NUANSA INFORMATIKA
Volume 20 Number 1 Januari 2026

p-ISSN :1858-3911 , e-ISSN : 2614-5405
https://journal.fkom.uniku.ac.id/ilkom

Analysis of Location Determination Using Wireless Signals at Low Range Using Third Order Polynomial Regression

Sutiyo*[1], Yogi Yudo[2]
[1]Telkom University, Bandung, Indonesia
[2]PT Telkom, Indonesia
E-mail: *[1]**tioatmadja@telkomuniversity.ac.id**,[2]yogisaloko@telkomuniversity.ac.id

Abstract

At short range, Location Determination Using Wireless Signals is considered a quite challenging problem. This paper discusses Location Determination Using Wireless Signals at short range with a Polynomial approach. The combination of retained independent effect of each component measure from Polynomial Regression and positioning in wireless fingerprinting produces a Polynomial that can provide good results for Location Determination Using Wireless Signals at short range. The measurement was conducted at Samas Beach Road, Yogyakarta, within a 0–100-meter range divided into 11 measurement points spaced every 10 meters. Validation results indicated that the third-order polynomial regression achieved a determination coefficient (R^2) of 0.9982, confirming its high accuracy in representing the measured signal strength variations at short range.

Keywords—*Wireless, Polynomial, Location*

Submission: October 7, 2025 Accepted: October 27, 2025 Published: January 20, 2026
DOI Article: https://doi.org/10.25134/ilkom.v20i1.509

1. INTRODUCTION

Broadband Wireless Access (BWA) is a high-speed data access technology with wireless media. A number of services that are developing using BWA bands include broadband internet access, VoIP, video streaming and other digital applications. BWA is divided into two categories, namely fixed BWA and mobile BWA. Several BWA device industries have joined in promoting the technology standards they have developed to become standards adopted worldwide. BWA technology is divided into three, namely mobile telecommunication system-based technology (GSM, CDMA), data communication-based technology (WiFi, WiMAX) and non-terrestrial-based technology (VSAT, DVB). WiFi is a technology that uses non-exclusive or free BWA frequencies. Non-exclusive BWA frequencies, namely 2.4 GHz, 5.2 GHz, 5.8 GHz. WiFi is also known as Wireless Local Area Network (WLAN). Wireless technology that works on non-exclusive BWA bands, such as 802.11b/g/n WLAN devices, has advantages in terms of economy, but from a technological perspective has limitations. This technology is intended for Industrial, Scientific and Medical (ISM) activities.

In 2021, Linear with polynomial regression: Overview was studied by Patil et al. [1]. In addition, in 2021, a study entitled “Towards a Mathematical Framework to Inform Neural Network Modeling via Polynomial Regression” was conducted by Morala et al. [2]. Subsequently, in 2023, Shi et al. [3] discussed a study entitled “Ensemble Regression Based on Polynomial Regression-Based Decision Tree and Its Application in the In-situ Data of Tunnel Boring Machine.” Furthermore, in 2023, Yao et al. [4] conducted a study titled “Toward a Holistic Perspective of Congruence Research with the Polynomial Regression Model.” Finally, in 2025, Mediation testing with polynomial regression: A critical review of extant approaches and a researcher's toolkit for the future was studied by Fu et al. [5].

In 2015, Xu et al. [6] investigated “Device Fingerprinting in Wireless Networks: Challenges and Opportunities.” Additionally, in 2017, Khalajmehrabadi et al. [7] conducted a study titled “Modern WLAN Fingerprinting Indoor Positioning Methods and Deployment Challenges.” Furthermore, in 2018, Hidayat et al. [8] proposed “Regression Analysis for Estimated Distance in Fingerprinting-Based WLAN Outdoor Localization System.” Finally, in 2019, Hidayat et al. [9] discussed a study entitled “Analysis of Accuracy and Precision of WLAN Position Estimation System Based on RSS.”

In 2021, Zhang et al. [10] discussed a study titled “Design Methodology of Free-Positioning Nonoverlapping Wireless Charging for Consumer Electronics Based on Antiparallel Windings.” In addition, in 2021, Xianjia et al.

p-ISSN :1858-3911 , e-ISSN : 2614-5405
https://journal.fkom.uniku.ac.id/ilkom

[11] reviewed "Applications of UWB Networks and Positioning to Autonomous Robots and Industrial Systems." Subsequently, in 2022, Koelemeij et al. [12] discussed "A Hybrid Optical–Wireless Network for Decimetre-Level Terrestrial Positioning." Furthermore, in 2022, Hong et al. [13] examined "Self-Powered Seesaw Structured Spherical Buoys Based on a Hybrid Triboelectric Electromagnetic Nanogenerator for Sea Surface Wireless Positioning." Finally, in 2024, Scavino et al. [14] investigated "Enhancing Indoor Positioning Accuracy with WLAN and WSN: A QPSO Hybrid Algorithm with Surface Tessellation."

Most previous studies have focused on theoretical aspects, long-range environments, or other application domains such as robotics, psychology, and industrial systems. Only a few have investigated the application of polynomial regression for wireless signal-based positioning, particularly in short-range areas. Therefore, this study aims to evaluate the accuracy of polynomial regression in estimating the position coordinates of an outdoor WLAN access point at short range using a single received signal strength (RSS) value.

2. METHOD

2.1. Transmit Power

Transmit power is the magnitude of the signal output produced by a transmitting device. Transmit power is expressed in Watts (W) or deciBelWatts (dBW).

The power equation is shown in Equation 2.1.

$$P\ (Watt) = V\ (volt) \times I\ (amp) \qquad (2.1)$$

Where:
P = transmit power (Watt)
V = voltage (Volt)
I = current (Ampere)

The equations for converting watts to dBm are shown in equation 2.2 and equation 2.3.

$$P\ (dbW) = \ 10Log\ P/(1\,Watt) \qquad (2.2)$$

$$P\ (dBm) = 10Log\frac{P}{1\ mWatt} \qquad (2.3)$$

Where:
P(dBW): power in deciBelWatts (dBW)
P: power in watt (W)
1 mWatt: standard reference of 0.001 W

The equation for converting dBm to watts is shown in equation 2.4.

$$P\ (Watt) = \frac{10^{\frac{P\ (dBm)}{10}}}{1000} \qquad (2.4)$$

Where:
P: power in watt (W)
P(dBm): power in deciBelmilliWatt (dBm)

dB (decibel) is a unit of ratio or difference in the strength of a signal emitted from a transmitter. The unit dBm (deciBelmilliWatt) is a unit of magnitude of the strength of a signal transmitted.

Log or logarithm is the inverse of exponent or power. Logarithma number with a cardinal number (written) is the exponent of the power number that results when raised to the power of that exponent. Logarithmic notation is shown in equation 2.5. $xaa_{\log x}xa$

$$a_{\log x} = n, \qquad (2.5)$$

Where :
a = cardinal number
x = logarithmic number with x > 0
n = algorithm result or exponent of base essence
For a > 0; a ≠ 1 and x > 0

Antilog is the inverse operation of logarithm to exponent or power. Equation 2.5 can be inverted to exponent to get Equation 2.6.

2.2. Wireless Fingerprinting

Wireless fingerprinting is a position localization method that involves two stages [15]: the offline stage and the online stage. Offline phase is the phase of collecting data values that serve as references for the final goal of wireless fingerprinting. Online phase is the implementation phase in the field which includes data processing to find a value y based on input data x. The general method of wireless fingerprinting is shown in Figure 1.

 p-ISSN :1858-3911 , *e-ISSN : 2614-5405*
https://journal.fkom.uniku.ac.id/ilkom

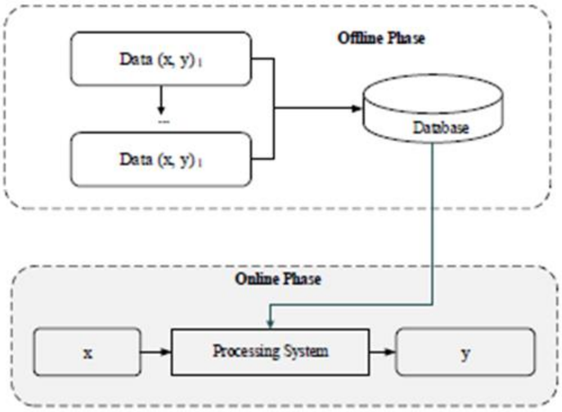

Figure 1. Wireless Fingerprinting Image

This wireless fingerprinting method is widely used in wireless localization systems. The implementation differences, when viewed from the offline phase, are in the data captured during wireless fingerprinting and the database storage system. The online phase is the processing system or algorithm and the search value.

2.3. Polynomial Regression

$$y = \beta_3 x^3 + \beta_2 x^2 + \beta_1 x + \beta_0 \quad (2.6)$$

Where:
y = Estimated received signal strength (RSS) or predicted power value (in dBm)
$\beta_1, \beta_2, \beta_3$ = Regression coefficients that determine the shape and curvature of the polynomial curve
β_0 = Intercept (constant term) of the polynomial regression equation

The highest power in polynomial regression indicates the order or degree of the polynomial.

$$y = 0{,}025x^3 + 1{,}69x^2 + 27{,}42x + 127{,}5 \quad (2.7)$$

At the final stage of polynomial regression, the entire research process is summarized in Figure 2. The diagram illustrates the complete workflow of the study, covering stages from data collection and transmit power calculation to the wireless fingerprinting process and regression modeling. Model validation is carried out using the coefficient of determination (R^2) to ensure that the polynomial regression accurately represents the relationship between Received Signal Strength (RSS) and distance.

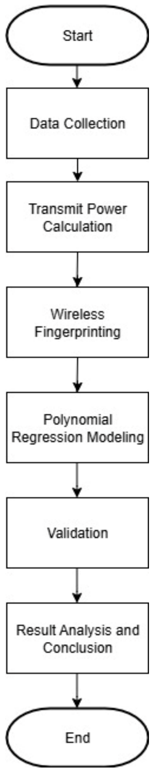

Figure 2. Workflow Diagram for Location Determination Using Wireless Signals

3. RESULTS

The experimental area has a low attenuation level and is located near the coast. The results of determining the coordinates of measurement points within the 0–100-meter range in the measurement area are shown in Table 1 and displayed in Figure 3.

p-ISSN :1858-3911 , e-ISSN : 2614-5405
https://journal.fkom.uniku.ac.id/ilkom

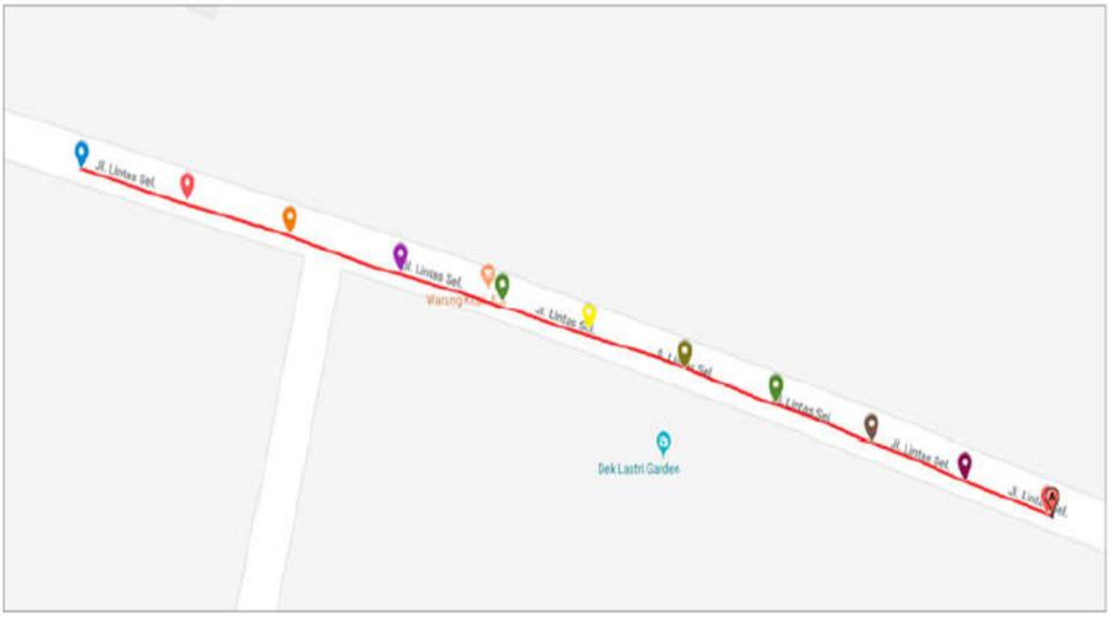

Figure 3. Site survey range 0 – 100 meters measurement areaan

Table 1 Coordinates of measurement points in the range 0 – 100 meters, area 1

Area	1	
Distance	0 – 100 meters	
Location	Samas Beach Road, Yogyakarta	
No	**Coordinate**	
	Lat.°	**Lon.°**
A1-100	-7.998882	110.264161
A1-90	-7.998904	110.264249
A1-80	-7.998927	110.264338
A1-70	-7.998948	110.264426
A1-60	-7.998871	110.264514
A1-50	-7.998993	110.264601
A1-40	-7.999015	110.264689
A1-30	-7.999037	110.264777
A1-20	-7.999059	110.264865
A1-10	-7.999081	110.264953
A1-0	-7.999103	110.265040

The site survey for wireless fingerprinting, covering a measurement range of 0 to 100 meters, was divided into 11 measurement points, each spaced 10 meters apart.

Table 2. Wireless fingerprinting analysis results range 0-100 meters

No	D_{real}	$RSS_{mean-A1}$ (dBm)	Stand. Deviation ()SD_{A1}	Stand. Error ()SE_{A1}
A1-100	100	-24.63	0.49	0.05
A1-90	90	-23.82	0.39	0.04
A1-80	80	-22.64	0.48	0.05
A1-70	70	-21.58	0.50	0.05
A1-60	60	-20.72	0.45	0.05
A1-50	50	-19.55	0.50	0.05
A1-40	40	-18.79	0.50	0.05

p-ISSN :1858-3911 , e-ISSN : 2614-5405
https://journal.fkom.uniku.ac.id/ilkom

A1-30	30	-17.42	0.89	0.09
A1-20	20	-16.49	0.50	0.05
A1-10	10	-14.29	0.56	0.06
A1-0	0.01	-12.91	0.49	0.05

Table 2 shows that the SD and SE of each measurement point have values smaller than the average RSSmean. Therefore, it can be concluded that the average RSSmean value can be a representation of the overall wireless fingerprinting measurement results in the range of 0-100 meters.

The resulting regression model has a coefficient of determination (R^2 = 0.9982), indicating that the third-order polynomial regression can represent the nonlinear relationship between Received Signal Strength (RSS) and distance with a very high level of accuracy. The R^2 value, which is close to 1, demonstrates that the model can explain almost all variations in the measurement data, thereby producing highly accurate position coordinate estimates in short-range wireless environments.

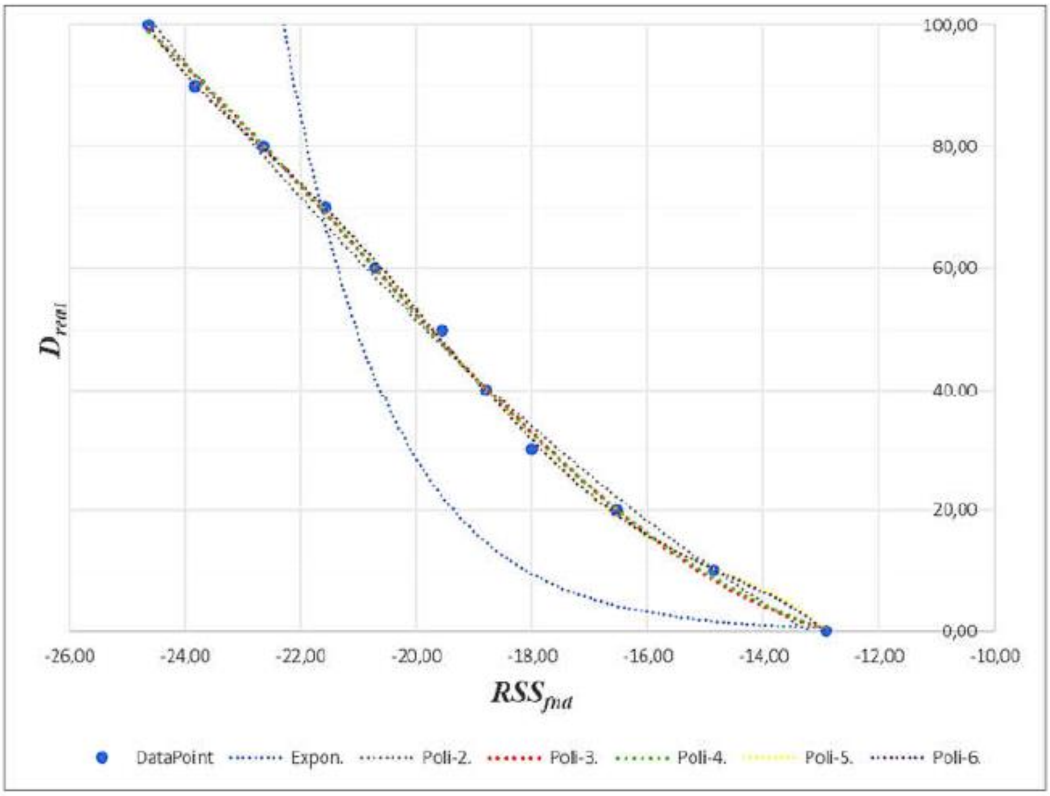

Figure 4. Regression graph of 0-100 meter range area 1

Based on the regression patterns of the six regression models shown in Figure 4, it can be concluded that the accurate regression pattern for wireless fingerprinting in the 0-100 meter measurement area range is 3rd order polynomial regression with an R2 value of 0.9982.

4. CONCLUSION

Based on the results of field research and discussion, several conclusions can be stated as follows: the accurate regression pattern for wireless fingerprinting in the range of 0 – 100 meters of the measurement area is third-order polynomial regression which obtains a fairly high R2 accuracy of 99.82%.

Nevertheless, this study has several limitations. The measurements were conducted in a single outdoor area with relatively stable environmental conditions and a limited distance range of 0–100 meters. These conditions may restrict the generalizability of the research findings when applied to different environments or distance ranges. For future studies, it is suggested to broaden the measurement area to encompass various environmental conditions and to investigate the integration of polynomial

p-ISSN :1858-3911 , e-ISSN : 2614-5405
https://journal.fkom.uniku.ac.id/ilkom

regression with optimization algorithms or neural networks to improve the accuracy of wireless positioning systems.

REFERENSI

[1] S. Patil and S. Patil, “Linear and Polynomial Regression: An Overview,” *Int. J. Appl. Res.*, vol. 7, no. 8, pp. 273–275, 2021.

[2] P. Morala, J. A. Cifuentes, R. E. Lillo, and I. Ucar, “Towards a Mathematical Framework to Inform Neural Network Modelling via Polynomial Regression,” *Neural Networks*, vol. 142, pp. 57–72, 2021.

[3] M. Shi, W. Hu, M. Li, J. Zhang, X. Song, and W. Sun, “Ensemble Regression Based on Polynomial Regression-Based Decision Trees and Its Application to In-Situ Data of Tunnel Boring Machines,” *Mech. Syst. Signal Process.*, vol. 188, p. 110022, 2023.

[4] Y. A. Yao and Z. Ma, “Toward a Holistic Perspective of Congruence Research with the Polynomial Regression Model,” *J. Appl. Psychol.*, vol. 108, no. 3, p. 446, 2023.

[5] S. Q. Fu, N. Dimotakis, and J. Koopman, “Mediation Testing with Polynomial Regression: A Critical Review of Extant Approaches and a Researcher’s Toolkit for the Future,” *J. Appl. Psychol.*, 2025.

[6] Q. Xu, R. Zheng, W. Saad, and Z. Han, “Device Fingerprinting in Wireless Networks: Challenges and Opportunities,” *IEEE Commun. Surv. \& Tutorials*, vol. 18, no. 1, pp. 94–104, 2015.

[7] A. Khalajmehrabadi, N. Gatsis, and D. Akopian, “Modern WLAN Fingerprinting Indoor Positioning Methods and Deployment Challenges,” *IEEE Commun. Surv. \& Tutorials*, vol. 19, no. 3, pp. 1974–2002, 2017.

[8] R. Hidayat, I. W. Mustika, and others, “Regression Analysis for Estimated Distance in Fingerprinting-Based WLAN Outdoor Localization Systems,” in *2018 4th International Conference on Science and Technology (ICST)*, 2018, pp. 1–4.

[9] R. Hidayat, I. W. Mustika, and others, “Analysis of Accuracy and Precision of WLAN Position Estimation System Based on RSS,” *Int. J. Adv. Comput. Sci. Appl.*, vol. 10, no. 7, 2019.

[10] Y. Zhang, S. Chen, X. Li, and Y. Tang, “Design Methodology of Free-Positioning Nonoverlapping Wireless Charging for Consumer Electronics Based on Antiparallel Windings,” *IEEE Trans. Ind. Electron.*, vol. 69, no. 1, pp. 825–834, 2021.

[11] Y. Xianjia, L. Qingqing, J. P. Queralta, J. Heikkonen, and T. Westerlund, “Applications of UWB Networks and Positioning in Autonomous Robots and Industrial Systems,” in *2021 10th Mediterranean Conference on Embedded Computing (MECO)*, 2021, pp. 1–6.

[12] J. C. J. Koelemeij, H. Dun, C. E. V Diouf, E. F. Dierikx, G. J. M. Janssen, and C. C. J. M. Tiberius, “A Hybrid Optical–Wireless Network for Decimetre-Level Terrestrial Positioning,” *Nature*, vol. 611, no. 7936, pp. 473–478, 2022.

[13] H. Hong *et al.*, “Self-Powered Seesaw-Structured Spherical Buoys Based on a Hybrid Triboelectric–Electromagnetic Nanogenerator for Sea Surface Wireless Positioning,” *Energy \& Environ. Sci.*, vol. 15, no. 2, pp. 621–632, 2022.

[14] E. Scavino, M. A. Abd Rahman, Z. Farid, S. Ahmad, and M. Asim, “Enhancing Indoor Positioning Accuracy with WLAN and WSN: A QPSO Hybrid Algorithm with Surface Tessellation,” *Algorithms*, vol. 17, no. 8, p. 326, 2024.

[15] F. Di Rienzo, A. Madonna, N. Carbonaro, A. Tognetti, A. Virdis, and C. Vallati, “Short-Range Localization via Bluetooth Using Machine Learning Techniques for Industrial Production Monitoring,” *J. Sens. Actuator Networks*, vol. 12, no. 5, 2023, doi: 10.3390/jsan12050075.