Indoor Positioning and Navigating System Application Using Wi-Fi with Fingerprinting Method and Weighted K-Nearest Neighbor Algorithm

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Abstract— **The need for accurate indoor location determination, object tracking, digital maps and indoor travel routes is increasing along with the construction of buildings that have complex and spacious layouts. The current Global Positioning System navigation system is only effective for outdoor use. However, when used indoors it becomes inaccurate due to factors such as signal attenuation and multipath caused by wall obstructions in the building. This study designed an application of Indoor Positioning and Navigating System Using Wi-Fi with Fingerprinting method and Weighted K-Nearest Neighbor algorithm. This system functions on the principle of utilizing the Received Signal Strength (RSS) emitted by a Wi-Fi *Access point* to determine the location of objects. In the design process, it is necessary to create a fingerprinting database by considering the number of *Access point*s and environmental conditions. Based on the results of the study, the location results of the application show that from floors 1,2, and 3. Floor 1 has a room accuracy result of 89% and a point accuracy of 86% with an average deviation of 1.42 px or 0.9 m, floor 2 has room accuracy results. of 65% and a point accuracy of 70% with an average deviation of 2.43 px or 1.7 m, and the 3rd floor has a room accuracy of 86% and a point accuracy of 68% with an average deviation of 2.27 or 1.5 m. Based on the data above, this application is proven to be able to detect the position of someone in the room with a success percentage on the 1st floor by 90%, the 2nd floor by 55%, and the 3rd floor by 80%.**

Keywords*— *Fingerprint, Indoor Positioning System, Navigation, Nearest Neighbor, RSSI

I. INTRODUCTION

With the rapid development of mobile communications and computing technology, the need for location-based services is also increasing. Buildings thrive with large indoor areas and lots of space. Generally, when someone enters a building such as a mall, hospital, large office, they will be confused to find their destination room. This is due to the lack of information about the room and the complexity of the streets and bends in the building. As a result, they get lost and take a long time to arrive at their destination.

One of the latest technologies that are widely used in determining location is the Global Positioning System (GPS). GPS is effective for outdoor location determination because of the high accuracy it produces. However, this system is not reliable when used for indoor navigation. The structure of the building, insulated walls and the many rooms in the building cause multipath effects and signal interference, so that the satellite signal cannot be relied on [1].

One of the developed technologies to answer this problem is the Indoor Positioning System (IPS). The Indoor Positioning System is an alternative technology behind the inability to use GPS to determine the position of objects in the building. IPS is a system to determine the position of objects in a room using radio waves, magnetic fields, or other sensors obtained by mobile devices [2]. Many technologies that can be used by IPS such as Wireless Local Area Network (WLAN), Bluetooth, cellular network, Ultra Wideband, and Near Field Electromagnetic Ranging [3]. This technology has been developed into an indoor location-based service that has been implemented in various activities such as navigation for humans, robots, asset tracking, blind guiding systems, factory automation, patient tracking in hospitals, and location-based advertising [4]. This technology addresses the problem of indoor tracking where visitors cannot determine the position and location of the destination room when visiting a building that is unfamiliar to them.

Wireless Fidelity (Wi-Fi) has become the most commonly used technology in IPS for several reasons [5]. First, the need for internet access via smartphones is directly proportional to the Wi-Fi network access points that have been installed in many places. Second, indoor localization based on Wi-Fi also has an inexpensive cost and easy accessibility. Third, IPS systems with Wi-Fi do not require additional infrastructure to be used [6-8]. Therefore, with the massive installation of Wi-Fi networks in public facilities, it can be used for indoor navigation purposes.

Wifi-based location determination techniques are generally divided into two, namely signal propagation models [9] and Fingerprinting [10]. Signal propagation works by determining the coordinates of the object based on the distance from an object obtained from the combination of three access points. This causes problems such as multipath fading because the signal from the Access Point (AP) is blocked by the walls of the room [11-12]. The Fingerprinting method comes by providing a better estimate of indoor positioning [13]. By working to combine the database at the offline stage containing digital maps containing RSS reference point (RP) data in each AP with the online stage data containing test data, namely the RSS user, the location of the user is found and fixes the problem of the propagation technique [14-15].

Based on the research and problems above, the research will be conducted entitled "Indoor Positioning and Navigating System Application Using Wi-Fi with Fingerprinting method and Weighted K-Nearest Neighbor algorithm."

II. METHOD

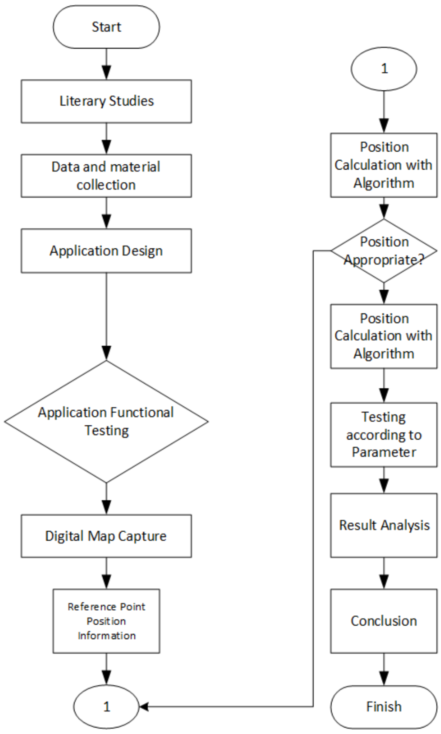

Figure 1. Flowchart Design

Design that will be carried out in making the system, with the following explanation:

1. The first stage is a literature study on Indoor Positioning System, Wi-fi, Fingerprinting Method, WKNN, KNN then Android Studio
2. The second stage is collecting data on the needs of tools and research, the need for tools can include 2 components, namely hardware and software used as a system design design.
3. The third stage is designing android application software, in designing this android application software using Android Studio software as an application builder.
4. The fourth stage is application testing, at this stage the application is installed on a smartphone to be tested for readiness.
5. The fifth stage is retrieval of RSSI data for calibration data that is entered into a digital map. The data taken at this stage is in the form of a connected Wi-Fi access point, fingerprint data according to the reference point
6. The next stage is to collect test point data or the online stage. This data is in the form of the latest user location RSSI which will later be combined with data at the offline stage.
7. The next step is that data from Fingerprinting will be processed using Euclidean Distance to determine the closest distance from the user's location to the RP in the database and after that the Weighted K-Nearest Neighbor algorithm is calculated to determine the estimated position of the object.
8. The next stage is testing according to the specified parameters, namely the number of reference points, changes in the value of K, and the shortest route distance
9. The next stage is Analysis, after successfully obtaining the data, an analysis is carried out on the accuracy of position information, application process delays and comparison of results according to other parameters.
10. The last stage is the conclusion, after doing the analysis, the results obtained will be processed into conclusions.

A. System Design

The research design to be carried out is shown in the block diagram shown in Fig. 2.

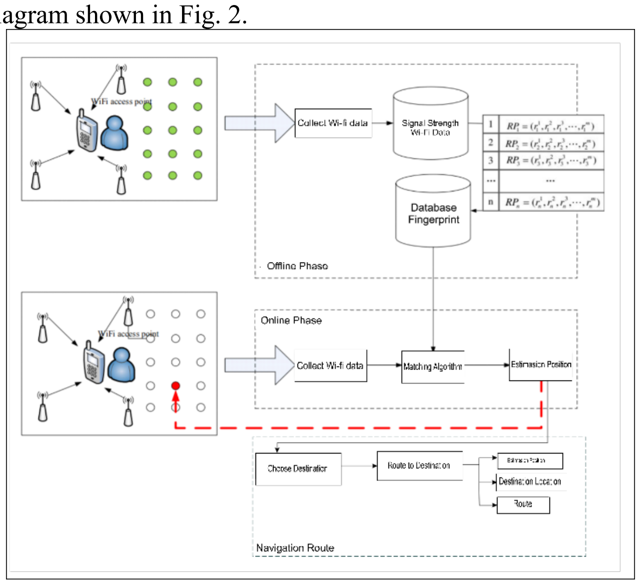

Figure 2. Block Diagram System

The following is a description of each function of the input and output system that is designed based on the block diagram from Fig. 2:

1. The android application is used to display location detection data, navigation routes to destinations, and destination locations.
2. The database is used as a place to store Reference Point and RSS data at the calibration stage.
3. Access Point is a Wi-Fi signal transmitter which will be received by the device and its RSS is used for positioning and navigation.

4. Location data is user position data when doing the positioning process
5. Destination data is position data that the user wants to reach during the navigation process.

In Fig. 2, it can be observed that there are three main stages, namely calibration, positioning and navigation. At the calibration stage, the mobile device records the RSS values from several Access Points that cover each reference point. Reference point is a test point used to capture RSS signal data in an Access point area. The recording results are the RSS value and the angle of arrival from the crossing of several Access points. The recording results are averaged and entered into a database that has a name according to the access point, the RSS value and the name of the room will be used as template data. The database can be saved to the database server by using a slim framework installed on the server. This is so that new users no longer need to perform the calibration phase from the beginning if they want to start the application. The template data in this calibration process serves as a comparison value against the RSS value in the positioning stage whose location is not yet known.

The second stage is detecting the user's position. After the calibration data is stored in the database, the user can detect the position at any point in the building. The user's presence will be detected by calculating the RSS value right at the point where he stands. The value generated from the calculation will be compared with the template data in the database with the WKNN algorithm. This happens because the user's position has been estimated with reference points scattered throughout the area. The detection results will then be displayed in the form of the current user's room name with the closest position to the detected reference point and the data will be stored in the firebase so that the user can find out the whereabouts of other users.

After the position is known, it enters the navigation stage. Here, enters a menu called edit destination, a display of various room options will appear and the user can choose which room to go to. After completion, it is processed and the user will enter the navigation interface in the application in the form of a map of the floor area which contains the user's current location and the route to the intended locations. The fundamental algorithm and system used in this thesis is the development of research by Suyash Gupta [9].

III. RESULTS AND DISCUSSION

A. *Offline Stage: Room Database Creation*

At this offline stage, RSS data retrieval is done manually using a smartphone that has this application installed in it. The database values consist of RSS values at reference points which are scanned for three minutes at each reference point. In this study, the values used came from 11 access points on three different floors.

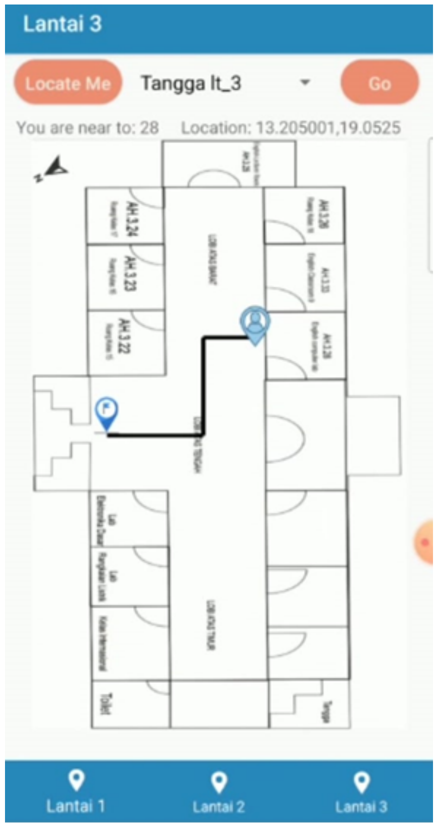

Figure 3. Access Point Scan Result

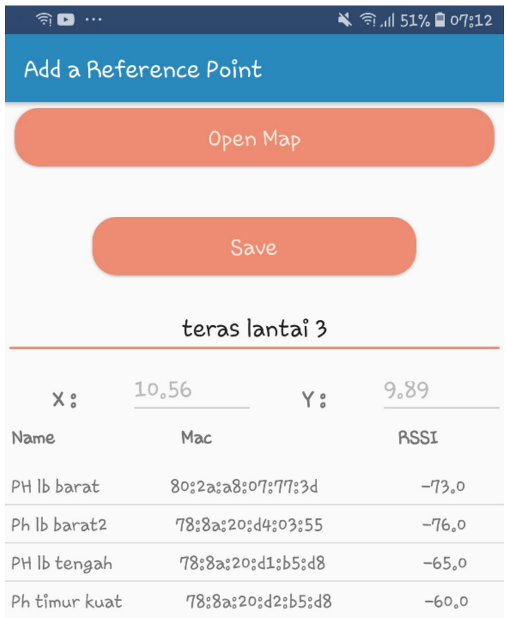

Figure 4. Room Database

Access point selection is based on signal strength and changes in 10-second intervals. If it is proven to be stable, it can be categorized as good enough to be included in the database. For example, on the 1st floor, there are three access Then RSS data is recorded at each testing point, totaling 11 points on the 1st floor, 12 points on the 2nd floor, 11 points on the 3rd floor. Each reference point has more than 5 times the recorded data.

B. Online Stage: Testing Algorithm Accuracy Between WKNN and KNN.

In testing the accuracy between the WKNN and KNN algorithms in Class Room 13 and the West Lobby of the Corner, it can be observed that there is a similarity in accuracy performance where both algorithms manage to provide the same accurate data. However, from 10 test data, the KNN algorithm has an average deviation of positional error that is greater than the WKNN algorithm with a deviation of 1.68, almost twice as large as WKNN. While the WKNN algorithm has an average deviation of 0.9.

TABLE I
WEST LOBBY ROOM CORNER FLOOR 1 K=3 WKNN AND KNN

Algorithm	Coordinate		Coordinate		Estimated Room Location	Error Distance (Meter)	Result
	10.2	16.6	10.2	16.51	Middle East lobby	0.084	Accurate
	10.2	16.63	10.21	15.13	Middle East lobby	1.050023333	Accurate
	10.2	16.63	10.28	14.84	Middle East lobby	1.254250772	Accurate
	10.2	16.63	10	15	Middle East lobby	1.149556871	Accurate
WKNN	10.2	16.63	10	16	Middle East lobby	0.46268888	Accurate
	10.2	16.63	10	14	Middle East lobby	1.84631552	Accurate
	10.2	16.63	10	16	Middle East lobby	0.46268888	Accurate
	10.2	16.63	10	14	Middle East lobby	1.84631552	Accurate
	10.2	16.63	10	16	Middle East lobby	1.84631552	Accurate
	10.2	16.63	10.33	11.75	Middle East lobby	4.88173125	Not Accurate
	10.2	16.63	10.29	14.87	Middle East lobby	1.762299634	Accurate
	10.2	16.63	12.9	5.46	Middle East lobby	11.4916883	Not Accurate
	10.2	16.63	10.29	14.87	Middle East lobby	1.762299634	Accurate
	10.2	16.63	10.29	16	Middle East lobby	0.636396103	Accurate
KNN	10.2	16.63	10.38	15	Middle East lobby	1.639908534	Accurate
	10.2	16.63	10	14.7	Middle East lobby	1.940335023	Accurate
	10.2	16.63	10	14.7	Middle East lobby	1.940335023	Accurate
	10.2	16.63	10	14.7	Middle East lobby	1.940335023	Accurate
	10.2	16.63	10.38	15	Middle East lobby	1.639908534	Accurate

In the test in another room, Class 13 with the WKNN algorithm, it showed an average deviation value of 0.5.

Meanwhile, the KNN algorithm has an average deviation value of 0.6. From these two room data, it can be seen that the performance of the WKNN algorithm can provide more accurate data than KNN.

For the entire test on the 1st floor using WKNN, the results obtained an average room accuracy of 89% and a point accuracy of 86%. As for the KNN algorithm, the average room accuracy is 74% and point accuracy is 78%.

C. Testing Algorithm Accuracy Level Based on Changes in K

Testing the accuracy between the WKNN and KNN algorithms in the Central West Lobby and Central Lobby, it can be observed that there is a similarity in accuracy performance where both algorithms manage to provide data that is equally accurate enough from both the same environment. From 10 test data, at the Central West Lobby point with the WKNN K=3 algorithm, it produces room and point accuracy results with a value of 100%. While the value of k=7 produces 100%-point accuracy and 70% room accuracy. In another room, namely the Central Lobby point, K=3 shows 80% results for room accuracy and 60% for point accuracy. While K = 7. shows the results for both parameters are equal to 100%.

TABLE II
3RD FLOOR CORNER WEST LOBBY ROOM WITH WKNN

Algorithm	Coordinate		Coordinate		Estimated Room Location	Error Distance (Meter)	Information
K=3	10.6	29.2	10.5	30.6	Corner West Lobby	1.403567	Accurate
	10.6	29.2	10.5	27.7	Corner West Lobby	1.50333	Accurate
	10.6	29.2	10.4	26.3	Corner West Lobby	2.906888	Accurate
	10.6	29.2	10.4	31.2	Corner West Lobby	2.009975	Accurate
	10.6	29.2	10.5	30.6	Corner West Lobby	1.403567	Accurate
	10.6	29.2	10.5	27.7	Corner West Lobby	1.50333	Accurate
	10.6	29.2	10.4	26.3	Corner West Lobby	2.906888	Accurate
	10.6	29.2	10.4	31.2	Corner West Lobby	2.009975	Accurate
	10.6	29.2	10.4	31.2	Corner West Lobby	2.009975	Accurate
	10.6	29.2	10.4	31.2	Corner West Lobby	2.009975	Accurate
K=7	10.6	29.2	10.5	27.8	Corner West Lobby	1.403567	Accurate
	10.6	29.2	10.9	28	Corner West Lobby	1.236932	Accurate
	10.6	29.2	10.5	28	Corner West Lobby	1.204159	Accurate
	10.6	29.2	11	28	Corner West Lobby	1.264911	Not Accurate
	10.6	29.2	10	27	Corner West Lobby	2.280351	Accurate
	10.6	29.2	10	31	Corner West Lobby	1.897367	Accurate
	10.6	29.2	10.6	28.9	Corner West Lobby	0.3	Accurate
	10.6	29.2	10	31	Corner West Lobby	1.897367	Not Accurate
	10.6	29.2	10.9	28	Corner West Lobby	1.236932	Accurate
	10.6	29.2	10.5	28	Corner West Lobby	1.204159	Accurate

In the average parameter, the deviation between the two location results shows the results for 3528 for K=3 and 2,5268 for K=7. The smallest deviation value obtained by K=3 is 0.8 in the middle west lobby with the results of data accuracy not matching and room accuracy being appropriate. while at k=7 the smallest deviation result is 0.5 with the appropriate room and point accuracy results.

From the above test, it can be observed that the K value of the nearest neighbor greatly affects the results of room and point accuracy. The use of a small number of K values can increase the accuracy of the estimation accuracy of the closest room position. By using K=3, the average room accuracy is 86% and the coordinate point accuracy is 68%. While using K = 7, the average room accuracy data is 80% with a point accuracy of 78%

D. Location Data Between Floors

Based on the table below, the three floors have different accuracy results. The 1st floor has a room accuracy of 89% and a point accuracy of 86% with an average deviation of 1.42 px or 0.9 m, the 2nd floor has a room accuracy of 65% and a point accuracy of 70% with an average deviation of 2.43 px or 1.7 m, and the 3rd floor has room accuracy of 86% and point accuracy of 68% with an average deviation of 2.27 or 1.5 m.

This difference is influenced by the different Access points and databases between floors. The Access point number parameter plays an important role in influencing the positioning results. On the 1st floor there are three access points installed in a straight line along the 1st floor lobby. This results in a Line of Sight condition along the lobby and good Access point signal stability.

As for the 2nd floor, the database uses four access points, all of which are able to cover the entire room well. However, because one of the Access points is in the room, namely the "Polinema Hotspot 2G Auditorium" Access point which is in the auditorium. So sometimes the RSS signal from the Access point if it reaches a room far from the auditorium such as the east lobby area, it will experience quite large fluctuations or there will be a dead Access point. When an Access point dies, the system will show a value of -110 or NaN.

On the 3rd floor, almost all of the Access points entered into the database are in Line of Sights condition and are lined up straight along the lobby. Only 1 Access point with MAC Adddress 78:5a:20:d1:b5:d8 whose position is unknown but can transmit a signal that is strong enough to be the same as other Access points.

Another parameter that affects the difference between floors is the reference point database. Each floor has a different number of reference points depending on the conditions on the ground. Not infrequently during the calibration process there are Access points that die or suddenly there are very large fluctuations. On the 1st floor alone there are 90 data while on the 2nd floor there are 100 data and on the 3rd floor there are 50.

TABLE III
WKNN K=3 BETWEEN FLOORS

1st Floor			**2nd Floor**			**3rd Floor**		
Location Room	Room Accuration	Coordinate Accuration	Location Room	Room Accuration	Coordinate Accuration	Location Room	Location Room	Coordinate Accuration
Lobby East Corner	90%	80%	Lobby East Corner	100%	100%	Lobby West Corner	100	100%
Lobby East Middle	100%	100%	Lobby Middle West	40%	0	Lobby West Middle	100	100%
Lobby Middle	80%	90%	Lobby West Middle	30%	60%	Lobby Middle West	60	40%
AH Door	100%	70%	Lobby West Corner	40%	40%	Lobby East Middle	100	100%
Lobby West Middle	90%	80%	Auditorium	-	-	Lobby East Corner	100	50%
Lobby West Corner	100%	100%	Entrance Door	100%	100%	3rd Floor Terrace	50	50%
Lab AH 10	60%	60	Lobby East Tengah	10%	100%	Electrical Circuit Lab	100	100%
R.AH.1.3	100%	100%	Reading Room	60%	60%	RK 15	100	90%
R.AH.1.3	50%	50%	Lecturer Room	90%	100%	RK 18	80	50%
R.AH.1.4.A	90%	90%	Lobby East Middle	20%	70%	RK 0	70	0%
Average:	89%	86%		65%	70%		86%	68%

E. *Calculation of Data Accuracy*

TABLE IV
PERCENTAGE OF SUCCESS OF EACH FLOOR

No	Floor	Percentage
1	1	90%
2	2	55%
3	3	80%
Average		75%

From the accuracy data above, it can be observed that the accuracy of the total position detection system is 75% of the average on the third floor. The first floor room has a higher percentage of success than the other two rooms. However, even though the other two rooms show a percentage with an intermediate value, that value can change according to the database created.

IV. CONCLUSION

The performance of the nearest K NEIGHBOUR algorithm is proven to give better results than the K nearest NEIGHBOUR algorithm and can provide accurate results until 75%. In the test results with the Weighted K Nearest Neighbor algorithm, the average value for the room on the 1st floor is 85% with an error deviation of 1.3, while on the 2nd floor it has an average of 66% according to the room with a deviation of 1.39. For testing on the 3rd floor, the results according to the room are 75% and the error deviation is 3.25.

The database fingerprint by considering the number of reference points and the location of the access points can affect the stability of the RSSI value. Stability is important because it becomes a major factor in causing errors when fluctuations are so large.

Other parameters such as the value of K or the nearest neighbor can affect the position, the smaller the value of K, the better the results.

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