International Journal of Engineering & Technology, 7 (4.40) (2018) 183-186

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

The Wide Range of Regression Analysis in Distance Estimation System of the Fingerprint-Based Outdoor Wireless Access Point Localization System

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Abstract

The development of utilization of outdoor wireless access point devices has progressed very rapidly. Mitigation and control of the use of the frequency spectrum are very important to do so that the use of the frequency spectrum can run in accordance with government regulations. This cannot be separated from the technique of localizing the use of wireless devices. There are various localization techniques with various methods and levels of accuracy but generally, these techniques are applied indoors. Localization techniques are generally used to find the location of wireless users, not to search for access point localization. In this paper the distance estimation system from the fingerprint-based outdoor wireless access point localization system is discussed, and wireless devices working in 2.4 GHz. The distance estimation system uses regression method, and this paper aims to prove that 3rd order regression polynomial is the right regression model used for the fingerprint-based wireless access point localization. Previously this technique was applied at a distance of 0-100 meters, so this paper confirms this technique is applied at a distance of 0-1000 meters. The fingerprint is carried out in the range of 0 to 1000 meters and is divided into eleven measurement points. DataPoint consists of received signal strength (RSS_{fnd}) and the distance of the finder to an access point that is being targeted (D_{fnd}). DataPoint from the fingerprinting process is analyzed by regression method and based on the results of the trendline and R^2 shows that in the range of 0-1000 meters the regression method that is right to use for distance estimation system is the 3rd order polynomial regression.

Keywords: *wireless localization, distance estimation, outdoor wireless access point localization, wireless fingerprinting*

1. Introduction

Wireless localization is very important nowadays especially for mitigation and controlling the use of frequency spectrum. Previous studies about localized methods use outdoor localization techniques [1], [2], [3], it is based on triangulation or trilateration methods. Other localization techniques apply the wireless fingerprinting method [4],[5], localized objects are wireless mobile users. In the application requires some reference nodes or anchors with the localization method is trilateration.

In this paper, localized objects are locations of wireless access points used outdoors. The application of this localization system only requires one received signal strength (*RSS*) value, no longer requires some reference nodes and can be applied under line-of-sight (LoS) or non-line-of-sight (NLoS) conditions, this is what distinguishes it from other wireless localization systems. This wireless access point localization system consists of the wireless fingerprinting, the distance estimation system and the position estimation system [6], and in this paper only discusses the distance estimation system. In this paper the range of measurement is 0-1000 meters.

This paper aims to prove that the 3rd order polynomial regression model is the most precise to estimate the distance in the fingerprint-based outdoor wireless access point localization system if applied at a longer distance more than 100 meters.

2. Theoretical background

2.1. Fingerprinting

The technique that records a number of data from a measurement variable is then stored into the database. The database is used for the comparison process on a new measurement. This technique is called fingerprint. Three kinds of fingerprinting techniques: visual fingerprinting, motion fingerprinting, and signal fingerprinting. Signal fingerprinting or also called wireless fingerprinting used in this paper for collecting the empirical data.

The main advantage of fingerprint-based localization systems is effective and efficient because it does not have to provide many additional devices [7].

2.2. Wireless Fingerprinting

Several methods for localizing wireless signals have been proposed, such as angle of arrival (AoA), time of arrival (ToA), time difference of arrival (TDoA), and signal fingerprint [8].

Localization techniques with signal-based fingerprinting produce higher accuracy when applied in complex radio wave propagation environments, this is compared to other methods that are often interfered with by multipath signals in the surrounding environment [1].

Wireless fingerprinting has been proven as part of a localization technique that provides effective value because of its simplicity and practicality [5] or it can reduce excessive costs because it can rely on existing wireless infrastructure [9]. Wireless fingerprints can consist of RSSI and SSID values [10], sequence ID-cells [11], or combinations of *RSS* values with MAC Address [12]. In this paper wireless fingerprints consist of *RSS* values and the distance between the signal receiving device and the access point.

3. Method

The method of fingerprint-based outdoor wireless access point localization as shown in Figure 1. It consists of three main part: wireless fingerprinting, distance estimation system and position estimation system, in this paper the focus confirms the results of the distance estimation system if the system is applied at a greater distance than previous research.

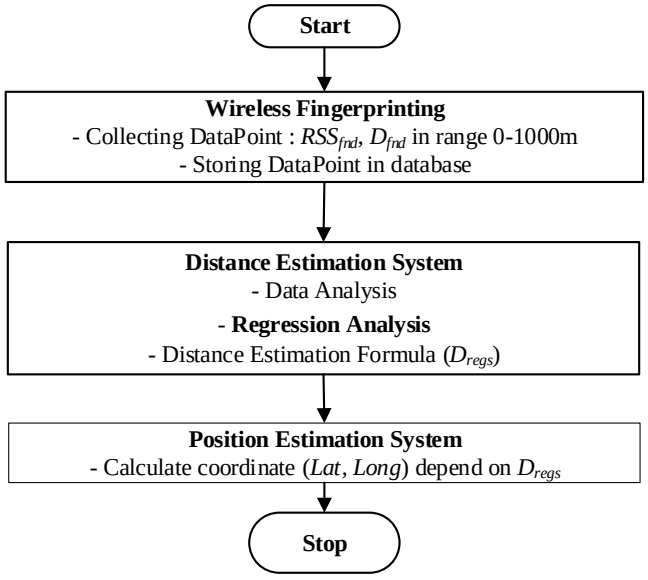

Fig. 1: The method of the fingerprint-based outdoor wireless access point localization system

3.1. Wireless fingerprinting in range 0-1000 meters

In the wireless fingerprinting section uses two main devices, namely: access point source and finder, finder is a device used to measure *RSS* from an access point, as shown in Figure 2. This technique is no different as in previous measurements at a distance of 0-100 meters [6]. Wireless fingerprinting is used to collect DataPoint, DataPoint is a database consisting of: RSS_{fnd} and D_{fnd}. RSS_{fnd} is the received signal strength received by the finder device. D_{fnd} is the real distance between the finder and the access point source. All wireless devices work at 2.4 GHz in this wireless fingerprinting.

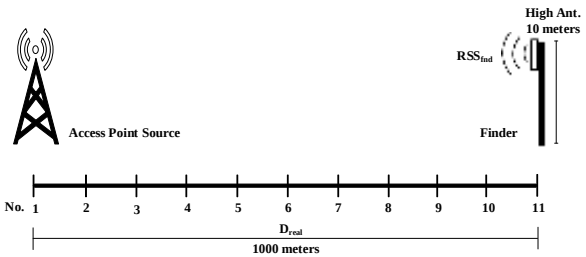

Fig. 2: Wireless fingerprint in range 0 – 1000 meters

The RSS_{fnd} measurements are at 1000m, 900m, 800m, 700m, 600m. 500m, 400m, 300m, 200m, 100m, and 0.01m; these points are referred to as measurement points. RSS_{fnd} measurements performed every 1 minute for 100 minutes, so that the amount of data at each measurement point is 100.

3.2. Database of DataPoint

The results of wireless fingerprinting in the form of DataPoint, it is stored in the database, the database uses the MySQL engine with HTML and PHP5 interpreters. Furthermore, DataPoint will be recalled at the data analysis stage and the results are used for regression analysis.

3.3. Distance Estimation System

Distance estimation system consists of 3 stages: data analysis, regression analysis, and distance estimation formula. This paper focuses on regression analysis by making several confirmations of some fingerprinting data retrieval. Data analysis is the DataPoint processing stage from the results of fingerprinting, this analysis aims to get values such as mean value, standard deviation value, and standard error. The mean value of RSS_{fnd} and D_{fnd} is the main data in the regression analysis stage.

The stages of regression analysis using three regression models: exponential regression, 2nd order polynomial regression, and 3rd order polynomial regression. At this stage as well as to confirm the results of the previous regression analysis, the previous regression analysis was applied at a distance of 100 meters [6] and this paper was applied at a distance of 1000 meters. If the most precise regression model at a distance of 100 meters and 1000 meters is the same regression model. It can be concluded that the regression model is the most precise to apply to the distance estimation system on wireless localization.

4. Results and discussion

4.1. Data analysis of DataPoint in range 0-1000 meters

Based on DataPoint values, especially the RSS_{fnd} value which varies with the number of RSS_{fnd} is 100 at each measurement point is very important to determine the mean value. It is a representation of the measurement results at each point of fingerprinting. Besides the mean value in this data analysis section also determines the standard deviation and standard error. Table 1 shows the mean value, standard error value and standard deviation value of RSS_{fnd}.

Table 1: Data analisys of RSS_{fnd} in range 0-1000 meters

No.	D_{fnd} (meters)	Mean of RSS_{fnd} (dBm)	Stand. Deviation	Stand. Error
1	1000	-59.90	0.326	0.033
2	900	-58.70	0.506	0.051
3	800	-56.30	0.383	0.038
4	700	-53.90	0.442	0.044
5	600	-52.10	0.245	0.025
6	500	-49.30	0.264	0.026
7	400	-46.20	0.200	0.020
8	300	-42.20	0.300	0.030
9	200	-36.80	0.494	0.049
10	100	-30.93	0.332	0.033
11	0.01	-7.90	0.302	0.030

Based on the results of data analysis as shown in Table 1, the standard deviation value and the standard error value is much smaller than the mean value, it shows that the mean value of RSS_{fnd} is a representation of all data resulting from fingerprinting.

4.2. Regression analysis

Regression analysis is the main part discussed in the distance estimation system. The purpose of this stage is to determine a precise regression model to be applied to the distance estimation system. The mean value of RSS_{fnd} and D_{fnd} is the main data in the regression analysis to create a regression line or also called trendline. The regression model that produces the trendline that is closest to the value of the results of fingerprinting is the one chosen for the calculation of estimating distance.

4.2.1 Regression analysis with the exponential regression

Figure 3 is graph of regression analysis with the exponential regression model.

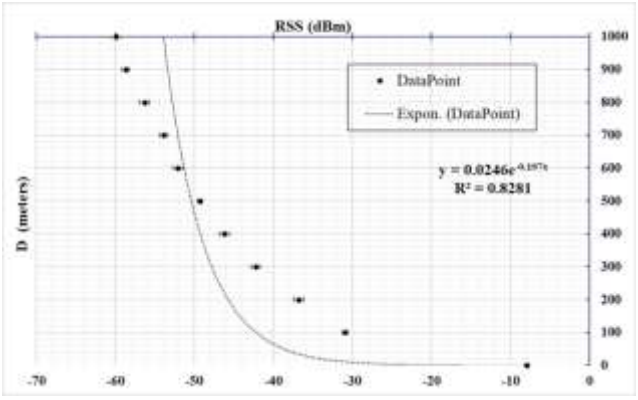

Fig. 3: Regression analysis with the exponential regression

This regression produces the formula: $y= 0.0246\ e^{-0.197x}$, where x is RSS_{fnd} and y are the distance estimation. The trendline of the exponential regression model shows a regression line that is too far from precision with the results of fingerprinting. This proves that the exponential regression model is not appropriate to be used in the distance estimation system in wireless access point localization.

4.2.2. Regression analysis with the 2nd order polynomial regression

The next regression analysis uses the 2nd order polynomial regression model is shown in Figure 4.

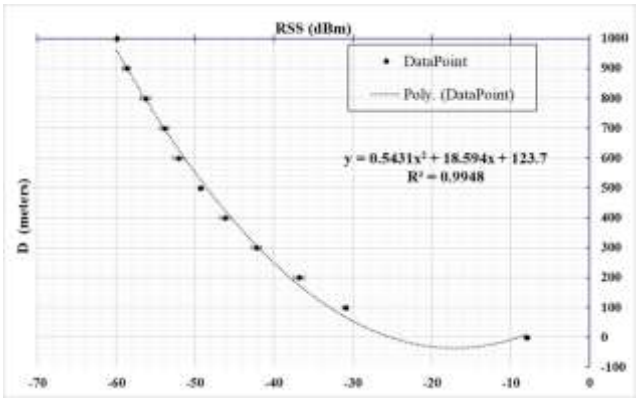

Fig. 4: Regression analysis with the 2th order polynomial regression

The formula produced when using the 2nd order polynomial regression is $y= 0.5431x^2 + 18.594x + 123.7$. The trendline from the 2nd order polynomial regression model shows a regression line that is closer to the results of fingerprinting. The 2nd order polynomial regression model is more precise then the exponential regression model.

4.2.3. Regression analysis with the 3rd order polynomial regression

The last regression analysis in this paper uses the 3rd order polynomial regression model is shown in Figure 5.

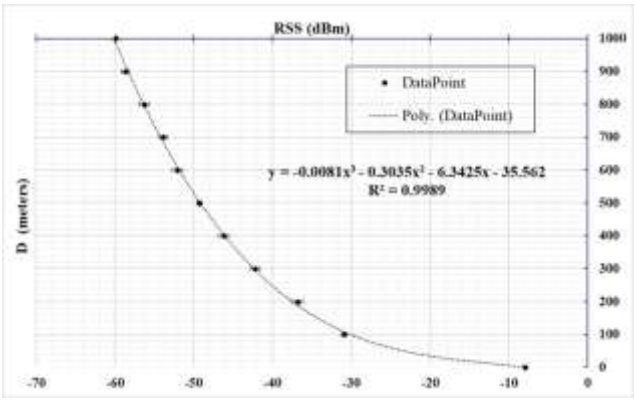

Fig. 5: Regression analysis with the 3rd order polynomial regression

The 3rd order polynomial regression resulting the regression formula $y= -0.0081x^3 - 0.3035x^2 - 6.3425x - 35.5620$. Compared to the previous 2nd order polynomial regression model, the order 3rd polynomial regression results the trendline that is very close to the DataPoint. It confirmed with the R^2 value which is close to the value of 1 that is = 0.9989 then it can be concluded that the 3rd order polynomial regression is the most precise then others regression model.

4.2.4. Regression model comparison

Comparison of 3 regression models in regression analysis of distance estimation system is shown in Figure 6.

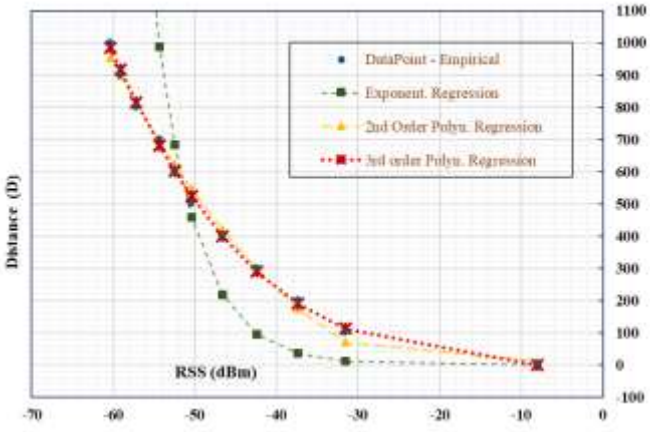

Fig. 6: The regression model comparison in regression analysis of distance estimation system

From Figure 6 it can be concluded that the 3rd order polynomial is the most precise with DataPoint.

4.2.5. Comparison of the 3rd order polynomial regression in 100 meters and 1000 meters

In this section is comparing the results of the 3rd order polynomial regression at a measurement distance of 0-100 meters and 0-1000 meters. Figure 7 is the 3rd order polynomial regression in the range 0-100 meters [6].

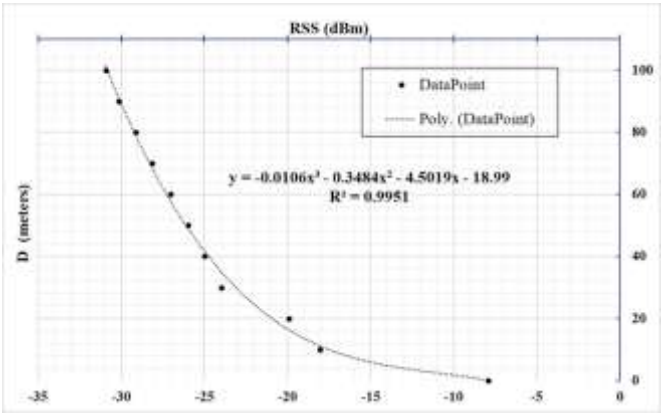

Fig. 7: The 3rd order polynomial regression in the range 0-100 meters

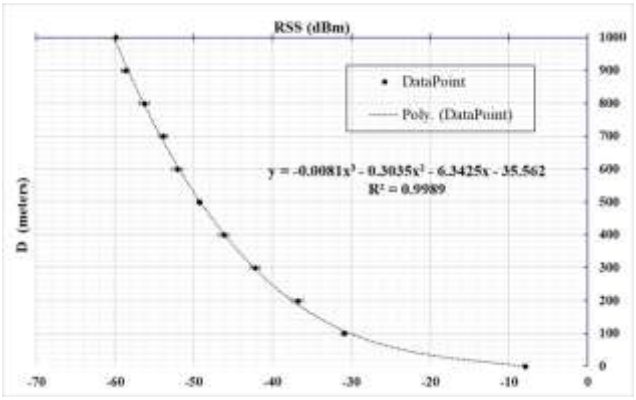

Fig. 8: The 3rd order polynomial regression in the range 0-1000 meters

The value of R^2 for range 0-100 meters is 0.9951, as shown in Figure 7 and the value R^2 for range 0-1000 meters is 0.9989, as shown in Figure 8. Both of R^2 values are closest to the value 1, it proves that 3rd order polynomial regression is the most precise for distance estimation system, even though it is applied to a longer range.

5. Conclusions

In this paper fingerprinting was carried out at a distance of 0-1000 meters using the same method of previously measured at 0-100 meters. The value of R^2 for range 0-100 meters is 0.9951 and the value R^2 for range 0-1000 meter is 0.9989, both closest to the value of 1. Based on the value R^2 and the trendline of regression analysis shows that 3rd order polynomial regression is the most precise. It can be concluded that 3rd order polynomial regression is the most precision used for distance estimation system of the fingerprint-based outdoor wireless access point localization system.

Further research is to conduct fingerprinting in several areas that have different characteristics to prove 3rd order polynomial regression remains the most precise for distance estimation system.

Acknowledgment

The authors would like to thank the anonymous reviewers for their valuable comments and suggestions to improve the quality of the paper. The authors are also grateful to Department of Electrical Engineering of Universitas Widya Dharma Klaten, Department of Electrical and Information Engineering of Universitas Gadjah Mada Yogyakarta, Nuclear Engineering and Engineering Physics Department of Universitas Gadjah Mada Yogyakarta.

References

[1] K. Li, J. Bigham, and L. Tokarchuk, "Validation of a probabilistic approach to outdoor localization," *IEEE Wirel. Commun. Lett.*, vol. 2, no. 2, pp. 167–170, 2013.

[2] A. Adewale and U. Kingdom, "Outdoor Propagation Prediction in Wireless Local Area Network (WLAN)," *Int. J. Eng. Sci. Innov. Technol.*, vol. 2, no. 2, pp. 269–274, 2013.

[3] O. S. Oguejiofor, V. N. Okorogu, A. Adewale, and B. O. Osuesu, "Outdoor Localization System Using RSSI Measurement of Wireless Sensor Network," *Int. J. Innov. Technol. Explor. Eng.*, vol. 2, no. 2, pp. 1–6, 2013.

[4] Q. D. Vo and P. De, "A Survey of Fingerprint-Based Outdoor Localization," *IEEE Commun. Surv. Tutorials*, vol. 18, no. 1, pp. 491–506, 2016.

[5] S. Yiu, M. Dashti, H. Claussen, and F. Perez-Cruz, "Wireless RSSI fingerprinting localization," *Signal Processing*, vol. 131, pp. 235–244, 2017.

[6] Sutiyo, R. Hidayat, I. W. Mustika, and Sunarno, "Regression Analysis for Estimated Distance in Fingerprinting-Based WLAN Outdoor Localization System," in *2018 4th International Conference on Science and Technology (ICST)*, 2018, pp. 557–560.

[7] Sutiyo, R. Hidayat, I. W. Mustika, and Sunarno, "Wireless Fingerprinting Technique for Outdoor Access Point Distance Estimation System," in *The 12th SEATUC Symposium Engineering Education and Research for Sustainable Development*, 2018, pp. 265–268.

[8] A. Roxin, J. Gaber, M. Wack, and A. N. Sidi Moh, "Survey of Wireless Geolocation Techniques," *50th IEEE Globecom07*, 2012.

[9] B. O'Hara and A. Petrick, *IEEE 802.11 Handbook: A Designer's Companion*. New York, NY, USA: Standards Information Network IEEE Press, 2005.

[10] M. Ibrahim and M. Youssef, "CellSense: An accurate energy-efficient GSM positioning system," *IEEE Trans. Veh. Technol.*, vol. 61, no. 1, pp. 286–296, 2012.

[11] J. Paek, K.-H. Kim, J. P. Singh, and R. Govindan, "Energy-efficient positioning for smartphones using Cell-ID sequence matching," *Proc. 9th Int. Conf. Mob. Syst. Appl. Serv. - MobiSys '11*, p. 293, 2011.

[12] A. Zhang, Y. Yuan, Q. Wu, S. Zhu, and J. Deng, "Wireless Localization Based on RSSI Fingerprint Feature Vector," *Int. J. Distrib. Sens. Networks*, vol. 2015, pp. 1–7, 2015.