IoT-Based Smart Farming Using Machine Learning For Red Spinach

1st Sultan Rizky Abdurahman
School of Electrical Engineering
Telkom University
Bandung, Indonesia
sultanrizkyabdulrahma@student.telkomuniversity.ac.id

2nd Nyoman Bogi Aditya Karna
School of Electrical Engineering
Telkom University
Bandung, Indonesia
aditya@telkomuniversity.ac.id

3rd Arief Indra Irawan
School of Electrical Engineering
Telkom University
Bandung, Indonesia
arifirawan@telkomuniversity.ac.id

***Abstract*— Red Spinach Plants have various benefits. those benefits are produced by the leaves, as well as the roots. However, this red spinach plant has numerous vulnerabilities and risks including watering, soil treatment, fungi, and pests that must be taken into account. Therefore, smarter agricultural technology is required to overcome that issues and formulate a solution. The DHT22 sensor is one of the sensors used in greenhouses to retrieve data from indoor humidity sensors. The BH1750 sensor collects light intensity sensor data in addition to room temperature, and the YL-69 sensor collects soil moisture data. This algorithm will generate classification results in the form of optimal and non-optimal values for each attribute used. The purpose of this final project is to create a classification model for the optimal growth of red spinach plants, especially seedling growth. The test results show that the system works well. During QoS testing, the average delay was 1.880 seconds. During QoS testing, the average throughput for reading data was 4,464 bps.**

***Keywords* — internet of things, sensor, mysql, dataset, raspberry pi 3b+.**

I. INTRODUCTION

Agriculture is becoming more and more popular in Indonesia and with the advancement of digital technology, farmers in Indonesia have more opportunities to practice farming for maximum results. One of the largest agricultural regions in Indonesia is West Java. West Java is one of the most important agricultural regions in Indonesia. West Java in particular is one of Indonesia's leading producers of vegetables such as red spinach, mustard, lettuce and spinach. Keeping the price of spinach raw materials stable requires the supply of high-quality red spinach, minimizing the factors of scarcity, opening up opportunities with industrial products 4.0, and maintaining the availability of spinach supply in terms of quantity and quality, so that people can enjoy it at a stable price. The specific parameter observed for the analysis was soil moisture as a growth-related factor for spinach cultivation[1].

There are several types of spinach, including snapper spinach, thorn spinach, and red spinach. Red spinach (Alternanthera amoena Voss) is a spinach variety with a distinct feature: the plant is red. This type of spinach is known as a highly nutritious vegetable because it contains protein, vitamin A, vitamin C, and mineral salts that the body requires. The stem color can be any other color, such as green, red, yellow, or a combination of these [1]. According to data released by the Central Statistics Agency (BPS), spinach production results vary, and the lack of popularity of red spinach has resulted in less intensive cultivation and marketing, despite the fact that red spinach is beneficial to the human body as an antioxidant.

The Internet of Things (IoT) could be the key to successfully running red spinach nurseries. The Raspberry Pi 3B+ supports additional sensors such as the DHT-22 humidity and temperature sensor, the YL-69 soil moisture sensor, the BH1750 light intensity sensor, the ADS1115 ADC, and relays. During irrigation, the sensor collects data on room temperature and humidity, soil moisture, light intensity, and water availability. If the available water supply is insufficient, the irrigation process can be performed using an automated method based on the dataset. The information is then stored in a database, allowing for real-time monitoring via the internet.

Based on the problems listed above, the solution can be implemented by searching for datasets and prediction models that are ideal for red spinach in order to produce quality red spinach while also meeting market demand, and the categories are included in the Livestock Monitoring category, as well as data storage based on the device used. As a result, the researchers carried out a study titled "IoT-BASED SMART FARMING WITH MACHINE LEARNING FOR RED SPINACH." In the system, IoT will save data to the MySQL database and then send data to Firebase, after which the researcher will access the data via a query that generates a collection of data that will be processed by Machine Learning and produced an ideal prediction model for red spinach.

II. THEORITICAL REVIEW

A. Internet of Things

IoT (Internet of Things) allows users to manage and optimize electronics and electrical appliances that use the internet. It is hypothesized that in the near future, computers and electronic devices would communicate and exchange information, minimizing human involvement. This will also encourage users to use the internet, which is becoming more accessible thanks to a variety of online facilities and services [2]. The Internet of Things (IoT) is a network architecture in which things and people are given unique identities and the capacity to transport data across it without the need for two-way human-to-human (source-to-destination) or human-to-computer interaction [3].

In its application, the Internet of Things can also identify, locate, track, monitor, and trigger connected events in real time. Computers, the Internet, information technology, and other forms of communication have had a tremendous impact on economic management, production operations, social management, and even personal life [4].

B. Smart Farm

IoT is a system for agriculture. The system is designed to make it easier for farmers to find solutions that alleviate their problems. The created dataset is a conceptual improvement using IoT systems that have been implemented in many domains[5].

C. Hardware

Raspberry Pi is a small computer board that runs Linux and may be connected to a computer monitor, keyboard, and mouse. Raspberry Pi can be used to build electronic structures and program networks; it can also be used as a personal computer with Apache Webserver and MySQL loaded [5].

FIGURE 1
RASPBERRY PI 3B+.

DHT22 is a digital sensor with a thermistor for temperature measurement and a capacitive sensor for humidity measurement. The DHT22 sensor monitors the room's temperature and humidity. The working temperature ranges from -40°C to 80°C, with a humidity range of 0-100%. The humidity is accurate to 0.5°C, and the temperature is accurate to 0.5°C. [6].

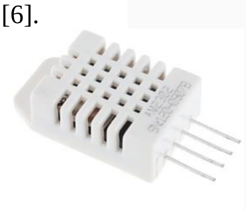

FIGURE 2
DHT22 SENSOR

The BH1750 IC is used in the GY-302 Digital Light Intensity Sensor Module, which is a light sensor module. The BH1750 is a light sensor integrated circuit with an IC interface. This module generates digital output values via the IC bus, eliminating the requirement for an ADC converter [7].

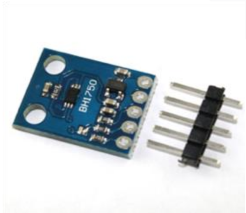

FIGURE 3
GY-302 BH1750 SENSOR

The YL-69 hygrometer sensor has two electrodes and is an electrical resistance sensor. It operates by sending a current through the soil between the two electrodes and returning the resistance measurement for determining soil moisture content [8].

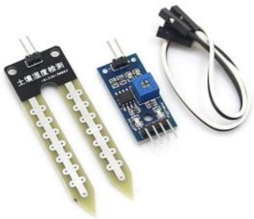

FIGURE 4
YL-69 SENSOR.

The water pump is a mechanical device that may suction or apply pressure to transfer fluids. There are two basic components to the water pump if we pay attention to it. The pump's driving power is the motor, and a pump is a tool that transfers or moves water[22].

FIGURE 5
WATER PUMP

A relay is an electronic component that looks like an electric switch or a switch that is powered by electricity. Relays are made up of two primary parts: a coil or electromagnet and a switch or mechanical contact, and are also known as electromechanical or electromechanical components[23].

FIGURE 6
RELAY

The ADS1115 module is a type of ADC with a 16-bit resolution. With bipolar and single differentials, four channels in this ADC can transform the value of four sensors at once[24].

FIGURE 7
ADS1115

D. Red Spinach

One type of waterproof plant was put in the red spinach plants, allowing them to be planted all year. Watering is done on a regular basis during the dry season. When planted at the start of the rainy season, this plant thrives. The land is appropriate for planting since it has loose soil, a lot of humus, is fertile, and has adequate water drainage. The soil's acidity (pH) should be between pH 6 and 7, which is ideal for growth. [9].

FIGURE 8
RED SPINACH

E. Room Humidity

Cultivation for the growth of red spinach plants requires air humidity in the range of 40% to 60%. Plant growth can be hampered by high humidity. The mechanism of nutrient application by red spinach can also be affected by air humidity[10].

F. Room Temperature

Each vegetable has a different room temperature that is just as crucial as the other criteria in optimizing its growth. The importance of room temperature in water spinach growing cannot be overstated. The ideal room temperature for growing water spinach is between 20 and 30 °Celsius [10].

G. Light Intensity

The growth of red spinach plants is influenced by sunshine, which affects the photosynthesis process. Sunlight is also necessary for the growth of red spinach. Water spinach requires a light intensity of 1000-2000 Lux to be optimally maximized in this study [11].

H. Soil Moisture

Water is sufficient throughout the growing period of water spinach. Red spinach is watered by keeping an eye on the soil moisture. Between 40% and 60% of the soil moisture is managed. If the soil moisture is less than 40%, the plant should be watered, if the soil moisture is greater than 60%, the plant does not need to be watered [12].

I. Database

A database is a collection of data that is stored together to serve as many applications as possible. Therefore, a database is often viewed as a repository of data needed to perform a specific task within a business or organization[13].

J. RDBMS

RDBMS stands for Relational Database Management System, and it is a database management system based on E.F Codd's relational paradigm. Data is kept in relations (tables) and represented as tuples in the relational model (rows)[14].

K. MySQL

MySQL is the most widely used database management system software for managing relational databases today. It is an open-source database that is supported by the Oracle Corporation[15].

L. Machine Learning

Machine learning is a field that focuses on two intertwined issues. Machine learning has come a long way in the last two decades, from a lab curiosity to a real technology with widespread commercial use. Machine learning has emerged as the method of choice for producing practical software for computer vision, speech recognition, natural language processing, robot control, and other applications in artificial intelligence (AI) [16].

M. Supervised Learning

The supervised machine learning methodology is based on labeled examples that are used to train and test a model that needs to learn to discriminate or generate new examples that are similar to those previously seen after automated standardization of its internal parameters and exploitation of a chosen loss function. The feed-forward neural network and polynomial regression models are the two most common models that can be used.

N. KNN Algorithm

In pattern recognition and machine learning, the KNN algorithm is a widely used approach for classification or regression. The KNN algorithm is an instance based lazy learning technique that is utilized in a variety of applications including statistical pattern identification, data mining, image processing, and many more. The KNN method is simple, but it takes a long time to run. When the train and test data sets are both very large, the application's execution time may become a bottleneck [17].

O. Firebase

Firebase is considered as web application platform. It helps developers‟ builds high-quality apps. It stores the data in JavaScript Object Notation (JSON) format which doesn‟t use query for inserting, updating, deleting or adding data to it. It is the backend of a system that is used as a database for storing data[26].

P. Python

Python is a high-level, general purpose programming language that is interpreted. The use of considerable indentation in its design philosophy emphasizes code readability[18].

Q. Wireshark

Wireshark is a network packet analyzer. A network packet analyzer attempts to capture network packets and present the data in as much detail as possible. Many network administrators want to use Wireshark, but this is often not possible due to lack of documentation [20].

R. Quality of Service

Quality of Service (QoS) is a measurement methodology of how good a network is and is an attempt to define the characteristics and properties of a service. QoS is used to measure a set of performance attributes that have been specified and associated with a service.

S. Throughput

The total number of successful packet arrivals seen at the destination process within a particular time period divided by the time intervals' duration is known as throughput. Bits per second are used to measure throughput (bps) used ITU-T G.1010 standarization [21].

TABLE 1
STANDARD THROUGHPUT BASED ON ITU-T G.1010

Category	Value (Kbps)
Very Good	> 2100
Good	1200 – 2100
Average	700 – 1200
Bad	338 – 700
Very Bad	0 – 338

$$Throughput = \frac{Number\ of\ Packets\ Received}{Data\ Transmission\ Time}$$

T. Delay

Delay is the time it takes to travel the distance from sender to receiver. Delay can occur due to several factors, such as the data packaging process, propagation, and the number of components that access it. The ITU-T G.1010 standard categorizes delays as shown in Table 2 [21]

TABLE 2
STANDARD THROUGHPUT BASED ON ITU-T G.1010

Category	Value (ms)
Very Good	<150
Good	150 - 300
Enough	300 - 450

$$Delay = \frac{Data\ Transmission\ Time}{Number\ of\ Packets\ Received}$$

U. Accuracy Score

Update the score of the obtained model to the accuracy value. The precision result of the value is a floating point number. These evaluation parameters come from the correct positive and negative examples, as these are also present in the classification report. This indicator is used to provide information visually. The formula for calculating the accuracy score is shown below [25].

V. Confusion Matrix

Confusion Matrix is a visual assessment tool for machine learning. The columns of the confusion matrix represent the predicted class scores and the rows represent the actual class scores, which enumerates all possible causes of the classification problem. Confusion matrices are also one of the most classic decision measurement techniques in supervised machine learning. It visualizes the degree of confusion between different classes of algorithms and is independent of a specific classification algorithm [25].

W. Classification Report

A summary of classifier performance measurements based on a specific test set, where positive and negative examples are specified. There is no limit to the classifier used. Various performance measures used to analyze the observed classifier, characterized by the presence of true positives and false positive rates, all other measures were derived[25].

III. METODE

A. The Architecture of Overall System

The operation of the components and sensors that are used to collect practical plant data for starting IoT. The Raspberry Pi will then run the smart farming system by evaluating the acquired data and handling all system components. In the IoT device system that will be designed using 3 sensors, YL-69 to obtain real-time health data for each plant, DHT22 is used to measure the temperature and humidity of the room that will be placed around the plant, then send data on temperature, and humidity inside. As for a more complete explanation, which we can see in Figure 9, it is explained that red spinach will be identified by the sensor which will then obtain data from the plant. After the sensor gets the data, the data is sent to the microcontroller, namely the Raspberry Pi, then the Raspberry Pi will send the data to the MySQL and send data to Firebase databases in real time which will later become CSV data. In the CSV data, a model will be made which will later be used for prediction models, after the prediction model is complete, then classification metrics are carried out to show the predictive power of the completed model.

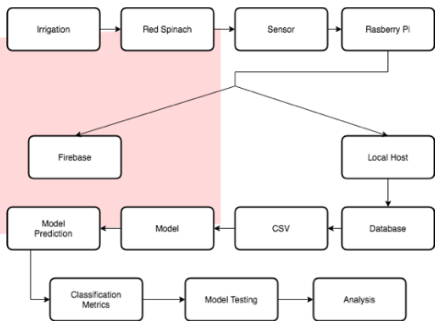

FIGURE 9
THE PROPOSED MACHINE LEARNING PHASE IS USED IN THIS THESIS.

B. Architecture of Observation Data Storing Management

As the final phase of the system design, machine learning is expected to create a forecast based on previously unknown cases. A vast amount of data must be included in the prediction to produce the best outcome of the model projection. If the model's predictions are satisfactory, the outcome of the unseen occurrences prediction is not far behind. The prediction model architecture is divided into seven steps, as illustrated in the diagram below: issue definition, data mining, data preparation, data visualization, data modeling, hyper parameter modify, and model deployment.

The steps begin with the problem being defined. When designing the problem solution, the type of data utilized as an input is taken into account. This thesis uses both categorical and continuous data. The expected output is represented by the type of plant condition label, which is a string. To develop a forecast based on the problem analysis, this system will focus on categorical attributes. In the second stage, the data is gathered. The technique comprises mining the datasets from scratch from the database and adding the manual observation attributes value to complete the dataset.

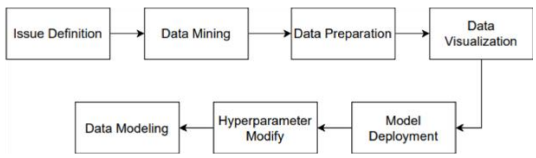

FIGURE 10
THE DIAGRAM BLOCK

C. The Architecture Topologi Client Server

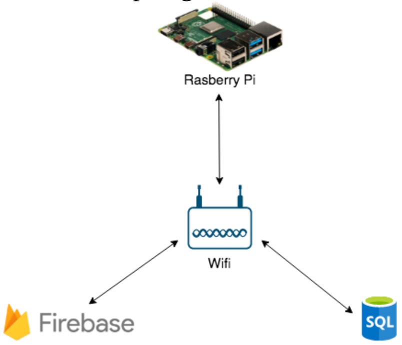

FIGURE 11
TOPOLOGI CLIENT SERVER

In Figure 11 above, it will explain the client-server topology where the Raspberry Pi as a client will send and receive data into 2 Firebase databases and SQL as a client via a wifi network as a server.

D. Architecture of Model

The following steps extract leads from the database as a draft dataset and check that the data is complete. The select statement of a MySQL query is used to load the entire collection of data faster. Each group then used Python commands to import the data into a Jupyter notebook on the laptop. After scraping of records is complete, use the merge function to concatenate all groups of information into one file.

To do this, drag and drop records into the notebook. Enter the data preparation phase, which includes scaling, encoding, and preprocessing. The program processes the statements in the correct order for data preparation. After data preparation, the model training phase begins.

Once the decision tree technique is used in the training phase, the model creates classifier predictions using the test data map.To see if the model is ideal, look at the percentage of outcomes created by the measurements. A model is good if the measurements show that it has the same accuracy and precision as a perfect classifier. Aside from that, there are flaws in the model. This condition will be used to describe the hyperparameter adjusting phase. The operation starts using the reload command argument from the data preparation step. Once the model has been assessed to be in ideal condition, it is finalized. Save the model to your computer’s hard drive so you can use it later. Then create a new notebook for the model, add a new value to the corresponding attributes, and the model will produce the forecast. The flowchart system is depicted in Figure 12 below.

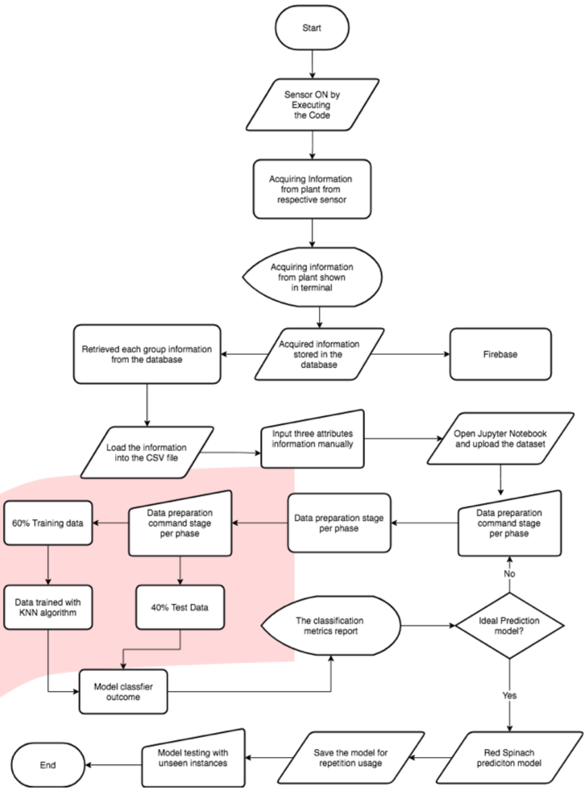

FIGURE 12
SYSTEM FLOWCHART

E. Label Classification

In this section, optimal and not optimal are determined by soil moisture because soil moisture is sufficient to determine optimal and not optimal labels. If the temperature is high, the soil moisture will be low and vice versa. If the light intensity is high, the temperature and humidity will also be high, which can affect the soil moisture. Therefore, the label on the soil moisture is sufficient to determine the optimal and not optimal. If the soil moisture is high and normal, then it is optimal, and if the soil moisture is low, then it is not optimal.

IV. RESULT AND DISCUSSION

A. Hardware Analysis

This section tests the system hardware to see if each hardware device used in the system is working properly. The following are the device states described in Table 3 below:

TABLE 3
HARDWARE TEST

No.	Hardware Function	Status
1	Raspberry Pi connected can receive data and send data to database.	Success
2	DHT22 Sensor, YL-69 Sensor, and BH-1750 Sensor can be integrated into Raspberry Pi.	Success
3	When the soil moisture status in plants is not optimal the relay can work.	Success
4	When the relay status is on or if the relay status is off the water pump can work.	Success

The results of the hardware analysis that has been carried out on the system used in table 3 above can be concluded that the hardware is running successfully

B. Monitoring Result Analysis

This test was conducted to determine the height of red spinach. This test compares automatic plant growth with conventional plant growth. Below are the findings of the seven-day monitoring period during which data will be collected over a 24-hour period. The monitoring results for each red spinach plant height are shown figure 12 below.

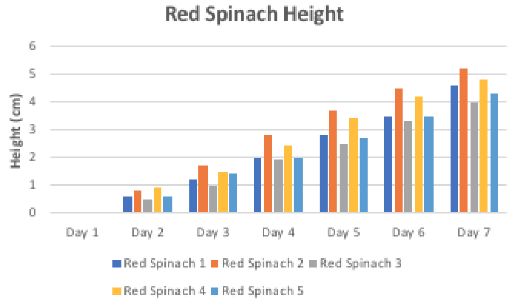

FIGURE 13
MONITORING RESULT ANALYSIS

C. The Quality of Service Test

In this section, a test will be conducted to verify the quality of the network from the device to the resulting database using the QoS delay and throughput parameters. Parameter checked every day. Testing is done using wireshark software.

Figure 13 below is the result of testing the delay from the tool to the database, for the smallest delay that occurs on day 3 is 1.834 s, while the largest delay occurs on day 7 which is 1.923 s. The average delay obtained is 1.880 s. According to the ITU-T G.1010 standardization, the results obtained are classified as good category. The following is a graphical representation of the test results data.

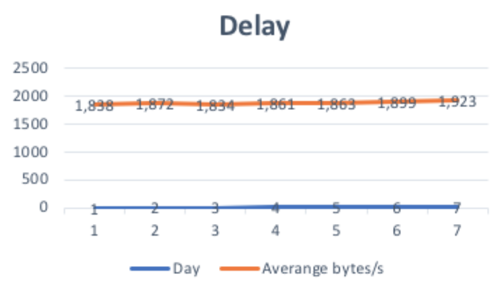

FIGURE 14
DELAY TEST ANALYSIS

Figure 14 below is the result of throughput testing that has been carried out, for the smallest throughput on day 7 was 4,145 bps while the largest on day 1 was 4,852 bps. The average throughput from the device to the database is 4,464 bps. According to the ITU-T G.1010 standardization with the results obtained, the total data transmission per unit time from the tool to the database is classified as very good category with index 4. The following is a graphical representation of the test results data.

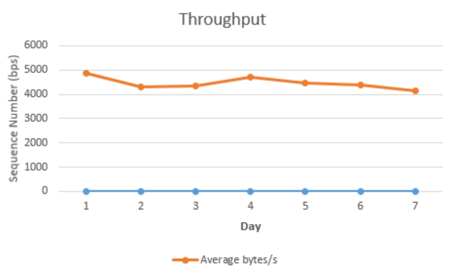

FIGURE 15
THROUGHPUT TEST ANALYSIS

D. Database Page Functionality Analysis

The test this time is to analyze the database on the web each page is working or not, as well as analyzing the features on the web that are functioning properly or not. The following results from web database analysis are described in table 4 below:

Table 4 Database Page Functionality Analysis

Test	Test Stage	Description	Status
Display dashboard page on web database	Dashboard access	Dashboard displayed on the web database	Success
On the Dashboard displays information on the condition of the room	Dashboard access	Managed to display a dashboard web database containing information on humidity, room temperature, and light intensity in the room.	Success
On the dashboard displays the height growth of the red spinach plant	Dashboard access	Managed to display information on the growth of red spinach plant height on the dashboard web database.	Success

E. Data Display Realtime Firebase

In this section, we will display the processed data between the Raspberry Pi and Firebase. This test is carried out to monitor the results of red spinach on the device remotely. The following is the result of processing data between the Raspberry Pi and Firebase, which can be seen in figure 15 below:

FIGURE 16
DATA DISPLAY REALTIME FIREBASE

F. Accuracy Score

In this section, the metric analysis system provides delicacy score information in addition to the content of the categorization report, because it's a special parameter. Figure 16 illustrates the process of determining the average delicacy score while Figure 17 illustrates the determined delicacy score.

```
# Model Accuracy, how often is the classifier correct?'
clf_report = classification_report(y_test[plant_name], y_pred, target_names=["Optimal", "Not Optimal"])
accuracy = metrics.accuracy_score(y_test[plant_name], y_pred) * 100
```

Figure 17 An overview of the accuracy score process in this final project.

```
KNN Performance Report for spinach models:
Accuracy : 90.74 %
```

FIGURE 18
AN OVERVIEW OF THE ACCURACY SCORE PROCESS IN THIS FINAL PROJECT.

From the results of the accuracy score that has been carried out using the KNN classific ation, the accuracy score is 90.74% and the results can be said to be good.

G. Confusion Matrix

In this section, measures are demanded for other performance characteristics bracket tables, for illustration, Accuracy, Precision, and so on. The affair of the confusion standard is illustrated in Figure 18 below.

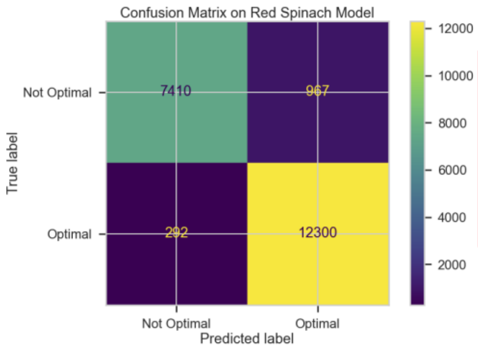

FIGURE 19
CONFUSION MATRIX

in Figure 18 it can be explained that the results of the confusion matrix on red spinach are divided into optimal and not optimal, after viewing the image, it can be seen that for optimal data, 12,300 data are obtained and for non-optimal ones, 7,410 data are obtained.

H. Classification Report

In this section the values generated from the confusion matrix, this matrix serves as the final analysis. Figure 19 below displays information in irregular format.

```
# Model Accuracy, how often is the classifier correct?'
clf_report = classification_report(y_test[plant_name], y_pred, target_names=["Optimal", "Not Optimal"])
accuracy = metrics.accuracy_score(y_test[plant_name], y_pred) * 100
```

FIGURE 20
THE OVERVIEW OF CLASSICATION PROCESS IN THIS THESIS.

```
KNN Performance Report for spinach models:
Accuracy : 90.74 %
Classification Report :              precision    recall  f1-score   support

     Optimal       0.93      0.83      0.88      8406
 Not Optimal       0.89      0.96      0.93     12563

    accuracy                           0.91     20969
   macro avg       0.91      0.89      0.90     20969
weighted avg       0.91      0.91      0.91     20969
```

FIGURE 21
GENERAL DESCRIPTION OF THE CLASSIFICATION REPORT IN THIS FINAL PROJECT.

V. CONCLUSION

Based on the research that has been done, there are several conclusions that can be explained as follows:

A. The spinach plant monitoring system is running well where data transmission by the microcontroller can be stored in the database and can be monitored by accessing the localhost microcontroller.
B. The results of the monitoring of room temperature, humidity, light intensity in the greenhouse are affected by erratic weather conditions, but this does not affect the plants because the plants are in the greenhouse.
C. In the QoS test of sending data tools to the website, the average delay value is 1.880 s, and the average throughput value is 4,464 bps.
D. The results of testing the database functionality can run well and all the features contained in it can run according to their functions.
E. The KNN approach with the Scikit-learn library is suitable for developing predictive models in this final project and the accuracy and precision metrics yield a score of 90.74%.

Several shortcomings in the system that emerged could be used as research material in the future, namely installing cameras to monitor plant growth for more clarity, adding a pH sensor to measure plant acidity, providing a web server to monitor each plant, and increasing the duration of data collection so that the resulting data conditions are more optimal and precise.

REFERENCE

[1] H. A. Arief, tanaman buah-buahan, tanaman sayuran, tanaman bunga/hias, Andi Offset, 1990.

[2] A. Junaidi, Internet of things, sejarah, teknologi dan penerapannya, vol. vol. 1, Jurnal Ilmiah Teknologi Infomasi Terapan, 2015.

[3] A. W. B. a. H. D. Misalkar, Review of internet of things in development of smart cities with data management & privacy, International Conference on Advances in Computer Engineering and Applications. IEEE, 2015, p. 189–195.

[4] Q.ZhouandJ.Zhang, Internet of things and geography review and prospect, vol. 2, International Conference on Multimedia and Signal Processing, IEEE, 2011, p. 47–51.

[5] S. J. a. P. Wuttidittachotti, Smart farm monitoring using raspberry pi and arduino, International Conference on Computer, Communications, and Control Technology (I4CT). IEEE, 2015, p. 284–288.

[6] S. U. J. Y.-D. L. a. I. K. U. Saeed, Machine learning-based real-time sensor drift fault detection using raspberry pi, International Conference on Electronics, Information, and Communication (ICEIC). IEEE, 2020, p. 1–7.

[7] L. L. a. Y. Zhang, Design of greenhouse environment monitoring system based on wireless sensor network, 3rd International Conference on Control, Automation and Robotics (ICCAR). IEEE, 2017, p. 463–466.

[8] G. T. a. G. G. L. Galbusera, Intelligent energy systems: Introducing powerict interdependency in modeling and control design, vol. 62, IEEE Transactions on Industrial Electronics, 2014, p. 2468– 2477.

[9] A. Susila, Panduan budidaya tanaman sayuran, 2006.

[10] Y. M. a. L. K. K. Hardiane, Pengaruh intensitas cahaya dan dosis pupuk kascing terhadap pertumbuhan dan hasil tanaman bayam merah(amaranthus tricolor l.),

vol. 1, Jurnal Ilmiah Agroust, 2017, p. 116–124.

[11] R. B. H. a. E. P. L. Khusni, Pengaruh naungan terhadap per- tumbuhan dan aktivitas antioksidan pada bayam merah (alternanthera amoena voss.), vol. 3, Buletin Anatomi dan Fisiologi (Bulletin of Anatomy and Physiology), 2018, p. 62–70.

[12] Y. B. a. N. Azis, Bayam, Cetakan ke V. Jakarta: Penebar Swadaya, 2001.

[13] R. G.˝.¨. G. P. a. A. O. C. G.˝.¨di, A comparative study: Mongodb vs. mysql, 13th International Conference on Engineering of Modern Electric Systems (EMES). IEEE, 2015, p. 1–6.

[14] T. Hariguna, Metode reset password level root pada relational database management system (rdbms) mysql, vol. 4, Telematika, 2011.

[15] M. H. H. J. A. B. a. A. L. E. M. Dawodi, Facebook mysql performance vs mysql performance, IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON). IEEE, 2019, p. 0103–0109.

[16] M. I. J. a. T. M. Mitchell, Machine learning: Trends, perspectives, and prospects, vol. 349, Science, 2015, p. 255–260.

[17] Q.KuangandL.Zhao,Apracticalgpubasedknnalgorithm, The 2009 International Symposium on Computer Science and Computational Technology (ISCSCI 2009), Citeseer, 2009, p. 151.

[18] D. Kuhlman, A python book: Beginning python, advanced python, and python exercises, Dave Kuhlman Lutz, 2009.

[19] G. V. R. e. al, Python programming language, vol. 41, in USENIX annual technical conference, 2007, p. 36.

[20] U. L. a. E. Warnicke, Wireshark user's guide, vol. 4, Interface, 2004, p. 1.

[21] I. UNION, ITU-T Recommendation G. 1010: End-user multimedia QoS categories (Quality of service e performance)., ITU, Novembro (2001).

[22] B. B. a. N. K. Sharma, IoT-based intelligent irrigation system for paddy crop using an internet-controlled water pump, International Journal of Agricultural and Environmental Information Systems (IJAEIS) 12.1, 2021, pp. 21-36.

[23] A. T. M. Irsyam, Sistem otomasi penyiraman tanaman berbasis telegram, vol. 2, eJournal Unikra, 2019, p. 81–94.

[24] Z. e. a. Muhammad, Smart agriculture using internet of things with Raspberry Pi, 10th IEEE International Conference on Control System, Computing and Engineering (ICCSCE). IEEE, 2020.

[25] M. Bramer, Principles of Data Mining, 2017.

[26] C. a. P. S. Khawas, Application of firebase in android app development-a study, International Journal of Computer Applications 179.46, 2018, pp. 49-53.

[27] A. S. N. K. a. R. M. Susilo, Decision Tree-Based Bok Choy Growth Prediction Model for Smart Farm, 4th International Conference on Information and Communications Technology (ICOIACT). IEEE, 2021.