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IoT Based Greenhouse Condition Monitoring System for Chili Plant Growth

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ABSTRACT

Over the last few years, most of greenhouses have been managed traditionally based on manpower to monitor and maintain the plants, such as watering, fertilizing, and using their skill in detecting plant diseases. Thus, this study focuses on developing a greenhouse monitoring system by using IoT technology. It aims to assist the local farmers in monitoring their greenhouse, instead of applying the conventional methods that are tedious and required more labour works. For data collection, parameters for chilli plants are measured using temperature and humidity sensors, soil moisture sensor, and light dependent resistor (LDR) sensor. The data are sent to microcontroller and transferred to the Ubidots cloud for the monitoring purpose. Watering pump and exhaust fan can be activated to control the plant parameters so that the plant remains in its normal condition. The sensor data are processed through classification using Support Vector Machine (SVM) to analyse the plant condition, whether the proposed method is suitable or not for the chilli plant to grow. Overall, a mini greenhouse prototype for chilli plant has been successfully constructed with a system interface on Ubidots dashboard to monitor the condition of the greenhouse plant. Results show that the developed system can be an alternative in monitoring the greenhouse condition with accuracy of 94.5%.

1. Introduction

As the human population grows, so does the demand for food. According to the World Health Organization (WHO), 70 percent of the world's food needs to be produced by 2050 [1]. There are many facilities and technologies that have been used in agriculture, to maximize their crops productivity. Greenhouses are one of the technologies that can maximize productivity, thus it will be the is the best way to maximize food crop yield under controlled environmental circumstances. According to Danita *et al.,* [2], a greenhouse is a closed structure designed to protect plants from elements such as the weather, animals, and other potential threats. Normally, the greenhouse is built from glass or clear plastic, to allow light transmission from the sunlight. In a greenhouse, the type of

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cover material seeks to allow plants to receive solar radiation easily [3]. The roof is usually covered with transparent material to maintain the necessary climatic conditions for plant growth such as temperature, humidity and illumination, as well as to protect the plants from pests, illnesses, and bad environmental circumstances [4]. Other than that, the greenhouse management system itself helps to control the parameters for crops grown healthily. Plant growth is influenced by the environment, and unstable environmental conditions can cause plant growth to be disrupted [5].

A greenhouse typically is a building made of glass or plastic, that protects the plant from external factors. The types of greenhouses are Spherical dome, Hyperbolic Paraboloid, Quonset, Modified Quonset (Modified IARI model), Gothic Arch, Mansard roof, Even span and uneven span [6]. Greenhouse farms can be used in a variety of different environments. In the event of extremely cold weather, "cold frames," a type of small-scale greenhouse farm, can be set up. A cold frame can help to retain the heat emitted by the sun while also maintaining the proper temperature for the plants. Shade house greenhouses, on the other hand, are used in dry and hot weather to provide shade and keep the moisture in the plants. Besides, there are a lot advantages of greenhouse technologies, for examples plants can be planted at any time of the year not only during the growing season, able to be protected from rainy seasons, storms, wind, and frost. Increasing the amount of plant by optimizing space, such as growing vertically, the ability in reducing the amount of fertilizer waste and controlling the pests and diseases. Moreover, to control the parameter for a plant in a greenhouse is much easier than to control at open space like the usual garden. The farmers can modify the soil acidity, the temperature, the humidity of the soil, the intensity of light and the other parameters by using the right techniques. According to Rayhana *et al.,* [4], the benefits of the greenhouse farms is including the ability to assist farmers in producing a variety of crops by altering local environmental conditions according to the plant's needs (temperature, light, moisture, nutrients). P. Dedeepya et *al.,* [7], stated that Green Houses are climate-controlled rooms where plants are physically inspected, temperatures are adjusted on a regular basis, and the number of pesticides and fertilizers required for cultivation is kept to a minimum by careful observation and testing.

Over the past few years, most of the greenhouse in Malaysia still apply the conventional way for managing their greenhouses. Most of the farmers only rely to their manpower to monitor the plants such as watering the plants, fertilizing the plants, used their experiences in detecting the diseases of the plants and others. Thus, it will affect the plants' health, because to keep the plant healthy it will need full care and precise decision making. Furthermore, for farmers that farm in the normal open space area, there will be a limitation of the light intensity due to the duration of light exposure. Basically, the farmers only rely on the sunlight exposure during the day for their plants. Next, to maximize productivity, the plant will need a longer light exposure. This is because light intensity can have a major effect on the photosynthesis rates, which are directly tied to a plant's growth capabilities. When the intensity of light increases, the photosynthesis process that will occur will increase too. Hence, the time for a plant to achieve its maturity state will be faster. It is important for a plant to achieve its maturity state faster as it will save a lot of precious time for the farmers to grow their plants.

There are a few types of control systems that can be applied in a greenhouse area such as irrigation systems and lighting systems which are for watering the plants and lighting up the surrounding when there is no sunlight. However, in greenhouse application, there are other significant parameters to be considered to increase the crop yield such as the temperature, the soil humidity, and the soil pH level. The method of the farmers used to monitor the plants is only by using their knowledge and experiences in farming. It is not wrong to use their experiences and knowledge, it will be better if the greenhouse farmers can monitor their crops based on the plant parameters that monitoring systems have provided. Some of the data that monitoring system have provide is where the farmers cannot see with the naked eyes, such as the acidity level of the soil, the soil humidity, the temperature of greenhouse, and the intensity of light, all this parameter does affect the plant growth.

Following that, by incorporating Internet of Things (IoT) technologies into the monitoring system, the farmers can precisely monitor their plant conditions. Implementation of IoT in agriculture can reduce the physical workload as in conventional way while increasing the production of crop yield. The efficiency of using an IoT platform in such works has been proved reliable rather than using the conventional method. The use of cloud networks to monitor the environment makes it possible, particularly in the agriculture industry, because it is well suited to harsh environmental conditions [8]. Furthermore, the application of IoT in agriculture is based on monitoring and controlling system where the user can monitor and control their crops condition from distance using their smartphones or computer.

This paper presents an IoT based Greenhouse Condition Monitoring System for Chili Plant on Ubidots platform. The remainder of the paper is as follows. Section 2 briefly explained the related works on Greenhouse Condition Monitoring System via IoT and Chili plant. Next, in Section 3 presented the system development and overall design approach. Section 4 discussed the experimental result of a Greenhouse Condition Monitoring System for Chili Plant via IoT Cloud performance. Finally, Section 5 provides the concluding remarks and points out the ideas for future extension of this work.

2. Related Works

Chili pepper or “capsicum” is one of the popular fruits where all around the world would have used it, according to Kim *et al.,* [9], The most popular spice and vegetable in Korea is red pepper (Capsicum annuum L.), which is a fundamental ingredient in traditional cuisines like “gochujang”, a red spicy pepper sauce, kimchi, and fermented vegetable snacks. The most essential quality factors cited by Korean customers are pungency and color. Capsanthin, the primary red pigment and peculiar to the capsicum species, is the emblematic pigment of red pepper. Long chains of double bonds that finish in one or two polar ketones absorb green light effectively, producing a red orange color. Chili is a popular vegetable in

Indonesia, and it has a high value in term of economic sector [10]. Chili is a top industrial vegetable crop, not only for its commercial value, but also for the nutritive and therapeutic benefit of its fruit, which is used to color and taste dishes, and chili fruits are noted for having a healthy balance of antioxidant vitamins A, C, and E [11]. Cayenne pepper is a kind of chili, the fruit of which is utilized for a variety of culinary reasons. It is a sort of plant that requires a certain amount of water to maintain crop quality [10]. The plants are classed as either single plants or short-lived plants that grow like straw and reach a height of 1.5 meters. In terms of growing the chili plant, there are a lot of parameters that should be take into account such as the temperature of the air, the humidity of the soil, the acidity of the soil, the light intensity and the others. Hidayat *et al.,* [5], in his study revealed that Chili plants necessitate regular watering. If water is given in excess, it can generate high humidity in the root area, which will encourage the spread of fungal and bacterial disease to the point of death. If there is a water scarcity, pepper plants can become thin and dwarf, wilt, and die.

The study in paper [12] using IoT to detect soil moisture and measure plant height with an addition of an automated system that can control the rate of fertilizer applied to the chili plants, as well as a water pump that supplies water to the chili plants via Remote XY Apps. Fares M. A. Taha *et al.,* [13], in his study revealed that within the IoT technologies, farmers can monitor their greenhouse online every 24 hours, regardless of time or location. In his studies, he had proposed a system that captures greenhouse characteristics such as temperature, relative humidity, and light intensity and sends them in real time to a raspberry pi acting as a server using internet of things technology. This system is made up of sensor nodes, a collection and control unit, a monitoring unit, and an actuation unit. Moreover, before the acknowledgement of IoT in the greenhouse industries, the farmer used the traditional method to control the parameters in a greenhouse, which requires a lot of physical activities. Many issues might arise because of this, as it has an impact on the production rate because temperature and humidity must be regularly controlled to ensure the plants' healthy output.

Bounnady *et al.,* [14] had proposed a crop cultivation monitoring system to help farmers in obtaining real-time data on soil moisture, temperature, and humidity on the field. The study using Firebase cloud as a platform for the data, while NodeMCU ESP8266 is the microcontroller. The proposed system was beneficial in terms of growth rate, productivity, and water conservation and the farmer can use the app to monitor and alter parts of the system's values. Besides that, Vimal *et al.,* [15], had proposed to create a simple, low-cost Arduino-based system that continuously monitors and controls the values of environmental elements in order to achieve optimal plant development and output. Global System for Mobile communication (GSM) had been used as a platform to send a Short Message Service (SMS) to the user for informing the status, while the microcontroller for the study is Arduino Uno. The system had successfully achieved his objective which is to control and monitor the greenhouse by using a low-cost budget.

The Ubidots IoT Cloud platform is already used in various IoT application such as in alert on LPG gas leakage [16,17]. It provides internet of things (IoT) platform that can link the hardware and software for monitoring, controlling and automatic process for riverbank monitoring [18]. The IoT based greenhouse [19-21] with adoption of machine learning also had been presented in previous studies. [22-26]. This IoT platform provide dashboard to visualize the data collected from sensor node monitor by user. It can also be used to automatically send signal on actuating the monitored sensor node using event manager or using manual actuator.

Therefore, this work opted to focus on implementing a greenhouse monitoring system by using IoT technology for Chilli Plant on Ubidot IoT Cloud. This will help in assisting the local farmers in monitoring their chilli plant in greenhouse with less labour works.

3. Proposed System and Methodology

In this project, a prototype of a greenhouse monitoring system for chili plants via IoT platform is proposed. The research work is focusing on using the chili plant (capsicum annum) as main product. The parameters that will be analyzed are the temperature, the humidity of soil and the intensity of the light. All these parameters are known to be the main factors that affect the growth of chili plants. Next, there the collected data will be used to classify the plant growth by using the SVM algorithm classifier. The dataset that will be used for this classification is from the data collected, temperature and the humidity of soil data. The best condition for the chili plant to grow healthily is identified. The software that will be used for this classification process is MATLAB software.

3.1 Block Diagram

Figure 1 shows the block diagram of a greenhouse condition monitoring system, there will be two sections of the system which are the monitoring section and the controlling section. The monitoring section consists of all the sensors which are the DHT 11 sensor (humidity and temperature sensor), the soil sensor and the LDR sensor (light sensor). NodeMCU ESP8266 will be used as a Wi-Fi module to send the data to the cloud platform, Ubidots. Next, for the controlling section, it will be the actuator which can control the parameter of the crop, the actuators are the exhaust fan, the water pump, the LED light.

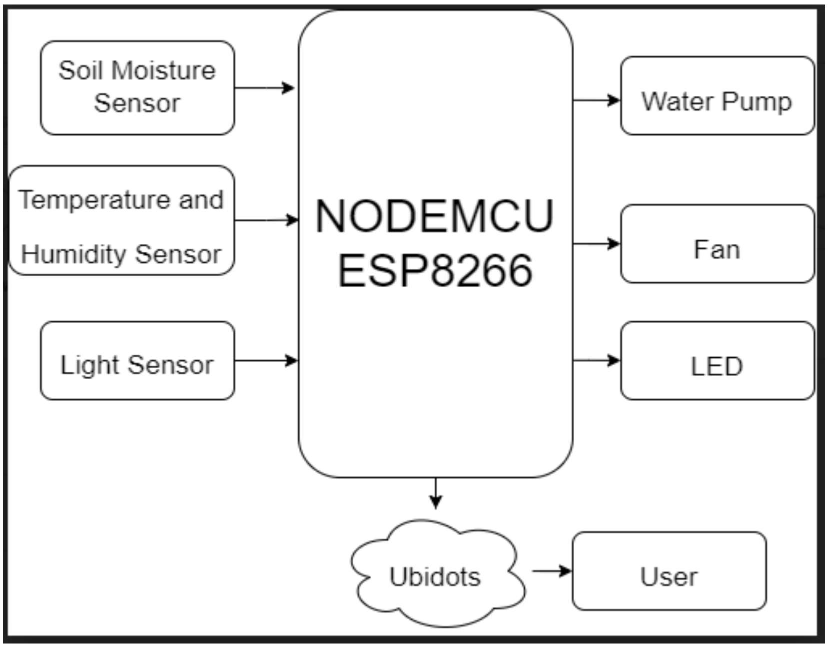

Fig. 1. Block diagram of Greenhouse Condition Monitoring System

3.2 System Operation

The system operations begin with the initialization of NodeMCU ESP8266, and all the sensors (LDR sensor, DHT 11 sensor, soil moisture sensor).

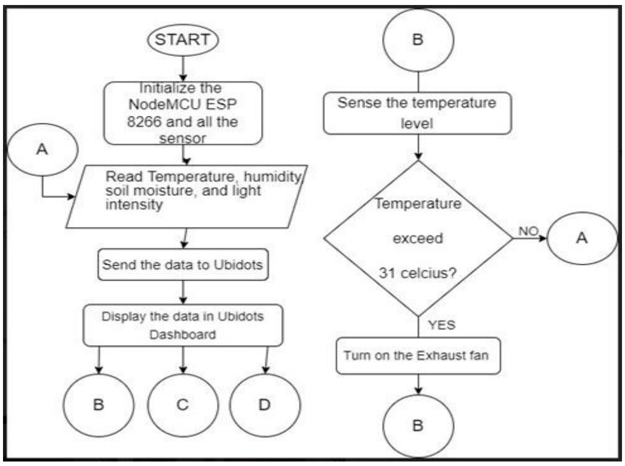

Fig. 2. Flowchart 1 of Greenhouse Condition Monitoring System

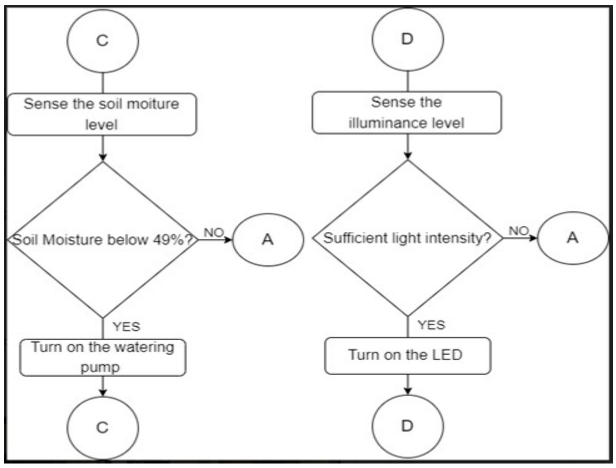

Fig. 3. Flowchart 2 of Greenhouse Condition Monitoring System

Then, all the sensors will take the reading value of the current parameter from the chili plant and send the data to the microcontroller. Next, the data will be sent to Ubidots cloud, to display the current parameters of the chili plant on the Ubidots dashboards. Besides, the system can control the actuators to maintain the greenhouse condition. Figure 2 and 3 shows the flowcharts of greenhouse condition monitoring system.

3.3 Hardware Development

Figure 4 shows the schematic diagram of greenhouse monitoring system that was implemented in the real-time circuit. The figure shows the sensor, microcontroller, the sensors, and motor used in this project. In addition, the relay, battery and diode will be need to simulate the motor, it is because the relay will acts as a switch for the motor and the diode will make the current flow in one direction, and for the battery, the microcontroller only can supply up to 5V, but there is another load for the microcontroller to supply such as the sensor, the led and the others, thus to run the motor, it will need external factor or battery to supply it, because the motor will consume a lot of voltage to run. However, during the hardware development, the microcontroller that was used only NodeMCU ESP8266, it is because the NodeMCU itself is a microcontroller and the pins are sufficient to connect to the loads.

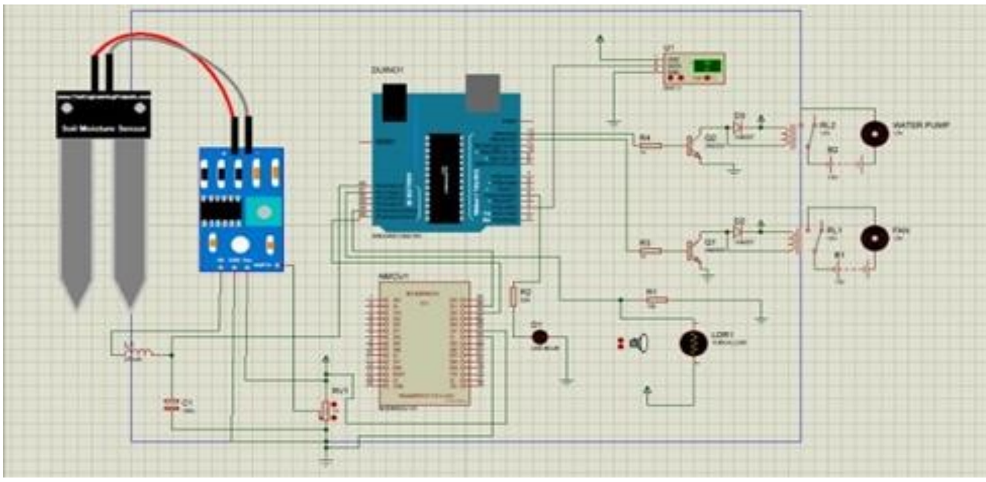

Fig. 4. Hardware Schematics Diagram of Greenhouse Condition Monitoring System

Thus, the Arduino microcontroller is not used in this study. The hardware part consists of NodeMCU ESP8266, temperature sensor, soil moisture sensor, LDR sensor, pH sensor and relay board. The pH sensor was added in this study, to give an extra parameter for classification. The component ratings are shown in Table 1.

Table 1
Hardware Specification

No	Component	Specification
1	Temp & Humidity sensor (DHT11)	Temperature range: 0°C to 50°C Humidity Range: 20% to 90%
2	Soil Moisture sensor (YL-69)	Operating voltage 3.3V-5V Module dual output mode
3	LDR sensor	Max voltage (0 lux) 200V Peak wavelength 600m Minimum resistance (10 lux) 1.8kohm
4	PH Sensor	Module Power: 5.00V. Measuring Range :0-14PH. Accuracy: ± 0.1pH (25 ℃) Response Time: ≤ 1min.
5	NodeMCU ESP8266	Operating voltage 3.3 V Input voltage 7 to 12 V 16 digital I/O pins 4 pins for Serial Peripheral Interface (SPI) communication

		Flash memory 4MB
6	Relay Module	12 V four channel multifunction remote relay 4 channel wireless controller

3.4 Data Classification

Machine learning is one of the branches in AI technology, it is only focused on developing data that increases their accuracy over time without being coded. the engineer can classify the data by using the algorithm from the machine learning, there a many different types of classification in machine learning for example, binary classification, multi class classification, multi label classification, and imbalanced classification. For each classifier have a lot of algorithm types, such as logistic regression, k-nearest neighbors (KNN), decision tress, SVM, naive bayes and others. In this project, SVM is used as the classifier. The data will be classified into two classes, which are normal and not normal. The normal condition is where all the parameter is in suitable range for the chili plant to grow healthily, and for the not normal condition, all the parameter is in non-suitable range for the chili plant, which it will affect the chili plant growth such as stunted plant, withered leaves, and yellow leaves. Table 2 shows the parameters and ranges of normal and not normal conditions for the chili plant growth.

Table 2
Parameters and Conditions of Chili Plants

Parameter	Normal	Abnormal
Temperature	25-30	24 and below 31 and above
Soil Moisture	50%-60%	49% and below 61% and above
PH Level	6—6.5	5.9 and below 6.6 and above

4. Results

Figure 5 shows the prototype of mini greenhouse that has been developed. The type that has been built for the prototype was an A-frame type, which can give the advantage to maximizing the intensity of light receive. Besides, the A shaped greenhouse can provide wider surroundings so that the plant can be thoroughly monitored. The fans were attached at the top of the greenhouse because the high temperature of air is lighter than the low temperature of air, so that, it can export the high temperature in the greenhouse to the outside of the greenhouse efficiently. Next, for the LED, it will be on the pillars of a greenhouse, so the LED can provide sufficient illuminance for the chili plant. The data collection was conducted over 5 weeks, the parameters of the temperature, pH level and soil moisture were taken every day, from 8am till 6 pm and the readings were displayed on the Ubidots dashboard in real-time such as in Figure 6. The pH sensor was calibrated regularly since the electrode of the pH sensor is quite sensitive over the time.

Fig. 5. Hardware Prototype

Fig. 6. Ubidots Dashboard

Figure 7 shows the email notification that has been sent from the Ubidots cloud to the user. The notification service was running throughout the project development and all the important information about the plant condition was received successfully by the user. Therefore, the user can monitor the plant condition even when the user is not available or out of range within the greenhouse area.

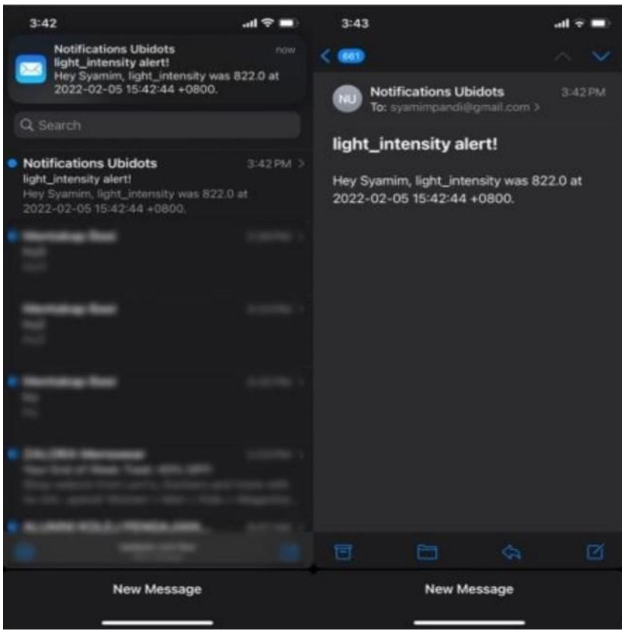

Fig. 7. Email Notification

Figure 8 displays the performance for temperature parameter throughout the study that was conducted. Based on the figure, it shows that there was a time the temperature was increasing and decreasing. The temperature parameter will be followed by the daylight situations, which means, when the daylight approaches noon (12 pm to 3 pm) the temperature will increase. Although there are fans to reduce the temperature, it still not enough to make the temperature drop rapidly. The fan succeeds in dropping the temperature to 1-2 degrees Celsius only. The temperature will decrease when daylight conditions are in the night or in the morning.

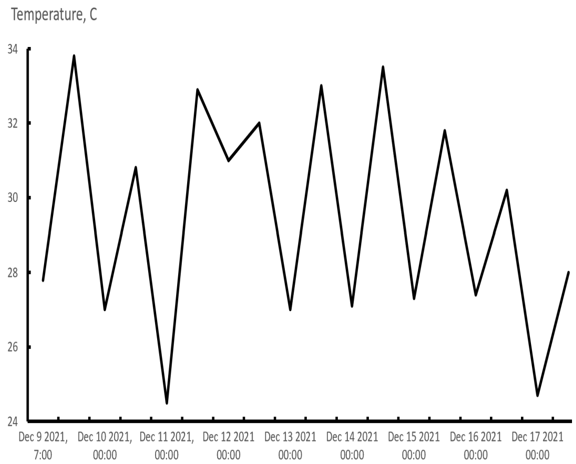

Fig. 8. Performance of temperature parameter

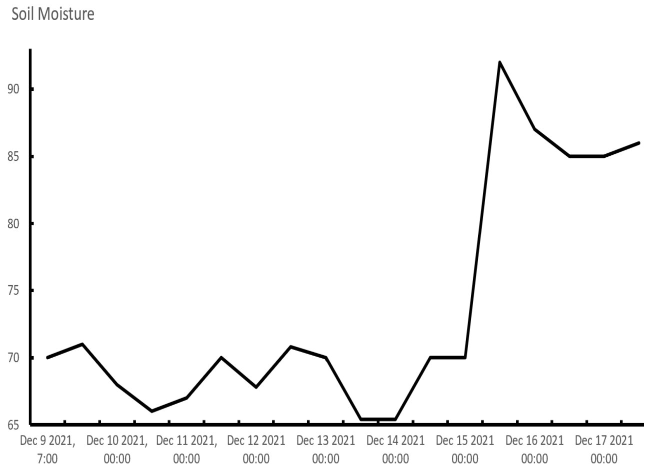

Fig. 9. Performance of soil moisture parameter

The performance for soil moisture throughout the study is shown in Figure 9. The soil moisture parameter and the temperature are related, because when the temperature increases, the soil moisture will decrease. It is because the water in the soil will evaporate when the temperature is high. The soil moisture will increase when the temperature decreases, it is because there is no evaporation process that occurs during that time. Based on the figure, there was a time that the soil moisture suddenly increases, it is because, the water pump accidently flows the water directly to the sensor, because of that, the sensor will keep reading a high value for soil moisture.

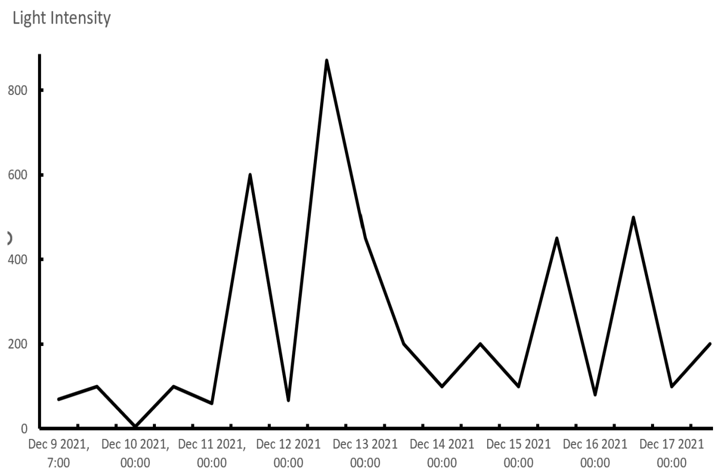

Fig. 10. Performance of light intensity parameter

Figure 10 shows the performance of light intensity throughout the study was conducted. The light intensity will decrease when the illuminance level is higher. The illuminance level range in sensor is set to 1-1000, 1000 is the dimmest and 1 is the brightest. Based on the figure, the light intensity increases because of daylight situations, when daylight is night, the illuminance level is higher, and when it’s in the morning, the illuminance will be lower.

For data analysis, a classification was carried out based on chili plant parameters using SVM classifier. The dataset was classified into normal and not normal condition. The performance of SVM classifier was then compared with other classifiers, i.e., K-Nearest Neighbor (KNN), Naive Bayes and Logistic Regression in terms of accuracy and error rate. To perform this data classification, the platform that was used is Classification Learner App in MATLAB. The confusion matrix and the scatter plot from Figure 11 and Figure 12 are the result after running the SVM classification on the dataset.

Fig. 11. The Confusion Matrix for SVM Classification

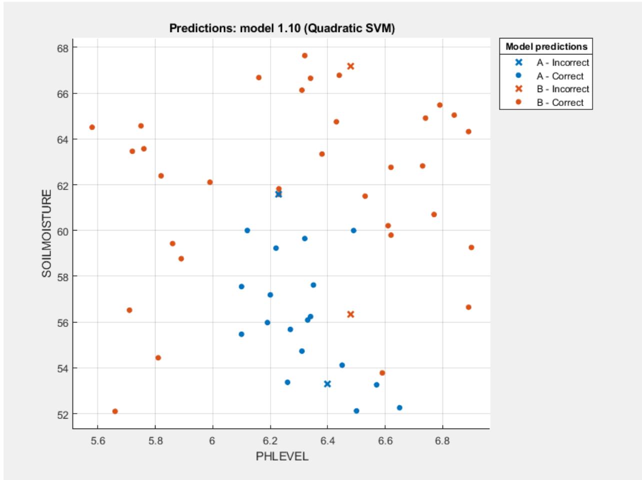

Fig. 12. The Scatter Plot for SVM Classification

Based on Figure 11, it shows that 27 data is in true positive which mean that the system correctly predict the parameters data while 2 of the prediction are in false positive which the system wrongly predict the parameters data. Next, 2 prediction was in false negative and 42 is in true negative which the system correctly predicts the negative prediction. The scatter plot in Figure 12, shows that only 4 is incorrect during the model prediction process.

From the result, the accuracy for the SVM algorithm is 94.5% which is the highest than the other classifiers. Table 3 shows the highest obtained by each classifier accuracy during the classification process. Furthermore, the error rate of the SVM classifier is the lowest compared to another classifier which is 0.05. Thus, based on these results, it can be seen that the SVM classifier is the most suitable for this project.

Table 3
Accuracy of Different Classification Algorithm

Algorithm	Accuracy	Error Rate
Support Vector Machine	94.5%	0.05
KNN	89.0%	0.11
Naïve Bayes	89.0%	0.11
Logistic Regression	74.0%	0.26

5. Conclusions

In conclusion, a greenhouse monitoring system has been successfully developed in this project. The data of chili plant parameters can be monitored on Ubidots dashboard. The system performance was analyzed by performing classification based on the chili plant conditions of normal and not normal using SVM classifier. The results have been proved that the system is reliable with the highest accuracy of 94.5% compared to others selected classifier. For future works, the system can be expanded towards real application with a larger scale implementation. Hence, it is recommended to install an intelligent camera which can detect the ripeness of the fruit. It will be easier for farmers to collect their products because the farmers can easily monitor the ripeness of the fruit through their phone. Next, it is recommended to develop computing system platform services for smart greenhouses with a variety of service characteristics such plant disease recognition.

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