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Indoor Location Estimation Utilizing Wi-Fi Signals

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ABSTRACT

Global Positioning System is commonly been used for locating a position of a specific structure in finding geographical coordinates of a target area. Though, this application is still having a restricted in term of the signals, might not well operated and ineffective for indoor usage. The study aim is to develop positioning and localization systems by using Wi-Fi signal. Estimation was made based on the measurement of wireless distance for estimation the user's coordinates. Analysis of views called the fingerprint algorithm is used in this study. The algorithm involved two phases over an offline and the online phases of the survey. Unidentified user's coordinates will be in the online phase by comparative databases collected in the survey phase. MATLAB Graphical User Interface and Android has been used to develop a user interface for simulation purposes. Several analyses were performed to define the precision and efficiency of occurred error as the number of access points and the traffic environment. Finally, the user required to provide several inputs e.g. the exact location and the RSS from AP's number at the present location. The simulation-based software will evaluate the estimation location and positioning of the user and will match to user's precise location.

Key words: Access Point, Fingerprint, Global Positioning System, Received Signal Strength, Wi-Fi.

1. INTRODUCTION

Wi-Fi is the common name for the standard framework of a Wireless Local Area Network (WLAN), as set up by the 802 committee of the Institute of Electrical and Electronics Engineers. In fact, the official name is IEEE 802.11. The commonly standards that are being used are the 802.11b, 802.11g and the 802.11n versions. Positioning system is a tool that been used to track a geo-location coordinate. Location is a coordinate or a place. Position is distance or specific location of an area. Position commonly denotes as a process to find two or more coordinates dimensional of a terminal nonetheless can be meant as a distance or a range [1].

The positioning system technologies can be separated into two categories which are outdoor and indoor positioning.

Table 1: Indoor and Outdoor Positioning.

Indoor	Outdoor
Wi-Fi	**GPS**
• System based design	• Requires minimal obstructions
• System assisted design	• Extended acquisition times
Sensor Network	• Synchronization
• Localization with beacons	• High in power consumption
UWB	**A-GPS**
• Localization with beacons	• Accuracy of 10-50m
• Localization with beacons	• Indoor positioning
	• Improves acquisition time (<10s)
	• Synchronous or asynchronous
	• Effective in cost
	• Less changes in hardware

Table 1 shows dissimilar indoor and outdoor positioning. The common outdoor positioning system that commonly been used is Global Positioning System (GPS). GPS uses several satellites to navigate user's location. While, in indoor positioning systems technology, Wi-Fi Alliance (Wi-Fi), RFID (Radio Frequency Identification), laser (Light Amplification by Stimulated Emission of Radiation), infrared, and ultrasound commonly had been widely used in many research field [2].

The system that related to indoor location sensing has become essential and widespread in past few years [3] [4]. It steadily plays a significant part in all parts of people's daily activities, including as a living assistant, place navigation, rescue and emergency detection, surveillance, or detection of target of interest [5].

2. ALLOCATIONTECHNIQUES

Different methodologies based on signal metrics can be used to allocate devices. Although there are more allocation techniques available,[20] distinguished two main methods: Triangulation and Trilateration were chosen to be used in this study.

2.1 Triangulation

Angulation refers to the use of angle data relative to points of known position to find a target location [1]. The angle of arrival (AOA) as illustrated in Figure 1 is an approach used for this positioning algorithm in computing distance

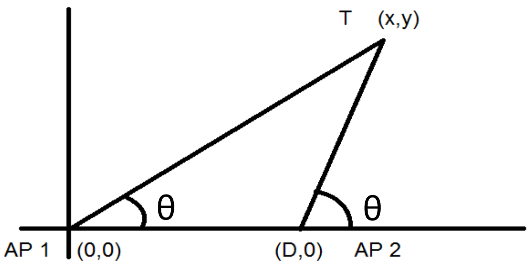

Figure 1: Investigated shapes of projectiles (Geometry and dimensions).

measurement and location. In AOA measurement technique, the location of the preferred target can be established by the connection of several pairs of angle direction lines, each formed by circular radius from a base station to the user [3]. It required as minimum two known reference (Access Point) APs and two other measured angles to locate user in 2D (two dimensions) views. Because of this method usually referred as direction finding, modification to the hardware is needed. It required additional antenna. Therefore, it is best to use directional or a multiple array antenna [5] to measure a phase shift of incoming signals. However, this method is costly because needs complex hardware modification. The estimation location deprivation as the target moves beyond the APs. Multipath is one of the core reasons of errors as it turns into a difficult to resolve the multiple signal's arrival direction with are strictly spaced at the sensor array.

The coordinates of target can be shown by using:

$$x = \frac{D\tan(\alpha_2)}{\tan(\alpha_2) - \tan(\alpha_1)}$$

(1)

$$y = \frac{D\tan(\alpha_1)\tan(\alpha_2)}{\tan(\alpha_2) - \tan(\alpha_1)}$$

(2)

However, this method is costly because needs complex hardware modification. The location estimate degradation as the target moves farther from the APs. Multipath is one of the main causes of errors because it becomes difficult to resolve the direction of arrival of multiple signals with closely spaced at the sensor array.

2.2 Trilateration

Number The "tri" in trilateration reveals that at least three fixed points are necessary to determine a position [5]. Lateration approximate the location of an object by determining its distances from multiple reference points [3]. Target distance from the AP is calculated from Received

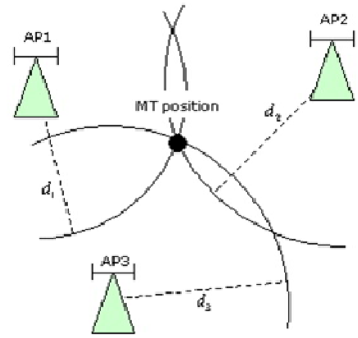

Figure 2: 2D target location by TOA measurement technique [1]

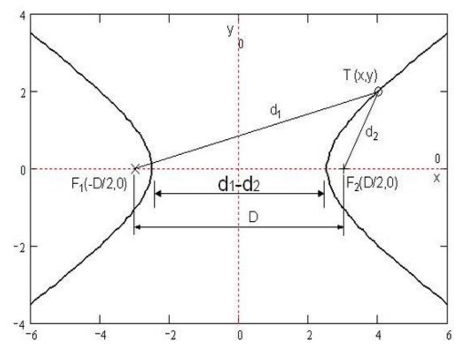

Figure 3: Geometric relationship between target and two APs

Signal Strength (RSS) measurement. Signal propagation model is used to convert the RSS onto distance value. Time of arrival (TOA) and time difference of arrival (TDOA) is measurement technique for distance estimation in this positioning algorithm. Both are based on time of flight (TOF) principle of distance measurement.

Figure 2 [1] shows calculation example of two APs in TOA measurement technique. The equations for the two inserting circles with canters at the APs and radius equal to distances from the target are:

$$d_1^2 = x^2 + y^2 \tag{3}$$

$$d_2^2 = (x - x_2)^2 + y^2 \tag{4}$$

These equations than can be solved explicitly for x, y, of the target:

$$x = \frac{d_1^2 - d_2^2 + x_2^2}{2 \cdot x^2} \tag{5}$$

$$y = \pm\sqrt{d_1^2 + x^2} \tag{6}$$

TOA needs synchronization of both receivers and

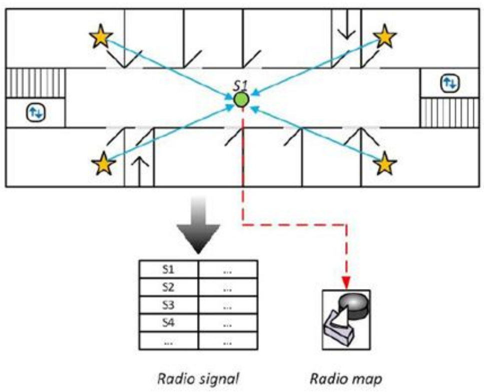

Figure 4: Locations methods [20]

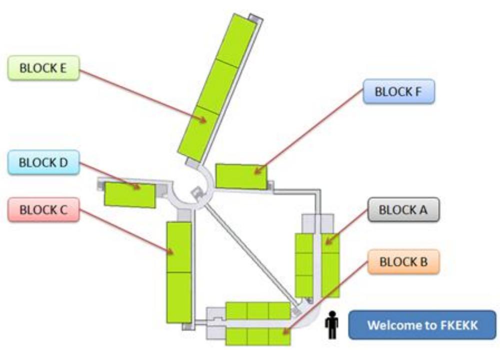

Figure 5: Online phase

transmitters, whereas the Time Difference of Arrival (TDOA) needs only synchronization of the receivers. Both methods belong to the trilateration group, as it involves the connection of the radii of the transmitters.

The distances expressed as follows:

$$d_2 = \sqrt{y^2 + (x + \frac{D}{2})^2} \tag{7}$$

$$d_1 = \sqrt{y^2 + (x - \frac{D}{2})^2} \tag{8}$$

The hyperbola equation defines the locus of the target as illustrated in Figure 3 is:

$$\Delta d = d_2 - d_1 \tag{9}$$

$$= \sqrt{y^2 + (x + \frac{D}{2})^2} - \sqrt{y^2 + (x - \frac{D}{2})^2}$$

2.3 Scene Analysis

Define Scene analysis denotes as one of an algorithm that collects features (fingerprints) of a scene. It then will estimate location of specific object by matching the online

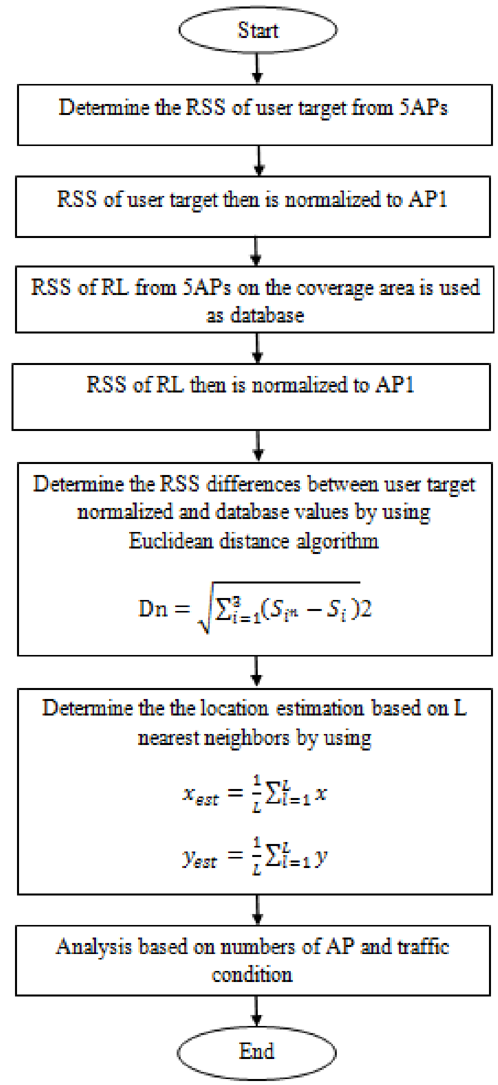

Figure 6: Flow chart of surveying phase

with the closest previous location fingerprints [3]. Fingerprinting traces a target by associating RSS from AP with database over a coverage area. An offline phase is the first from of two stages that must go through for this position algorithm. In this phase, a site survey is implemented on the real coverage area. The locations with a unique RSS from nearby the APs are gathered. All the fingerprints then will be stored as database. Figure 4 [20] shows an example of surveying phase while Figure 5 shows location estimation during online phase.

Fingerprint positioning algorithm desires no hardware alteration in defining target position [5]. It also does not need a knowledge of APs, not necessitate an estimation of distance between AP and client and static object in the environment do not affect the system [2]. Nevertheless, the problem is the RSS value could be affected by diffraction, reflection and scattering in the propagation environments [3].

3. METHODLODGY

3.1 Scene Analysis

In this phase, the study of triangulation, trilateration and scene analysis ranking algorithms have been found. Software requirements are also being investigated to measure RSS.

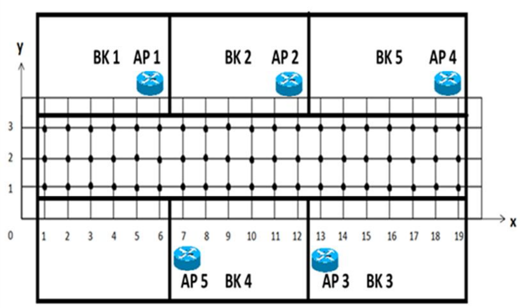

Figure 7: Coverage Area

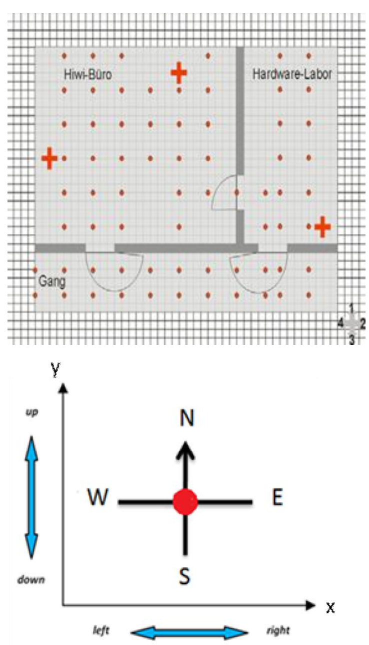

Figure 8: Orientations during Taking Measurement

3.2 Measurement

In this phase, the study of triangulation, trilateration and scene analysis ranking algorithms have been found. Software requirements are also being investigated to measure RSS.

VisiWave Site Survey is used in this phase. The process called surveying phase as in Figure 6 is make on the coverage area to determine each unique set of detectable APs that associated with SS which illustrated in Figure 7. At each point, a laptop computer transmits while it is oriented in four different positions: facing right and left of the x-axis and up and down on the y-axis. Figure 8 shows how to take measurement at each point on map.

Based on Figure 8, Signal Strength (SS) on the area is based on UTeM-Student network coverage. This is the only network that students allowed to connect. The Table 2 shows, the lowest SS from nearby APs is select to be connected. This surveying phase is done on Ground Floor, FKEKK, UTeM.

Table 2: RSS in dBm at each Reference Location

Ref. Location	x, y	AP1	AP2	AP3	AP4	AP5
1	1, 1	-75	-82	-84	-87	-71
2	2, 1	-78	-80	-82	-85	-72
3	3, 1	-79	-79	-79	-85	-70
4	4, 1	-73	-78	-79	-81	-69
5	5, 1	-73	-78	-79	-80	-65
6	6, 1	-70	-74	-73	-79	-57
7	7, 1	-59	-72	-74	-75	-46
8	8, 1	-63	-68	-74	-77	-60
9	9, 1	-73	-67	-73	-76	-62
10	10, 1	-69	-74	-69	-74	-69
11	11, 1	-68	-61	-81	-68	-67
12	12, 1	-66	-62	-58	-68	-78
13	13, 1	-69	-77	-49	-65	-70
14	14, 1	-76	-79	-55	-66	-72
15	15, 1	-74	-75	-63	-69	-75

3.3 Location Analysis

After phase 2, the data collected from the surveying phase was extracted to getting the RSS for each point [21-23]. The data collected is extracted in WordPad.

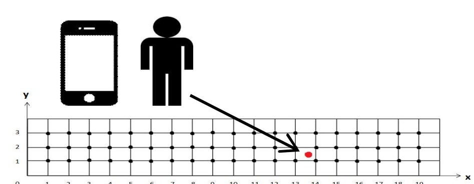

Figure 9: Analysis phase on defined the location

The Figure 9 shows a sample RSS of user target that has been taken. The actual location of user target is x = 13.7 and y = 1.4. RSS of target user from all APs can be used to determine the location estimation:

$$\text{User\_target} = (\text{AP1 AP2 AP3 AP4 AP5})\ \text{dBm} = (-65\ -60\ -60\ -64\ -73)\ \text{dBm} \quad (10)$$

It then normalized to AP1: User_target_normalized = (0 5 5 1 -8) dBm. The RSS normalized at Access Point is tabulated by Table 3 below.

Table 3: Received Signal Strength Normalized at Access Point 1

Ref. Location	x, y	AP1	AP2	AP3	AP4	AP5
1	1, 1	0	-7	-9	-12	4
2	2, 1	0	-2	-4	-7	6
3	3, 1	0	0	0	-6	9
4	4, 1	0	-5	-6	-8	4
5	5, 1	0	-5	-6	-7	8
6	6, 1	0	-4	-3	-9	13
7	7, 1	0	-13	-15	-16	13
8	8, 1	0	-5	-11	-14	3
9	9, 1	0	6	0	-3	11
10	10, 1	0	-5	0	-5	0
11	11, 1	0	7	-13	0	1
12	12, 1	0	4	8	-2	-12
13	13, 1	0	-8	20	4	-1
14	14, 1	0	-3	21	10	4
15	15, 1	0	-1	11	5	-1

Table 4: RSS Differences between User Normalized and database values

(a) RL 39 - 44

RL	39	40	41	42	43	44
Distance	30	28	26	26	25	28
RL	20	21	22	23	24	25
Distance	29	19	22	22	26	28
RL	1	2	3	4	5	6
Distance	25	20	20	21	23	26

(b) RL 44 - 50

RL	45	46	47	48	49	50
Distance	30	26	20	22	13	13
RL	26	27	28	29	30	31
Distance	43	24	18	21	16	9
RL	7	8	9	10	11	12
Distance	38	25	19	15	20	6

(c) RL 51 - 57

RL	51	52	53	54	55	56	57
Distance	15	22	21	15	18	22	23
RL	32	33	34	35	36	37	38
Distance	21	29	27	15	17	13	21
RL	13	14	15	16	17	18	19
Distance	21	23	11	10	8	18	14

The Euclidean distance between users normalized and database value which can be obtain by using:

$$Distance^2 = (AP1\ target\ normalized - AP1\ normalized)^2 + (AP2\ target\ normalized - AP2\ normalized)^2 + (AP3\ target\ normalized - AP3\ normalized)^2 + (AP4\ target\ normalized - AP4\ normalized)^2 + (AP5\ target\ normalized - AP5\ normalized)^2 \quad (11)$$

Figure 10 below shows the three lowest values then are extracted to obtain its matrix form for location estimation. The lowest values are 6, 8 and 9 at RL 12, 17, and 31 with matrix of (1, 12), (1, 17) and (2, 12).

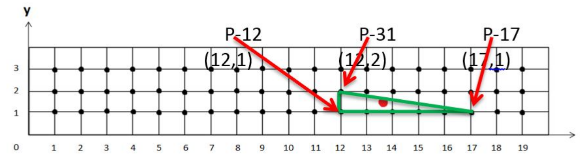

Figure 10: Analyses on fingerprint technique

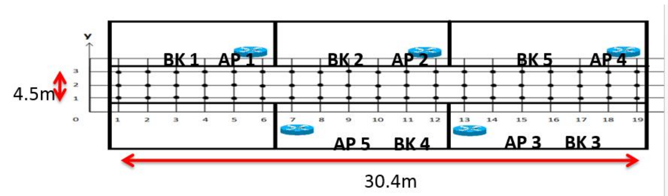

Figure 11: Scale on the coverage area

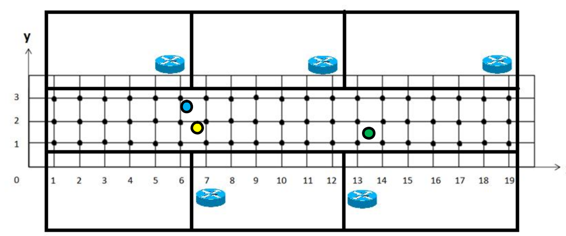

Figure 12: Sample location

These matrix forms of x and y can be used to determine the location estimation of user by using L nearest neighbor's algorithm:

$$x_{est} = \frac{1}{L}\sum_{l=1}^{L} x \ , \quad y_{est} = \frac{1}{L}\sum_{l=1}^{L} y$$

Location estimation by using equation 4.1 and 4.2 resulted at x = 13.6667 and y = 1.3333:

$$x_{est} = \frac{1}{3}\sum_{l=1}^{3}(12+17+12) = 13.6667$$

$$y_{est} = \frac{1}{3}\sum_{l=1}^{3}(1+1+2) = 1.3333$$

Figure 11 above shows the location estimation area of user target. Based on previous paper [15], 2.5m average error from actual location is still accepted and valid. It also states that there is no need to take too nearest RL between neighbors.

The scale used for real time measurement is in meter and is shows in Figure 12. As illustrated in Figure 13, Table 4 and Table 5, a sample location with RSS measurement has been taken for testing phase.

$$x_{est} = x \times 1.6m$$

$$y_{est} = y \times 1.5m$$

Table 5: Received Signal Strength Normalized at Access Point 1

Sample Location	Actual Loc.	AP1	AP2	AP3	AP4	AP5
		(dBM)				
Blue	(6.3,2.5)	-62	-67	-68	-79	-58
Yellow	(6.8,1.8)	-67	-71	-77	-72	-49
Green	(13.5,1.6)	-65	-60	-60	-64	-73

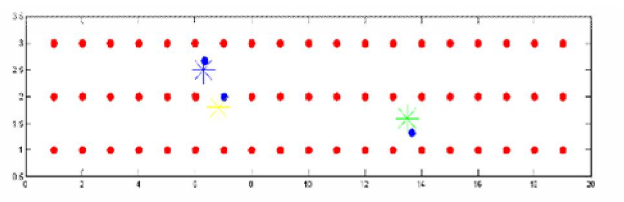

Figure 13: Location estimation of sample taken

3.4 Development

The data obtained is used to determine the vectors of each point on the surveyed map. L Nearest Neighbor is uses for database comparison. MATLAB GUI and Android Applications then are used as user interface that allows interaction between user and electronic devices. It is going to shows and plots an actual location and estimate location of user during simulation process.

Simulink is an interactive tool for modelling, simulating, and analyzing dynamic, multi-domain systems. It lets accurately describe, simulate, evaluate, and refine a system's behavior through standard and custom block libraries. Simulink models have ready access to MATLAB and Android, providing the flexible operation and an extensive range of analysis and design tools.

4. RESULTS

4.1 Location Estimation

The actual location of user target RSS from all APs is normalized to AP1. The same process also goes for the database collected earlier in surveying phase. RSS differences between user normalized and database values is calculated. Figure 13 below shows comparison between actual location and location estimation of samples taken. The result show only a bit differs from actual location (*).

From the analysis that has been done regarding the numbers of AP and traffic condition, it can be said that the higher the numbers of APs, the higher the accuracy. However, when it comes to the traffic condition, the heavy traffic does not mean it will give a huge error rather than light traffic. It may cause by several factor like blocking line of sight and environmental condition.

5. CONCLUSION

Upon completion of this project, it can be said that the objective to develop a location and positioning simulation using MATLAB and Android software at FKEKK, UTeM is successfully functioned. The user needs to give several inputs such as actual location and RSS from number s of AP at the current location. This simulation software will estimate location and positioning of the target user and compared to the precise location. Several analyses have been done regarding Euclidean distance algorithm. The first analysis is based on the numbers of AP which up to five APs while the second analysis is based on the traffic condition at each Block, FKEKK, UTeM.

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