Kale Growth Model Analysis Based On Smart Farm Iot Using Machine Learning

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Abstract*— Kale is one of Indonesia's most popular vegetables. Kale is often found across agricultural area in Indonesia, not just in restaurants. Kale farming is one of the prospective agricultural business opportunities and is considered simple. However, Kale plantation presents unique obstacles due to the kale's vulnerability and impacted to the harvest instability. Therefore, the agricultural system of smart farming for growing Kale must be revitalized. Previously, a global system schema using Internet of Things (IoT) for Kale's farming was proposed. That research technique then upgraded with the current research technique, which employs a Machine Learning System to support Kale cultivation through smart farming. Machine learning system strategies can be a solution for accurately and intelligently growing kale. This strategy can be combined with the acquisition of fresh kale growth data, prediction models in the planting phase, and the production of an ideal growth model. The method employed is to create a systematic design for predictive model datasets, beginning with data collecting in IoT, data storage in MySQL databases, Firebase, and data modeling using machine learning methods utilizing supervised learning. The results of monitoring room temperature, humidity, and light intensity in the greenhouse are impacted by irregular weather conditions, but they have no effect on the plants because they are in the greenhouse. QoS testing obtained an average delay of 2.472 seconds and a throughput of 6851 bits per second. Accuracy and precision metrics yield a perfect score of 100%. Based on the test results, it can be explained that the value of the Quality of Service measure and machine learning performance reaches the best value for the optimal dataset and prediction model outputs, specifically developing an ideal kale growth model for the farmer's environment.

Keywords — IoT, kale, QoS, MySQL, firebase, machine learning

I. INTRODUCTION

Indonesia is an agricultural country, one of which supports the horticulture industry, which is an important aspect in the national economy. The number of individuals who live and work in the agriculture industry demonstrates this effect. West Java, for example, is a cool-climate region with several mountains appropriate for plantations, such as kale, lettuce, mustard greens, and kale, and West Java is the major kale grower. Based on data from the Indonesian Ministry of Agriculture, specifically data for 2019, 56,229 tons, 2018, 58,228 tons, and 2017, 51,383 tons, there were relatively big changes in harvest seen in the year of observation, ranging from 2000 tons to 6000 tons [1].

Kale is a popular vegetable in Indonesia, particularly in West Java, which has a tropical climate. This plant is coming from the tropic regions, mainly Africa and Asia [2]. Kale is a vulnerable vegetables and unstable. Due to this unpredictability of kale supply, the fluctuating yield can lead to volatile market pricing. Weather sensitivity, limited resources such as producers, planting expertise, infrastructure, land availability, the impact of fertilizers, and climate change can all contribute to fluctuating yields. Therefore, the agricultural system of smart farming for growing Kale must be revitalized. Previously, a global system schema using Internet of Things (IoT) for Kale's farming was proposed. Then, that research technique upgraded with the current research technique, which employs a Machine Learning System to support Kale cultivation through smart farming.

The Internet of Things is a form of computing system in which little electrical devices equipped with sensors can detect their surroundings. Smart agriculture or smart farm is feasible to apply. The use of the Internet of Things to farming can save labor and money, improve temperature and humidity control, and collect more precise information about plant development variables [3]. MySQL, one of the most widely used Relational Database Management System solutions, is well known for its benefits. MySQL is also known for executing queries faster than other RDBMS systems [4]. In order to maximize the utilization of data in a database, Machine Learning can be used to investigate data usefulness for commercial purposes. Machine learning is the study and development of an algorithm that can learn and predict data using a computer system employing supervised learning or unsupervised learning techniques. This concept is acquiring the data model in various forms, depending on the machine's requirement and learning objective [28]. This technique will typically execute a model validation process on each learning process. Instead of following procedural instructions from the computer program, the learning algorithm predicts or determines the future by applying the model obtained from the sample dataset. This technique enables the machine to learn and increase its efficiency by learning from a sample dataset or the surroundings.

In this Thesis, a design architecture is formulated to create an ideal growth prediction model for kale, especially in the seedling phase. This research is based on three final projects published internally, the smart farm concept followed by an Internet of Things-based automation system [5]. MySQL database for raw data storage [6]. Machine learning techniques to develop models [7]. Finally, an integrated system is adopted, and combining concepts have been defined to create a seamless data set.

II. THEORITICAL REVIEW

A. Internet of Things

Internet of Things (IoT) is an advanced technology for monitoring and controlling device everywhere and anywhere in the world. It can connect devices with living things. IoT is making a significant mark in many fields. Nowadays, the adaptive nature of IoT has transformed, can be utilized by an ordinary user [8]. IoT has developed several methodologies that made people's lives more manageable and comfortable, like innovative education, cities, the e-health sector, and automation. The IoT is a new type of computing system where small electronic devices equipped with sensors are used to detect the operating environment, smart agriculture or smart farming [3].

B. Smart Farm

IoT is a smart system to be applied in agriculture. The word smart itself comes from IoT, which includes automation for greenhouses. This system is expected to make it easier for farmers to find solutions that can help their problems. The green houses system can control and monitor plantations such as room humidity, room temperature, light intensity, and soil moisture. The specific correlated environment also takes data to be stored as data sets [9]. The dataset created is an idea put forward using the IoT system that has been implemented in various fields. The model is based on a system that integrates IoT systems in agriculture, namely a smart farm for realtime data retrieval based on automatic control, a MySQL database for data storage, and supervised learning techniques on machine learning to create predictive models from datasets as a guideline.

C. Hardware

Raspberry Pi is a small computer board working on the Linux operating system, which connects to a computer monitor, keyboard, and mouse. Raspberry Pi can be applied to an electronic structure and programming network work. It can also be served as a personal computer and Apache Webserver, MySQL could be installed on the board [10].

FIGURE 1
RASPBERRY PI 3B+.

DHT22 is a digital sensor consisting of a thermistor (temperature measurement) and a capacitive sensor for determining the humidity. The DHT22 sensor measures both temperature and humidity in the room. The working temperature is -40C to 80C, and the humidity range is from 0 - 100%. The temperature has an accuracy of 0.5C and the humidity [11].

FIGURE 2
DHT22 SENSOR

BH1750 is a kind of digital light intensity sensor, which the light sources are not needed to distinguish. From Japan RHOM Corporation R& D products, BH1750 is an integrated circuit with two wires serial bus interface, which can monitor the external environment, at any time, according to different light intensity. BH1750 has with high resolution, which reached 1-65535 lux so that a wide range of light intensity changes can be monitored and collected [12].

FIGURE 3
GY-302 BH1750 SENSOR

The YL-69 hygrometer sensor is an electrical resistance sensor that consists of two electrodes. It works by passing a current across the two electrodes through the soil and returns the resistance measurement for soil moisture content determination [13].

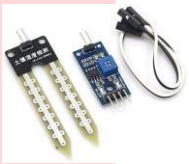


FIGURE 4
YL-69 SENSOR.

The water pump is a mechanical device that can move fluids by sucking or by applying pressure. If we pay attention to the water pump, there are two primary components that we will find. First, the motor is the pump's driving force, and a pump is a tool that transports or moves water [14].

FIGURE 5
WATER PUMP

Relay is an electronic component in the form of an electric switch or switch operated using electricity. Relays are also commonly referred to as electromechanical or electromechanical components, consisting of two main parts: a coil or electro magnet and a switch or mechanical contact [14].

FIGURE 6
RELAY

ADS1115 module is a type of ADC that has a resolution of 16 bits. In this ADC, four channels can convert the value of 4 sensors at once with bipolar and single differentials. Analog Digital Converter (ADC) is a device that converts analog signals into digital signals. ADC has two parameters. This ADC feature is an onboard reference and oscillator. The data received will be transferred or sent via I2C communication consisting of SCL and SDA [15].

FIGURE 7

ADS1115

D. Kale

West Java is the largest kale producer in Indonesia based on the results of the Indonesian statistical center. The need for water kale in Indonesia is increasing in line with increasing public awareness of health's importance by eating green vegetables. Kale contains nutrients such as protein, fat, carbohydrates, calcium, phosphorus, iron, sodium, potassium, vitamin A, vitamin B, and vitamin C. Kale is also a plant whose economic value lies in the leaves, which are vegetative organs, so if photosynthate resulting in a high photosynthetic process, then the harvest index is high [2]. In the aspect of kale growth, several aspects need to be considered, such as room humidity, room temperature, light intensity, and soil moisture.

FIGURE 8
KALE

E. Room Humidity

Cultivation for the growth of kale plants has air humidity with a humidity range ranging from 60% - 82%. High humidity can adversely affect plant growth. Air humidity can also affect the process of nutrient application by kale plants [16].

F. Room Temperature

As important as other parameters, each vegetable has a different room temperature in optimizing these vegetables' growth. Room temperature for the growth of water kale is an important aspect of kale cultivation. Ideally, in the cultivation of water kale, the room temperature ranges from 28C to 33C [16].

G. Light Intensity

When cultivating kale plants, sunlight affects the growth process through photosynthesis. Sunlight also has a vital role in the growth of kale. Water kale requires a light intensity of 1000 - 2000 Lux needed for this research to be optimized optimally [17].

H. Soil Moisture

In the growth phase of water kale, water is sufficient. Watering kale is done by paying attention to soil moisture. Soil moisture is controlled between 40% - 80%. Soil moisture is below 40%, the plant should be watered, and if the soil moisture is above 80%, it does not need to be watered [18].

I. Database

In this final project to collecting the structured information, or data, typically stored electronically in a computer system are used as follows:

J. RDBMS

RDBMS is a technique provide users with effective and efficient ways to access structured data. RDBMS provides users with a query language SQL to query information maintained in large RDB as the information that can be expressed using SQL [19].

K. MySQL

MySQL database is small in size, fast, and low in total cost of ownership, especially Its open source feature makes the current information systems and networks of many universities All stations choose MySQL as their back-end database [20].

L. Machine Learning

Machine Learning is a subset of Artificial Intelligence that is concerned with the computer systems or machines' capability to improve the performance automatically throughout. a Machine Learning refines the automotive learning process through training and lead towards adaptation of its algorithm [21].

M. Supervised Learning

The supervised machine learning methodology is based on labelled examples used to train and test a model that must learn to discriminate or generate new examples based on those previously seen after the automatic tuning of its internal parameters and exploiting a specific loss function. The first models that will be exploit are the feed forward neural network and the polynomial regression models [22].

N. Dataset

The dataset used for this research gathered from the previous research, which collected the kale farming data and compilation of the data observed through the information source which is the sensors [3].

O. Decesion Tree

Decision tree is a machine learning classifier based on the data structure of the tree that can be used for supervised learning with a predictive modelling approach, each internal node is labelled with an input feature, while the arcs that link a node to many others are labelled with a condition on the input feature that determines the descending path that leads from the root node to the leaves [22].

P. Python

In this final project python is more preferable for coding because unlike Matlab, Python provides numerous options for free open source packages to address general and specific methods for computation, optimization, visualization, data storage, etc. This language is continuously developing, which there are two current versions available, version two and three. The differences are located in its syntax operation. The use of Python is increasingly massive, especially in the field of machine learning research area by providing many free functions corresponds to the related libraries and packages [23].

Q. Firebase

Firebase is a combination of many Google services in cloud, including instant messaging, user authentication, real-time database, storage, hosting, and so on. This lesson mainly uses user authentication and real-time database functions, supplemented by instant messaging, to complete the event notification and SMS notification functions. Firebase cloud system provides data transmission SSL encryption. Firebase has many libraries that make it possible to integrate this service with Android, iOS, JavaScript, Java, Objective-C and Node.JS. Firebase databases are also accessible via REST APIs. The REST API uses the Server-Sent Event protocol by establishing an HTTP connection to receive push

notifications from the server. Developers use the REST API to post data which then the Firebase client library that has been implemented will retrieve data in real time[1].

R. Wireshark

In this final project, Wireshark is used as software to monitor or record data on a network between the Raspberry Pi and the server. Wireshark has the ability to scan any kind of Ethernet, Wi-Fi, monitor mode, or even bluetooth networks [24].

S. Quality of Service

Quality of Service (QoS) is a measure of how well the network is and attempts to determine the characteristics, nature of services and attempt to define a service's characteristics. QoS is used to measure a set of specified performance attributes associated with a service. QoS is designed to help end-users be more productive by ensuring that end-users get reliable performance from network-based applications [25].

T. Throughput

Throughput is the actual measured bandwidth at a particular time in transmitting files. Unlike bandwidth, even though the unit is the same as bits per second (bps), throughput describes the actual bandwidth at a time and under certain conditions and networks used to download a file of a specific size. The equation of this type of QoS is shown below [25].

$$Throughput = \frac{R_p}{D_p} \qquad (2,1)$$

U. Delay

Delay is when it takes for a packet to be sent from a device to the destination device. Delay in a packet transmission process in a computer network is caused by a long queue or taking another route to avoid routing congestion. To find the delay in the transmitted packetThe equation of this variety of QoS is shown below [25].

$$Delay = \frac{P_\iota}{B_\iota} \qquad (2,2)$$

V. Confusion Matrix

Confusion Matrix is a visual evaluation tool used in machine learning. The Confusion Matrix columns represent the prediction class results, and the rows represent the actual class results. It enumerates all possible causes of a classification problem. Confusion Matrix also one of the most classical decision measure methods in supervised machine learning. It visualizes the degree of algorithm confusion within different classes and is independent of the concrete classification algorithm [26].

W. Accuracy Score

The type of metrics to update the model evaluation is base on the accuracy value. The essential outcome is resulting in a float number. This evaluation parameter derives from the real positive and correct negative instances as it was also available in the classification report content. The function of these metrics to make intuitive delivery of information. The formula to calculate accuracy score is shown below [26].

X. Classification Report

Various performance measures used as the analysis of the observed classifier that characterizes by the existence of correct positive and false positive rate, which derive all other measures. The classification report is depicted in table 2.2 [26].

III. METHOD

A. The Workflow of the Global System

The workflow is initiated by switching on the components and sensors. It is done by executing structural code. This process will lead to acquiring information from the two observation plants based on the respective sensor. The result of receiving information is seen in the terminal on the Raspberry Pi. The acquired data is done every 0.05 seconds, considering the delay of sensing data by the sensor. In achieving the information for build the model, the received information is used only the rate of total data divided by 10 minutes, so then there will be only 6 data stored every one hour in the database. The acquired information is sent through the localhost connection when the code is still executing.

In the database, the acquired information is saved based on the desired groups. The subsequent process retrieves the lead as the dataset scratch from the database and ensures that the stored data has been completed. Select statement of MySQL query is used to more effortless loading the set of the information as a whole. Then, the data is loaded by each group with the python command in the Jupyter notebook on the laptop. In accomplishing the dataset's scratch as one file, adopt the merge function to concatenating all the information group. Input three attributes information manually by typing it into the file. Creating the model is processed in the Jupyter notebook. Upload the dataset to the notebook.

Advance to the data preparation phase, such as scaling, encoding, and preprocessing. The application will process the command by each of the relevant order of data preparation. The model training phase is started after the data preparation. Like the previous phase, this step will begin with inputting the command by each related process. Unlike the last stage, that not pointed out one of the processes in the diagram blocks, this phase has mentioned the allocation of the train and test also the related subsequent operation. The training scheme is different from the test scheme. It is because the learning algorithm operation is implemented in the training procedure. The test procedure does not have a process to conduct. After the decision tree algorithm is implemented in the training phase, the model will generate the classifier prediction using the allocation of the test data.

The classification metrics is performed to check the performance quality of the model. These metrics also consider the model whether it has already ideal or vice versa. To examine the model is ideal, look at the percentage of outcome produce by the metrics. If the metrics show that the accuracy and precision equal the perfect classifier, the model is ideal. Otherwise, the model is not ideal. This condition will refer to the hyperparameter tuning phase. The step is starting from the reload the command parameter of the data preparation phase. After the model is considered an ideal condition, then the model is finished. Save into the local disk to use the model repeatedly in the future. A new notebook is suggested to create for using the model, adding a new value of the related attributes, and the model will produce the prediction. The overall overview of the workflow is seen in figure 9.

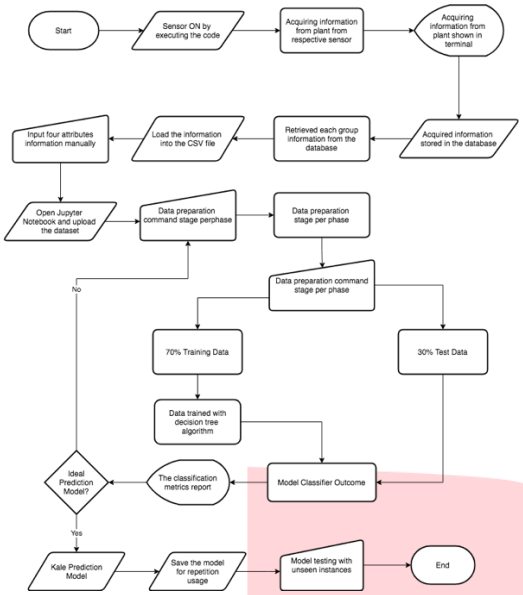


FIGURE 9
WORKFLOW OF THE GLOBAL SYSTEM

B. The Workflow of the Machine Learning

As the final phase of the system architecture, machine learning is expected to derive a prediction based on unseen instances. In creating the prediction, the amount of data must be huge to produce the best outcome of the model forecast. If the model forecast results are satisfied, then the outcome of the unseen instances prediction is not far. The prediction model architecture is divided into seven stages of machine learning: problem definition, data mining, data preparation, data visualization, data modelling, hyper parameter tuning, and model deployment as seen in figure 10.

The stages are started from the problem definition. The formulation of the problem solution looks at the type of data as the input. In this thesis, categorical and continuous data are used. The expected output is the type of plant condition label, which in string. Based on the problem analysis, this system will focus on the categorical attributes to make a prediction. The second stage is collecting the dataset. The process consists of mining the datasets scratch from the database and adding the manual observation attributes value to finish the dataset.

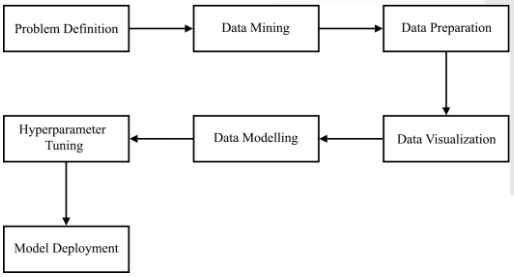


FIGURE 10
THE DIAGRAM BLOCK

C. Diagram Blocks of the Model Creation Architecture

The diagram blocks proposed in this thesis is initiated from the components and sensors calibration to the overall analysis of the global system. In providing a complete system explanation, the diagram blocks architecture is divided into three stages of technological usage: IoT, MySQL database, Firebase and machine learning. The comprehensive system for model creation is shown in figure 11.

IoT starts from the operation of the components and sensors used to acquire practical plant information. There are one device and three additional units, a sensor. The database used to store information gathered from the observation is one of the RDBMS type products widely used. Last, to use the information for advantage in the future, machine learning techniques are used based on input data to predict unseen instances.

In a related section of this chapter, an explanation of the application of the relevant parameters carried out as one of the phases included in the system will also be discussed. Starting from the system requirements for applications and devices to execute the designated system architecture other than IoT devices, namely laptops with the help of the platform. The collection of information obtained through sensors, which will be stored in a single file with the extension CSV, will also be discussed in the use of available attributes based on sensors and manual observations. The dataset separation method for modeling and the types of learning algorithms will also be explained. As for the performance review, this parameter analysis will be analyzed based on technology, QoS for data transmission from Raspberry Pi to localhost, then Raspberry Pi to Firebase to view data in real time and classification metrics for model results. The overall analysis is based on the results collected from each phase. This stage will be written to compile a complete thesis book.

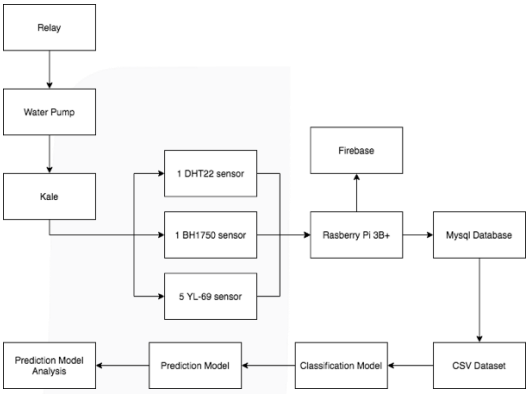


FIGURE 11
SYSTEM FLOWCHART

IV. RESULT AND DISCUSSION

A. Hardware Analysis

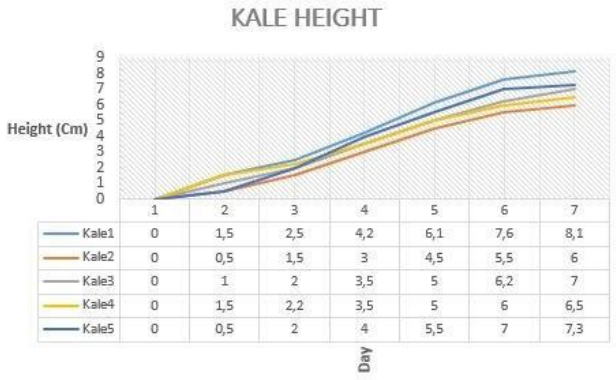
This section tests the system hardware to see if each hardware device used in the system is working properly. The following are the device states described in Table 3 below:

TABLE 1
HARDWARE TEST

No.	Hardware Function	Status
1	Raspberry Pi connected can receive dataand 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 plantsis not optimal the relay can work.	Success
4	When the relay status is on or if the relay status is off the water pump canwork.	Success

B. Monitoring Result Analysis

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



	1	2	3	4	5	6	7
Kale1	0	1,5	2,5	4,2	6,1	7,6	8,1
Kale2	0	0,5	1,5	3	4,5	5,5	6
Kale3	0	1	2	3,5	5	6,2	7
Kale4	0	1,5	2,2	3,5	5	6	6,5
Kale5	0	0,5	2	4	5,5	7	7,3

FIGURE 12
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. QoS testing was carried out for nine days after dataset retrieval, with the average of each QoS 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, from the test results obtained an average delay of 1,680 s for the smallest delay that occurs on day 1, which is 1.079 s, while the largest delay occurs on day 2, which is 2.130 s. The following is a graphical representation of the test results data.

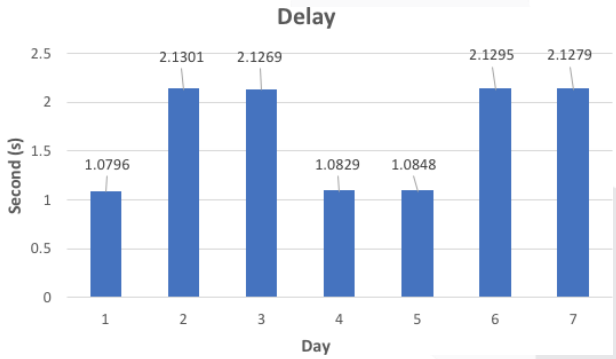


FIGURE 13
DELAY TEST ANALYSIS

Figure 14 below is the result of throughput testing that has been carried out, the average throughput from the tool to the database is 512.5 bps for the smallest throughput on day 2 of 355.0 bps while the largest on day 5 is 704.6 bps. The following is a graphical representation of the test results data.

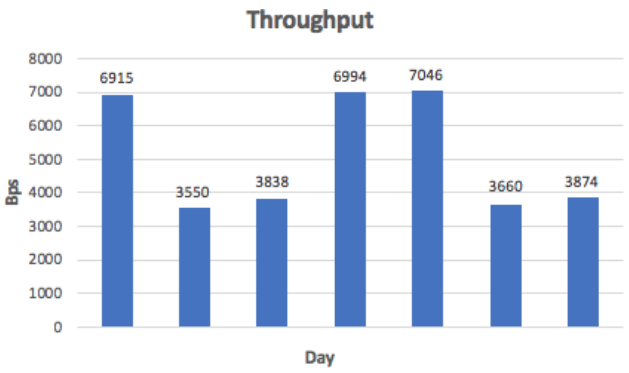


FIGURE 14
THROUGHPUT TEST ANALYSIS

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 4.2 below:

TABLE 2
DATABASE PAGE FUNCTIONALITY ANALYSIS

Test	Test Stage	Description	Status
Display dashboard page on web database	Dashboard access	Dashboard displayed on theweb database	Success
On the Dashboard displays informationon the condition ofthe 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 thekale plant	Dashboard access	Managed to display information on the growth of kale plant heighton the dashboard web database.	Success

E. Firebase Data Display Analysis

In this section, we show processing data between Raspberry Pi and Firebase. This test was performed to remotely monitor the results of red kale on the device. Here is the result of processing data between the Raspberry Pi and Firebase, as shown in the figure 15 below:

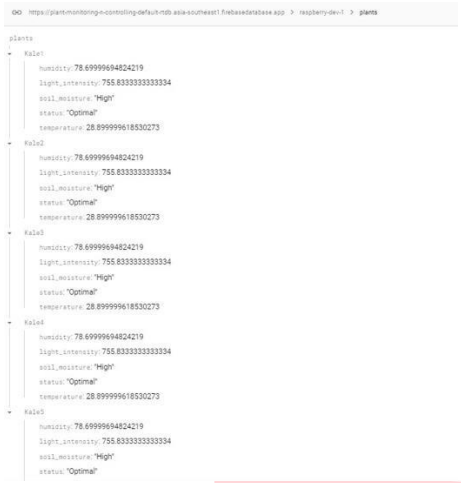


FIGURE 15
FIREBASE DATA DISPLAY ANALYSIS

F. Accuracy Score

In this section, the metric analysis method provides accuracy score information in addition to the content of the categorization report, because it is a special parameter. Figure 16 illustrates the process of determining the average accuracy score while Figure 17 illustrates the determined accuracy 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 16
THE OVERVIEW OF ACCURACY SCORE PROCESS

```
Decision Tree Performance Report for kale models:
Accuracy : 97.80 %
```

FIGURE 17
THE OVERVIEW OF ACCURACY SCORE

G. Confusion Matrix

In this section, measurements are needed for other performance characteristics classification tables, for example, Accuracy, Precision, and so on. The output of the confusion metric is illustrated in Figure 18 below.

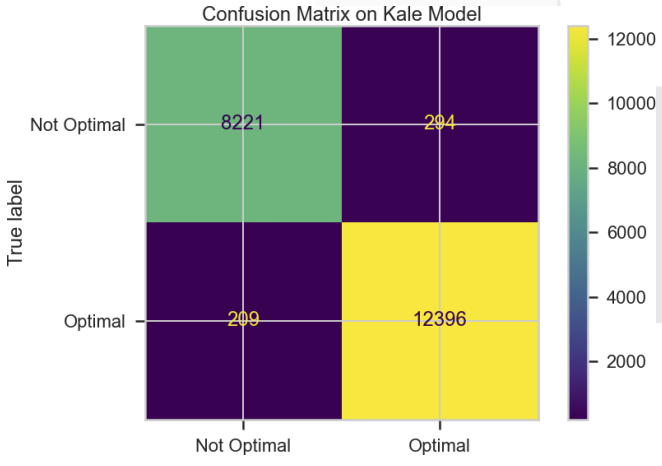


FIGURE 18
CONFUSION MATRIX

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 tabular 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 19
THE OVERVIEW OF CLASSIFICATION PROCESS

```
Decision Tree Performance Report for kale models:
Accuracy : 97.71 %
```

FIGURE 20
GENERAL DESCRIPTION OF THE CLASSIFICATION REPORT

V. CONCLUSION

Based on the results and analysis of this study, it can be concluded that the kale monitoring system, the database function and all the functions contained in it are running well, according to their function, the data transfer from the microcontroller can be stored in the database and can then be monitored by accessing the localhost microcontroller, the monitoring results get room temperature, humidity, and light intensity in the greenhouse which are affected by unstable weather conditions. In QoS testing, the average delay value is 1,680 s and the average throughput value is 5125 bps. Successfully created an RDBMS-based database in SQL form. The results of accuracy and precision reached a score of 97.80%.

The shortcomings of the emerging system can be used as research material in the future, namely the lack of cameras to monitor plant growth to make it clearer, need to add a pH sensor to measure plant acidity, provide a web server to monitor each plant, and increase the duration of data collection so that the resulting data conditions can be more optimal and precise.

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