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Smart Agriculture Systems Monitoring and Prediction Platform Using Big Data Analytics Together with Internet of Things

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The purpose of this research were to present Smart Agriculture Systems Monitoring and Prediction Platform Using Big Data Analytics Together with Internet of Things. This research is divided into two parts. The first part is hardware section and the second part is software section. The hardware section is Internet of Things (IoT) technology, divided into 3 parts, including 1) The watering and fertilizing controlling systems. It works by using a wireless network, 2) crop parameter monitoring system, and 3) crop parameters receiver system. The second part and third part is use LoRa technology for sender and receiver data transfer to cloud database. The software part is farm management that works on smartphones for farmer section to manage information such as crop management, plantation management and cost management, which farmers can know the costs and expenses incurred in each crops. When the volume of data collected that large, it becomes big data. It can be used in big data analytics to help the farmer in various ways and it can also be used to predict future trends as well. The research show how to develop a Smart Agriculture Systems by integrating various technologies to achieve smart operations, automatic works, reducing labor costs and promote the application of technology and innovation use for agriculture in the digital trends.

Keywords: *Monitoring and Prediction Platform, Smart Agriculture, Big Data Analytics, Internet of Things*

1. INTRODUCTION

We are undeniable that in the past several decades, most of the people of Thailand still have low incomes. Due to being affected by economic problems that have slow growth. The government has set a policy to accelerate the Thai economy that wants to change the model of economic development and Thai society to a new model known as the Bio-Circular-Green Economy Model (BCG) by using scientific mechanisms. Technology and innovation to produce high-value goods and services and change the economic system from "Do more but get less" to "Do less but get more" for the purpose of agricultural sector. Including encouraging entrepreneurs who are ready able to produce products with a higher level of technology and innovation. Encourage farmers to bring smart farm technology adapted to increase efficiency and productivity, this will reduce production costs and still produce safe results. Achieving stable quality and quantity that meets market demand. It can also bring safe and stable products to be processed for higher value (National Science and Technology Development Agency, 2020).

Farming today has evolved with the times and advances in technology. Machines, tools, and various information technologies have been introduced. However, today's agriculture uses sophisticated technology to perform more diverse tasks. To achieve accuracy in farming, such as environmental sensor robots aerial photography and GPS technology, precision farming, make the farming process efficient. It is safer and more environmentally friendly.

From the continuous research and development of technology, especially the Internet of Things technology that creates a variety of changes and unpredictable applications. We found that many modern technologies have been applied for our daily life. Therefore, it plays an important role to create a modern city system, transportation system, health care system, security systems and many others, including agriculture which known as smart farming systems (Rehman A. et al, 2022). At the present, it is found that the agricultural sector is popular in adopting a large number of IoT technologies. Technology is constantly evolving, especially digital technology, internet technology and wireless sensor network technology, to be used to detect the environment in various fields and develop to have higher abilities evolving into smart, small embedded systems compatible with various sensors; agriculture soil sensors, meteorological weather sensors, water quality sensor and sensors for use in crop cultivation, etc. These sensors can also gather information that is important in agricultural production. IoT has become popular for application in various fields, even in the growing agricultural sector. Innovation dynamics lead to change of the agricultural production sector in addition to improve agricultural productivity (Xu J. et al, 2022), IoT can also effectively improve the quality of agricultural products. Reduce labor costs increase farmer's income it has smart work, There is intelligence that comes from integrating with other technologies (Xu J. et al, 2022). There is important information in all aspects of seeding. Such as environment information, plantation management, plant information, real-time data collection and combined into big data.

Therefore, it is necessary to study to find the best solution. So that agricultural technology can meet the needs of farmers at all levels, especially small-scale farmers, to be able to develop sustainable production. Flexible production system and reduce emissions to cope with climate and variability that will occur in the future. The researchers presented Smart Agriculture Systems Monitoring and Prediction Platform Using Big Data Analytics Together with Internet of Things, it is a new approach that brings knowledge of IoT, wireless sensor networks. Internet technology and big data are integrated with applications. In the application of agricultural management. Which needs to be developed all factors that affect productivity in every step of melon cultivate in Chiang Rai, Thailand. Therefore, this article is about the development of smart agriculture using IoT and can be practical for farmers.

2. LITERATURE REVIEW

Internet of things (IoT)

The Internet of Things (IoT) is a network of physical and tangible devices, vehicles, home and office appliances, and other objects integrated with electronics, software, sensors, actuators, and connections that enable these objects. This can connect and exchange information, everything can be clearly identified by the embedded computing system. Which they can interoperate within the existing internet infrastructure, also a computer device system that connected to each other. Including mechanical and digital, objects, animals or people are issued with a unique identifier for the bearer and capable of transmitting information over a non-human, human-to-human network or human-computer Interaction (Oforji et al, 2018). It is one of the emerging and promising technologies to revolutionize information as part of the advent of the Internet. IoT is a large intelligent network that links a large number of objects. That can communicate through the Internet to exchange information and integrate devices together through standard protocols. Able to work intelligently such as searching, tracking, monitoring, and managing things. It is part of the Internet network that supports connections between people and between objects (Wesam Ibrahim et al., 2022).

2.1.1 IoT Architecture

The IoT architecture network has four functional hierarchies (Patel, K. K., & Patel, S. M., 2016).

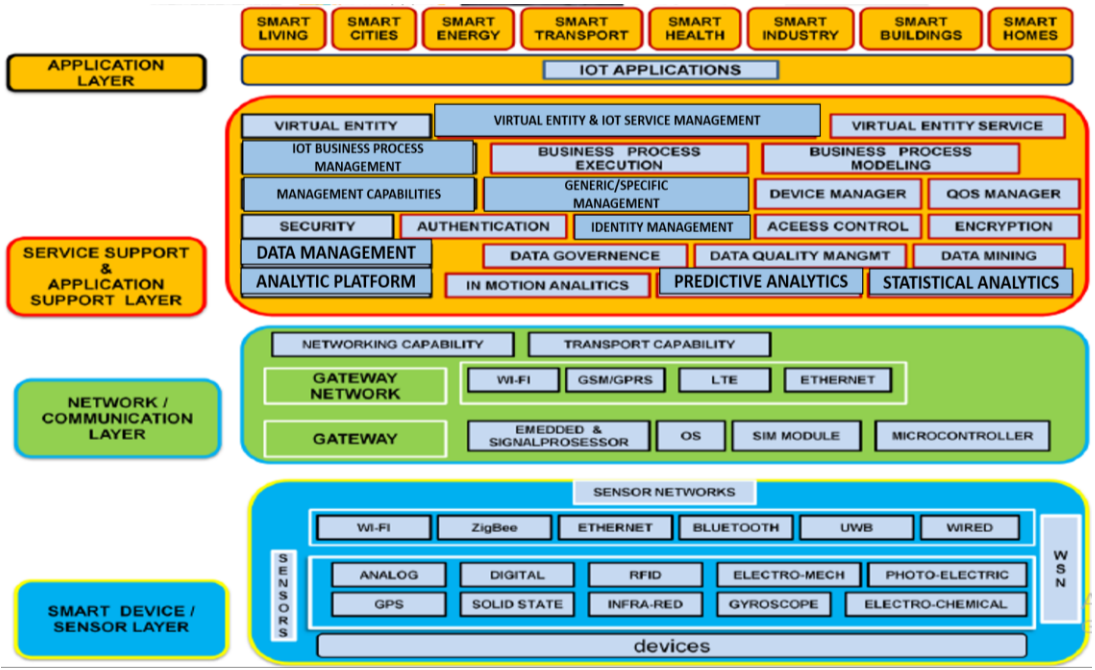

Figure 1. The hierarchy of the Internet of Things
Source : (Patel, K. K., & Patel, S. M., 2016)

Figure 1 describes the hierarchy of the Internet of Things. It consists of the following hierarchies.

Smart Device / Sensor Layer

Smart device / Sensor layer are the lowest layer of the Internet of Things architecture consist of devices and sensors. Which serves to connect between the physical and digital worlds, enabling real-time data collection and processing as the following qualification;

1) Be able to measure air temperature, velocity, humidity, pressure, motion and current, etc. There may be some memory to save measurements in some sensors.
2) Be able to measure physical values and convert them into understandable signals in the form of digital signals.
3) Be able to connect to network gateways within Local Area Network (LAN) such as Ethernet, Wi-Fi connections, Personal Area Network (PAN) (ZigBee, Bluetooth and Ultra Wideband (UWB))
4) Unnecessary to be connected to a server or data management module in some sensors.
5) Be able to provide by network outside Wide Area Network (WAN) as GSM, GPRS and LTE.

Gateways and Networks

The huge amounts of data generated by various sensors, the network infrastructure that mediates the transmission of data requires high performance, either wired or wirelessly, as today's networks tend to use different protocols. Each device can send data between each other (Machine to Machine M2M). According to the application, the popularity of the Internet of Things services is increasing, such as high-speed transaction services in various contexts. Different networks use different technologies and protocols. These networks can be in the form of private networks, public or consolidate network to support or security system of gateways and various gateway networks.

Management Service Layer

The Management Service Layer enable analytical data processing. Security controls, modeling processes, and device management. Which an important features of the Management Service Level are the business tools and process rules of the Internet of Things.

Application Layer

The connection and interaction of objects and systems together to obtain information in the form of events or information as needed

2.1.2 Basic Feature of Internet of Things

Basic feature of Internet of Things consist of seven parts:

1. Connecting devices can be linked to global data and communication infrastructures.
2. Servicing the device; the Internet of Things has the ability to provide services to various connected devices under the limitation of devices such as privacy protection.
3. Diversity devices are different but can communicate and interact with each other, such as hardware, networks or services.
4. Constantly changing; Devices are constantly interacting/changing such as sleeping and waking up to connect and/or disconnect, as well as device context including location and speed. In addition, the number of devices can change at any time.
5. Multiple devices; that need to be managed and communicated with them will at least take precedence over current internet-connected devices. The key is efficient data management.
6. Security; creators and users of the Internet of Things must be designed to be safe both in terms of device and personal data.
7. Connection; that allows a device to access the network in order to use it.

2.2 Big Data

2.2.1 Definition of Big Data

Big data including high volume of data (Volume), in a variety of formats (Variety), and rapidly changing (Velocity). It can be used to analyze, synthesize, support planning decisions to drive the works, respond to the need for improve the quality of life quickly, accurately and sustainably (Sak Sekkhuntod, 2017). Big data is high volume of data have high speed and/or highly diverse data, requiring new forms of efficient and cost-effective data processing that enable a better understanding of decision-making and automated processes. Data volumes have a fast rate of data accumulation and they are either unstructured or semi-structured structure, which traditional database systems cannot handle. Unlike traditional data, big data means huge increases. Data comes in many formats both structured semi-structured and unstructured complicated It requires highly efficient technology to process information. Therefore, traditional tools cannot be used effectively in data processing (Oussous, A. et al, 2017). Big data is an abstract concept. In addition to the large amount of information, there are other features, which generally still have different opinions. Big data typically refers to data sets that cannot be manipulated and processed with traditional methods or technologies and software/hardware tools (Chen M. et al., 2014).

2.2.2 Characteristics of Big Data

Nowaday, characteristic definition of Big Data is comprised of five essential attributes (5Vs): Volume, Variety, Velocity, Veracity, and Value.

Volume refers to a high volume of data. Volume sizes range from Terabytes, Petabytes, to Zettabytes.

Variety refers to complex data such as structured data, semi-structured data, or unstructured data.

Velocity refers to data that changes rapidly over time.

Veracity refers to data is accurate.

Value refers to data has value.

2.2.3 Benefits of Big Data

Benefits of Big Data are many things but two things are clear:

1. Analytical Use is the analysis of those high volume of data to reveal deep hidden knowledge, such as weather data from satellite detectors, balloon radar, weather craft and ocean buoys; and

2. Enabling New Products: Big data with high volume of data can be used to create products or develop services to suit the needs of customers or users such as delivery service Reservation or ticketing service Money transfer service (Dumbill, 2012). Big data has triggered a data revolution in agriculture. The information can help farmers make informed decisions. Choose to produce agricultural products that meet the needs and meet the standards can prepare against climate change and as a tool to accelerate adaptation. Helping the government in designing government policies to fix the problem on the spot helping the private sector in research and development of technology efficiently, answering questions and can be used in practice (Niphon Puapongsakorn, 2017).

Organizations or companies use it as a guideline for product development. By applying new technologies and innovations to analyzing big data. To use the results from the analysis to improve and plan the work of the business as well as to reduce operational risks and reduce the high cost of purchasing and upgrading the hardware needed to handle large amounts of data.

Managing and analyzing big data will provide opportunities to conduct business efficiently and effectively in line with changes in information that are available immediately and over time (Panida Tansiri, 2013).

Examples of leveraging big data include: South Korea uses big data to recommend adding or relocating bus stops to be appropriate according to the changing city conditions in 2 parts: the first part, the information obtained from the system is areas inaccessible by buses and bus usage information. The second part is the data used in the analysis. Traveler location data from mobile phones, credit card usage data, bus's ticket data and data from social media (Sak Sekkhuntod, 2017). In the field of smart agriculture, development has been focused on the use of information and communication technology to manage farms with new technologies such as the Internet of Things. Cloud computing Robots and Artificial Intelligence. This is the acquisition of big data that can be analyzed and used for decision making. Make decisions, applications of big data in smart agriculture create huge socio-economic challenges affects the entire food chain big data is used to gain insights, apply forecasts in agricultural operations, drive real-time operational decisions and design business processes for business models changed (Wolfert, S. et al., 2017). In addition, big data has been applied to predict watermelon quality from vibration. So as not to damage the watermelon. It is difficult to determine the quality of watermelon by size or skin color. It was found that the vibrational response. It is useful for analyzing the quality of agricultural products. The stepwise approach is a method to extract the most suitable data to model for predicting fruit quality.

2.2.4 Big Data Analytics

Big data analytics and deep learning are two areas of data science. Big data has become important as many organizations, both public and private, receive massive amounts of data that may contain useful information. Such as national intelligence, cyber security, fraud investigation, marketing and medical data. Other companies such as Google and Microsoft are analyzing vast amounts of data for analytics and making business decisions, impacting existing and future technologies. Deep learning algorithms extract abstract information. The complexity of the complexity is expressed through a hierarchical learning process (Najafabadi M. M. et. al., 2015). When the advancement of digital technology making our world produce a huge amount of information every second. Most of the data generated is open data on social media, as well as data produced by various sensor devices around the world. The huge amount of data we know as "Big Data" coming into role and is a national issue. Many countries have announced big data analytics as a national strategy. Big data analytics will open up many opportunities for government organizations to create. Employment in new jobs for the country as a whole. Create knowledge more quickly in research and development (R&D) and create rapid growth for SMEs to enable the government to administer the country more efficiently many well-known research houses agree that big data analytics is a powerful tool. The needs for government of all countries to drive the administration of national affairs effectively and driving the economy to keep pace with the technological change in the 21st century

(Setthapong Malisuwan, 2017) from the advancement of technology artificial intelligence (AI) mobile phone social networks and the Internet of Things (IoT) are creating complex information and new format of big data analytics is to apply advanced analytical techniques to large and diverse data sets containing structured, structured and unstructured data from different sources and at different sizes (Oussous A. et al., 2017)

2.3 Smart Agriculture

"Smart Agriculture" has come to play a role in the agricultural sector. In which various countries have given importance to the development of the country continuously. It is a new innovation of agriculture in the digital age. To take many aspects of digital technology to be used in the farm (Jakrit Manwicha, 2015) integrated crop management system that is suitable for each crop (Davis et al., 1998) or may be described as a management method resulting from the introduction of digital technology and appropriate work methods that enable farmers to grow crops more accurately (Blackmore, 1994), starting with data such as moisture content, nutrient content, local weather in spatial data analysis such as image technology, remote sensing and UAV. These technologies help create maps showing planted area information and plot-by-field information. Accurate and fast lead to the decision to use the factors of production by converting (Office of the Science, Technology and Innovation Policy Office, 2015) Smart Agriculture or High Precision Agriculture (PA) It is the introduction of science and digital technology to be applied as a tool to create convenience comfortable and easy to manage agriculture Helps to process quickly, accurately and precisely, reducing waste and making efficient use of resources. It is a farm management system that incorporates data and technology to analyze and manage environmental uncertainties (Singh A. K., 2010). To increase the quantity and quality of produce, reduce costs, increase safety for consumers and the environment to achieve greater efficiency. There can reduce the use of labor for agriculture more. Due to the current reduction of labor in the agricultural sector (Krisada Chuenjit, 2016), agriculture is coupled with innovation (Shashwathi Priyam & Suhas, 2012).

3. METHODS

In this research, the researcher demonstrates with the following steps.

3.1 Step of study process

In this study process, the researcher has studied of problems, obstacles, concepts and theories in agriculture from the beginning to the harvesting process, farm management and knowledge of the local wisdoms. To be used in the system design step and processes step of smart agriculture.

3.2 Step of system design

In this research, the researchers studied the cultivation of melons grown using bags, drip irrigation and planted in greenhouses. The researcher divided the design into 3 parts as follows.

3.2.1 First part : Water and Fertilizer Control System. It is IoT system that controls the operation of water pumps and fertilizer pumps as shown in Figure 2.

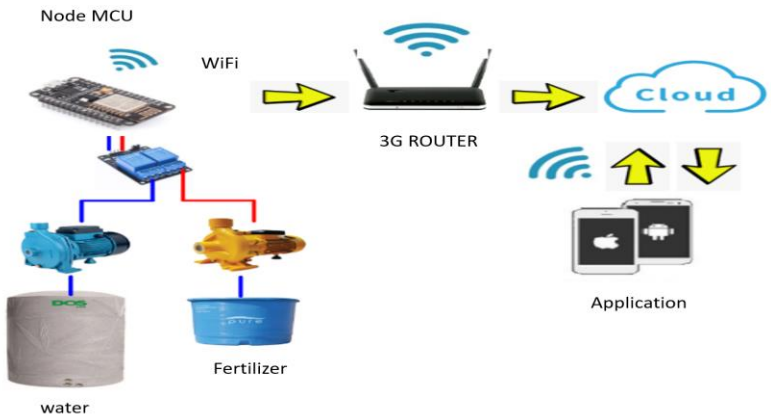

Figure 2. The water and fertilizer control system

From Figure 2, the NodeMCU ESP8266 acts as the main controller and controls the operation of the relay switch module 2 channel to controls the power on-off of the water pump, channel 1 controls the operation of the fertilizer pump and channel 2 controls the operation of the water pump. Which in the operation of NodeMCU will serve to connect to the Internet network system via 3G Router WiFi for connect to the database on Cloud Computing, keep command checking and working conditions from users through mobile applications.

3.2.2 Second part Sender data set : It is the IoT system that collects environmental data that is important for plant growth in the green house, including temperature, relative humidity, soil moisture and light, Then, transfer the data to the receiver data set in step 3.2.2 as shown in Figure 3.

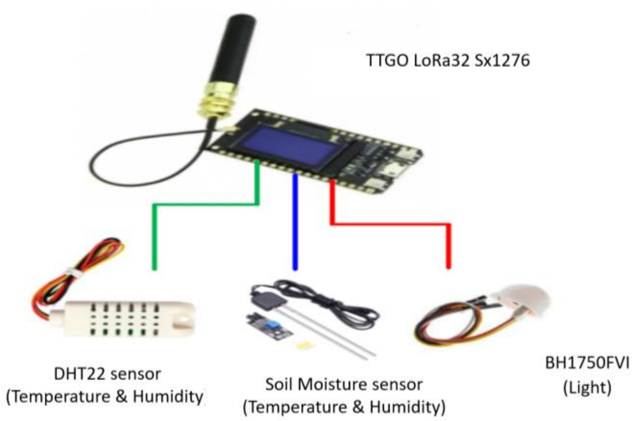

Figure 3. Sender data set

3.2.3 Third Part Receiver data set : The receiver data set is a IoT system that serves to receive data from the sender set using by LoRa technology, then data is transmitted via the Internet to cloud computing system as shown in Figure 4.

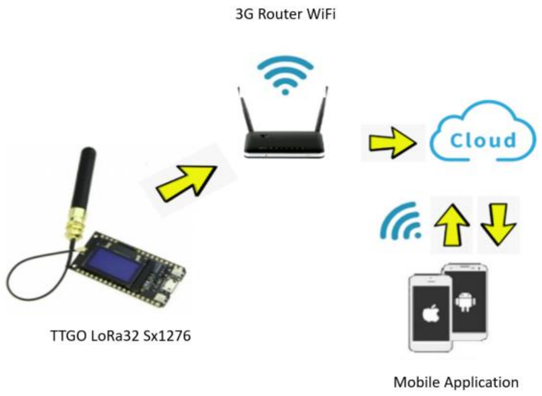

Figure 4. Data receiver set

3.3 Steps of development
The researcher divided the development into 3 parts as following.

3.3.1 Part 1 : Water and fertilizer pump control unit.
The researcher developed with the Arudino IDE version 1.8.15, C++ language together with the NodeMCU 1.0 (ESP-12E Module) board to connecting via a wireless network system to the Internet for data transmission between devices and cloud database.

3.3.2 Part 2: Sender data set
The sender data set is data collecting, consisting of 1) DHT22 sensor for measures temperature and relative humidity, 2) BH1750FVI sensor for measures the light, and 3) Soil moisture module for measures the humidity as shown in Figure 5.

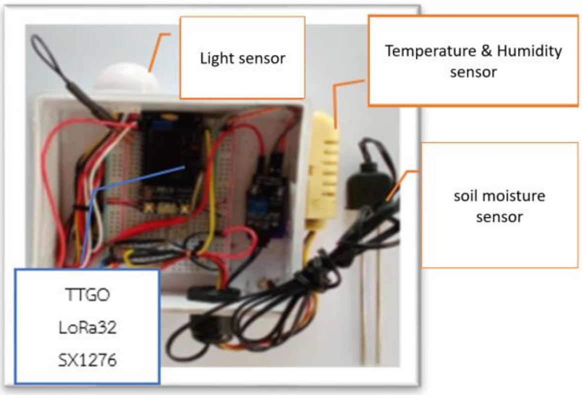

Figure 5. Sender data set

When the researcher has finished developing a sender data set it's still unable to works. The researcher has developed a program to control the operation of TTGO LoRa32 SX1276 board to collecting data from sensor devices that are connected and then transfer data to receiver data set.

3.3.3 Receiver data set

The receiver data set is used to receive data from the sender data set in step 3.3.2. The researcher using by TTGO LoRa32 SX1276 for receive data from the sender data set via LoRa technology at a frequency of 433 GHZ.

3.4 Farm Management Platform Development

The Farm management platform is a platform of the researcher designed and developed that can be applied to all farms. As a tools for farmers to manage their own farms such as plant data set, plantation, each crop, farm management, cost and harvest information. So that the farmers can know the costs, expenses and profits of their own cultivation in each crop. It is developed to work in conjunction with the IoT monitoring system to bring a variety of data type, a variety of data sources are integrated together for analysis to use in forecasting and predicting in the future, which has a conceptual framework for developing the platform as shown in Figure 6.

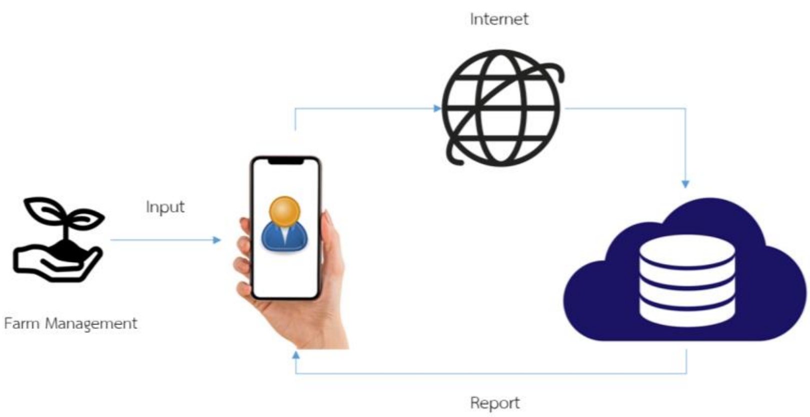

Figure 6. Farm Management Platform Concept

From Figure 6, there are 7 development steps as follows.

Step 1 Problem Definition:

This step is study the operation of planting from the beginning to harvesting in each crop, study the various problems and obstacles after analyzing the needs in order to comply with the digital technology, consisting of 2 part included design part and technology part.

Step 2 Second step Analysis :
This step is to study the sequence and process of planting each crop. and daily care operations from planting to harvesting and reports required for farm management. To be used in the development of a farm management platform.

Step 3 Design :
This step is study and design the system that will be used in the form of actual operation, analyze and design database, study programs in application, development principles in application design such as database, workflow and UX/UI will appear on the platform at various stages.

Step 4 Development:
This step is application development and database development according to the established design process.

Step 5 Testing:
This step is test the application to identify problems and errors to bring improvements.

Step 6 Implementation:
This step is installation a system that tests and fixes errors for farmers.

Step 7 Maintenance:
This step is the verification of data and accuracy during the operation of the application platform improve various errors to always be accurate.

3.5 Step of Installation.
This step is to bring the tools used in the research to be installed on the actual site for data collection and install a platform for monitoring and predicting smart farming systems for farmers to use.

3.6 Step of Data Analytics
This step is the process of importing data from IoT systems and farm management platforms. to analyze to help farmers make decisions, with 7 steps: 1) import data, 2) select columns in data set, 3) Cleansing data, 4) Split data, 5) Train model, 6) Score model, and 7) Evaluate model as shown in Figure 7. The researcher divided the data into 2 parts for Split data consisting of training the model (80%) and testing the model (20%) as shown in Figure 8.

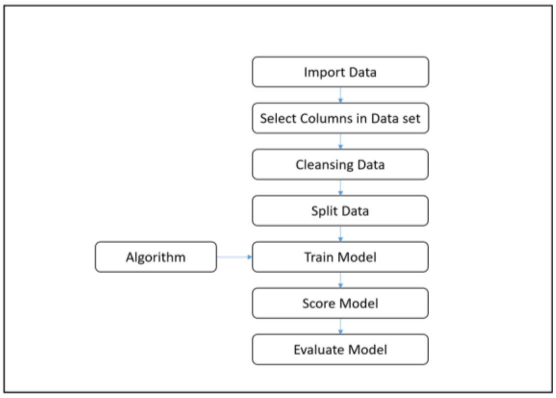

Figure 7. Step of Data Analytics

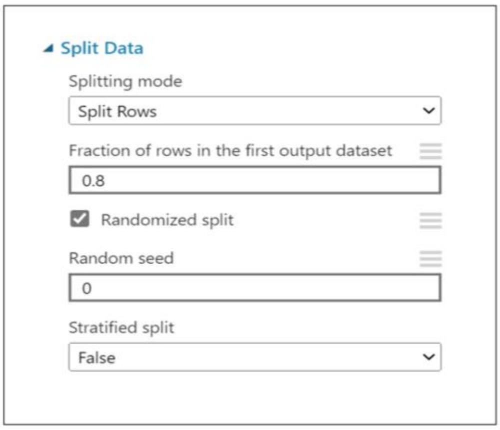

Figure 8. Step of Split Data

The step of train model, the researchers used the Neural Network Regress algorithm for modeling. The parameters are set as Create trainer mode as Single Parameter, Hidden layer specification as Fully-connected case, Number of hidden node as 50, Learning rate =0.01, Number of learning interations as 50 cycles and Learning weights as 0.1 as shown in Figure 9.

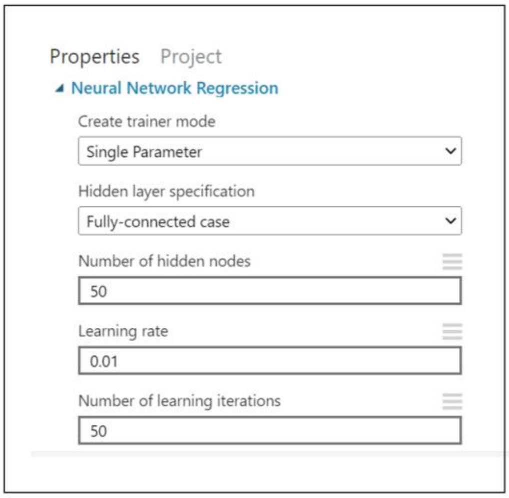

Figure 9. Parameters of Train Model with Neural Network Regression

3.7 Step of Summary.

The step of summary is explaining research results about research tools consists of IoT operation control system (water and fertilizer control system, data transmission set data receiving set), Farm Management Platforms and Data analytics.

4. RESULTS

In this research, the results of the study and discussion can be described as follows.

4.1 Workflow of the Smart Agriculture Systems Monitoring and Predicting Platform. This research brings together a variety of technologies to work together in agriculture. It has the integrated Internet of Things, Lora technology, Big data, Data analytics and Mobile applications as shown in Figure 10.

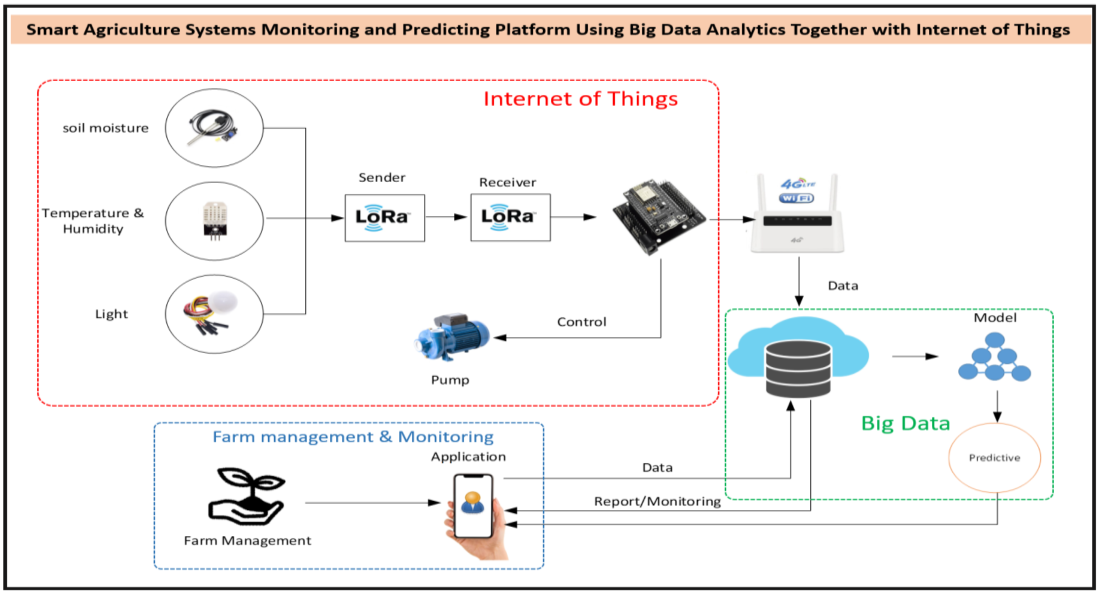

Figure 10. Workflow of the Smart Agriculture Systems Monitoring and Predicting Platform

4.2 Pump and Fertilizer Control Unit

The Pump and Fertilizer Control Unit able to work in 2 modes: 1) Manual mode, the users able to control switch ON/OFF through the application and 2) Automatically mode, the users able to control switch ON/OFF by configs the application to control various devices.

4.3 Sender data set unit

The sender data set has the following steps: 1) collecting data from the sensors consisting of temperature, relative humidity, soil moisture and light, and 2) transmit data to the receiver data set with LoRa technology.

4.4 Receiver data set

The receiver data has the following steps: 1) receiving data from a sender data set via LoRa technology, 2) connecting to the internet network with 4G technology, 3) transmit the data to cloud computing via API.

4.5 Farm Management Platform.

The farm management platform can manage the information such as crop, planting, each crop , daily management, harvest and related reports to help farmers for check the data both now and in the past according by the conditions from the farm management platform as shown in Figure 11.

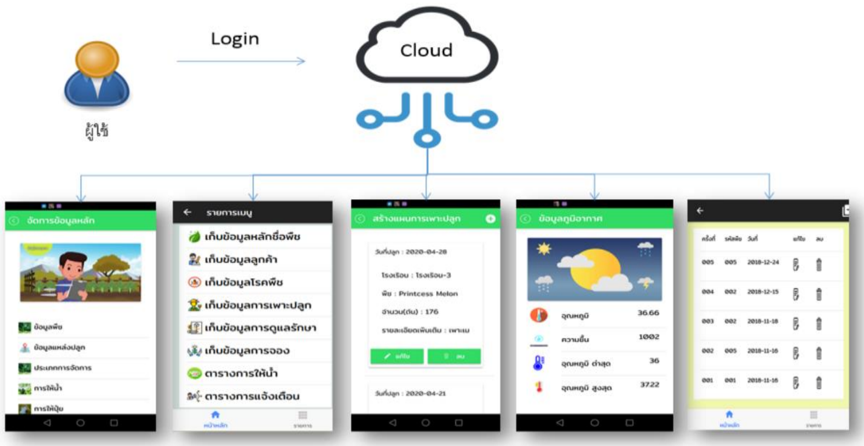

Figure 11. Example of Farm Management Platform

4.6 Data Analytics

4.6.1 Score Model

The results of Score Model as shown in Table 1.

Table 1. The results of score model

Statistics	Values
Mean	0.4243
Median	0.0844
Min	-0.3512
Max	1.0421
Standard Deviation	0.4709

From Table 1., the prediction results were Mean = 0.4243, Median = 0.0844, Min = -0.3512, Max = 1.0421 and Standard Deviation = 0.4709.

4.6.2 Evaluate Model

The step of Evaluate Model, the researcher used the statistics to measure the accuracy incuding:

1) Mean Squared Error (MSE)

   It's called the mean squared error as finding the average of a set of errors. The lower of values is the better prediction. It's can be calculated from the equation (1).

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(A-P)^2 \qquad (1)$$

Where

A	is the actual data value.
P	is the result obtained from the forecast.
n_i	is the total amount of data.

2) Root Mean Square Error (RMSE)

Root mean squared error (RMSE) is the square root of the mean of the square of all of the error. The lower of values is the better prediction. It's can be calculated from the equation (2).

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_t - \hat{y}_t)^2} \quad (2)$$

Where

n	is the amount of data used
y_t	is the actual value at any *t*
$\hat{y}_t$	is the predicted value at any *t*

3) Coefficient of determination (R^2)

The Coefficient of determination, or R-square (R^2) is a value used to prove whether the resulting model is suitable or not, with a value of 0-1, which is closer to 1 is higher accuracy. The generally is greater than 0.6 the resulting model is considered to be a good model. The results of this research as shown in Table 2.

Table 2. Model Performance Measurement Results

Statistics	**Values**
Mean Absolute Error	0.10763
Root Mean Squared Error	0.149209
Relative Absolute Error	0.226443
Relative Squared Error	0.09368
Coefficient of Determination	0.90632

From Table 2, the results of model performance measurement show that the model obtained has an accuracy of 90% with a Mean Absolute Error (MAE) = 0.10763, Root Mean Square Error (RMSE) = 0.149209, Relative Absolute Error (RAE) = 0.226443 and Relative Squared Error (RSE) = 0.09368.

5. CONCLUSION AND DISCUSSION

From the research results, it can be concluded that Smart Agriculture Systems Monitoring and Predicting Platform Using Big Data Analytics Together with Internet of Things. It is an application of IoT technology that works with a variety of sensors to collect environmental data from physical sense into numerical digital data and then transfer the data save into a database on the cloud computing real time by LoRa technology. In this research, we have developed a platform that can use the data to manage farms of farmers in various ways. When more data is collected, it will become big data that can be used to help farmers analyze the data in various ways and can predict future trends.

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