IoT Architecture based on Information Flow Diagram for Vermiculture Smart Farming Kit

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Abstract **– IoT technology is widely applied to many areas, including agriculture. The smart farming design and implementation deal with farm operations and management effectively. The aim of this research enables supporting a vermiculture smart farming kit based on IoT technology. The layered architecture design is represented to support the deployment of sensors, networks, monitoring systems, data collections, and watering decision system. Information flow diagram is proposed to improve how the web application of our smart kit system can implement based on the system requirements. The evaluations of the smart kit are investigated to deal with consistency and effectiveness comparing between a traditional and the smart kit of earthworm vermicomposting. The gaps of farmers' needs can be satisfied to advance the better solutions of the smart farming kit.**

Keywords **– Smart agriculture, Smart farming kit, IoT, Architecture, Information flow diagram**

1. Introduction

The Internet of Things (IoT) extensively impacts human daily life from small wearable devices to huge enterprise systems.

By consideration the digital transformation of smart things, IoT could be a challenging task to transform manual methods to any automation for reducing human interventions [1], including in a farm production. Precision agriculture [2], [3] is a key element to progress the agriculture effectively and automatically. The smart farmer system brings the intelligent connections that allow us to control the powerful innovations in a sustainable way. The possible changes in soil, production, crop [4], management, and environment [5] can disturb the workforce using innovative results. Farmer responsibilities are concerned as a domain solution to coordinate the smart devices and to adapt the new transformation. For example, the daily farming operations such as irrigation and atmospheric monitoring, fertilization management such as verifying good materials and manuring [6], and financial management [7] such as cost calculation and expense records. The farm clarifications are studied in various areas such as soil stages, environmental conditions, plants, and animals.

While the advantages of the smart agriculture system are widely studied, Ammar, Russello, and Crispo [8] mention that there are a number of challenging gaps related to increase the efficiency of IoT systems in a high complexity, the framework design for high and low communications, multi programming languages, infrastructure management, variety of communication protocols , and hardware and software layers. Since 2015 the IoT systems have been delivered and enhanced for actual usages from 30 million devices [9]. The applications of IoT could make the intelligent artifices capable to satisfy the user requirements for adequate flexibility and adaptability [10]. The IoT development of smart connections attracts to remote sensor-equipped and Internet-connected devices [11] for data collections, centralized management, and Information analytics. There are many accelerating operations can be applied to access and control variables such as temperature, humidity, vibration [12], and traceability products [13]. Based on the component layers design of IoT smart farms of [14], [15], we have adapted the agricultural architecture supporting the automatic vermiculture smart farming kit. We have also applied the information flow diagram of [16] to brighten the system design of the web application in this study.

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To overcome the solutions, we believe that the applications of the vermiculture farming kit can accomplish the IoT infrastructure gaps. The vermiculture technology is an important waste treatment. Vermicompost [17] has a high potential of nutrients and microbes for growing plants. Vermicompost is the product of the decomposition process. There are various species of worms, red wigglers, white worms, and other earthworms. The earthworms can create a mixture of decomposing waste vegetable or food waste, materials, and vermicast for reducing levels of contaminants and increasing a higher saturation of nutrients [18]. We believe that the automatic vermiculture smart farming kit is advantageous for cultivating poor quality soils. Soil degradation is associated with poverty and lack of access to land and water in areas with high levels of poverty. For some agricultural producing countries, the farmers may cause of unhealthy problems of using toxic substances. Earthworms need the minimum care requirement, but a regular schedule has to be made for them and a consistency condition. Thus, the vermiculture smart farming kit seems to support the automatic monitoring and environmental management such as temperature, humidity, moisture, and watering. Therefore, the farmers are able to arrange along with saving time management and increase a number of earthworm composting.

2. Literature Review

IoT stand for Internet of Things. IoT is a current technology to connect various smart devices through the Internet. The network communications allow us to control objects remotely accessing the network infrastructures. The IoT applications become increasingly with ubiquitous and mundane physical artifacts in the fields of transports and logistics, smart home, smart cities, smart factories, retails, E-Health, smart energy [19], and smart agriculture [20]. The characteristics of IoT are able to connect sensors, objects, devices, data, and applications. The IoT technology has been principally used for smart agriculture systems in many ways such as measuring of temperature, humidity, sunlight [21] and PH (acidity - alkalinity), monitoring water and biogas, and traceability in animal farms [22]. In addition, the compatibility of IoT can combine with smartphones to make the good conformation, ease of use, and reduce cost.

Few researches studied on the IoT architecture designs and applications for agriculture. FarooQ, Riaz, Abid, Abid, and Naeem [14] have presented the major components of the IoT smart farming systems. The components consist of data analytics, data processing, data acquisition, and physical structure. The components are divided into the important factors. The most important component is the physical structure such as sensors, and actuators because of avoiding every undesirable situation. Moreover, the IoT devices and sensors can be adjusted differently depending on plats requirements [23]. Verdouw, Sundmaeker, Tekinerdogan, Cozon, and Montanaro [24] have proposed the architecture of IoT-based food and farm systems. By applying the architecture design, the framework can be developed, adapted, and reused to the remote identification, sensing, and control smart devices by IoT layers. The IoT layer viewpoints are considered in many areas: 1) concerns can be adopted for components, IoT functionalities, and system deployments, 2) stakeholders are provided and interacted technically in the systems, 3) elements are for capabilities management, including an application layer, an application support layer, and a network layer. Tummers, Kassahun, and Tekinerdogan [5] have studied on the reference architecture design of the farm management information system. The design is dedicated to the specific significant domains that can be applied as a guideline for the better understanding of stakeholders, a clear definition of IoT features, and a great management for any obstacles.

According to this research, we focus on the interface software design of vermiculture smart farming kit. We propose the design and process workflow of the system. Chomngen and Netinant [16] are firstly proposed Information Flow Diagram (IFD). IFD is defined as a user interface diagram of the symbol layering design. The layer is represented by the process of interface design on each screen. IFD shows the running stages of data retrieval, results, interfaces, and information flow processes using the illustration design. The diagram is able to compose of user interfaces, processes, data and information flows, and data stores. Thus, the interface flow diagram is helpful for increasing the potential design and the efficient software comprehension.

3. Objectives and Research Questions

To address the earlier issues on the proper scopes of the smart farming system, the objectives of this research are to develop a vermiculture smart farming kit based on the component architecture design and the information flow diagram, and to evaluate the implementation of the vermiculture smart farming kit by comparing between the traditional growth of earthworms and the proposed smart kit. To complete the objectives, the following research questions are defined.

RQ1: Which infrastructure and technology of IoT are appropriate for the vermiculture smart farming kit development?

RQ2: How effectiveness of the smart kit can make the better results?

The first research question aims to identify the system design, IoT sensors, and connections for developing the smart farming kit. The second research focuses on evaluations of the consistency and effectiveness by comparing between a traditional and the smart kit of earthworm vermicomposting.

4. Research Methodology

4.1. Architecture Design of the Vermiculture Smart Farming Kit

The conceptual component designs of the IoT smart farming system based on Farooq et.al. [14] is applied in this research. We have reorganized the four components as the main layers of our vermiculture smart farming kit as publicized in Figure 1 that characterizes the four component layers for supporting the design of the vermiculture smart farming kit. Our system design is based on the layering system and components. Each layer consists of many components. We have considered the suitable components for each layer. From the bottom layer to the top layer, the Infrastructure structural layer consists of temperature sensors, humidity sensors, a solenoid valve, and a relay device. The IoT devices are controlled by a raspberry PI 3 Model B+. The control operations are performed by a mobile device through the Internet (the upper layer). The data acquisition layer contains HTTP (Hyper Text Transfer Protocol), WIFI, MQTT (Message Queuing Telemetry Transport), and web sockets. All pots setup closely together in the usual environment. Every sensor is not far apart, so a regular WIFI can be used to communicate between a host and sensors. The data processing layer is for sensors monitoring. Soil moisture, humidity, temperature, and water monitoring are concerned on a dashboard. The data analysis layer consists of data loading, data logging, and watering decision system. Consequently, the automatic water pump can be accomplished to make the proper environment consistently for earthworms.

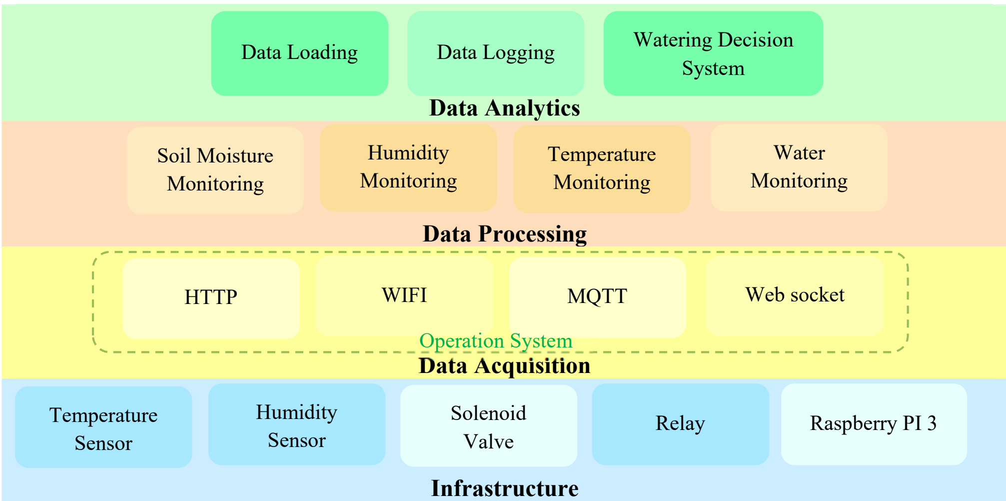

Figure 1. The major layers of the vermiculture smart farming kit

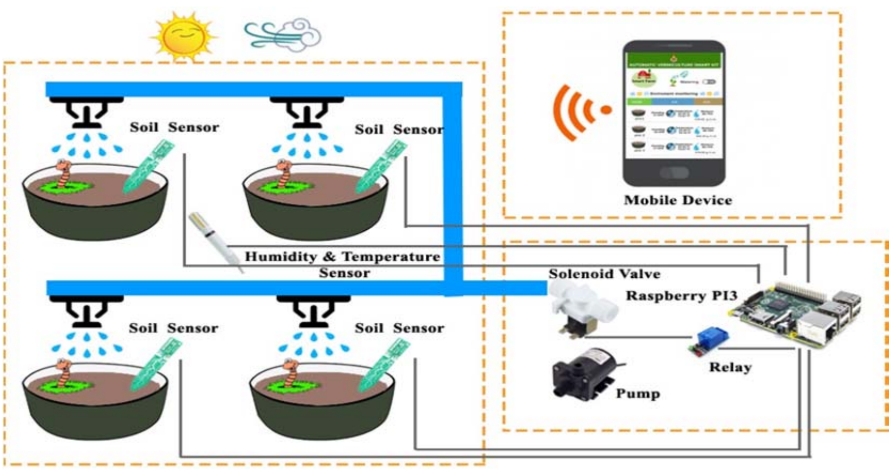

Figure 2. The infrastructure design of the vermiculture smart farming kit

An infrastructure design of the vermiculture smart farming kit shows in Figure 2. The design consists of the IoT devices, the example of the earthworm pots and the web application on a mobile phone. In this study, the IoT devices are Raspberry Pi 3 Model B+, a relay module (1 channel 5v 1 channel relay), AM2315 - Encased I2C Temperature/Humidity Sensors, Adafruit STEMMA Soil Sensors - I2C Capacitive Moisture Sensors, and Solenoid Valve 12V-DC 1/2". The control box is placed to avoid the water and the sunlight.

4.2. System Design of the Web Application

The functional scope of the system is designed using the principle design of the information flow diagram in Figure 3. The structural design of the vermiculture smart farming flow is represented with the start menu.

The user can register to become a new member or an existing user can login to the dashboard. Then the login component will perform to load a user session, check for network connections, sensors and environmental conditions, and detect water status and volumes. We intend to create the monitoring system of soil moisture, humidity, and temperature. The decision system supports watering automatically and flexibility. The critical circumstances are configured to support the automatic spraying system. For instance, the temperature is higher than 40°C or the soil moisture is lower than 60%. When the critical condition is occurred, the system delivers water in earthworm pots automatically. The control water component is created to manipulate the toggle switch of water pouring. The user interfaces are designed to prove the overview flow of the system design through the prototype. The database tables are related to the web page designs.

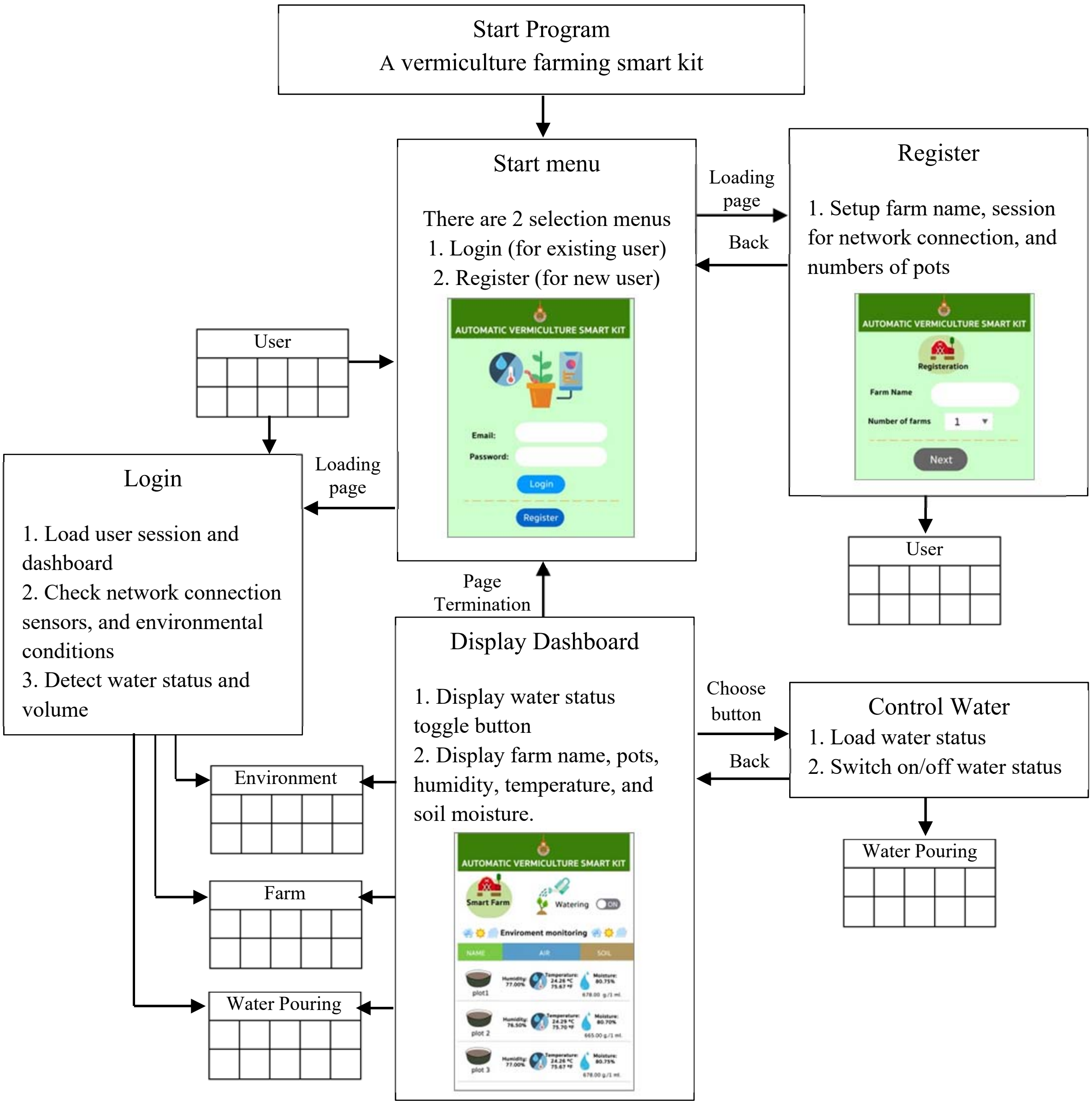

Figure 3. The information flow diagram of the system

4.3. Situation Test

We intend to design and evaluate the implementation of the vermiculture smart farming kit. The evaluation results of the situation test are to compare the effectiveness of using the smart farming kit to the traditional growth of earthworm in the usual circumstances. The factors of the effectiveness test are IoT environmental information, consistency, and volumes of vermicomposting. We let the earthworm grow for three months, then collect the IoT information, and detect the water status every 1 hour. We record the volumes of vermicompost and fill the waste fruits and vegetables for them every 1 week.

5. Results

The vermiculture smart farming kit system can collect data from temperatures, humidities, and soil moistures applying IoT technologies such as sensors, devices, networks, and the web application as showed in Figure 4. The volumes of vermicompost are represented in Figure 5. The productivity of vermicompost is recorded by using the traditional growth and a smart kit. We have compared the results of both techniques in Figure 6.

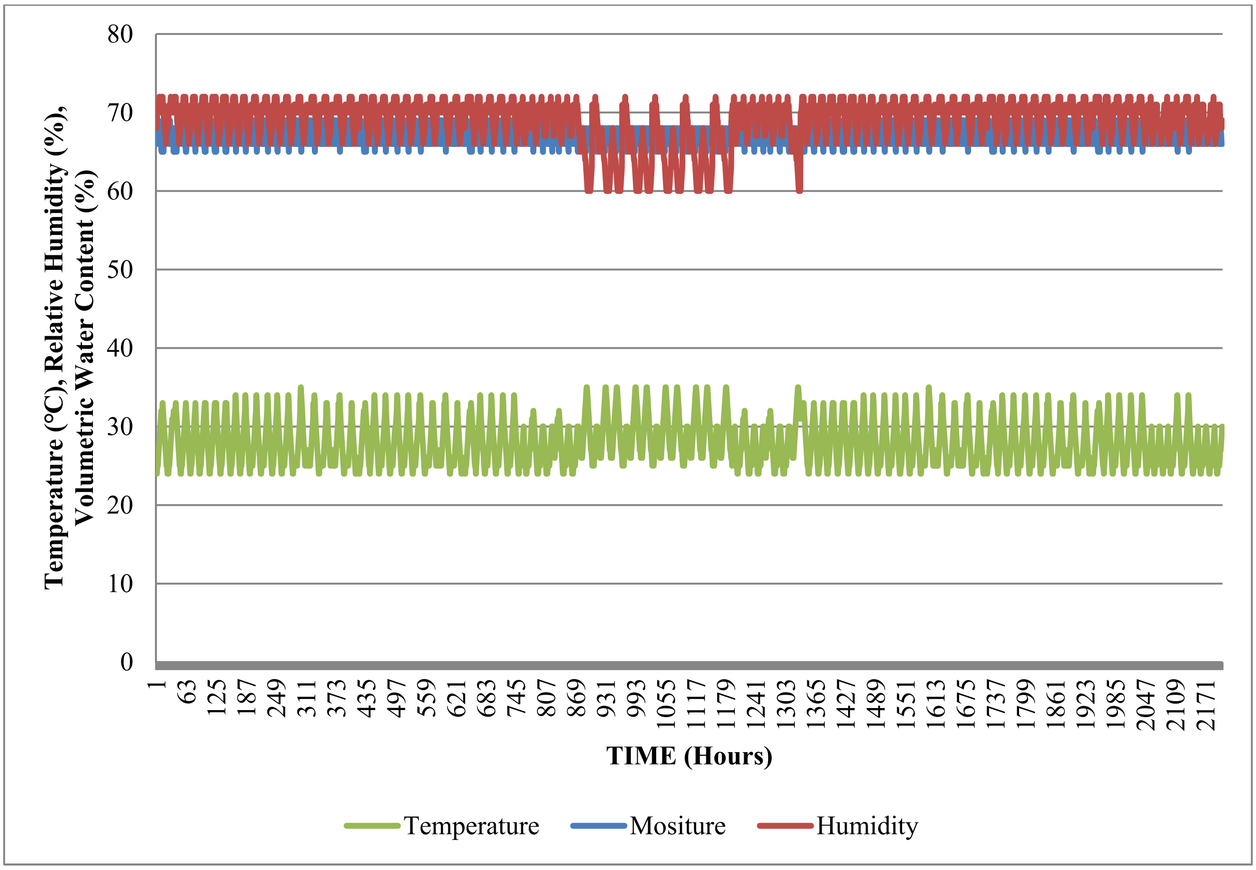

Figure 4. The IoT information of temperatures, humidities, and soil moistures

Figure 4 shows how the system is monitoring and controlling of moisture affecting development of the earthworms growth in pots for approximately 3 months. It is taken from our system records in every hour for nearby 3 months. The system monitors and records temperature, humanity, and moisture in every hour for approximately 3 months. The system will spray water for pots when moisture is below 65% VWC. The system stops spraying water for pots when moisture is around 68% VWC. There are three graphs in the chart as illustrate. The green graphs show average temperatures for 3 months in every hour. The red graph shows the natural humanities for 3 months in every hour. The blue graph deals with the controlling environment of average soil moistures of every pot for 3 months in very hour. Every graph shows the average hourly temperatures, humidity, and moistures for 3 months. Temperature graph shows that the highest temperature is 35 Celsius and the lowest temperature is 24 Celsius. Humidity graph shows that the highest humidity is 72% relative humidity and the lowest humidity is 60% relative humidity. Moisture graph shows that the highest soil moisture is 69% volumetric water content and the lowest soil moisture is 65% relative humidity. The system can control and monitor the soil moistures in between 65% and 69% of volumetric water content for nearby 3 months, regardless temperatures and humidity are.

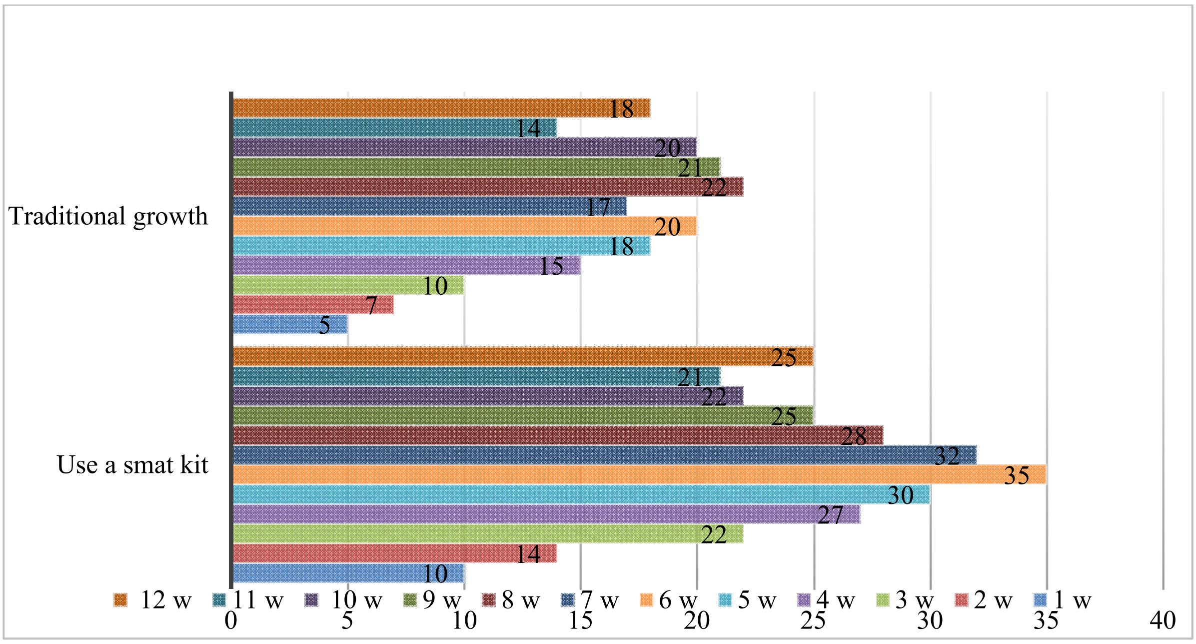

Figure 5. The volumes of vermicompost in 3 months

There were four earthworm pots monitored and controlled by a smart kit for vermicomposting. There were four earthworm pots using a conventional vermicomposting. We collected the volumes of vermicompost at the end of every week for 3 months. One unit of the vermicomposting volumes is a teaspoon. Figure 5 shows the total volumes of vermicompost at the end of every week for 3 months. At the end of the first week, the volumes of vermicompost from earthworm pots are monitored and controlled by a smart kit have as twice as the volumes of vermicompost from traditional vermicomposting. The graph shows that a smart kit can produce the volumes of vermicompost between 10% and 100% more than a traditional vermicomposting. At the end of 3 months, the volumes of vermicompost from earthworm pots monitored and controlled by a smart kit have 64% more than the volumes of vermicompost from a conventional composing.

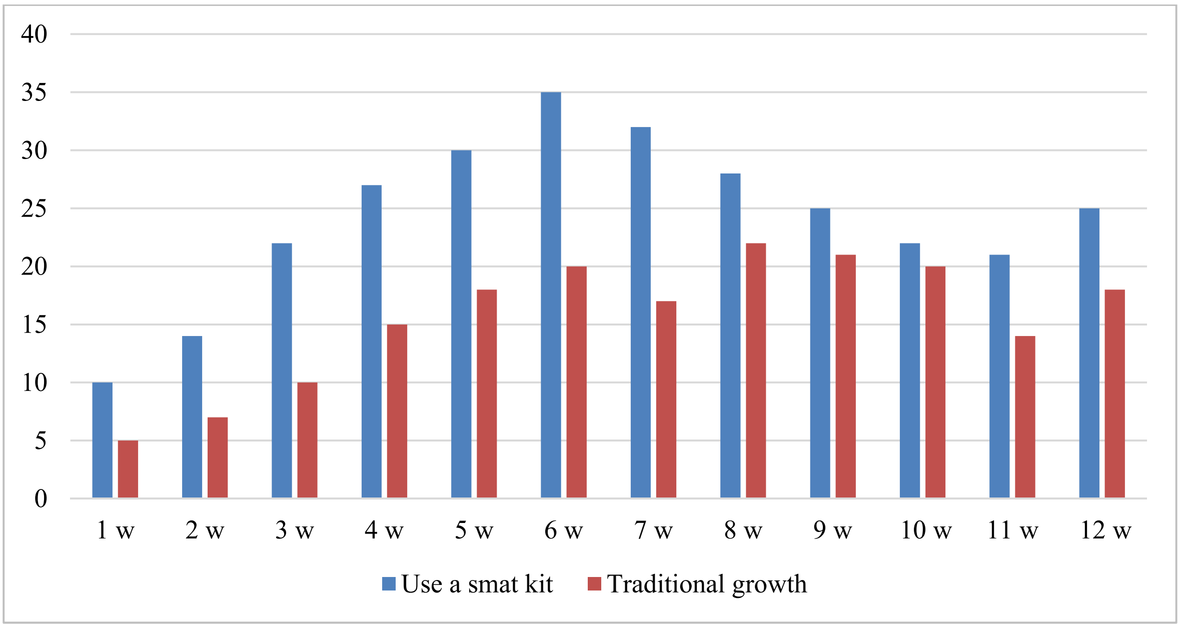

Figure 6. The comparison of vermicompost using the traditional growth and a smart kit.

Figure 6 shows a comparison of the volumes of vermicompost in every week for 3 months. The volumes of vermicompost composed by earthworm pots are monitored and controlled by a smart kit compared with earthworm pots monitored and controlled by a conventional vermicomposting. The volumes of vermicompost from smart kit earthworm pots in every week were 100%, 100%, 120%, 80%, 67%, 75%, 88%, 27%, 19%, 10%, 50%, and 38% more than the volumes of vermicompost composed by a conventional growth of earthworm pots, respectively from the first week.

6. Discussion

Digital technology plays a significant role in precision farming and empirical IoT development based on the smart farming innovations. The agriculture systems can apply diversity research areas [25]. The architecture design of the vermiculture smart farming kit is premeditated following the layered proposal and the architecture design for precision agriculture. The software composition divided into layers has claimed to support in many researches [7], [24], [26]. Elijah, Rahman, Orikumhi, Leow, and Hindia have cited that IoT technology consists of a multilayer architecture and devices. Basically, each layer belongs to infrastructure for sensing, data acquisition for network devices, data processing for system monitoring, and data analytics for data driven and decision system. We believe that any traditional farms can be easily changed to the smart farmers. However, it depends on environment and climate information of fruits and animals such as temperatures, moistures, PH values, gases, and intensities of the sunlight. The suitable circumstances should be deliberate for the decision support system automatically. The collaboration of devices can show the results through a remote monitoring platform [14]. In this study, we have developed our web application for supporting the monitoring system responsively. The application can be added a number of earthworm pots as much as the farmers need. Moreover, the architecture framework design and implementation of the smart farming system should be concerned according to farmers' needs [5] and readiness. An effective and sustainable smart farming system should be asserted for the mindset of the farmers. Therefore, the technological breakthroughs [27] in a precision farming can be transformed the complex agriculture equipment to the simple innovation.

7. Conclusion

The objectives of the research were to develop the vermiculture smart farming kit according to the design of component architecture and to evaluate the implementation of the vermiculture smart farming kit by comparing between a traditional and the smart kit of earthworm vermicomposting. The consistency of environmental information is observed for improving the earthworm growth platforms. The automatic water pouring is performed to make the natural environment consistently. The volumes of vermicompost using the smart kit are higher than growing in the traditional composing. Especially in the summer, the heat affects earthworms. Therefore, the smart kit deals with environmental monitoring and automatic watering at all times. The earthworms can live naturally and steadily. We believe that our system design of vermiculture smart farming kit can be modified and implemented to wide-ranging animal farms. Hence, the farmers are able to simply connect and practically monitor their farms anywhere and anytime. The future work will focus on applying the solar cell system in the farms and calculating the values for the investment. We also plan to use more sensors such as PH, and movement detection sensors to advancement the smart kit more practically and beneficially.

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