Plaboratory Asset Localization System through RFID Sensor Using Kalman Filter Algorithm

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Abstract: Loss of assets that often occurs in the Manufacturing Automation and Mechatronics Engineering laboratory environment at the Bandung Manufacturing Polytechnic. Where assets that should exist in certain laboratories do not exist when learning activities will be carried out. This proposed research aims to create a laboratory asset tracking system through UHF RFID using the Kalman filter algorithm, track the last location of laboratory assets that have an RFID tag and have been registered in the system, limit the search area for laboratory assets that have an RFID tag and have been registered in the system, improve laboratory asset management system. By utilizing scanning technology using UHF RFID and creating a laboratory asset tracking application. Where in its application the RSSI value output from unstable RFID will be estimated by estimating a value based on known data using the Kalman filter calculation method. From the estimation results, a classification system will be made based on 3 groups of areas that have been determined and the estimation of the unstable RSSI value has been successfully carried out. The test results in detecting the detected object area have an error percentage of 13.3%, but from these results there is a drawback where when there is a transfer of assets during the detection period there will be a delay in adjusting the value to its steady-state for approximately 25-30 seconds.

1 INTRODUCTION

This often happens in the Manufacturing Automation and Mechatronics Engineering laboratory environment at the Bandung Manufacturing Polytechnic (Nur Rahmawati et al., 2020).Where there is often loss of assets that should be in certain laboratories to support the course of learning activities in accordance with the courses in the laboratory (Aminah et al., 2020).

The use of Indoor Localization technology where this technology can determine the position of the object or person being sought is very useful for many applications (for example, tracking, monitoring, or routing) in several industries such as factories, health, and the construction industry (Fali Oklilas & Rozi, 2016) Where the position of the object can be estimated using the RSSI (Received Signal Strength Indication) value using the path loss calculation algorithm (Firaldi et al., 2017)Detection can be done by classifying the RSSI (Received Signal Strength Indicator) value detected by the reader. RSSI is a technology used to measure the signal strength indicator received by a wireless device. However, direct mapping of distance-based RSSI values has many limitations, because basically, RSSI is susceptible to noise, multi-path fading, interference, etc. which results in large fluctuations in the received power. (Ma'arif et al., 2020)Then a filter is needed to minimize the fluctuation of the disturbance. To overcome the noise problem, the Kalman filter can be applied to filter the RSSI measurements. The true RSSI value (without noise) is defined as the approximate state. (Bulten et al., 2016).

Based on the problems and results of previous research, in this final project the author will create a smartphone-based asset position tracking system in the Laboratory of Manufacturing Automation and Mechatronics (AE) POLMAN Bandung. This research uses RFID technology with passive RFID tags and the focus of the research is to track the position of the last area of the RFID tag that is read

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by the reader and use a cellular-based application (smartphone). The result of the research that will be achieved is tracking information on an asset in the AE department laboratory using RFID technology which will later be displayed through a mobile application. From the results to be achieved, it is hoped that in the future the assets of the AE department of laboratory can be easily tracked in a lab so that asset management in the AE department can be carried out properly.

2 PROBLEM FORMULATION AND SOLUTION METHODS

The system is made using RFID and utilizes the RSSI output received by the RFID reader from the RFID tag. The value fluctuation of RSSI will be stabilized using Kalman filter algorithm. From the RSSI value, it will be classified into 3 areas. the prediction results of the detected asset area will be displayed in the Android application so that the location of the asset area can be monitored directly.

In making this system there are aspects that need to be considered, namely how the RFID sensor can find out the position of the asset being sought and the Kalman filter algorithm that stabilizes the RSSI value, which is then displayed on the UI prediction results and registered asset information.

The objectives to be achieved in this research are to create a laboratory asset tracking system through UHF RFID using the Kalman filter algorithm, limit the search area for laboratory assets that have RFID tags, and improve the laboratory asset management system so that assets can be arranged systematically.

2.1 Figure System Architecture

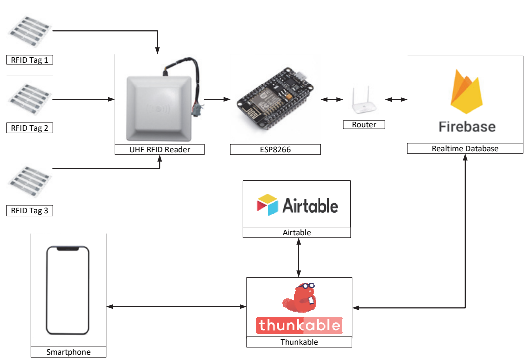

Figure 1: Figure System Architecture (source: private collection).

The system that will be made uses technology from RFID which functions as a tool to track the position of the asset to be tracked. Where in this system the RFID tag used is a passive RFID tag which will later be detected by a UHF (Ultra High Frequency) RFID reader. The output of the RFID is serial data in hexadecimal format, the received data contains information about the identity of the RFID tag and also the RSSI (Received Signal Strength Indicator) detected by the reader. The data will be parsed to separate the identity of the RFID tag with the RSSI value of the RFID tag. The RSSI value of RFID which is very volatile because of the amount of noise in the received RSSI value will be filtered using the Kalman filter algorithm on the microcontroller to stabilize the RSSI value. After filtering the RSSI value, the system will then predict the distance between the RFID tag and the reader and classify the area where the RFID tag is detected.

After that the data that has been processed will be sent to the database, the database used is firebase where the type of database used is a realtime database so that the operations carried out can take place in real time. Then from the database it will be sent to the interface which in this final project uses Thunkable as the interface of the system which will be displayed on a cellular application on a smartphone.

The application used is able to register a newly registered asset by entering some information about the asset and the existing RFID tag on the asset, the data entered in this application will be stored in a spreadsheet database used in this system is airtable.

The general mechanism for this final project can be described in a flowchart where the detection of asset positions begins with the detection of RFID tags in the laboratory which will be detected by an installed RFID reader. After detection, data parsing is carried out so that the incoming data via serial is organized and makes it easier to process the data. If the detected RFID tag is not registered in the database and is not entered in the Arduino program, it is required to register first by filling in whatever information you want to register on the RFID tag and parsing on the Arduino according to the registered tag id. if it is detected then there will be a value in the form of HEX which contains information on RSSI data generated from the signal strength detected by the RFID reader against the RFID tag. Then the classification of the detected tag area and calculation of the predicted distance from the detected asset RFID tag is carried out. After the classification is done, the results will be displayed in the interface. In addition, the predicted value of the distance will also

2.2 System Usage Procedure

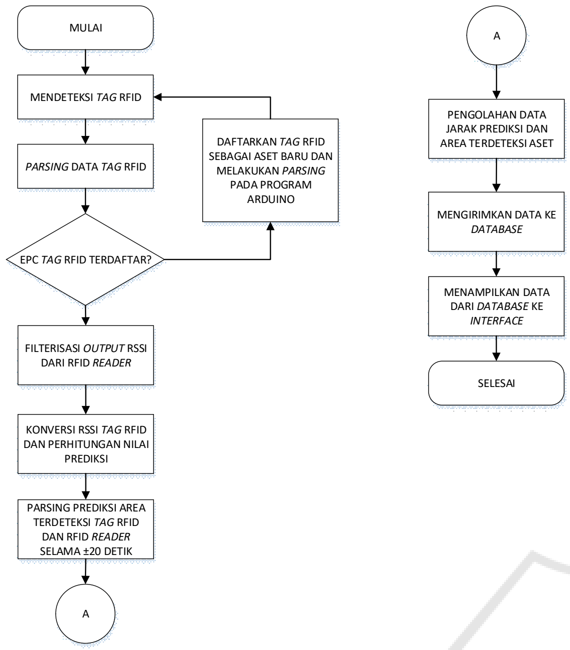

Figure 2: System Flowchart Image. (source: private collection).

be displayed on the interface. After the area and distance calculation of the RFID tag asset position are generated, the microcontroller will update the database according to the results obtained and the information will be displayed on the interface.

2.3 System and Software Design

In this detection system, 1 UHF RFID reader of type HW-VY06K is used and also several objects with RFID tags attached to implement the search for goods through RFID. For communication between the sensor and the microcontroller via RX and TX from the sensor or microcontroller, serial software is needed in the communication which will produce some information about the tag which can be defined as shown in Figure 3.

Head	Len	Address	Cmd	Freq_Ant	PC	EPC	RSSI	Check
0xA0			0x89		2 bytes	N bytes		

Parameter Description	Freq_Ant	The high 6 bits are frequency parameter; the low 2 bits are antenna ID.
	PC	Tag's PC. 2 bytes.
	EPC	Tag's EPC.
	RSSI	The RSSI when tag is identified.

Figure 3: Picture of RFID response parameters (source:(Nur Rahmawati et al., 2020)).

Which requires 2 parameters of the RFID response for the system here, namely the EPC parameter as the identity of the detected RFID Tag and also RSSI as the signal strength value detected by the RFID Reader. These values will be detected in a hexadecimal number format which is specifically for the RSSI value itself, it is necessary to convert the hexadecimal format into two's complement form which will show the signal strength in dBm units received by the reader.

2.3.1 Asset Detection Area Plan Design

The system design is done by creating a detection area which is divided into 4 detection areas from the RFID tag where each area has an area of 1 m2, for the reader position to be placed in a position that is assumed to be position 0 so that the detection will only have a position on the positive x axis and y axis. positive., for the direction of the reader is positioned to lead ± 45°with a height of 1,5m from the reader to the floor

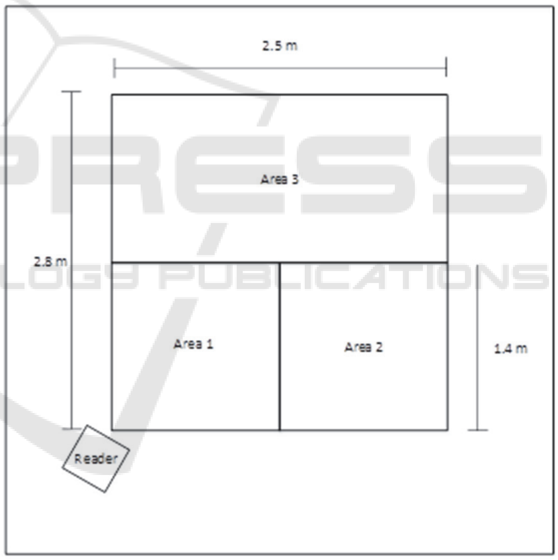

Figure 4: Asset Detection Area Plan Image (source: private collection).

This area grouping is based on detecting the RSSI value in each area where the range of values of each detected RSSI value in the area is used as a value to classify the position of the detected asset, if the read RSSI value is in the range of values in that area, then, the variable of the area will contain the identity of the area.

2.4 Electrical Design

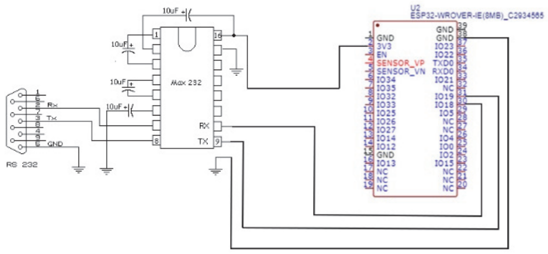

Figure 5: Schematic Circuit Drawing. (source: private collection).

In Figure 5 there is a schematic wiring diagram of the system that has been created. Where to communicate between the RFID sensor and the microcontroller a MAX232 component is needed as an RS232 to TTL converter where for the wiring configuration from RS232 only uses the ports for RX, TX, and ground from the sensor. The RX and TX of the sensor are adjusted to the port on the MAX232 and then forwarded to the sensor via TTL communication where RX from MAX232 to TX on the microcontroller while TX from the sensor to the RX port of the microcontroller.

2.5 Path Loss

For the calculation of the RSSI to the distance in meters can be seen in the equation below.

$$d = d_o \,.\, 10^{\frac{(C-RSSI)}{10.n}} \quad (1)$$

d = Distance of RFID Tag to RFID Reader
C = Signal strength at reference distance
RSSI = Signal strength received by Reader
n = Path loss exponent

The path loss coefficient is an important parameter where this value is different for each environment according to the conditions in the environment. It can be seen in the table for the grouping of exponential values for different types of regions and environments.

2.6 Kalman filter

Kalman filter is a state estimator that makes estimates of several unobserved variables based on noise measurements. (Bulten et al., 2016) Kalman filter serves to estimate a value based on known data. The main function of the kalman filter is not to filter or filter the incoming signal, but to estimate it according to the given input. The Kalman filter equation consists of 2 parts, namely the prediction section and the update section as follows.

Table 1: Table of path loss exponent values for each type of area (source :(Nur Rahmawati et al., 2020)).

Environment	Path Loss Exponent, n
Free space	2
Urban area celullar radio	2.7 to 3.5
Shadowed urban celular radio	3 to 5
In building line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

Prediction :

$$\hat{x}_{t|t-1} = F_t \hat{x}_{t-1|t-1} + B_t U_t \quad (2)$$

$$\hat{P}_{t|t-1} = F_t P_{t-1|t-1} F_t^T + Q_t \quad (3)$$

Update :

$$\hat{x}_{t|t} = \hat{x}_{t|t-1} + B_t(y_t - H_t \hat{x}_{t|t-1}) \quad (4)$$

$$\hat{K}_t = P_{t|t-1} H_t^T (H_t P_{t|t-1} H_t^T + R_t)^{-1} \quad (5)$$

$$\hat{P}_{t|t} = (\mathrm{I} - K_t H_t) + P_{t|t-1} \quad (6)$$

where $\hat{x}$ is the state estimate, F is the transition matrix, u is the control variable, B is the control matrix, P is the state variation matrix, Q is the process variation matrix, y is the measurement variable, H is the calculation matrix, K is the kalman reinforcement, R is measurement variation matrix. (Ma'arif et al., 2019).

2.7 Testing Procedure Design

The software testing that has been made consists of testing the characteristics of detecting signal strength by an RFID reader and testing the level of accuracy in detecting asset areas. In calculating the error percentage in the system, the Mean Absolute Percentage Error (MAPE) calculation formula is used. Where MAPE uses the actual value reference minus the predicted value of the system and divided by the actual value of the test. For more details, see the MAPE formula below.

$$MAPE = \frac{100}{n} \sum_{t-1}^{n} \left| \frac{At - Ft}{At} \right| \quad (7)$$

n : Total data
At : Actual result value
Ft : Test result value

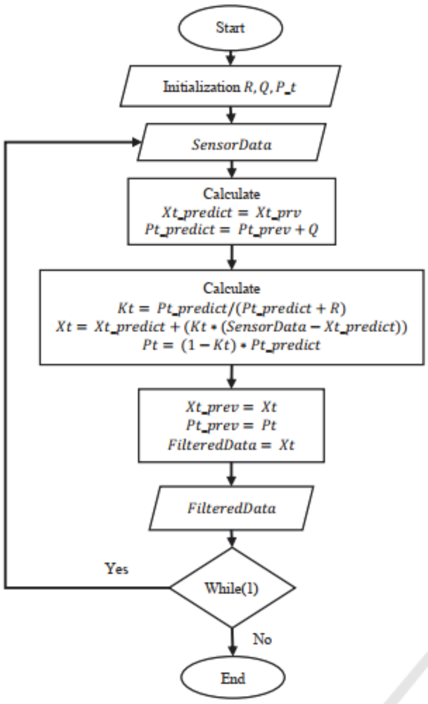

Figure 6 : Picture of the Kalman filter Algorithm Flowchart (source:(Ma'arif et al., 2019)).

3 RESULTS

3.1 RSSI Testing using Kalman Filter

Testing is done by adding the kalman filter algorithm. The test is carried out by placing an asset that has an RFID tag at a distance of 2 meters for the distance from the RFID tag to the position of the RFID reader.

The following in Figure 7 is the result of testing the RSSI value against the filtered RSSI value.

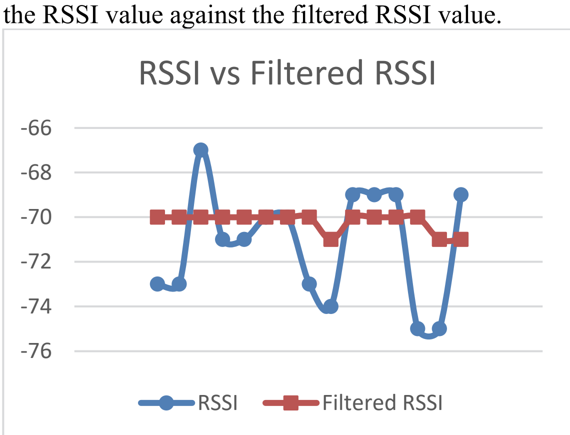

Figure 7: Comparison of RSSI Value Against Filtered RSSI Value. (source: private collection).

The comparison data can be seen in the graph in Figure 7, which shows the change in the RSSI signal which has a lot of noise but with the Kalman filter algorithm it can reduce the noise significantly. However, the response obtained from changing the filter will be slow when there is a change in the position of the asset.3.2 RSSI Value Reading in Each Detection Area.

In testing the RSSI readings in each asset detection area, the area has been determined for the size of each area as in Figure 4, for the results of the RSSI reading in each detection area can be seen in the graph in Figure 8 below.

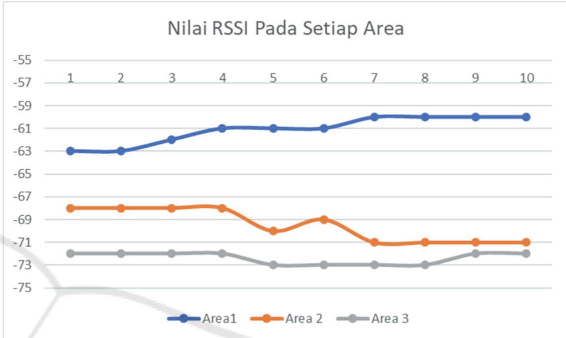

Figure 8: Graph of RSSI value in each detection area. (source: private collection).

For area 1, it can be seen in table (a) that area 1 has a range of RSSI values ranging from -60 dBm to -63 dBm so it can be concluded that the range of values in area 1 is between -60 dBm to -67 dBm. For area 2, it can be seen in table (b) that area 2 has a range of RSSI values ranging from -68 dBm to -71 dBm so that the RSSI value range in area 2 can be defined for a range of values from -68 dBm to -71 dBm. area 3 can be seen in table (c) that area 3 has a range of RSSI values ranging from -72 to -73 dBm.

3.3 Object Area Detection Test

In this test used 1 object with 3 different areas where this test is intended to measure the accuracy of the system that has been made, this test is also carried out using a reader height of 150 cm from the floor and the actual position of the object in each area, namely in area 1 the object distance to the reader is 1 meter, while for the area the distance from the reader to the object is 1.9 meters, and the last for area 3 the distance from the object to the reader is 2.6 meters. The results can be seen in table 2.

Table 2: Object Area Detection Test Results.

No	Actual Distance (m)	Actual Area	Predicted Distance (m)	Predicted Area	Status
1	1	Area 1	1.18	Area 1	OK
2		Area 1	1.18	Area 1	OK
3		Area 1	1.09	Area 1	OK
4		Area 1	1	Area 1	OK
5		Area 1	1	Area 1	OK
6		Area 1	1	Area 1	OK
7		Area 1	0.92	Area 1	OK
8		Area 1	1.09	Area 1	OK
9		Area 1	1.18	Area 1	OK
10		Area 1	1.18	Area 1	OK
11	1.9	Area 2	2.1	Area 2	OK
12		Area 2	1.93	Area 2	OK
13		Area 2	2.47	Area 3	Not OK
14		Area 2	2.47	Area 3	Not OK
15		Area 2	2.28	Area 2	OK
16		Area 2	1.93	Area 2	OK
17		Area 2	1.93	Area 2	OK
18		Area 2	1.93	Area 2	OK
19		Area 2	2.1	Area 2	OK
20		Area 2	2.1	Area 2	OK
21	2.6	Area 3	2.68	Area 3	OK
22		Area 3	2.68	Area 3	OK
23		Area 3	2.68	Area 3	OK
24		Area 3	2.47	Area 3	OK
25		Area 3	2.47	Area 3	OK
26		Area 3	2.28	Area 2	Not OK
27		Area 3	2.28	Area 2	Not OK
28		Area 3	2.47	Area 3	OK
29		Area 3	2.47	Area 3	OK
30		Area 3	2.47	Area 3	OK

From the results of the object area detection test, it is found that the system can detect well in area 1, but in area 2 and area 3 the system still has errors in detecting object areas. From the test, it was found that the error in the prediction system for calculating the distance in area 1 was 8.2%, while in area 2 it was 11.7% and in area 3 was 4.03%, while the error in detecting the area where objects were detected was 13.3%. This error is caused because the object detection RSSI value system has errors in several locations, it is possible that this error is due to the unstable RSSI value obtained by the reader.

4 CONCLUSION

From the results of testing and analysis that have been discussed in the previous chapter. It can be concluded that the object area detection system has been successfully created and has an error rate of 13.3%, with the condition of the height of the reader and objects not changing, as well as detecting objects against RFID there is no obstacle. The use of Filtration in this system can help stabilize the RSSI value so that it does not fluctuate too much when detecting objects. This can help in classifying the detected object area. The UI created on this system is able to compile and display the results of detecting assets that have been registered.

REFERENCE

Aminah, S., Bhaskoro, S. B., & Sunarya, A. S. (2020). Penerapan Quick Response Code pada Sistem Digitalisasi Inventaris Laboratorium Berbasis Android. *JTERA (Jurnal Teknologi Rekayasa)*, *5*(2), 207. https://doi.org/10.31544/jtera.v5.i2.2020.207-214

Bulten, W., van Rossum, A. C., & Haselager, W. F. G. (2016). Human SLAM, indoor localisation of devices and users. *Proceedings - 2016 IEEE 1st International Conference on Internet-of-Things Design and Implementation, IoTDI 2016*, 211–222. https://doi.org/10.1109/IoTDI.2015.19

Fali Oklilas, A., & Rozi, F. (2016). *Pelacakan Posisi Tag RFID Menggunakan Algoritma Genetika* (Vol. 2, Issue 1). http://ars.ilkom.unsri.ac.id

Firaldi, Y., Sallu, S., & Kurniawan, H. (2017). *ANALISA POLA KEHADIRAN MAHASISWA DALAM PERKULIAHAN DENGAN TEKNOLOGI RFID (Radio Frequency Identification) STUDI KASUS : JURUSAN TEKNIK INFORMATIKA UMRAH*.

Ma'arif, A., Dwi Puriyanto, R., Fadlur, D., Hasan, T., & Dahlan, A. (2020). Robot Keseimbangan Dengan Kendali Proporsional-Integral-Derivatif (PID) dan Kalman Filter. *Journal Research and Development (ITJRD)*, *4*(2), 117–127. https://doi.org/10.25299/itjrd.2018.vol4(2).3900

Ma'arif, A., Iswanto, I., Nuryono, A. A., & Alfian, R. I. (2019). Kalman Filter for Noise Reducer on Sensor Readings. *Signal and Image Processing Letters*, *1*(2), 11–22. https://doi.org/10.31763/simple.v1i2.2

Nur Rahmawati, A., Bagas Bhaskoro, S., Aminah, S., & Rekayasa Otomasi -Politeknik Manufaktur Bandung, T. (2020). Sistem Pelacakan Posisi Aset Laboratorium melalui Sensor Tanpa Kontak Fisik menggunakan metode K-Nearest Neighbor. In *Jurnal Sistem Cerdas*.