Item Localization System for Inventory in a Room Using IoT-Based RFID

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ABSTRACT

This study aims to develop an RFID-based localization system capable of recognizing and tracking the location of objects within an inventory room. The Landmarc method is employed to improve the localization system's accuracy by utilizing the RSSI values from RFID tags. To determine the location of objects, Euclidean distance calculations are used to compare the RSSI values of test tags with reference tags and distance to predict the object's location. Inventory data is stored in a database where the inventory can be tracked, and the history of specific inventory items can be viewed online. The final outcome of this research is a tool capable of detecting objects in three-dimensional buildings with a success rate of up to 68%. This achievement represents a significant improvement compared to previous research, which may have had lower accuracy. With the capability to detect in three-dimensional space, this system is more effective in tracking and identifying the location of objects, thereby increasing the accuracy and efficiency of the inventory process.

Keywords: RFID, Landmarc, RSSI, Euclidean Distance.

INTRODUCTION

In an industry, there is usually a warehouse used to store parts or goods, be it raw materials, semi-finished goods [1], or finished goods. Each item is stored in a specific location or place so that it can be easily found when it is needed.

The recording of the location where goods are stored is still widely done using manual methods. However, manual recording often results in inconsistencies between the data of goods and the data of the location where the goods are stored, especially if the goods have a high turnover rate. This will certainly cause a lack of efficiency in the time it takes to find the goods [2].

To anticipate this, a localization system is needed that can reduce the error rate in recording data and the location of goods. There are many technologies that can be used to help this localization system, including GPS, RFID, infrared, ultrasonic, and Wi-Fi technology.

This research specifically uses RFID technology, where this technology uses radio frequencies to give an identity to objects in the form of tags to be identified by a reader [3]. This technology has two main components, namely the tag component and the reader with a working mechanism according to the type of tag used, such as passive tags that do not have their own power source and active tags that already have their own power source through a built-in battery [4].

The method used in this research is the Landmarc method using the calculation of Euclidean Distance between the reference tag and the tag to be tested or which will be attached to the object later, where this method is useful for knowing the location of the tag to be tested based on the RSSI (Received Signal Strength Indicator) received by the reader from the tag to be tested [5].

This research is an improvement on previous research that was only able to detect objects in 2-dimensional shapes, so it was limited to identifying the position of objects in a flat plane. In this latest research, the developed system is now able to detect objects in 3-dimensional space, and also increases the amount of training data used so that it is possible to measure and track the position of objects more accurately and comprehensively in a room so that it can be applied to tracking goods or objects that are on a shelf.

In making this tool, several components will be used such as Raspberry PI, RFID reader, and tag. While the K-NN algorithm and Euclidean distance calculation will be used to predict the location of the object [5]. Meanwhile, Bootstrap and PHP are used as frameworks in making websites and MySQL will be used as a database. The results of reading this tool can be monitored and traced from the website page in real-time.

Before this research began, the researcher first sought several references related to the research to be conducted in order to find support and research results. In addition, the references used to provide references as to what kind of research will be carried out.

The research conducted by Franz Gualoto Suárez, Germán Ñacato Caiza, and Sang Guun Yoo titled "Stock Management System Using RFID and Geolocation Technologies" explains that RFID can be used to track and inventory assets quickly. RFID can read and inventory 658 items in 16.25 minutes, which is faster than barcodes which take 38.9 minutes [6].

Furthermore, the research conducted by Akbar, Kamelia Elektrika, Siti Aminah, and Afaf Fadli Rifa'I titled "Ultra High Frequency RFID for Large-Scale Warehouse Inventory Systems" explains that the tool is made using Ultra High Frequency. The UHF range covers frequencies from 300 to 1000 MHz, but only two frequency ranges, 433 MHz and 860-960 MHz, are used for RFID applications. UHF tags are used because they have a reading range of about 5 to 6 meters [7].

The research conducted by Qiuying Han titled "Inventory System Based on ThinkPHP and Bootstrap Framework" explains that the system is built with the PHP scripting language, MySQL database, Bootstrap framework, and a three-tier architecture design mode. The levels in question are the database operation layer, the logic layer, and the display layer. This method is used because it is beneficial for system maintenance and expansion [8].

Next, the research conducted by Sony Febrian and Azinurrachman Maulana titled "Goods Localization System for Inventory Using RFID" explains a localization system to detect an object in a room to conduct an inventory. However, in this study, the reading results of the location are still limited to two-dimensional shapes.

METHODS

A. System Block Diagram Design

Based on Figure 1, the system block diagram starts from the tag on the object or inventory item located on the storage compartment, then it is scanned by the RFID Reader (HW-VY06K UHF RFID), after that the tag data will be processed through the Raspberry Pi4 B to be processed and the output will be in the form of information about the location of the object or inventory item, and location information will enter the database. The obtained data will be displayed on the website in real-time.

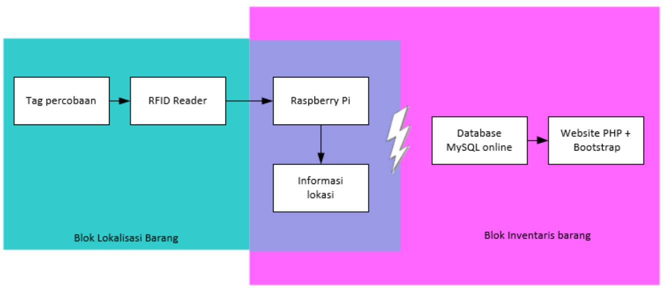

Figure 1. System block diagram

B. Hardware Design

The hardware design of the RFID-based localization system within a room is illustrated in Figure 2. The system comprises an RFID reader and a Raspberry Pi, which is equipped with a small 3.5-inch touchscreen LCD for real-time data visualization and user interaction. The RFID reader is strategically positioned 1 meter above the floor to optimize the detection range and accuracy. This setup allows the system to efficiently monitor and track the location of tags within the room, ensuring that the data is captured and displayed promptly on the touchscreen for immediate analysis.

Figure 2. Hardware design using RFID and Raspberry Pi

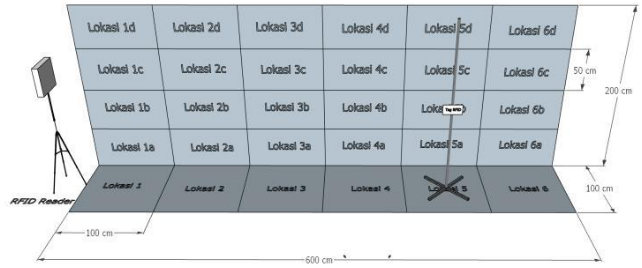

Figure 3. Test design used in the room

Figure 3 depicts the tag locations that will be read by the RFID. A total of 24 locations will be read, each within a cubic area measuring 50 cm in width, 100 cm in length, and 50 cm in height. Instead of using racks, PVC pipes with a height of two meters will be used. These pipes will be divided into four 50 cm sections and supported by iron tripods.

C. Data Acquisition

Training data was acquired by collecting RSSI values from specific distances and heights at a single location. Figure 4 illustrates the data points where training data will be collected. A total of 18 training data points were collected at each location. The distance between each training data point at the same location was 0.3 meters, and the height difference was 0.2 meters. The distance between training data points at different locations was 0.4 meters horizontally and 0.3 meters vertically.

Data was collected up to a maximum distance of 6 meters and height of 2 meters. This limitation was due to the fact that at certain heights and greater distances, data could not be obtained. Therefore, the author and supervisor agreed to set the maximum distance at 6 meters.

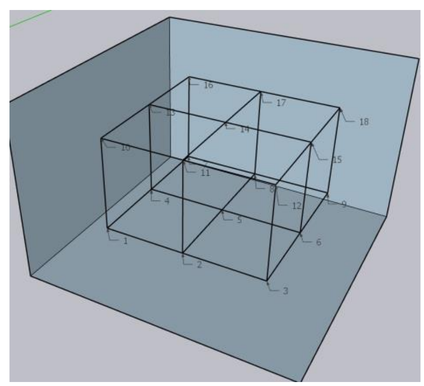

Figure 4. Training data collection points

D. Website and Dabase Creation

The website was developed using the PHP programming language and the Bootstrap framework. PHP is used to create the website, while Bootstrap is used to make it visually appealing. As shown in Figure 5, this website will display several types of data, such as:

- Inventory Data: Shows information from the scanned tag, including the tag ID, real-time location of the tag, and the time when the tag was scanned.
- Item Data: Displays tags that have been entered into the database, including the tag ID and the associated item name.
- Account Data: Displays registered user accounts, with information such as username, email, status, and access level.

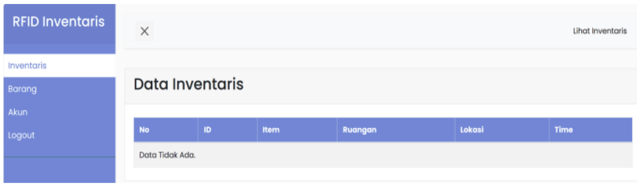

Figure 5. Website design layout

The database will be designed to store all data related to the inventory system. The database structure will include several interconnected main tables.

This database will be implemented using MySQL, which is a popular relational database management system known for its reliability and scalability. The integration between the database and the website will be handled using PHP, ensuring that data can be accessed and manipulated efficiently. For a visual representation of how this integration is structured, please refer to Figure 6.

```
CREATE TABLE `Inventory` (
  `ID` varchar(100) NOT NULL,
  `Ruangan` varchar(100) NOT NULL,
  `Lokasi` varchar(100) NOT NULL,
  `Time` datetime NOT NULL DEFAULT current_timestamp()
) ENGINE=InnoDB DEFAULT CHARSET=utf8mb4 COLLATE=utf8mb4_unicode_ci;

--
-- Dumping data for table `Inventory`
--

INSERT INTO `Inventory` (`ID`, `Ruangan`, `Lokasi`, `Time`) VALUES
```

Figure 6. Inventory table database

E. *Item Registration in the System*

On the website, there will be an Item Registration page, where a form will be available for registering items into the database. The item registration process is depicted in Figure 7, showing a page where users can add new tag data to the system through the "Add Tag" option. This tag data includes the tag ID and item description. The system will validate the data and store the tag information in the database. Figure 8 shows the page after the entered data has been saved, with options to edit and delete the existing tag data.

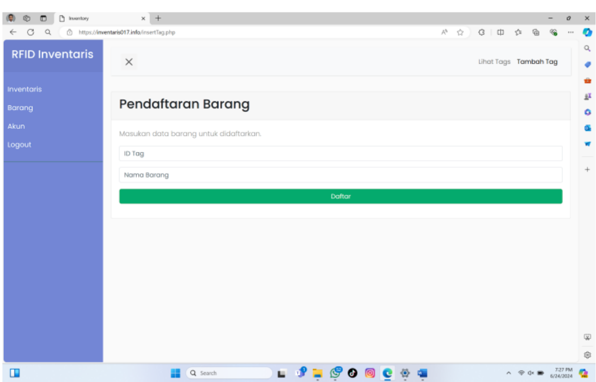

Figure 7. Item registration flow in the system

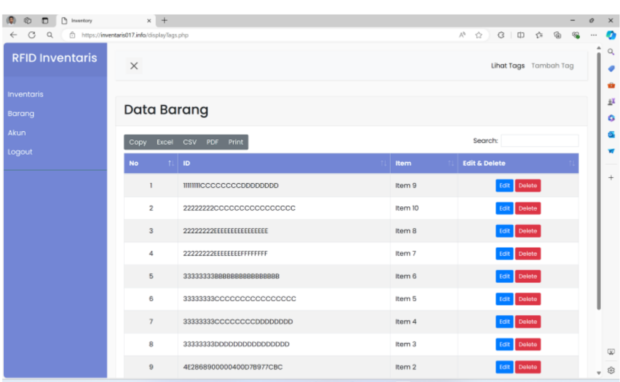

Figure 8. Display of added tag data

RESULT AND DISCUSSION

A. *Program Localization Execution*

To execute the localization program, use the following command as shown in Figure 9. Start by opening the terminal on the Raspberry Pi, then enter the command cd followed by the location of the file. Next, type the file name to open the program file.

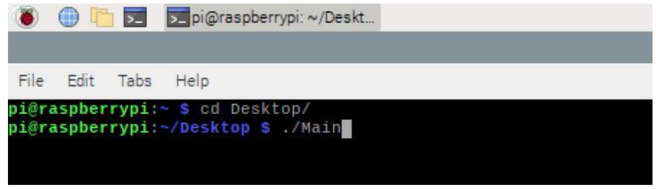

Figure 9. Program execution

The program interface, as shown in Figure 10, features three options: the first mode is used to determine the location of the tag being tested, the second mode is for scanning within the localized room, and the third mode is to stop the process.

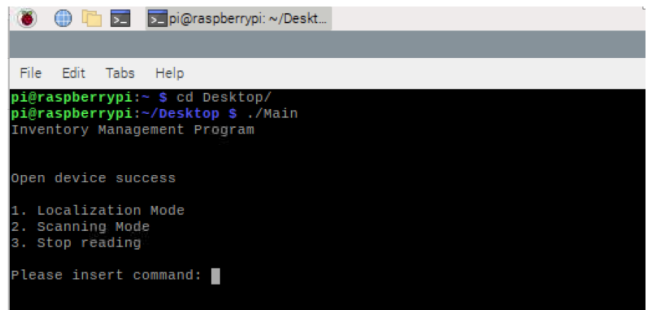

Figure 10. Program Menu Display

In Localization Mode, the user will be prompted to input the distance and height of the item to be scanned, as well as the name of the room used. Subsequently, the RFID system will detect the RSSI values of the test tag, which will be calculated using Euclidean distance.

The location reading display of the test tag can be seen in Figure 11, which shows the tag ID, RSSI value, and location for each parameter K used. The location output will appear once the distance and height of the RFID tag from the RFID reader are input by the user.

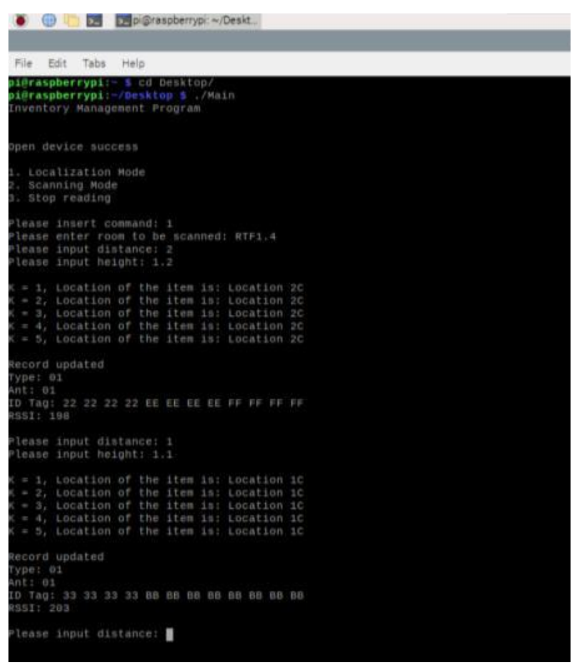

Figure 11. Location Reading Results

B. Display on the Website

This website will perform real-time inventory management. Users can view a list of registered items, including details on location and the current status of each item. This information is automatically updated based on RFID readings. Figure 12 shows the condition where the device has not yet detected any objects, so the inventory page on the website still indicates that no items are registered.

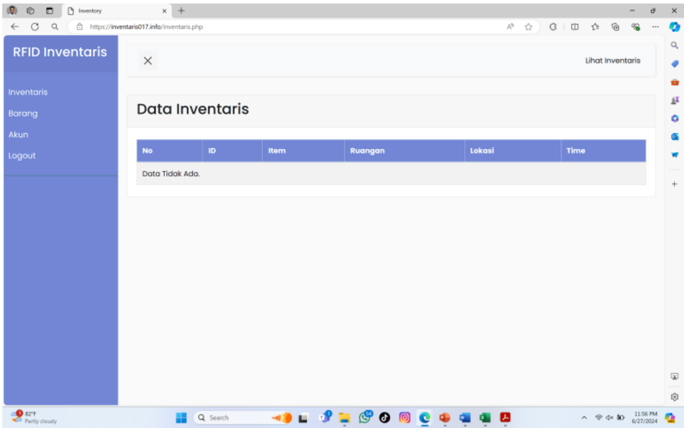

Figure 12. Display When No Data is Available

Meanwhile, Figure 13 illustrates the display that appears when tag data is successfully detected. The webpage will present detailed information from the detected tag, including the tag ID, the name of the tag, and the specific room where the tag is located. In addition to these details, the webpage also provides the primary information, which includes the precise location of the tag within the room and the exact time at which the tag was detected.

This comprehensive display ensures that all relevant data about the tag's status and whereabouts is readily available for monitoring and analysis.

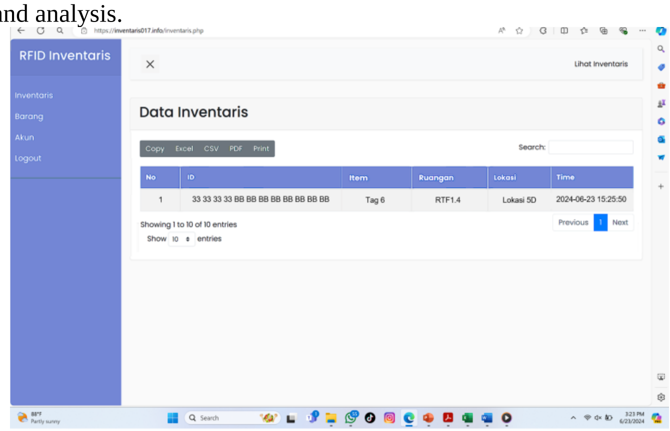

Figure 13. Real-Time RFID Readings Displayed on the Website

C. Test Data Experiment

In this test, the test tag is evaluated at six different points to achieve accurate and precise results. The test locations are the same points where the training data was collected. The test data is recorded in a table showing the RSSI values, the location readings of the test tag based on the K value, and the location data sent to the website.

Below is Table 1, which contains the test data including the distance and height of the object relative to the RFID reader and the K values from the K-NN algorithm integrated into the program. Each K value affects the resulting location data. It is important to note that Table 1 only displays the test data for Location 1 and does not include data from Locations 2-6. However, the data for these locations can be found in Table 2, which contains the success rate percentages, and in Figure 14, which provides a graphical representation of Table 2.

If the test data matches the actual location, the text will be black. If the data does not match the actual location, the text will be red.

Table 1. Test results data

Actual Location	Distance (m)	Height (m)	RSSI value of the test tag	Location of the device's reading				
				K= 1	K= 2	K= 3	K= 4	K= 5
Location 1A	0.2	0.15	192	Location 1A	Location 1A	Location 1B	Location 1A	Location 1A
	0.2	0.15	186	Location 1A	Location 1A	Location 1A	Location 2A	Location 1A
	0.5	0.15	182	Location 1A	Location 1A	Location 1A	Location 1A	Location 1A
	0.5	0.35	197	Location 1B	Location 1A	Location 1A	Location 2A	Location 1A
	0.8	0.35	193	Location 1A	Location 1A	Location 2A	Location 1A	Location 1A
	0.8	0.35	195	Location 1A	Location 1B	Location 1A	Location 1A	Location 1A
Location 1B	0.2	0.65	204	Location 1B	Location 1B	Location 1B	Location 1B	Location 1B
	0.2	0.65	213	Location 1B	Location 1B	Location 1B	Location 1B	Location 2A
	0.5	0.65	200	Location 1B	Location 1B	Location 1B	Location 1B	Location 1B
	0.5	0.85	198	Location 1B	Location 1A	Location 1B	Location 1C	Location 1B
	0.8	0.85	200	Location 1B	Location 1B	Location 1B	Location 1B	Location 2A
	0.8	0.85	193	Location 1A	Location 1A	Location 1B	Location 1B	Location 1B
Location 1C	0.2	1.15	192	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C
	0.2	1.15	190	Location 2A	Location 2A	Location 1C	Location 1C	Location 1C
	0.5	1.15	182	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C
	0.5	1.35	184	Location 1C	Location 1C	Location 1C	Location 1D	Location 1C
	0.8	1.35	194	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C
	0.8	1.35	195	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C
Location 1D	0.2	1.65	190	Location 1D	Location 1D	Location 1D	Location 1D	Location 1D
	0.2	1.65	186	Location 1D	Location 1D	Location 1D	Location 1D	Location 1C
	0.5	1.65	189	Location 1D	Location 1D	Location 1D	Location 1D	Location 1D
	0.5	1.85	184	Location 1D	Location 2C	Location 1D	Location 1D	Location 1D
	0.8	1.85	183	Location 1D	Location 1D	Location 1C	Location 1C	Location 1D
	0.8	1.85	194	Location 1D	Location 1D	Location 1D	Location 1D	Location 1D

From the test data presented above, the data will be grouped based on the type of K-NN parameter used, specifically dividing it into odd and even values. After categorizing the data, a detailed analysis will be conducted to determine which type of K-NN parameter—odd or even—yields a higher success rate in accurately predicting the tag's location. This analysis will help identify the most effective parameter for improving the overall performance of the localization system.

D. Success Rate Percentage with Odd K

Table 2 presents the success rate percentage for each location reading when using odd K values in the K-NN algorithm. The success rate for each location is calculated by first determining the number of successful trials and then multiplying that number by 100% to convert it into a percentage. This result is then divided by the total number of trials conducted for that location. This method provides a clear indication of the accuracy and effectiveness of the K-NN algorithm with odd K values in predicting the correct location.

Table 2. Success rate percentage of testing with Odd K

Location	Percentage K =1 (%)	Percentage K =3 (%)	Percentage K =5 (%)
Location 1A	83.3	66.7	100
Location 1B	83.3	100	66.7
Location 1C	83.3	100	100
Location 1D	100	83.3	83.3
Location 2A	83.3	50	50
Location 2B	66.7	66.7	66.7
Location 2C	66.7	83.3	83.3
Location 2D	66.7	83.3	50
Location 3A	50	66.7	33.3
Location 3B	50	50	50
Location 3C	50	83.3	66.7
Location 3D	50	66.7	66.7
Location 4A	33.3	50	50
Location 4B	66.7	66.7	33.3
Location 4C	50	50	66.7
Location 4D	50	50	16.7
Location 5A	33.3	33.3	33.3
Location 5B	50	50	16.7
Location 5C	50	33.3	50
Location 5D	50	33.3	33.3
Location 6A	33.3	16.7	33.3
Location 6B	50	16.7	50
Location 6C	50	50	33.3
Location 6D	33.3	16.7	33.3

Figure 14 illustrates a graph of the test percentage using odd K values, where the X-axis represents the various locations tested, and the Y-axis reflects the number of correct readings as a percentage. The graph reveals that as the reading location becomes more distant, there is a noticeable decline in the number of correct readings. Furthermore, it is observed that locations labeled with the letter C (such as Location 1C, Location 2C, Location 3C, Location 4C, Location 5C, and Location 6C) generally exhibit a higher percentage of correct readings compared to other locations at the same distance. This trend is likely influenced by the position of these C locations, which have a height that closely matches the height of the RFID reader, thereby enhancing the accuracy of the readings.

Additionally, the graph indicates that for K=1, the correct readings tend to fluctuate more significantly but are generally higher compared to those for K=3 and K=5. In contrast, for K=3 and K=5, the correct readings are more stable and consistent, though slightly lower than those observed with K=1. This suggests that while K=1 may offer a higher potential for correct readings, K=3 and K=5 provide a more reliable and steady performance, albeit with a marginal reduction in accuracy. This analysis helps in understanding the trade-offs between accuracy and stability in the context of different K values used in the K-NN algorithm.

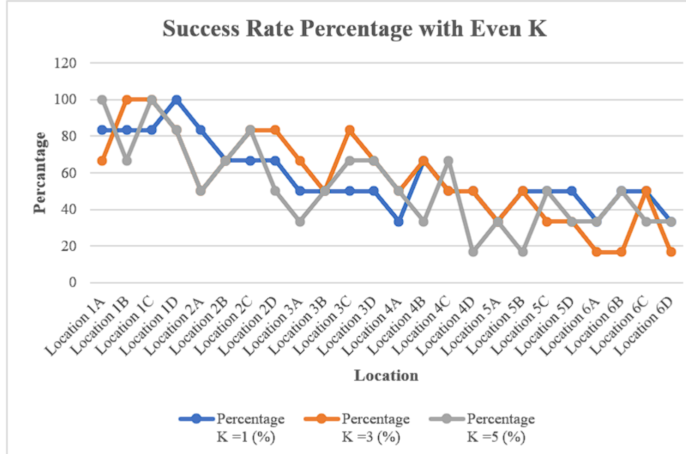

Figure 14. Graph of success rate percentage wihg odd K

E. Success Rate Percentage with Even K

Table 3 presents the success rate percentage for each location reading with even K values. This table provides a detailed analysis of the algorithm's performance in accurately determining object locations at different positions using even K values.

Table 3. Success rate percentage of testing with even K

Location	Percentage K= 2 (%)	Percentage K= 4 (%)
Location 1A	83.3	66.7
Location 1B	66.7	83.3
Location 1C	83.3	83.3
Location 1D	83.3	83.3
Location 2A	83.3	66.7
Location 2B	50	66.7
Location 2C	83.3	100
Location 2D	66.7	83.3
Location 3A	50	50
Location 3B	33.3	66.7
Location 3C	66.7	66.7
Location 3D	50	66.7
Location 4A	33.3	50
Location 4B	50	50
Location 4C	50	50
Location 4D	50	50
Location 5A	33.3	33.3
Location 5B	50	50
Location 5C	50	50
Location 5D	50	33.3
Location 6A	33.3	16.7
Location 6B	50	16.7
Location 6C	33.3	50
Location 6D	33.3	16.7

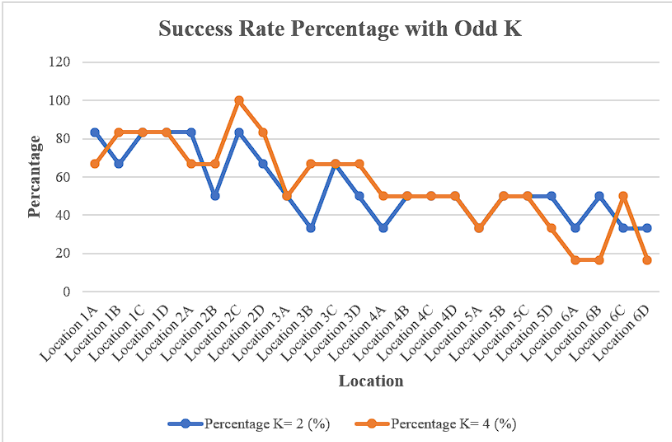

Figure 15. Graph of success rate percentage with even K

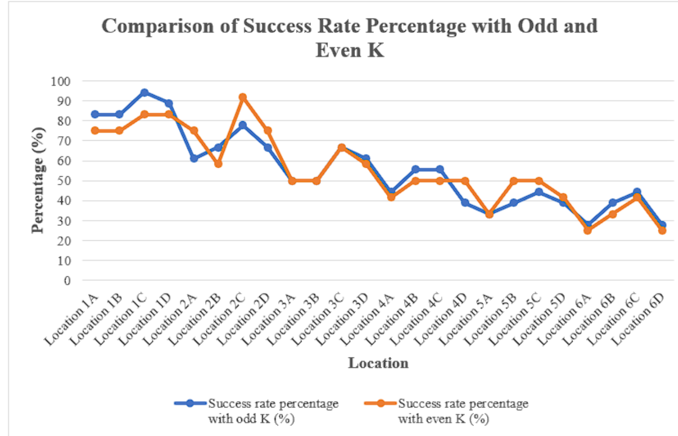

Figure 16. Graph of comparison of success rate percentage with odd and even K

Figure 15 is a graph of the data where the X-axis represents the location and the Y-axis represents the number of correct readings. This graph compares the reading results with values of K = 2 and K = 4.

Analysis of the graph shows that at some locations, there is a non-constant variation in the number of correct readings. It can be seen that at the 7th location with a measurement distance of 5 meters, there is a non-constant increase in the number of correct readings. This non-constant increase is indicated as an error, which is most likely caused by the RSSI values in the training data for locations 5 and 7 having a distance that is not too far. This causes the model to have difficulty distinguishing between the two locations with high accuracy, resulting in fluctuations in the number of correct readings

F. Comparison of Success Rate Percentage with Odd and Even K

To determine which type of K yields a better reading success rate, it is necessary to compare the results of each type of K. Table 4 presents a comparison of the percentages for odd and even K values, where these values are obtained from the average of K (K=1, 3, 5 for odd K and K=2, 4 for even K).

Table 4. Comparison of Success Rate Percentage with Odd and Even K

Location	**Success rate percentage with odd K (%)**	**Success rate percentage with even K (%)**
Location 1A	83.3	75
Location 1B	83.3	75
Location 1C	94.4	83.3
Location 1D	88.9	83.3
Location 2A	61.1	75
Location 2B	66.7	58.3
Location 2C	77.8	91.7
Location 2D	66.7	75
Location 3A	50	50
Location 3B	50	50
Location 3C	66.7	66.7
Location 3D	61.1	58.3
Location 4A	44.4	41.7
Location 4B	55.6	50
Location 4C	55.6	50
Location 4D	38.9	50
Location 5A	33.3	33.3
Location 5B	38.9	50
Location 5C	44.4	50
Location 5D	38.9	41.7
Location 6A	27.8	25
Location 6B	38.9	33.3
Location 6C	44.4	41.7
Location 6D	27.8	25
Average	**55.79**	**55.55**

From Table 4, it can be seen that the reading success percentage using odd K is better compared to even K. However, the difference between odd and even K is not very significant, only 0.23%.

Figure 16 is a graphical representation of the data from Table 4. It can be seen that both odd and even K values have fluctuating values and decrease as the distance increases.

G. Test Results Displayed on the Website

The test results to be displayed on the website will show the most frequently occurring location (mode) for each tested K value (K=1, 2, 3, 4, 5). In some cases, the location that appears may differ for each K value. For example, at the actual location of Location 1A, but in the device reading, K=1 indicates Location 1A, K=2 indicates Location 1A, K=3 indicates Location 1B, K=4 indicates Location 1A, and K=5 indicates Location 1A. The data that will be sent and displayed on the website is Location 1A because it is the most frequently occurring location.

Table 5 is the data of the location read based on the K parameter used and the location data sent to the website. The data sent and displayed on the website is the data that occurs most frequently for each K parameter used. If there are two data points with the same frequency, the data with the smaller order will be sent and displayed on the website.

Table 5. Test results displayed on the website by the K parameter

No	**Actual location**	**Device reading location based on parameter K**					**Location read on the website**
		K= 1	**K= 2**	**K= 3**	**K= 4**	**K= 5**	
1	Location 1A	Location 1A	Location 1A	Location 1B	Location 1A	Location 1A	Location 1A
		Location 1A	Location 1A	Location 1A	Location 2A	Location 1A	Location 1A
		Location 1A	Location 1A	Location 1A	Location 1A	Location 1A	Location 1A
		Location 1B	Location 1A	Location 1A	Location 2A	Location 1A	Location 1A
		Location 1A	Location 1A	Location 2A	Location 1A	Location 1A	Location 1A
		Location 1A	Location 1B	Location 1A	Location 1A	Location 1A	Location 1A
2	Location 1B	Location 1B	Location 1B	Location 1B	Location 1B	Location 1B	Location 1B
		Location 1B	Location 1B	Location 1B	Location 1B	Location 2A	Location 1B
		Location 1B	Location 1B	Location 1B	Location 1B	Location 1B	Location 1B
		Location 1B	Location 1A	Location 1B	Location 1C	Location 1B	Location 1B
		Location 1B	Location 1B	Location 1B	Location 1B	Location 2A	Location 1B
		Location 1A	Location 1A	Location 1B	Location 1B	Location 1B	Location 1B

No	Actual location	Device reading location based on parameter K					Location read on the website
		K= 1	K= 2	K= 3	K= 4	K= 5	
3	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C
		Location 2A	Location 2A	Location 1C	Location 1C	Location 1C	Location 1C
		Location 1C	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C
		Location 1C	Location 1C	Location 1C	Location 1D	Location 1C	Location 1C
		Location 1C	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C
		Location 1C	Location 1C	Location 1C	Location 1C	Location 1C	Location 1C
4	Location 1D	Location 1D	Location 1D	Location 1D	Location 1D	Location 1D	Location 1D
		Location 1D	Location 1D	Location 1D	Location 1D	Location 1C	Location 1D
		Location 1D	Location 1D	Location 1D	Location 1D	Location 1D	Location 1D
		Location 1D	Location 2C	Location 1D	Location 1D	Location 1D	Location 1D
		Location 1D	Location 1D	Location 1C	Location 1C	Location 1D	Location 1D
		Location 1D	Location 1D	Location 1D	Location 1D	Location 1D	Location 1D

Table 5 presents the percentage of successful location readings that have been sent and displayed on the website. At a distance of 1 meter, the website displays 100% accurate readings. For distances of 2-3 meters, the percentage of accurate readings displayed on the website tends to decrease, although some locations (2B, 3B, and 3C) still show 100% accuracy. For distances of 4-6 meters, the percentage of accurate readings displayed on the website decreases further, with some locations at 5 and 6 meters only achieving 33.3% accuracy.

Table 6. Percentage of successful location reads on the website

Location	Percentage of successful location reads (%
Location 1A	100
Location 1B	100
Location 1C	100
Location 1D	100
Location 2A	66.7
Location 2B	100
Location 2C	83.3
Location 2D	83.3
Location 3A	83.3
Location 3B	100
Location 3C	100
Location 3D	83.3
Location 4A	50
Location 4B	83.3
Location 4C	50
Location 4D	33.3
Location 5A	33.3
Location 5B	33.3
Location 5C	33.3
Location 5D	50
Location 6A	33.3
Location 6B	50
Location 6C	50
Location 6D	33.3

Figure 14 is a graph of the data in Table 6. The graph shows that as the distance between the tag and the RFID reader increases, the accuracy of the data displayed on the website decreases.

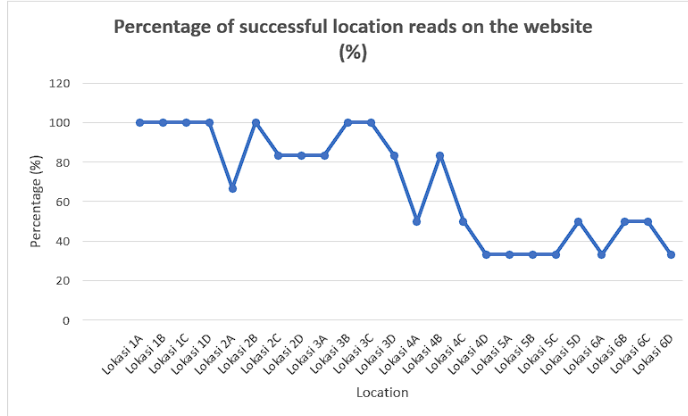

Figure 17. Percentage of successful location reads on the website

CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

This research successfully developed a goods localization system for inventory using RFID technology based on the Internet of Things (IoT). The system utilizes the Landmarc method and the K-NN algorithm to improve the accuracy of object location detection. Several key conclusions can be drawn.

Firstly, this localization system can classify new objects or items by entering tag data on the website. Secondly, with an increase in training data and the use of the Euclidean distance algorithm in spatial construction, this tool is capable of detecting objects in 3D space, allowing for the detection of objects on a table or shelf. Thirdly, inventory data is stored in a database connected to the internet, allowing users to access inventory information online. This facilitates efficient and accurate inventory management from various locations.

The conclusion of this research is that the developed tool is capable of detecting objects in a three-dimensional space with a success rate of 68%. This achievement marks a significant improvement compared to previous research, which may have had lower accuracy rates. With the ability to detect objects in three-dimensional space, this system is more effective in tracking and identifying object locations, thus increasing accuracy and efficiency in the inventory process.

B. Recommendations

Based on the research results and experience during the development and testing process, several suggestions can be considered for further research and development:

- Use of Additional Technologies: To improve the accuracy and range of the localization system, the use of additional technologies such as Wi-Fi, Bluetooth, or ultrasonic can be considered. The integration of these technologies can help overcome the limitations of each technology and provide more comprehensive results.
- Use of Distance Sensors: The addition of distance sensors (such as LIDAR or ultrasonic sensors) can help improve the precision of object location detection. Distance sensors can provide more accurate additional information about the position of objects in a room, thus increasing the reliability of the system.
- Algorithm Optimization: The K-NN algorithm used in this system can be further optimized. In-depth research on the selection of the optimal K value and the use of other machine learning algorithms such as SVM (Support Vector Machine) or Random Forest can be done to improve detection accuracy.
- Increasing Training Data: Increasing the quantity and variety of training data can improve the accuracy of the K-NN algorithm.

More and more diverse data will help the algorithm recognize more complex patterns and improve its predictive ability.

- System Scalability: The developed system needs to be tested on a larger scale to ensure that its performance remains optimal in environments with a larger number of items and areas. This testing is important to ensure that the system remains reliable and efficient under various conditions.
- Website Interface Improvement: Although the developed website is already able to display data in real-time, the user interface can be further improved to enhance user experience. The addition of features such as notifications, automatic reports, and inventory data analysis can provide added value for users.

By considering the above suggestions, it is hoped that the development of this RFID-based goods localization system can continue to be improved and applied widely in various industrial sectors, providing greater benefits in efficient and accurate inventory management.

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