A Smart Farm Prototype with an Internet of Things (IoT) Case Study: Thailand

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***Abstract*—This paper presented the design for smart farm prototypes by using sensors for measuring the temperature and humidity using the Internet of Things (IoT) as a case study in Thailand. The system is designed to be a part of an automatic water control system using IoT devices. There are two main components including the hardware and a web-based application. The hardware system consists of two main devices, which includes a Raspberry Pi board installed in a control box to collect data from the field using a DHT22 sensor. This is used to collect temperature and humidity data from the environment of the plant that is sent by the control unit in the control box. The second component is a web application that was designed and implemented to collect and display useful, real-time data for users. This system is very important for the automatic control water system because it is used to collect the data necessary for controlling optimal water quantity for plant growth. The system was tested and worked effectively on a rice farm in Suphan Buri Province, Thailand. The results showed the system was useful for Agricultural 4.0, in which technology can help farmers to increase their productivity while significantly decreasing costs.**

***Index Terms*—smart farm, Internet of Things (IoT), sensor, water control, temperature measurement, humanity measurement, Thailand**

I. Introduction

With the advancement of the Internet, there has been tremendous growth in the era of globalization around the world. The internet has become an important communication tool that is applied in every sector including business, education, healthcare and agriculture. Currently, the application of Internet of Things (IoT) technology is apparently used in many industries. It is estimated that the growth of the IoT will reach 26.3 billion units connected to the Internet by 2020 [1] and [2]. IoT is defined as “things that are associated over the Internet” [3]. IoT technology is associated with the internet via a Wireless Sensor Network (WSN) as well as various other smart communication technologies [3]. Further, IoT technology is used in many domains such as education, health care, automation, industry and agriculture. [1], [3], [4]. With the capability of IoT technology, it has been used with regularity in agriculture, especially the smart farm concept [4]. The smart farm concept can be used to remotely and automatically control the growth environment of crops and livestock by combining information technology with greenhouses [5]-[7]. IoT technology has been used for farm measurement and the analysis of temperature, humidity and sunshine levels of farm facilities [5], [8]-[11]. The concept of a smart farm is a global issue with potential application as a solution to problems including the increased demand for food, labor force shortages, and the aging of farmers, as well as the expansion of cutting-edge agricultural technology [5], [12]-[15].

Currently, Thailand has a plan to develop the country with innovation under the Thailand 4.0 policy and new technology for Thai agriculture [16]. Most Thai farmers grow and export rice for the global market. The important problems in the cultivation of Thai rice farmers is a lack of knowledge and innovation that is used to control the environment. Therefore, it is necessary to develop a prototype for a smart farm system to support local Thai rice farmers.

This research aims to design IoT technology to develop a prototype for a smart farm using a case study of a local rice farm in Suphan Burin Province, Thailand. In the study, a Wireless Sensor Network (WNS) was deployed in the rice field, which was used to measure the temperature, humidity and monitor control factors that influenced crop growth and yield [4]. In this study, the focus was on specific data consisting of the temperature, humidity and soil moisture in rice crop fields [4] and [16]. The IoT system for smart farms was designed to connect to a database system via a web-based application. The data was used for decision making to control the automatic watering of the crops [14].

II. Review of Literature

This section contains a review of the literature related to the work involving IoT and smart farms.

A. *Internet of Things (IoT)*

Recently, IoT was introduced and became a very significant technology that is applied in many industries

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[4], [17], [18]. The definition of IoT has been given as ‘Global infrastructure for information society, enabling advanced services by interconnecting things based on existing and evolving, interpolatable information and communication technology [3] and [19]. Though IoT concerns the synchronization of objects (things) over the Internet [3], these IoT devices connect via sensors over the Internet, which can generate data that supports decision making [3]. Since the research in IoT was interested in the academic and industrial section, there was a need to find new methodologies for associating various devices over the Internet with the help of additional sensors [3] and [4]. This concept creates innovation in many dimensions such as smart grids, smart homes, medical and healthcare, industrial processing, and smart agriculture or smart farms [3], [4], [16].

An IoT application was applied in the agricultural field to improve crop yields and reduce costs [4]. The application of WSN assisted the farmers with statistical data from the IoT devices [4], [20], [21]. An IoT platform has been developed to increase agricultural production for crop monitoring, disease prediction and the control of water consumption for irrigation [22].

B. *Smart Farm*

The concept of the smart farm is part of precision agriculture to use Information and Community Technology (ICT) for the control and measurement of crops and soil for optimum productivity [3] and [4]. The objective of a smart farm is to use technology to help the farmers increase their profitability and sustainability while also protecting the environment [4]. Many researchers working in this domain have incorporated smart devices in order to evaluate the parameters that contribute to the growth of plants and observe the agricultural activity performed. Thao *et al.* (2010) conducted research concerning the agricultural activities within greenhouse technology and IoT technology. Hence, a framework that combines both a Remote Monitoring System (RMS) with Internet and Wireless Communications (IWC) was proposed. The results found suitable plant growth in greenhouses, which were easier to operate when compared to open fields [23].

Many studies have attempted to improve the functionality of IoT [4], [24], [25] by presenting the development of a WSN based on IEEE-802.15.4 for use in agriculture by precision measurement of the temperature. Hashim *et al.* (2015) [4] and [24] conducted a study using an electronic device (Arduino) for temperature and soil moisture as well as an Android-based smartphone application for flexibility and functionality. The results found an advantage in low cost flexibility for agricultural control in contrast with expensive components such as a high-end personal computer. [26]

III. RESEARCH METHODOLOGY

The research methodology using a System Development Life Cycle (SDLC) concept, which included the following:

A. *Design and Overview of the System*

The smart farm system design is shown in Fig. 1. The system has two main devices including a Raspberry Pi board (IoT device) and temperature as well as humidity sensors (DHT 11). The system is designed for controlling the system to measure and store data for rice farmers.

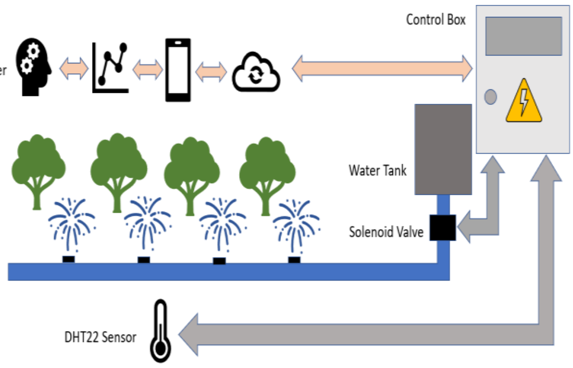

Figure 1. The system layout.

The major components of the system are illustrated in Fig. 1, including a Raspberry Pi, sensors, a web server, database and an application.

B. *Raspberry Pi*

Firstly, a Raspberry Pi must be initialized by getting Raspbian, which is an operating system based on Linux. The latest version is called Debian. Fig. 2 shows the designed for the Raspberry Pi board, which is fully capable of basic programs. The system uses the Raspberry Pi 3 Model B+ for processing, which has a GPIO and a port that is used to connect other devices. The Raspberry Pi uses an SD Card for installing Linux operating systems. SD card capability of more than 2GB is necessary, but it is recommended to use 4GB or more for the system. The system in this study uses a high-speed SD card, Class 10, for best system performance.

Figure 2. Raspberry Pi 3 model B+ installed in a box.

C. *Sensors*

Many factors can affect the growth of plants, especially the environment. The temperature and humidity in the air are the main factors for plant growth. Fig. 3 shown the DHT11 temperature and humidity sensor was chosen for the system, which is a small module that provides digital temperature and humidity readings. Additionally, it is easy to set up and install and only requires one wire for the data signal. DHT11 sensors are popular for use in various weather applications and automation systems. These sensors operate at 3.3V or 5.5V and require no calibration at low energy values, while at standby it uses approximately 150 micro amps. In Fig. 4, the DHT11 is shown connected to the Raspberry Pi.

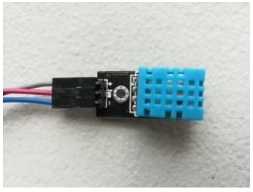

Figure 3. The DHT11 temperature and humidity sensor.

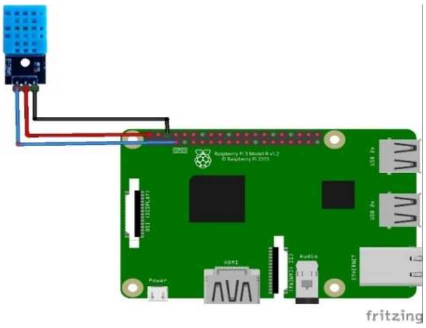

Figure 4. The system schematics.

D. Web Sever

A web server is a data service that uses connection through HTTP protocol. The client's devices can connect to a web server from anywhere via LAN or internet. Farmers can connect to the system from anywhere so they can view data. Raspberry Pi works as a web server so that other devices can access data via a web browser on a computer, phone, or tablet. The web server on the Raspberry Pi is suitable for the application because it does not require any third-party applications. Therefore, Apache web server was chosen for the installation. The Apache HTTP Server Project is available on https://httpd.apache.org/. When the installation is finished, the web browser is opened and the IP address of the Raspberry Pi (192.168.1.6) is opened. Alternatively, opening a web browser on the Raspberry Pi and going to http: //localhost is another option. The default page can be viewed, which means that Apache can work normally.

E. Database

A web server is a data service that uses a connection through the HTTP protocol. The client's devices can connect to the web server from anywhere via LAN or internet. Farmers can connect to the system to view data from anywhere. Raspberry Pi works as a web server so that other devices can access data via a web browser on a computer, phone, or tablet. The web server on the Raspberry Pi is suitable for the application because it does not require any third-party applications. Therefore, Apache web server was chosen for the installation. The Apache HTTP Server Project is available on https://httpd.apache.org/. When the installation is finished, the web browser is opened and the IP address of the Raspberry Pi (192.168.1.6) is opened. Alternatively, opening a web browser on the Raspberry Pi and going to http: //localhost is another option. The default page can be viewed, which means that Apache can work normally.

F. Application

The system can be connected via the internet so devices such as computers, smart phones, and tablets can access the system. It is necessary to install additional programs to display the data. In the application development, three languages are used together: HTML (Hypertext Markup Language), Python, and JavaScript. Each language has a different function. HTML works as the core of the display, while Python connects to the database to forward data. JavaScript displays in the form of graphs by using the CanvasJS module, which is flexible and customizable. The code is written or edited in Raspberry Pi, which may be inconvenient because of various limitations. Choosing to develop on the Editor is more convenient by using a computer and developing in Notepad ++, which is free and has a UI. Various configurations are popular tools that can be downloaded at http://notepad-pluse-plus.org/download. Therefore, developing the code for the system in this work includes sending the code from a computer to the Raspberry before running the code. The algorithm for the system and flow diagram are shown in Fig. 5.

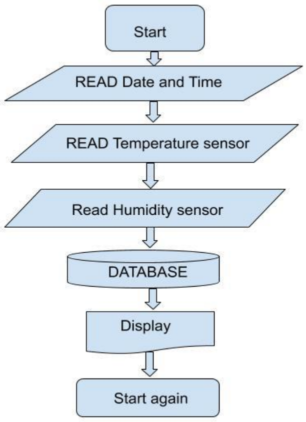

Figure 5. Flow diagram of the system.

The steps for running Raspberry Pi start from installing the DHT 11 Library for Python by downloading from Github with the following commands:

```
$ git clone https://github.com/adafruit/Adafruit_Python_DHT.git
Go to the Folder Adafruit_Python_DHT
$ cd Adafruit_Python_DHT
Instill Library
$ sudo apt-get update
$ sudo apt-get install build-essential python-dev python-openssl
$ sudo python setup.py install
$ cd Adafruit_Python_DHT
$ sudo pico temp.py
#!/usr/bin/python
import sys
import Adafruit_DHT
while True:
 humidity, temperature = Adafruit_DHT.read_retry(11, 8)
 if humidity is not None and temperature is not None:
   print'Temp={0:0.1f}*C
Humidity={1:0.1f}%'.format(temperature, humidity)
 else:
   print 'Failed to get reading. Try again!'
Run Program
$ python temp.py
```

```
time.sleep(1)
#!/usr/bin/python
import time
import sys
import Adafruit_DHT
while True:
 humidity, temperature = Adafruit_DHT.read_retry(11, 8)
 if humidity is not None and temperature is not None:
   print'Temp={0:0.1f}*C
Humidity={1:0.1f}%'.format(temperature, humidity)
   time.sleep(1)
 else:
   print 'Failed to get reading. Try again!'
  $ python temp.py
```

IV. Results

The system was developed for monitoring temperature and humidity for farmers as shown in Fig. 6. The data can be displayed via a web browser. The system can store data and has been developed as well as tested in the field of an agriculture farm as shown in Fig. 7. The system can work well and store data in addition to displaying the results as graphs of temperature and humidity without stopping work, as shown in Fig. 8 and Fig. 9. It was tested in the field of an agriculture farm in Suphan Buri Province.

The system is a prototype that can be further developed to the industrial level in the future to enable it to operate for longer periods in order to cover plant life.

Future systems will be able to measure the statistics for the growth of plants. It may use standardized tools to compare and correct to get accurate values.

Figure 6. Temperature data for 10 April 2019.

Figure 7. The IoT prototype test in Suphan Buri Province.

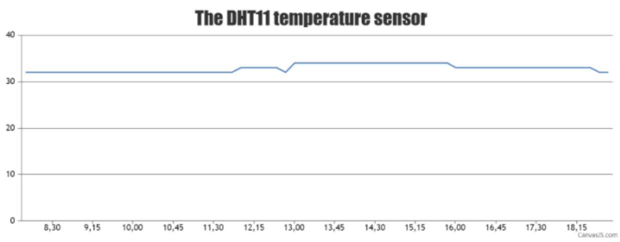

Figure 8. Temperature data for 10 April 2019.

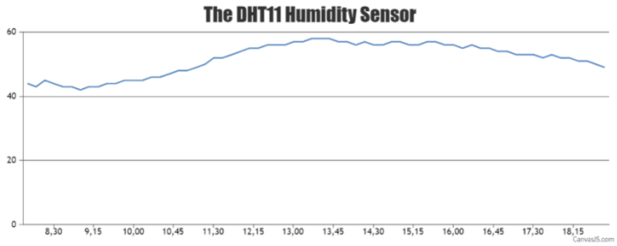

Figure 9. Humidity data for 10 April 2019.

V. Discussion

Thailand is an agricultural country. Most of the population grows rice and exports the majority of the top quality rice throughout the world. However, many Thai farmers lack the knowledge and innovation needed for use to control the environment systems such as water, temperature, humidity, and fertilizer. Therefore, it is necessary to develop a prototype for a smart farm system for local Thai rice farmers. This research aims to design a prototype for a smart farm by using sensors to measure the temperature and humidity with Internet of Things (IoT) using a case study of a rice field in Thailand. The prototype is designed to be a part of an automatic water control system using IoT devices.

The system is a part of automatic control water system which is very important for a smart farm because humidity can directly affect the growth of crops. The system is stable during operation and can continually run without unexpected stoppage. Hardware devices can collaborate well with the Raspberry Pi and the DHT22 sensor works accurately without overheating. The software and web application were designed to display information in the crop field and store data in the system continually without any problems. The results displayed a temperature from °32 C to °35 C and humidity between 43–58%.

The prototype system is a requirement to conduct various experiments because testing the stability and validity of the hardware and software enables expansion on a large scale.

The developed system was installed in Suphan Buri Province (in Fig. 7), Thailand and worked for one month in the field. Moreover, the system can work effectively in an area where the internet is not stable because it stores data on an SD card in the Raspberry Pi.

For future work, collected data could be processed by applying machine learning or data mining for forecasting to improve the system performance. Finally, a smart farm has a major role and is turning traditional agriculture into modern agriculture. IoT technology is an important factor for improving traditional agriculture in several ways, which will increase the effectiveness of farm management.

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