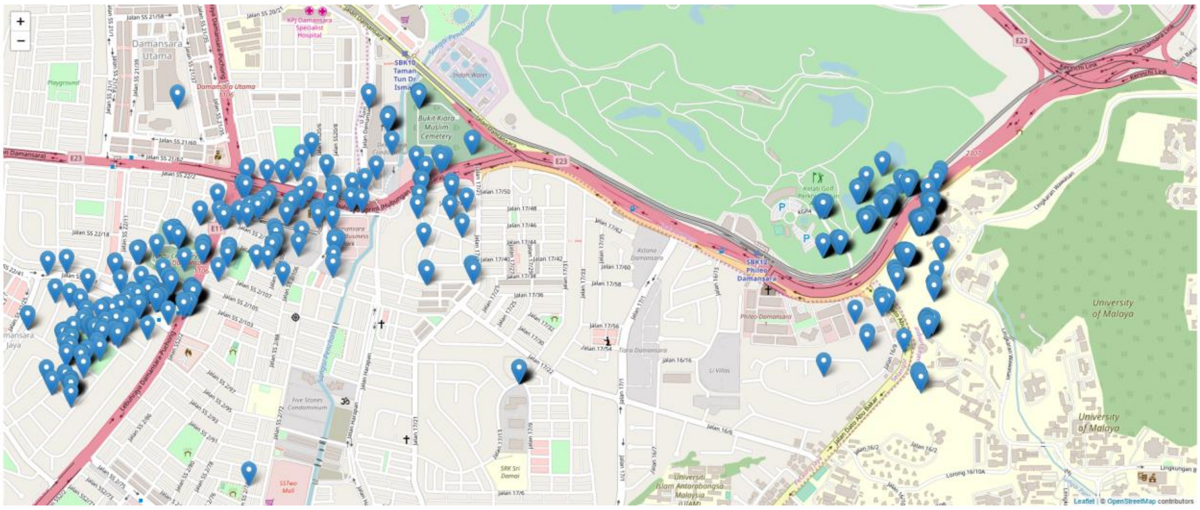


Figure 23 Result from developed module for comparison

From the visualization above, the API provided by Google is clearly inaccurate compared to the developed module.

7 Module Deployment

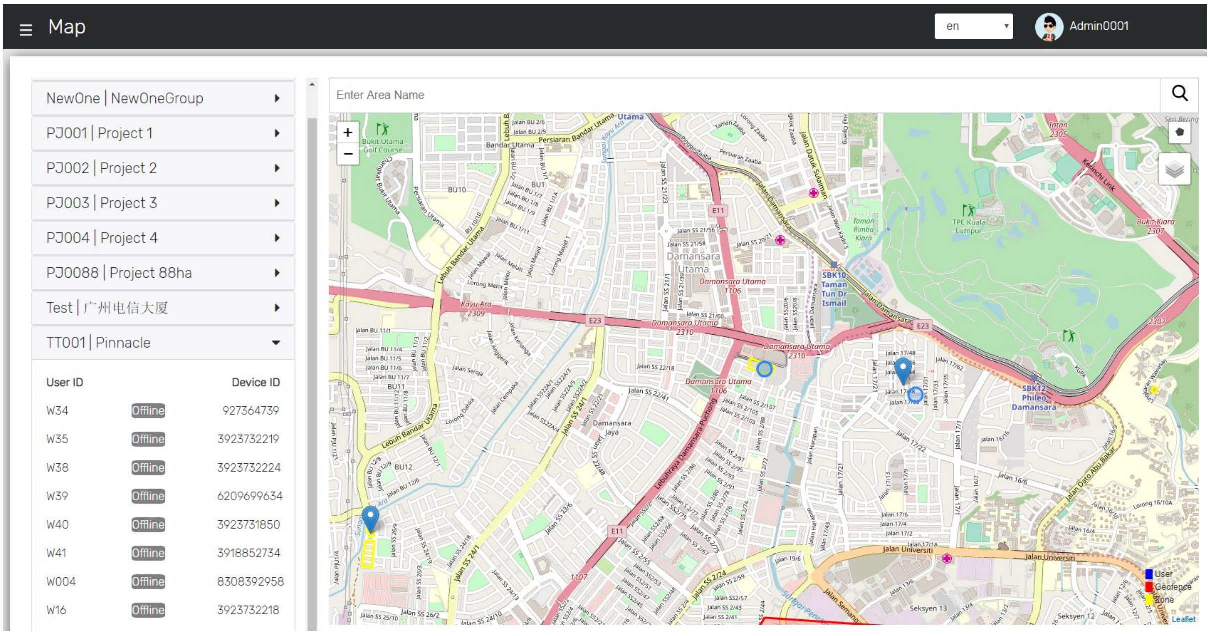


Figure 24 Map page

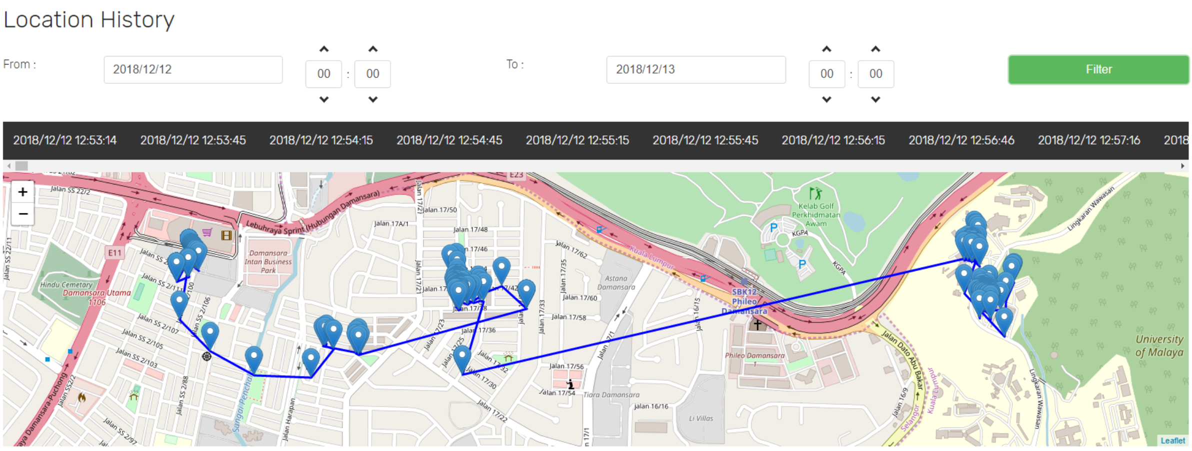


Figure 25 Location history of a worker

The module has been integrated into server backend and frontend to provide a visual on where the workers are. In location history, the supervisor will be able to watch where the worker has been to at any given time, based on the data packets sent from the device worn by worker. The map framework is from Leaflet.

8 Conclusion

Indoor positioning is a prominent research field at the moment as it provides a better navigation experience. With a lot of research going on in this, a robust indoor positioning in the near future is very promising.

With the current state of this project, the future work will be to benchmark its accuracy and research more ways to increase its accuracy. The problem with some outliers with the result is due to the hardware limitation, which there is nothing much can be done. There is also another factor of the limitation of cell tower positioning, where its accuracy at best is 50 meters. Wi-Fi positioning will be a better solution for indoor positioning as 50 meters accuracy at best is not very good when taking into account that 50 meters can be a position in another building across the street.

8.1 Commercialization

Our system has been adopted by our collaborator company MDTi as a personnel tracking platform package. The system has been pushed to sell at not just Malaysia, but also the neighbouring countries such as Thailand and Indonesia, even China. Due to the wearable device requiring a SIM card to function, MDTi has been partnering with Celcom in Malaysia and China Telecom in China to acquire their SIM cards together with the device as a package for potential customers.

9 Future Work

$$(x-x_1)^2+(y-y_1)^2=r_1^2$$
$$(x-x_2)^2+(y-y_2)^2=r_2^2$$
$$(x-x_3)^2+(y-y_3)^2=r_3^2$$

$$2(x_2-x_1)x+2(y_2-y_1)y=r_1^2-r_2^2+x_2^2-x_1^2+y_2^2-y_1^2$$
$$2(x_3-x_2)x+2(y_3-y_2)y=r_2^2-r_3^2+x_3^2-x_2^2+y_3^2-y_2^2$$

$$Ax+By=C$$
$$Dx+Ey=F$$

$$x=(CE-FB)/(EA-BD)$$
$$y=(CD-AF)/(BD-AE)$$

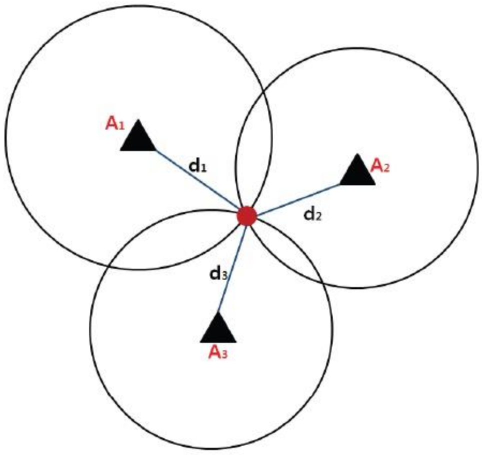


Figure 26 Trilateration algorithm

In the future, implementing trilateration algorithm will be able to improve the accuracy of the module. With the device returning signal strength in dBm, we have to calculate the distance using the below equation.

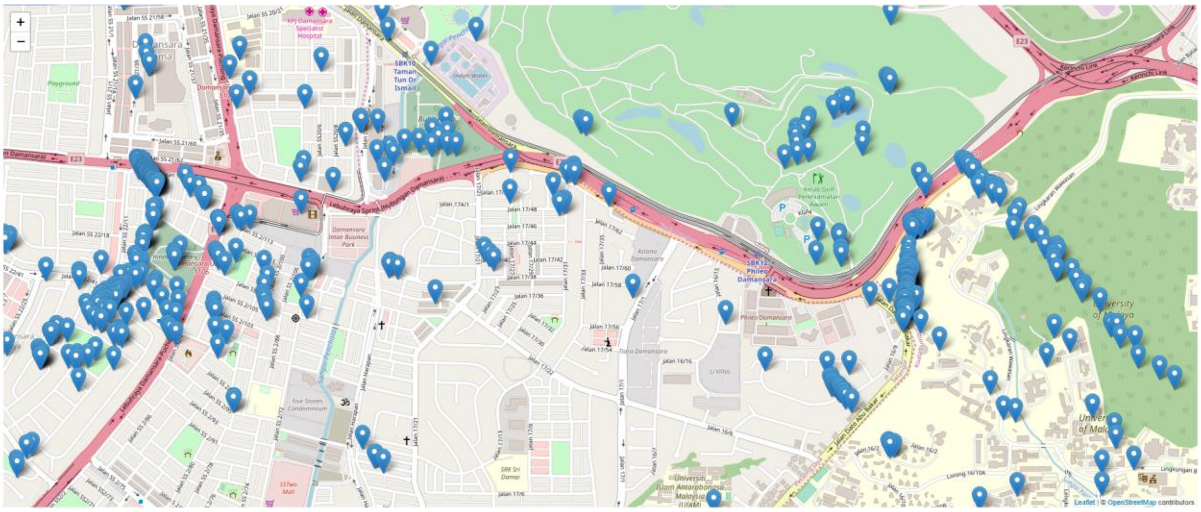
$$\mathrm{dBm_e} = -43.0 - 40.0\ \log_{10}\left(\frac{r}{R}\right)$$

```php
function trilateration($arrT){
    // trilateration
    for($i=0;$i<sizeof($arrT)-1;$i++){
        for($j=0;$j<sizeof($arrT)-$i-1;$j++){
            if($arrT[$j]['sig'] < $arrT[$j+1]['sig']){
                $temp = $arrT[$j];
                $arrT[$j] = $arrT[$j+1];
                $arrT[$j+1] = $temp;
            }
        }
    }

    $lat = 0;
    $lon = 0;
    $pm = 0;
    for($i=0; $i<sizeof($arrT)-2; $i++){
        for($j=$i+1; $j<sizeof($arrT)-1; $j++){
            for($k=$j+1; $k<sizeof($arrT);$k++){
                $i1 = $arrT[$i];
                $i2 = $arrT[$j];
                $i3 = $arrT[$k];
                $coord = getCoord($i1, $i2, $i3);
                $lat += $coord[0];
                $lon += $coord[1];
                $pm ++;
            }
        }
    }
    if($pm>0) $lat/=$pm;
    if($pm>0) $lon/=$pm;
    if(is_nan($lat) || is_infinite($lat)) $lat = 0;
    if(is_nan($lon) || is_infinite($lon)) $lon = 0;

    return [$lat, $lon];
}
```

Figure 27 Trilateration translated to PHP code



Translated into code, it is tested with the same data as above. The result is seemingly worse than the simple weighted average algorithm. The reason behind this is because the equation does not take into account the path loss exponent. The path loss exponent refers to the environmental factor where the signal loses strength when travelling through objects. This will result in lower signal strength, thus affecting the accuracy when calculating for location based on RSS. For example, one might receive a stronger RSS from a tower further away in plain sight compared to a weaker RSS from a tower closer but blocked by a mountain. Thus, the second equation comes into play.

$$\mathrm{dBm_e} = -43.0 - 10.0\,\gamma\,\log_{10}\left(\frac{r}{R}\right)$$

The blocker to overcome is to research on the path loss exponent of the equation. The path loss exponent is a variable that changes depending on environment and hardware sensitivity [13]. If when path loss exponent is provided, it may not be accurate. The future work might be focusing on resolving the path loss exponent and thus able to get accurate result.

10 References

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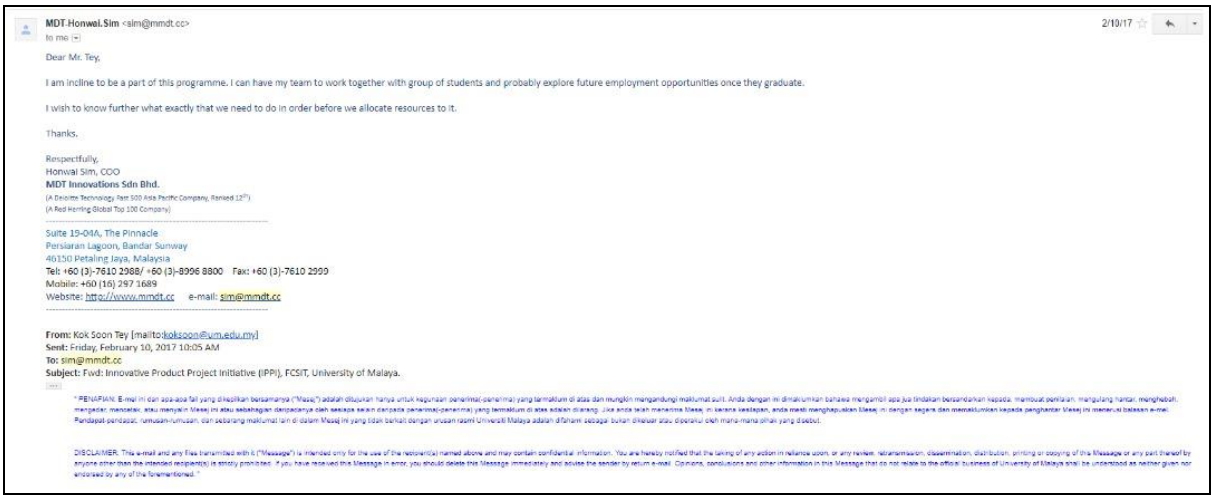
[13] Miranda, Jorge & Abrishambaf, Reza & Gomes, T & Cabral, Jorge & Tavares, Adriano & Monteiro, João. (2013). Path Loss Exponent Analysis in Wireless Sensor Networks: Experimental Evaluation. 10.1109/INDIN.2013.6622857.

11 Appendices

Formal collaboration with the industry has been done with Multimedia Display Technologies (MDT) Innovations Sdn. Bhd. MDT Innovations Sdn. Bhd. specializes in Internet-of-Things as well as proprietary RFID technologies. In recent years, they are venturing into personnel tracking systems.


MDT-Honwai.Sim <sim@mmdt.cc>
to me
2/10/17

Dear Mr. Tey,

I am incline to be a part of this programme. I can have my team to work together with group of students and probably explore future employment opportunities once they graduate.

I wish to know further what exactly that we need to do in order before we allocate resources to it.

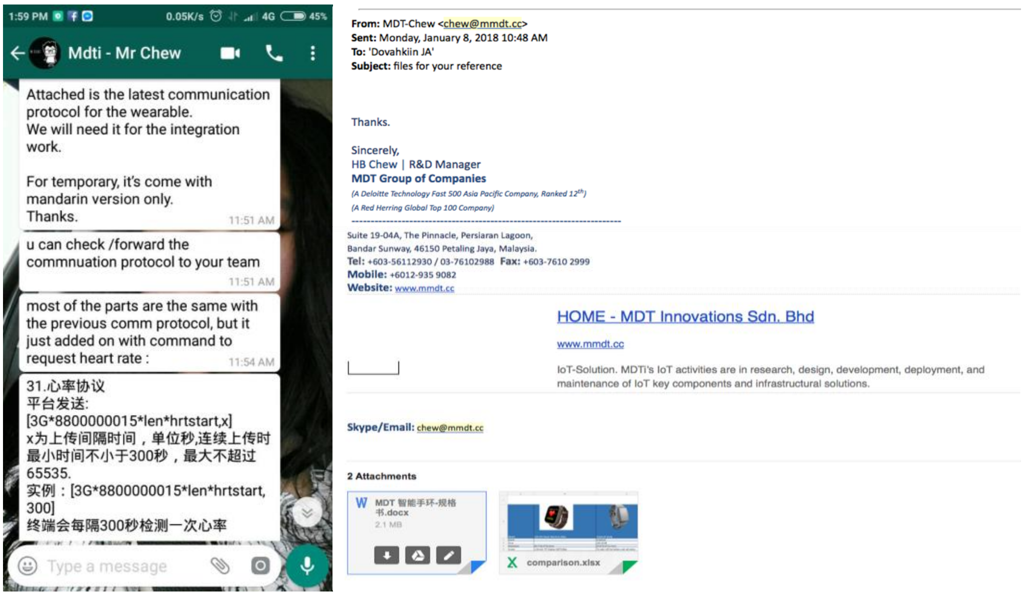
Thanks,

Respectfully,
Honwai Sim, COO
MDT Innovations Sdn Bhd.
(A Deloitte Technology Fast 500 Asia Pacific Company, Ranked 12th)
(A Red Herring Global Top 100 Company)

Suite 19-04A, The Pinnacle
Persiaran Lagoon, Bandar Sunway
46150 Petaling Jaya, Malaysia
Tel: +60 (3)-7610 2988/ +60 (3)-8996 8800 Fax: +60 (3)-7610 2999
Mobile: +60 (16) 297 1689
Website: http://www.mmdt.cc e-mail: sim@mmdt.cc

From: Kok Soon Tey [mailto:koksoon@um.edu.my]
Sent: Friday, February 10, 2017 10:05 AM
To: sim@mmdt.cc
Subject: Fwd: Innovative Product Project Initiative (IPPI), FCSIT, University of Malaya.

Figure 28 Collaboration initiative with MDT Innovations


1:59 PM 0.05K/s 4G 45%
Mdti - Mr Chew

Attached is the latest communication protocol for the wearable.
We will need it for the integration work.

For temporary, it's come with mandarin version only.
Thanks. 11:51 AM

u can check /forward the commnuation protocol to your team 11:51 AM

most of the parts are the same with the previous comm protocol, but it just added on with command to request heart rate : 11:54 AM

31.心率协议
平台发送:
[3G*8800000015*len*hrtstart,x]
x为上传间隔时间，单位秒,连续上传时最小时间不小于300秒，最大不超过65535.
实例：[3G*8800000015*len*hrtstart,300]
终端会每隔300秒检测一次心率

Type a message

From: MDT-Chew <chew@mmdt.cc>
Sent: Monday, January 8, 2018 10:48 AM
To: 'Dovahkiin JA'
Subject: files for your reference

Thanks.

Sincerely,
HB Chew | R&D Manager
MDT Group of Companies
(A Deloitte Technology Fast 500 Asia Pacific Company, Ranked 12th)
(A Red Herring Global Top 100 Company)

Suite 19-04A, The Pinnacle, Persiaran Lagoon,
Bandar Sunway, 46150 Petaling Jaya, Malaysia.
Tel: +603-56112930 / 03-76102988 **Fax:** +603-7610 2999
Mobile: +6012-935 9082
Website: www.mmdt.cc

HOME - MDT Innovations Sdn. Bhd
www.mmdt.cc
IoT-Solution. MDTi's IoT activities are in research, design, development, deployment, and maintenance of IoT key components and infrastructural solutions.

Skype/Email: chew@mmdt.cc

2 Attachments
MDT 智能手环-规格书.docx 2.1 MB
comparison.xlsx

Figure 29 Communications with the Person In Charge

MDT Innovations Sdn. Bhd.

A Deloitte Technology Fast 500 Asia Pacific Company (Ranked 12)
A Red Herring Global Top 100 Company
671184-H

Suite 19-04A, The Pinnacle, Persiaran Lagoon, Bandar Sunway, 46150 Petaling Jaya, Malaysia
Tel: +60(3) 7610 2988 Fax: +60(3) 7610 2999 http://www.mmdt.cc
GST Reg No : 001433399296

16th Jun 2017

PRIVATE & CONFIDENTIAL

RE: COLLABORATION ON WECARE PROJECT

With reference to above matter, we **MDT Innovations Sdn. Bhd** agree to collaborate on the project as part of their **IPPI** (Innovative Product Project Initiative) with students as below:

1. Ong Jia Aun WEA150022
2. Ong Seow Sze WER150031
3. Wang Zhong Qi WES150037
4. Teoh Khau Kheng WES150035

Respectfully,

....

CHEW HOO BENG (MEngSc)

R&D Manager

MDT Innovation Sdn Bhd

Figure 30 Formal letter for collaboration

From: Rita Winarto [mailto:rita@mmdt.cc]
Sent: Thursday, 29 June, 2017 11:29 AM
To: 'jiaaun96@hotmail.my' <jiaaun96@hotmail.my>
Cc: sim@mmdt.cc; 'Kok Soon Tey' <koksoon@um.edu.my>
Subject: FW: Student Internship

Dear Ong Jia Aun,

Herein attached is Letter of Appointment and Application Form for your internship with our company.

Please fill up the Form and sign the Letter and returned to us.

Your internship will be starting on 01st July, but due to his absence on Monday, could you come and meet Mr Sim on Friday, 30th June 2017 at 3:00 PM for your assignment details.

Kindly confirm and acknowledge the above schedule.

Thank You.

Yours Sincerely,
Rita Winarto
Human Resource Department

MDT Innovations SDN BHD
Suite 19-04A, The Pinnacle
Persiaran Lagoon, Bandar Sunway

MDT Innovations Sdn. Bhd.
A Deloitte Technology Fast 500 Asia Pacific Company (Ranked 12) 671184-H
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GST Reg No : 001433399296

MSC Malaysia Status Company
Deloitte. Technology Fast 500 Asia Pacific 2011 Winner
Red Herring Global Winner 100

Our Ref: MDTi/HR/2017/007

16th June 2017

Ong Jia Aun (NRIC: 960411-04-5077)
Lily and Rose Apartment
Jalan SS 26/12, Taman Mayang Jaya,
47301 Petaling Jaya,
Selangor, Malaysia

PRIVATE & CONFIDENTIAL

RE: APPOINTMENT AS INTERN

With reference to above matter, subsequent to your interview, we are pleased to offer you an internship position in our company.

Your internship with **MDT Innovations Sdn. Bhd.** is effective from 01st July 2017 to 31st January 2018:

1. Your allowance shall be RM800 per month, payable at the end of each calendar month;
2. Official working hours shall be from 9.00a.m. to 6.00p.m., 5 days a week, from Monday to Friday;
3. You will faithfully and honestly serve the Company and discharge your duties diligently and will at all times observe and comply with the Company's regulations and instructions whether expressed or implied, and punctually attend at such place as your duties may require according to the regulations of the Company;
4. During your internship, you are not to disclose any information accessible to you or acquired in the course of your work, respecting the affairs of MDT Innovations Sdn. Bhd. and its parent, and associates to any unauthorized person without the permission of the Company;
5. All intellectual properties developed during your internship period belongs to the Company;
6. Your internship may be terminated forthwith by the Company without prior notice if at any time you:
   a. are guilty of any misconduct, dishonesty, willful neglect or gross inefficiency in relation to your employment;
   b. abuse your position;
   c. are convicted of any criminal offense.

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Figure 31 Formal letter for internship