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An Efficient Position Estimation of Indoor Positioning System Based on Dynamic Time Warping

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ABSTRACT

Fingerprinting is an effective indoor localization technique used for indoor positioning systems. However, this localization technique has drawbacks in terms of efficiency of position estimation. In this study, the increase in efficiency of position estimation was considered. To achieve this, a method was developed to reduce the number of comparisons. Result shows that a reduction on number of comparisons was 86.06% as compared with the brute force method of determining the estimated position.

Key words : Dynamic Time Warping, Position Estimation

1. INTRODUCTION

The Received Signal Strength (RSS) – based fingerprinting localization technique is also known as scene analysis and fingerprinting, a technique that requires environmental survey to obtain features of the environment where the localization system is to be implemented [1]. This technique has called the attention of several researchers in the field of Indoor positioning system because of its advantages over the other techniques [2]. RSS is the signal power strength transmitted by a source and received by a receiver measured in decibel-milliwatts (dBm) [3]. In connection with other localization techniques, the RSS-based fingerprinting localization technique provides significant advantages like cost efficiency and adaptability to several technologies like Wireless Fidelity (WiFi) and Radio Frequency Identification (RFID) [2]. Several position estimation techniques has been developed and shown an improvement in efficiency in the position estimation [4] and [5]. However, these algorithms require an intermediate training stage after site survey but before the operating stage which still requires laborious collection of data and calibration of RSS. This motivated the researcher to develop an alternative position estimation algorithm that will improve the efficiency by reducing the number of comparisons of the localization process. The concept of dynamic time warping and heuristic steps of [6], [7], [8] and [9] are considered in this study while the careful investigation used by [12], [3] and [14] was became the model on how the study was conducted.

2. MATERIALS AND METHOD

2.1 Hardware Requirements

A Dell Inspiron with Intel ® Core™i5-6200U CPU @2.30Ghz and Samsung Galaxy A7 running android 8.0.0 with 2.2 Ghz. Octa-Core processor were used for the development, testing and implementation. In addition, three Wireless Access Points (WAP) are utilized in development, testing and implementation of the position estimation method.

2.2 Software Requirements

The android studio version 3.5 for Windows 64-bit which is compatible with Android 8.0.0 operating system was used in the development, testing and implementation of the position estimation method. In addition, a 64-bit Windows Operating System 10 Home Single Language was utilized for the development of the position estimation method together with the android studio.

2.3 Testing Setup

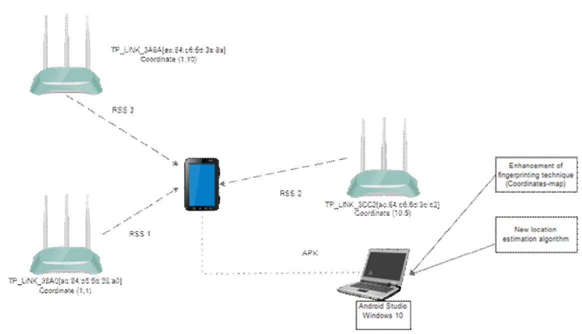

Figure 1: Setup of the Study

The Samsung A7 served as the mobile sensor. The laptop was used to develop the android application to be installed in the mobile sensor. The WAPs are the providers of RSS signals that detected by mobile sensor. After the detection of the RSS signals from the WAPs, the position estimation method is performed. The following presents the detailed procedure to develop the output of the research.

2.4 Pseudo-code of position estimation

Table 1: Pseudo-code of the Position Estimation

Pseudo code of the position estimation

Input: Reference Point and 100 set of points

Start

1. Compute the distance between the reference point and the set of points (1, 1)… (10, 10).
2. Plot the points in the 10 x 10 matrix (x, y)
3. Compare the values of the outer values (36 values)
4. Determine the smallest on the 36 values
5. Make the smallest value as the first reference value
6. Determine the smallest distance of the four nearest to the right of the reference value.
7. Make the smallest value as the next reference value and stop until the reference value did not change.
8. Determine the coordinates of the smallest values.

End

Output: Coordinate of the smallest value

To illustrate the implementation of the heuristics, a matrix is first obtained showing the computed distances between the reference point and the coordinates of the coordinates map. A sample matrix is shown in Figure 2.

7.1	7.0	7.1	7.3	7.6	8.0	8.5	9.2	9.8	10.6
6.1	6.0	6.1	6.3	6.7	7.2	7.7	8.4	9.1	9.9
5.1	5.0	5.1	5.3	5.8	6.3	7.0	7.7	8.5	9.3
4.1	4.0	4.1	4.4	4.9	5.6	6.3	7.1	8.0	8.9
3.2	3.0	3.1	3.6	4.2	4.9	5.7	6.6	7.5	8.5
2.3	2.0	2.2	2.8	3.5	4.4	5.3	6.2	7.2	8.1
1.5	1.0	1.3	2.1	3.1	4.0	5.0	6.0	7.0	8.0
1.1	0.1	0.9	1.9	2.9	3.9	4.9	5.9	6.9	7.9
1.5	1.0	1.3	2.1	3.1	4.0	5.0	6.0	7.0	8.0
2.3	2.0	2.2	2.8	3.5	4.4	5.3	6.2	7.2	8.1

Figure 2: Sample Matrix Representation

Heuristic Steps are shown in figure 3 and 4.

7.1	7.0	7.1	7.3	7.6	8.0	8.5	9.2	9.8	10.6
6.1	6.0	6.1	6.3	6.7	7.2	7.7	8.4	9.1	9.9
5.1	5.0	5.1	5.3	5.8	6.3	7.0	7.7	8.5	9.3
4.1	4.0	4.1	4.4	4.9	5.6	6.3	7.1	8.0	8.9
3.2	3.0	3.1	3.6	4.2	4.9	5.7	6.6	7.5	8.5
2.3	2.0	2.2	2.8	3.5	4.4	5.3	6.2	7.2	8.1
1.5	1.0	1.3	2.1	3.1	4.0	5.0	6.0	7.0	8.0
1.1	0.1	0.9	1.9	2.9	3.9	4.9	5.9	6.9	7.9
1.5	1.0	1.3	2.1	3.1	4.0	5.0	6.0	7.0	8.0
2.3	2.0	2.2	2.8	3.5	4.4	5.3	6.2	7.2	8.1

Figure 3: Step 1

7.1	7.0	7.1	7.3	7.6	8.0	8.5	9.2	9.8	10.6
6.1	6.0	6.1	6.3	6.7	7.2	7.7	8.4	9.1	9.9
5.1	5.0	5.1	5.3	5.8	6.3	7.0	7.7	8.5	9.3
4.1	4.0	4.1	4.4	4.9	5.6	6.3	7.1	8.0	8.9
3.2	3.0	3.1	3.6	4.2	4.9	5.7	6.6	7.5	8.5
2.3	2.0	2.2	2.8	3.5	4.4	5.3	6.2	7.2	8.1
1.5	1.0	1.3	2.1	3.1	4.0	5.0	6.0	7.0	8.0
1.1	0.1	0.9	1.9	2.9	3.9	4.9	5.9	6.9	7.9
1.5	1.0	1.3	2.1	3.1	4.0	5.0	6.0	7.0	8.0
2.3	2.0	2.2	2.8	3.5	4.4	5.3	6.2	7.2	8.1

Figure 4: Step 2

Y										
10	7.1	7.0	7.1	7.3	7.6	8.0	8.5	9.2	9.8	10.6
9	6.1	6.0	6.1	6.3	6.7	7.2	7.7	8.4	9.1	9.9
8	5.1	5.0	5.1	5.3	5.8	6.3	7.0	7.7	8.5	9.3
7	4.1	4.0	4.1	4.4	4.9	5.6	6.3	7.1	8.0	8.9
6	3.2	3.0	3.1	3.6	4.2	4.9	5.7	6.6	7.5	8.5
5	2.3	2.0	2.2	2.8	3.5	4.4	5.3	6.2	7.2	8.1
4	1.5	1.0	1.3	2.1	3.1	4.0	5.0	6.0	7.0	8.0
3	1.1	0.1	0.9	1.9	2.9	3.9	4.9	5.9	6.9	7.9
2	1.5	1.0	1.3	2.1	3.1	4.0	5.0	6.0	7.0	8.0
1	2.3	2.0	2.2	2.8	3.5	4.4	5.3	6.2	7.2	8.1
	1	2	3	4	5	6	7	8	9	10 X

Figure 5: Step 3

From among the values within the rectangle, the smallest value is identified, as indicated in Figure 3-5. Another rectangle is then constructed and the smallest value within the succeeding rectangle is identified following the steps previously done. The process repeats until the smallest value within the rectangle is the previous smallest value. This value is then used for the determination of the coordinates.

2.5 Evaluation

To determine the number of comparison which is the basis of the efficiency of the algorithm for position estimation, the formula was introduced. Number of comparisons was determined to compare the new position estimation method. The Brute force used Equation 1 and the new position estimation method used Equation 2.

Brute Force Method

The formula to solve the number of comparisons of Brute Force Method is:

$$TNC = \frac{n(n-1)}{2} \quad (1)$$

where: n = total number of distance to be compared

TNC = Total number of comparisons

Position Estimation Method

The formula of the total number of comparison of the proposed position estimation method:

$$TNC_{new} = 6\sqrt{n} + \frac{t(t-1)}{2} \quad (2)$$

where: n = Total number of distance to be compared

TNC_{new} = Total number of comparisons

n_1 = Total number of distance to be compared on the succeeding heuristics

Constant (6) = $\frac{n_1(n_1-1)}{2}$

$t = 4\sqrt{n} - 4$

3. RESULTS AND DISCUSSIONS

3.1 Evaluation

The accuracy of the position estimation method was determined using the distance between reference point determined using RSS and the estimated point based on the coordinates map and the Euclidean distance.

Table: 2: Result of Trial 1 and 2

TEST	Distance (in)		TEST	Distance (in)	
	True Value	Observed Value (RSS-BASED)		True Value	Observed Value (RSS-BASED)
1	19.74	22	1	16.09	15
2	17.61	23	2	24.20	21
3	22.45	21	3	21.20	18
4	16.81	17	4	15.75	17
5	33.93	36	5	10.64	8
6	16.32	18	6	23.89	24
7	18.34	19	7	25.81	21
8	18.07	20	8	14.79	16
9	33.00	34	9	38.41	35
10	25.01	27	10	35.27	32
11	13.63	12	11	16.60	17
12	33.84	35	12	30.75	29
13	19.42	21	13	16.18	15
14	13.62	16	14	11.51	10
15	19.93	22	15	25.73	23
16	17.13	18	16	16.87	14
17	17.13	19	17	19.14	18
18	30.95	33	18	33.08	32
19	15.91	14	19	34.82	33
20	19.14	21	20	16.98	14
21	24.17	27	21	19.45	21
22	23.51	28	22	30.99	30
23	17.61	20	23	12.03	11
24	16.44	18	24	16.50	15
25	31.48	32	25	13.40	12
26	18.79	25	26	13.84	10
27	17.54	18	27	27.36	28
28	13.63	16	28	13.03	12
29	12.41	14	29	16.18	14
30	18.12	21	30	27.48	28
31	12.26	14	31	8.03	7
32	30.95	29	32	16.34	17
33	26.29	26	33	19.57	20
34	25.84	26	34	52.50	53
35	28.42	27	35	28.47	29

The results of the two trials show a normal deviation of the observed distance to the predicted distance. This may be attributed to external factors such as signal strength and physical obstructions present in the environment consistent with previous findings [10].

To determine the accuracy of the method, the results for each trial were plotted in order to determine the number of measurements that fall outside the accuracy threshold following the method of [11].

For this study, a threshold absolute distance difference of 4 in is adopted based on true distance. This threshold represents a 0.000014-threshold-to-area ratio, which is two orders of magnitude lower than the threshold adopted in another study that utilized WiFi for localization [11]. Using this value, it can be seen that three points exceeded the threshold indicating an accuracy of 91.43%.

As for the second trial, it can be seen that only one test exceeded the threshold limit, indicating an accuracy of 97.14%.

Taking the average accuracy from the two trials, the average accuracy in terms of distance can be taken to be 94.29%.

3.2 Efficiency in terms of Reduction of Number of Comparisons

Using 100 instances of distance measurements, the number of comparisons were computed based on formula. Using Equation 1, the number of comparisons (TNC) was determined to be 4,950 for the brute force method, as follows:

$$TNC = \frac{n(n-1)}{2} = \frac{100(100-1)}{2} = 4,950$$

On the other hand, the total number of comparisons for the new position estimation was computed to 690 using Equation 2, as follows:

$$TNC = 6\sqrt{n} + \frac{t(t-1)}{2} = 6\sqrt{100} + \frac{36(36-1)}{2} = 690$$

Where t was computed to be:

$$t = 4\sqrt{n} - 4 = 4\sqrt{100} - 4 = 36$$

5. CONCLUSION AND FUTURE WORKS

This study has enhanced the fingerprinting technique of indoor localization through the development of a new approach to position estimation. Initially, the drawbacks of the current localization technique in terms of complexities in the calibration and efficiency of position estimation solutions were presented to identify the challenges to be addressed in this study. To specifically address these drawbacks, enhancement was introduced to simplify the calibration phase and to increase the efficiency of the new approach of position estimation in terms of reduction of the number of comparisons and computational cost. This was accomplished with the use of RSS as basis for location estimation.

In this study, RSS detection from three WAP sources and position estimation were implemented with the use of android programming using dynamic time warping as underlying method. A coordinates map composed of 100 sets of points was used and the reference point coordinates, R(x, y), of the mobile sensor was computed using the trilateration method. A position estimation method was developed to determine the closest point on the coordinates map to the reference point. The position estimation method was able to determine the distances between the points on coordinates map and the reference point, compare the distances, and determine the minimum distance using modified dynamic time warping. Results of the study show that the new position estimation method outperformed the brute force algorithms in terms of the number of comparisons. Future testing of the applicability of the method in different technology such as in radio frequency identification, Bluetooth and ultra-wide band and future application in traffic control with security system is also recommended.

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