Centralizing Real-time Data Using Remote-Sensing towards Smart Farming Applications in A Public Area: A Case Study of Ayutthaya

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Abstract

Real-time data play a crucial role as a fuel for various smart systems including smart farm and smart home for automation. This work studies on scaling up the collection of real-time data from remote-sensing for centralizing the data for openly sharing to many agriculture-based smart applications. The widely-used environmental parameters necessary to smart farm applications are collected from the deployed sensors and managed for usage. In this paper, we provide the setting and management for deployed sensors and report on issues from practical usages in a private and public area. The results of collected data indicate that they are useful for related parties and improved farming efficiency. For over a year of sensor deployment, we however encounter practical issues in maintaining the devices and found that the main issues are the durability of the deployed device and interference from natural and human incidents. These issues lead to the further challenges of integrating sensing and automation devices into the practical utilization of IoT technology.

Keywords: Centralizing Real-Time Data, Remote-Sensing, Smart Farming.

1. Introduction

The internet of things (IoT) refers to the network of devices that exchange data via internet for collecting and sharing data, as well as controlling the devices wirelessly [1]. The IoT bridges the gap between the digital world and the physical world, which enables data monitoring, effective operation and automation [2]. In an IoT ecosystem, there are two core components as the Internet and physical devices (things). Sensors as ‘things’ in an IoT system play a major role to collect specific data to represent data of the objects or surrounding environment in a physical world into digital data [3].

The sensor-based data are an output of a device that detects and responds to a specified type of input from the physical environment. The data are used to provide information or input to another system. With the ability to detect real time information from environment, the sensor-based data are famous to be utilized in robotic system, warning system, healthcare application and agricultural AI system. For agricultural AI systems, the frequently used data are sensor data which are detected for environmental factors affected to a cultivation process specified to their own proposed issues. In common, the detected data include temperature, humidity, water level, rain level and sunlight time. These data then are processed with their proposed method. For example, [4] proposed using sensor data as input for ontological inferencing to recommend a solution for tamarind cultivation problem. [5] applied machine learning technique to detected water level data from sensors to suggest a setting of water management in rice farming. [6] presented a method to collect macadamia farm data from sensors and use them in knowledge-based expert system to suggest optimized farming procedures. These aforementioned works require environmental data from similar sensor devices as base information to calculate for their system. Hence, the information from the same sensor types are found to be used in common. The information is

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about environment factors which are used as basic information that can be applied to many applications.

This work aims to gather live information from affordable sensor types to represent environmental factors of the designated area to create a live data-center to support agriculture-supporting applications in the area of Thap Nam tumbon, Bang Pahan district, Phra Nakhon Si Ayutthaya province, Thailand. The live information is measurable factors from environment including temperature, humidity, water level, rain level, and daylight hour. We then demonstrate how usefulness of the information by applying it to agriculture-supporting applications. As there are many existing IoT systems to assist work in an agriculture field using the same sensor data, the collected data can be used as fuel for the existing works. Furthermore, the public works usually propose how to apply the sensors for smart-farm systems, but there are little to none studies on issues of the used sensors in the practical IoT systems after deploying the devices. Thus, this work also studies on the possible issue that may cause problems for the sensor and IoT system in the practical uses in the real environment.

The rest of this paper is organized as follows. Section 2 presents background knowledge related to Internet of things (IoT) and sensor as well as related works. Section 3 describes the methodology of the work including deployed sensor type and setup, and demonstration of usage. Section 4 gives the evaluation of the proposed methods. Last, Section 5 provides the conclusion of the research and discussion of the results.

2. Background

2.1 IoT and Sensors

The internet of things (IoT) is a term referring to the network of devices that exchange data via internet [7]. Commonly, an IoT system consists of sensors, devices, and software with network connectivity to detect real time data, making decision and performing actions such as sending an alert and automatically performing a task without human intervention [8]. As such, IoT helps to offer smart devices to automate tedious tasks to save time and money. Thus, IoT has been applied in several fields such as healthcare, agriculture, and business to increase automation in their endeavors.

Sensors play a crucial role in an IoT system as to collect specific data to be processed for automation [9]. Many sensors are invented to detect their responsive data required for different tasks. To support agriculture, sensors to detect agricultural factors which are important for crops to grow such as humidity, water level, soil quality, and light are deployed to help farmers realizing necessary factors relating to plant growth. Most sensors are designed to specifically detect one data; thus, it requires several types of a sensor for detection of various required data for a more complex task. In smart agriculture, the common used sensors are as follows.

- Water level sensor: using sensor probes to indicate water levels and send information back to the control panel.
- Humidity sensor: detecting changes that alter electrical currents or temperature in the air. There are three basic types of humidity sensors including capacitive, resistive and thermal to monitor minute changes in the atmosphere in order to calculate the humidity in the air.
- Ph sensor: using the ion selective electrode which react on a hydrogen ion comparing to a reference electrode. The difference of reaction can determines the pH value based on the Nernst equation.
- Rain level sensor: The sensing pad with series of exposed copper traces together acts as a variable resistor whose resistance varies according to the amount of water on its surface. This resistance is inversely proportional to the amount of water. The sensor produces an output voltage according to the resistance.
- Water current speed sensor: When water flows through the valve it rotates the rotor. The change can be observed from the speed of the motor and calculated as output as a pulse signal by the hall effect sensor to represent a rate of flow of water.
- Light sensor: measuring the radiant energy that exists

in a very narrow range of frequencies to generate an output signal indicating the intensity of light.

With the remote sensing data, IoT systems can make a pre-defined decision and send signal to activate connected devices accordingly. Rapid growth in IoT induces many researches in smart devices and frameworks leading to the era of automation.

2.2 Related Works

IoT technology possess a power to overcome distance and place constraints of wired communication systems by wirelessly connecting devices. It induces development of a smart system of automation that can response accordingly to the situation. IoT technology has been spread to various domain, and one of the focus is a smart farming to support agriculture. IoT-based remote sensing utilizes sensors deployed in farms to gather data, and the real-time data are analyzed and processed for various purposes. With the agricultural data, the trend of smart farm has been studied, and several utilizations have been proposed. In general, tasks of smart farm using IoT/sensor can be separated into three main groups as follows.

- **Anomaly Monitoring:** The main aim of remote sensing in this task is to prevent the spread of diseases and keep an eye on the growth of crops. Sensors are deployed in farms to monitor the crops for anomaly such as a sign of disease and invaded pest. Anomaly is automatically detected, and farmer is notified for handling the issue accordingly.
- **Environmental Condition Detection:** For this task, the data are collected to determine weather and other feathers required for crops to growth. The features are such as humidity, temperature, moisture precipitation, light, soil quality and water quality. This information is necessary for farmers to realize the need of preparation for their crops such as the amount of water needed and prediction of pest invasion.
- **Automated Farming:** Sensors in this task plays a role of identifying surrounding environment to feed data in an automation reaction system. The system decides the actions such as turning on a light or water pump to handling cultivation task according to submitted data. Some may apply a robot to solve a specific issue including spraying pesticides and removing the detected weed.

We then survey the works related to using IoT in agriculture in Thailand and make a brief summary of the works into Table 1.

The applications of IoT in farming aim to create conventional farming operations to meet the increasing demands and to decrease production loses. The sensors are setup for monitoring crops, surveying the farms, and providing data to farmers for decision making and man agement plans to save time and money. The recent IoT works for supporting smart farming in Thailand are specified to indicate agricultural parameters based on environmental features affecting plant growth and automatic responding to the parameter in need, especially automatic water supplying system. The works however focus on gathering necessary data specific for the need of their own application. Hence, the scale and usage of the work is limited to their tested farms. The data thus cannot be shared and integrated with other applications despite they require the same information for processing. This work thus designs a framework for collecting various type of real-time data to centralize the data for usage of supporting agriculture endeavor. The collected data can be reused and processed in several types of applications to provide the most benefits to local farmers.

These existing smart farm applications in Thailand provide the details on the development and design of the applications along with the test on how effective they are. However, none mentioned and experimented on the issues of deploying sensor devices on actual environment in Thailand to prepare the farmers who interest in applying the method for the possible problems. Since the devices including sensors and connecting devices are to deploy in harsh environment in a farm, there can be many possible problems that may damage the devices or lower the efficiency of the applications. This work thus includes on design of live data-center to support agriculture-supporting applications and a study on issues of the deployed devices in an actual environment.

3. Materials and Methods

This work presents a method and design of live data-center to support agriculture-supporting applications. An overview of the data-center is illustrated in Figure 1.

Table 1. *A brief summary of existing IoT/sensor-based smart farm applications in Thailand.*

Paper	Task	Agricultural Products	Study location	Remarks
Ontological and Sensor-Based Supporting System on Damage Prevention for Tamarind Farming: a Case Study of Phetchabun Tamarind Farms, [4].	Anomaly Monitoring	Tamarin	Phetchabun Province, Thailand	using sensors to gather data to detect possibility of having diseases and pests to destroy tamarin crop as well as making suggestion to prevent invasion
Ontology-based Decision Support System for Macadamia Nut Smart Farming, [6]	Environmental Condition Detection	Macadamia	Lampang Province, Thailand	using sensors to gather weather features related to grow macadamia nuts with an ontology-based recommendation in cultivation process
IoT and agriculture data analysis for smart farm, [10]	Automated Farming	Vegetables and Lime	Makhamtia District, Suratthani Province, Thailand	using wireless sensor network to monitor soil moistures to automatically activate a watering system for agricultural crops
AQUARIUM FISH SMART FARMING, [11]	Automated Farming	Fish	not-informed	using water level sensor to indicate the need of water in an aquarium to activate a water pump for controlling a water system
Design and Application for a Smart Farm in Thailand Based on IoT, [12]	Environmental Condition Detection, Automated Farming	Orchard	not-informed	using several sensor types to measure and record agricultural parameters for monitoring and controlling an orchard water management system via smartphone
A Smart Farm Prototype with an Internet of Things (IoT) Case Study: Thailand, [13]	Environmental Condition Detection, Automated Farming	Rice	Suphan Buri Province, Thailand	using sensors for monitoring temperature and humidity for automatic controlling a water system to rice field accordingly

An objective of this work is to gather live information from low-cost sensor types to represent environmental factors of the designated area to create a live data-center to support agriculture-supporting applications in the area of Thap Nam tumbon, Bang Pahan district, Phra Nakhon Si Ayutthaya province, Thailand. The area periodically encounters issues of flood, low harvest rate, and unstable weather. Seven farms in the area volunteer to participate in the work. With a cooperation of the local government organization, we are allowed to setup devices in a public area.

3.1 Deployed Sensors and IoT Network

Sensors are a tool to feed real time data to our framework for supporting agriculture management for the locals. We design to deploy specific sensors related to the known periodic issues as a flood problem and unstable weather. The list of selected sensors is given in Table 2.

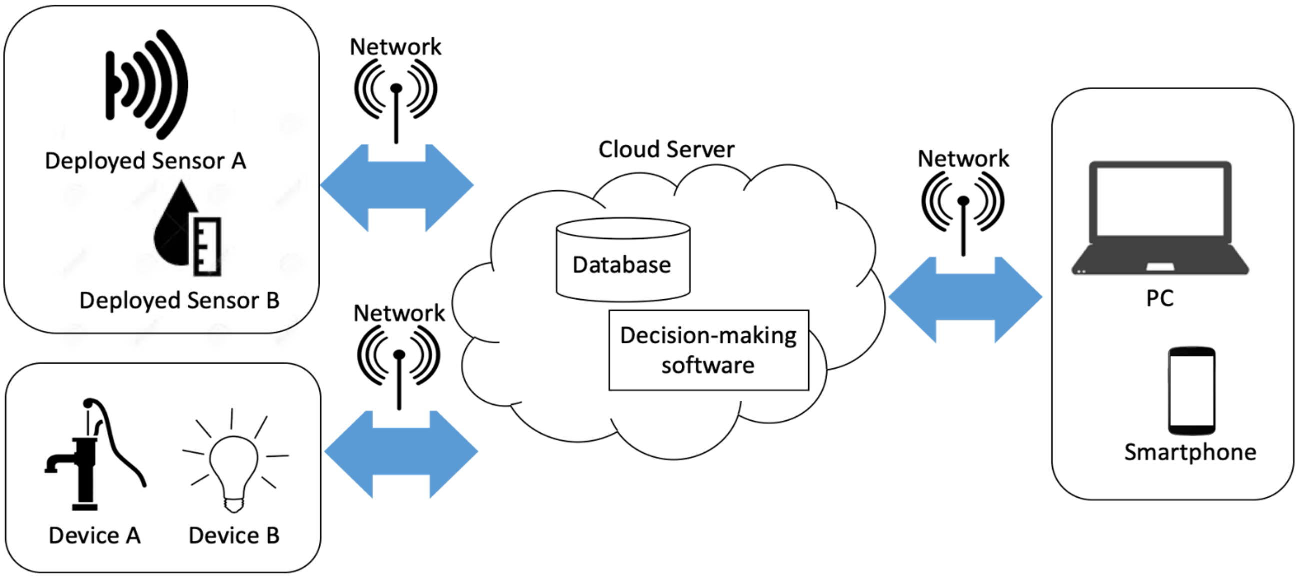

Figure 1. *An overview of the live data-center to support agriculture.*

Table 2. *Selected sensors and their setup for supporting agriculture management.*

Sensor	Detection Description	Setup Specification
water level	To measure a water level in a canal and irrigation	deploying in the upstream and the middle of a canal and irrigation way
humidity	To detect quantity of water vapor in an atmosphere	deploying in a central area of a farm
pH	To detect a scale of the acidity or basicity of water in a canal and irrigation	deploying in the upstream of a canal and irrigation way
pm 2.5	To detect particulates with a diameter of 2.5 µm or less	deploying in a central area of a farm
rain level	To measure amount of rain	deploying in a central area of a farm
water current speed	To measure a current speed of water in a water way	deploying in the middle of a canal and irrigation way
temperature	To measure an outdoor temperature in a Celsius degree	deploying in a central area of a farm
sun light level	To measure sun light level and hours of sunny time	deploying in a central area of a farm
soil moisture	To measure water level in soil a agriculture field	deploying in a central area of a farm

The sensors are to record the data for every hour to detect the change. To supply the sensors with electricity, solar cell panels are also established. The sensors and devices are connected to the internet using local WI-FI signal and cellular network in case it is out of WIFI range. In this work, the sensors are deployed in the real farm environment and public area. Thus, the sensors used in this work are factorial grade which has higher durability. Sensor data are wirelessly connected to secured IoT network for collection. We set up layer IoT architecture consisting of perception, network, and application layers.

First, the perception layer is the layer for sensors to detect the surrounding factors and generate a numeral parameter for gathering information in the environment. In this layer, the most concerns in the setup is to electricity-power the sensor devices and to securely locate the sensor devices. The outdoor environment requires permission from the farm owner and local authorities to set up the devices properly. In addition, the location of the deployed sensor must be secured and safe since it can be damaged or interfere with activities on the farm. For the ground-based sensor type such as soil moisture sensor, a cover is necessary to prevent the accident to destroy the sensor, but the cover must not reduce the ability to sensing detection as shown in Figure 2. For water related sensor type including water level and water current speed, electricity cord to power the detecting device should be managed to prevent electrical hazard.

Figure 2. *Devices setup in the testing site with a locked cover to prevent hazard and accident from surrounding.*

Second, the network layer is to connect a sensor device to the cloud servers and also to process sensor data. In this work, we have two kinds of setup as 'in-farm' and 'in-public'. The 'in-farm' is usually setup with WIFI from the farm if the devices are in range. Otherwise, cellular network from a sim card is used to connect the device to the Internet for transmission the data to the cloud data server. In this work, we use the cloud server with 100 TB storage and 20 TB bandwidth data transfer for handling sensor data.

Last, the application layer is for providing application services to the user. The services for this work include the data statistics of the environment factors and the use of data for supporting tasks such as flood detection and flood alert. As a data center, the farm owners are allowed to access their own farm data for planning and analysis, and the responsible local organization can use the provided data to develop more supporting applications.

3.2 Data Management

With the collected real-time data from sensors, the quantity of the data is massive and grows exponentially with time. The data are needed to be handled efficiently to keep them alive properly. Fortunately, the data from remote sensing are a structure data with stored, accessed and processed in the form of fixed format and definition. However, the data still possess a threat with volume (size of the data) and velocity (speed of generation of data).

To efficiently handle the data, we follow the management procedures as follows.

- Data Preservation: keeping raw data raw by do not make any changes to the original raw data. This can improve monitoring and traceability for data. For data usages, a copy of data or sampling data are mandatory to be processed in a different server to the data collection server.
- Data Storage: keeping backup raw data frequently in at least 2 or more data warehouse with sufficient security controls. For storage, it is wiser to keep backup data in both cloud data server and physical server to prevent trouble of inaccessible internet issue or electricity blackout.
- Data Monitoring: keeping data monitored and analyzed by including an alert system to notify when data are not fed to the database properly. In fact, the real-time data can be missed for several reasons such as malfunction of the hardware, losing power source and internet connection instability. Thus, it is necessary to split an alert in terms of temporary issue for a short loss of signal and long-term issue with a given timely threshold.

- Data Collection Log and Audit: having a log system to record issues in data collection for analyzing of the cause of the trouble. The collected data should also be audited to keep them cleaned and corrected as intended.

With the real-time data, it is not always necessary to analyze data instantly for all applications. Depending on usage, some may need real-time processing and some may not. However, as intention to be a live data-center to support for agriculture, we need to prepare an infrastructure to be ready for both usages. Accessing to the data however requires authentication which is essential to keep data secured. With frequent backup and alignment of data, unauthorized access to alter data or losing data can be prevented properly.

3.3 Demonstrative Usage

The collected data themselves are only a collection of data. To make use of them, processing is necessary. Since we collect several kinds of real-time data, they can be used in various applications and purposes. In this part, we demonstrate how the data are used in applications that can provide benefits to local communities including local government organization, farmers, and researchers.

3.3.1 Weather Collection

Among the obtained data, weather information in a standard measurement are detected to reflect important parameters for growing a crop in a designated area. The data can be visualized in a form of table and graph-based on statistical calculation such as mean, median, min, max, and standard deviation. The weather parameters include temperature, rain level, water level, humidity, Sun light level, pH, and PM2.5. They can be compared using various criteria such as same time in different years, multiple parameters of the specific time, and average value for each month. This information leads to several utilizations; for example, it can alert farmers to prepare appropriate equipment and protective gears including rain coat for probably raining period, hat and sun screen in a scorching season, and face mask to protect against polluted PM 2.5. In addition, the weather data can be fed into a prediction model for forecasting weather to plan out crop management. However, a prediction model requires a huge amount of past data, and the current data yet reach the sufficient quantity.

3.3.2 Flood alert and detection

Flood is one of damaging disasters on agriculture that farmers need to be aware of. Not only flood damages the plant directly with washing then away, but even after floodwaters recede, crops also continue to suffer damage and yield resulting losses from oxygen depletion and nitrogen loss in soil [5]. However, floods are hard to be prevented if the farm location is close to canal and river. Alerting system thus can prepare farmers to evacuate or prepare as much as possible. With the remoted sensing data including water level and water current speed, a development of flood alert system can be developed. Since the relevant sensors are deployed in the upstream and the middle of a canal and irrigation way, the measurements in real-time data are usable to determine possible flood incidents. The sudden rise of water level than usual (calculated from ordinary circumstance with specific threshold) and water current speed are key data for providing an alert to farmers. Furthermore, the recorded data of flooding can also be used by local government organization to plan on further development of the area as well as an evidence for considering an official compensation for flood damage. Details of this system can be read in Surveillance System and Forecasting Report for the Damage of Farmers Affected by Floods in the Watershed, Pha Nakhon Si Ayutthaya Province. [14] on URL: http://tabnam-wm-new.org/water-monitoring/

4. Results and Discussion

In this part, we conducted two evaluations. The first evaluation is done by users who involve in the research project including voluntary farmers who allow us to setup the sensors in their farm and local organization officers who response for agricultural affair in the area. The second is analysis evaluation of the framework usage.

4.1 Results of Data Collection

The data were collected from the area of Thap Nam tumbon, Bang Pahan district, Phra Nakhon Si Ayutthaya province, Thailand. The sensors were deployed in 7 volunteered farms and a public area. The area covers around 12.56 km2., and there is a main canal (Thap Nam canal) linking to irrigation canals to each farm. For statistics, we deployed the sensors as follows.

- **water level:** 7 sensors at the irrigation canal connected to each of the volunteered farms and 2 sensors in the public canal in the area.
- **humidity:** 7 sensors in the center of each of the volunteered farms and 4 sensors in the public area.
- **pH:** 7 sensors deploying in the upstream of an irrigation way of each of the volunteered farms and 2 sensors in the public canal in the area.
- **PM 2.5:** 7 sensors in the center of each of the volunteered farms and 6 sensors near the local street and open field in the public area.
- **rain level:** 7 sensors in the center of each of the volunteered farms.
- **water current speed:** 7 sensors deploying in the upsensors in the center of each of ream of an irrigation way of each of the volunteered farms and 2 sensors in the public canal in the area.
- **temperature:** 7 sensors in the center of each of the volunteered farms and 6 sensors near the local street and open field in the public area.
- **sun light level:** 7 sensors in the center of each of the volunteered farms.
- **soil moisture:** 7 sensors in the center of each of the volunteered farms.

Since the data are collected minutely in practice resulting massive data and unable to display as a whole, the data then are calculated in average, min and max based on month and specific times including 6:00, 12:00, 18:00, and 24:00 for representation. The collection of shown sensor data was from 1st February, 2020 to 30th August, 2020. The deployed sensors were set up as mentioned in Table 2. The collecting results are shown in Figure 3, 4, and 5 for water level in a canal, temperature and PM 2.5, respectively. For the time, we separate time into 4 durations as morning (M; 6:00-11:59), afternoon (A; 12:00-17:59), evening (E; 18:00-23:59), and night (N; 0:00-5:59).

The data from the sensors represent environmental factors in the collection site. These data can be used to analyze for several purposes including water management to prevent flood or handle a drought problem, and monitoring PM 2.5 in the area. For instance, the collected water level in the canal shown in Figure 3 indicated that water level in April was

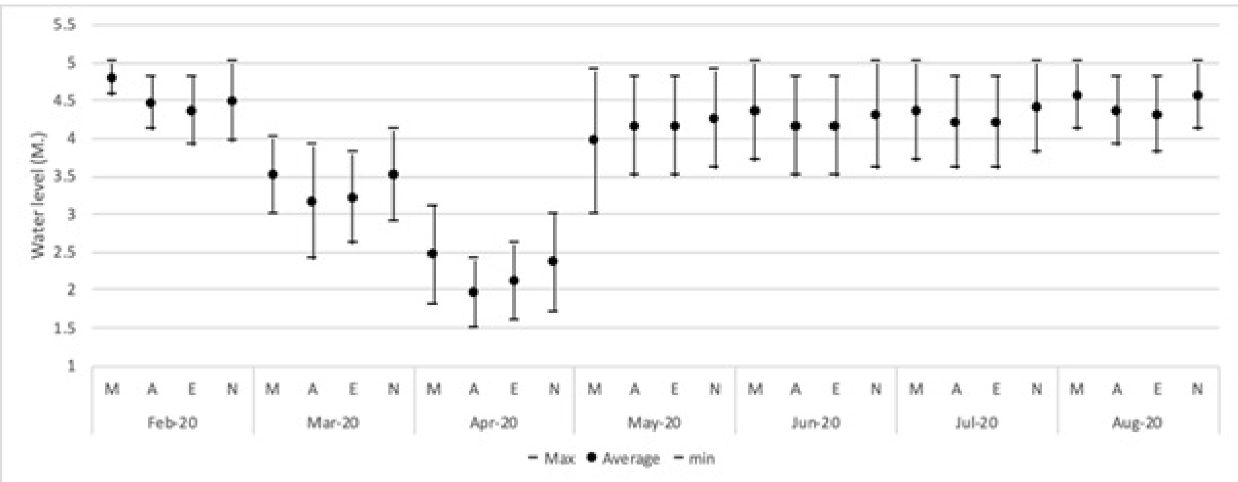

__Figure 3.__ Collected sensor data of a water level of the canal in the testing sites for average, min and max based on time and month.

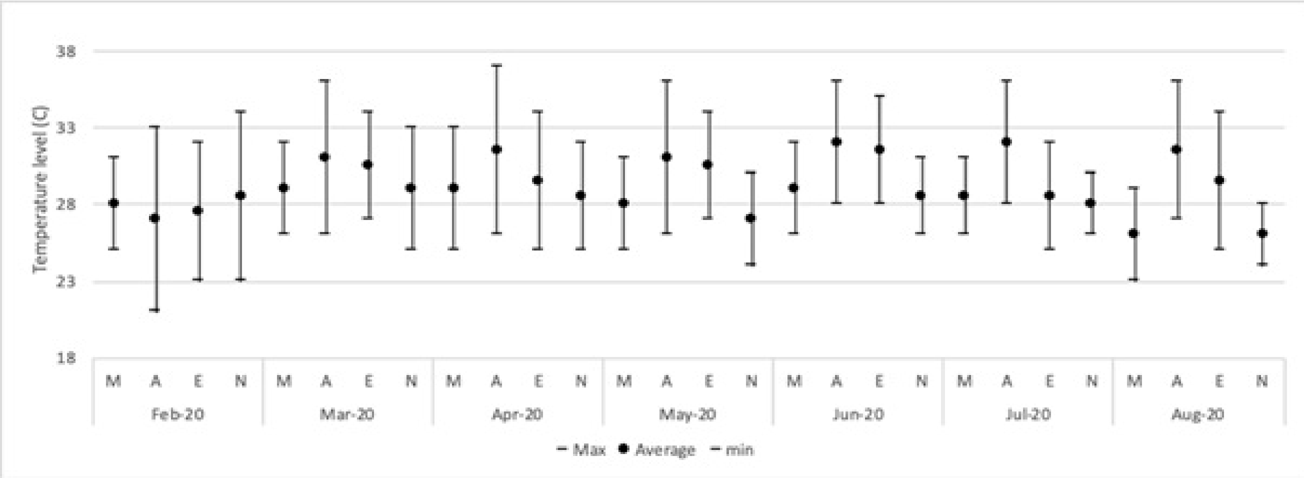

Figure 4. *Collected sensor data of a temperature in the testing sites for average, min and max based on time and month.*

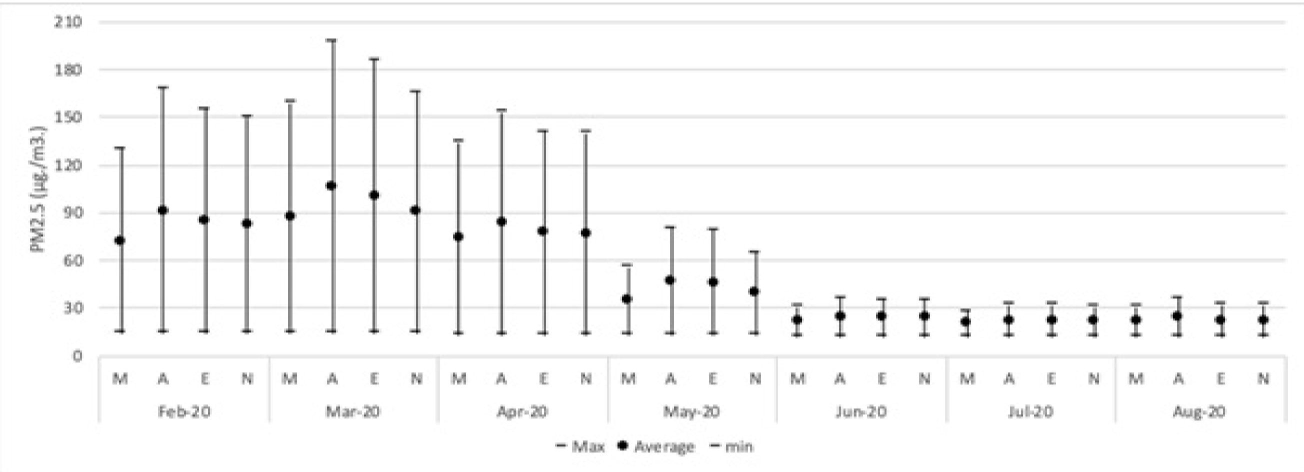

Figure 5. *Collected sensor data of PM 2.5 in the testing sites for average, min and max based on time and month.*

tremendously low, and agricultural farmers may require irrigation or need to store water for their farms. Moreover, responsible organization can use such data to plan for assistance or as a reference data for compensation. Furthermore, unlike common data from a general area, these data are specified to the sensor-deployed area making them more useful for tackling problems and planning accurately and effectively.

4.2 User Evaluation Results

The tool for the first evaluation is a questionnaire consisting of questions to rate the utility of the data. The rating is defined according to 1 to 5 score in Likert scale [15] where 5 refers to 'highest rating' and 1 stands for 'lowest rating' respectively, respectively. Participants to rate the use include 7 farmers representing the volunteer farms and 3 local organization officers who response for agricultural affair in the experiment area. The topics for evaluation are about how the proposed framework assists the farmers in their endeavor. The evaluation results from users are given in Table 3.

The results from Table 3 indicate that users agree on good ratings for performance and usefulness of the framework. They rated the highest for easy to understand aspect since data are processed into a form of a graph. For farmers, they added that the devices were not in the way of their work, but they need to be mindful of the device since they look fragile. For local organization officers, they praised that the data were useful to keep tracking of emerging issue and helped them to plan on allocation of their budget to solve the issue with referable information.

Table 3. *Evaluation results from users.*

Topic	Average	SD	Rating Interpretation
Able to reduce times in a agricultural management	4.47	0.84	High
Able to plan ahead using the obtained data	4.33	0.92	High
Able to reduce a risk of unwanted circumstance	4.42	0.94	High
Data are easy to understand	4.55	0.91	Highest
The deployed devices are safe and do not interfere with farming	4.42	0.94	High
Overall average	**4.44**	**0.91**	**High**

4.3 Usage Evaluation Results

As the sensors were deployed in September, 2018, the data have been collected continuously. In this part, we report the circumstantial results of the deployed sensors and issues we found during practical usage.

Apparently, we were able to gather real-time data and used them to provide services to support farmers and responsible local officers. However, there were frequently alerts to notify on missing data retrieved from the deployed sensors. From analysis, we found that internet connection was occasionally instable in which resulting in missing data. Furthermore, the electricity applied to the devices may sometime get disturbed by surrounding circumstances including electricity blackout and power shortage. These issues though result in temporal losing of real-time data. For this type of issues, no particular action is needed, and the device should resume their function after circumstance returns to normal. Nevertheless, the database should be monitored since data may be collected incorrectly while the issue occurs. For a year, we summarize the found cause of missing data in Figure 6.

4.4 Discussion

With the setup in the actual environment, the vulnerabilities of sensor devices become one of the most prominent issues. Since the sensors in this work have been deployed outdoor, there are several factors that cause issues to the device. Unlike IoT and sensor systems setting indoor such as smart home system, owners of the system realize its vulnerability and they are located properly for protecting the devices. The factors are classified into 3 types as 1) environmental damage, 2) animal and human unintentional interference, and 3) human disturbance.

The first type is the environmental factor. the sensors placed outdoor have been worn down with the contact of water, moisture, wind, sunlight and dust. These environmental factors can damage both sensors and control boards. Even though it is suggested to build a shell and cover to prevent direct contact with those factors, some are not applicable since it should reduce sensing ability of the deployed sensors such as sunlight sensor and pm 2.5 sensor. In a duration of a year, 6 of sensors and 3 control boards were crashed and needed a replacement. From examining the crashed devices, the core circuits were worn out and damaged from rusty and electrical short circuits. Although this issue can be fixed easily with replacement, it needs to be done instantly since the data from this source are lost and will affect relevant applications. This issue also leads to additional costs of maintenance. The vulnerabilities of sensor devices thus should be one of key research topic to be solved for IoT technology to become fully integrated into our day-to-day lives.

The second type is the issue from animal and human unintentional interference. As outdoor devices, animal and human unintentional interference cannot be easily avoided. Setup of some sensors requires specified angle to measure the required parameter accurately such as sunlight sensor or water current speed sensors. Unintentional hit or bump from animal and human may at least shift the setting angel or at most cause the device to fall off. Furthermore, some were reported to be damaged from mice and lizard. This issue will affect the collected data to be inaccurate and resulting in bad performance of the related application. In terms of fixing the issue, the inaccurate data are difficult to be detected; hence, it requires a scheduled inspection of the deployed devices. The devices deployed in a farm however can be asked to be inspected by farmers, but the rest needs to be inspected by a developer.

The third type is the disturbance from human. The outdoor devices incur the risk of being destroyed and stolen. One of the deployed sensors was destroyed while we lost a set of a sensor and a circuit board. Since the devices need to be exposed to environment for measurement, the location for deployment is limited. The design of the device setup in a public area thus requires a concern of such uncooperative matter such as reducing a risk to be destroyed of a sunlight sensor by attaching them to the electricity post, but this also requires additional permission to responsive agency.

5. Conclusions

IoT technology enables automation in many fields including agriculture. To obtain real-time data, specific type of sensors is deployed to measure required parameter for using in a decision-making model. However, scalability of the collected real-time data to cover larger area becomes a challenge in practical. In this work, the main objective is to centralize real-time data in a scale of a sub district (Tumbon) for using and sharing in several smart farm systems to support various parties.

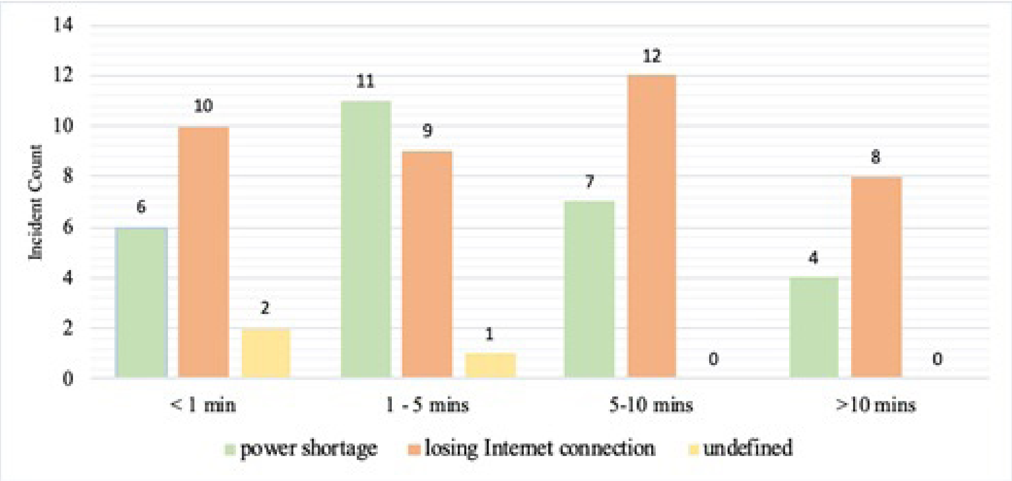

Figure 6. *the causes of temporary error and duration of the missing data.*

Deploying many types of sensors outdoor in a public area comes with several practical issues. This research presents a framework to gather various types of real-time data related to agricultural endeavor. The data are centralized and sharable among several applications; thus, reducing the cost for individual deployment of the same type of a sensor.

For satisfactory result from users, the deployed sensors were appreciated for their fast and accurate parameter collection. However, the practical results come with the found issues needed to be address. Considering that the sensor data are responsible for being key inputs in applications such as watering system and flood detection, the data must be reliably accurate. From practical results, outdoor sensors have been interfered with various factors including unstable network and power, vulnerability of a device towards weather and human disturbance. These factors cause the devices to be temporary malfunctioned or destroyed in which affects the additional maintenance cost and reliability of the collected data. The results of this study thus demonstrate that deploying sensors for IoT-based application in a large-scaled outdoor public area must be considered carefully regarding environment factors and possibility of human intervention. These issues will become research challenges that must be addressed for IoT-based application to become reliably practical and fully applied into large-scaled projects in a society.

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