INTI JOURNAL | eISSN:2600-7320
Vol.2020:49

Smart Vertical Farming Using Iot

Rajermani Thinakaran[1*], Sarasvathi Nagalingham[2], Eng Jing Hui[3]

[1,2,3]Faculty of Information Technology, INTI International University, Nilai, Malaysia

***Email:** rajermani.thina@newinti.edu.my

Abstract

The vegetable industry is one of the important industries in Malaysia. It provides food for people, creates jobs for rural community and generates revenue for economic development. However, in current years, vegetable industries in Malaysia could not fulfil the demand due to shortage of workers in the farms. Thus, in this paper, Smart Vertical Farming System (SVFS) using IoT was proposed. It is a green revolution using emerging Information and Communication Technologies, into farming field. The system was developed using waterfall model with qualitative approach. The system able to monitor soil humidity, grow light and temperature of the planting environment. Initially the system was tested together with traditional farming method by growing 2 different kind of vegetables. After nineteen days, vegetables grown under SFVS could grow much faster and produce more leaves. From the finding it shows the system able to help the farmer to increase the quantity and quality of vegetables and ensure that the market having enough stock with reasonable price.

Keywords

IoT, Smart Vertical Farming, waterfall model, soil humidity, grow light, temperature

Introduction

The production of vegetable in Malaysia could not fulfil the demand of the current market (Chuah et al., 2019). The major reason is shortage of workers in the farm (Fong & Lokman, 2019). Two factors lead to this cause: 1) local young people did not wish to get their hand dirty with the agricultural job (Talib, 2019); 2) Most of the current farmers are in "ageing population" (The Star, 2018) range which is 65 and above defined by World Health Organisation (WHO). Their age condition and working environment did not permit them to work.

To overcome this issue, Malaysian government had decided to import vegetables from other countries such as Thailand and China (The Edge Malaysia, 2018). However, relying on imported goods has related to another issue which is food security (Shamsudin, 2016). While, Lopez (2019) has stated that relying on imports can leave the country exposed to vulnerabilities during an economic downturn. Another alternative to solved this issue is by hiring a foreign worker. Still this is not a proper solution because, the levy of hiring a foreign worker in agricultural

International Conference on Innovation and Technopreneurship 2020
Submission: 4 September 2020; Acceptance: 23 November 2020

filed cost RM640 (Immigration Department of Malaysia, 2019), this may be a burden to most of the small-medium farmers.

To mitigate these problems facing by the farmer and community, researchers have introduced smart farming (SF) and vertical farming (VF). SF is combination of information and communication into machinery, equipment and sensors for use in agricultural production systems (Pivoto et al., 2018). While, VF refer to growing the vegetables inside a building (Zulqarnain at al., 2020). This technology become popular in many modern-countries due to minimum usage of the land, cost of implementing, healthy food provision, improved food security, and reduction of water demand (Kalantari et al., 2018). Thus, in this study the authors proposed and developed smart vertical farming system (SVFS) combination of SF and VF to overcome the previous stated problems.

Methodology

In this study, waterfall model was adopted as system development methodology. In this model there are 4 phases which are: Requirement Gathering and Analysis, System Design, Implementation and Testing. The stages are summarized as follows:

Requirement gathering and analysis

In this phase qualitative approach was chosen which are interview and observation, for assessing and analyzing the benefit and limitation of commercial and indoor farming techniques. The interview was carried out with 2 interviews, a well experiences farmer (Madam Ng Cui Yi) and a housewife (Madam Wong) in growing vegetables. The outcomes are: 1) the author needs to concern on the humidity of the soil or else the roots of the vegetables will be easily getting rotten. The soil moisture needed to be concerned as it is an important indicator to the roots. Therefore, the author will focus on the watering system to make sure the soil does not contain too much of water. 2) Sunshine also another important factor for the plants to grow. 3) Using too much pesticides and chemical fertilizers will affect the soil. The soil will become acidified and the minerals will be diminished. The advice is to use uses organic fertilizer.

For observation, the authors identified 3 videos which are: Singapore urban farming provides sustainable solutions (CCTV, 2016); TechKnow - The farmers growing vegetables with LED lights (Al Jazeera English, 2015); and Growing Roots - Farmers growing vegetables at rooftops (Discovery Channel, 2016). From the observation, the authors had discovered that growing the crops vertically can increase the production in a limited space while water and lights are key factors in indoor farming.

Functional requirements describe what the system should do and non-functional requirements describe how the system works. For the proposed system, automated control, mobile application supported, monitoring and log record were identified as functional requirement. For non-functional requirement, a user friendly interface and ease of use was considered. These requirements were identified during interview and observation sections by the authors.

System design

Use case diagrams are used to model the system requirements and to declare the functions/services provided by the system to the user. Figure1 and 2 illustrate use case for System Monitoring and System Controlling. System Monitoring consist 5 actors: 1) User - able to read the parameter such as temperature, humidity and soil humidity, will receive a notification when one of the growing conditions is not fulfil the requirement, take further action according to the notification and can keep track details of planted vegetables such as type of vegetable, date and duration planted through log file; 2) Microprocessor - read the parameter from sensors and send notification to the user; 3) Humidity & Temperature Sensor monitor the humidity and temperature; 4) Soil Moisture Sensor monitor the soil humidity; 5) Sonar which measure the height of grow light. While System Controlling consist 2 actors: 1) User - able to modify automated condition, the system will create a log when the user plants the vegetable, can switch on/off manually through the mobile application; 2) Microprocessor - on/off switch for grow light, water pump and cooling fan will be started automatically if the sensor is triggered according to condition setting.

Figure 3 is graphical circuit diagram of IoT device for the proposed system. It consists 3 sensors, 1 Wi-Fi module and 3 transistors include in the circuit. The transistors work as a switch. Besides transistors, relays (L1 and L2) were used as switches. When there is enough voltage pass through L1, then the K1 will be triggered and the grow light will be turned on.

Figure 1. Use Case for System Monitoring

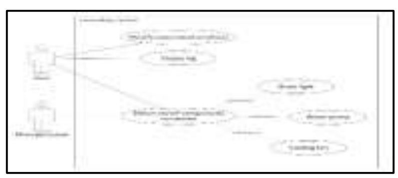


Figure 2. Use Case for System Controlling

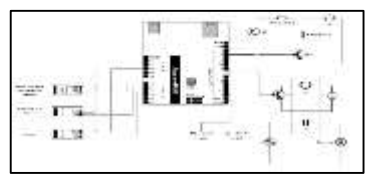


Figure 3. Circuit IoT Device Diagram of

While Figure 4 (a, b, c and d) illustrate an initial user interface design for the proposed system. Figure 3a is system home page which direct the user to components page, auto control page, view log page, plant new vegetable page and edit log page. Figure 3b is manually component control interface. In this interface user able to control grow light, cooling fan, water pump and also can view the farm condition in term of temperature, humidity and soil humidity. Figure 3c is auto control condition design where the user can set when to on or off the cooling fan. The last design (Figure 3d) where the user able to view the log details such as vegetable planted, date planted, and date collected.

(a) (b) (c) (d)

Figure 4. User Interface Design of IoT Based Smart Vertical Farming System

Implementation

The proposed system was implemented in Windows platform using Android Studio IDE. The IDE is useful for integrating hardware with software (Nuvvula et al., 2017) and this helps the authors to connect all the sensors and I/O devices. For microcontroller, Arduino circuit board (Figure 5) was chosen to develop the prototype. Microcontroller is a single integrated circuit which used for detecting signals and performing logical tasks (Nuvvula et al., 2017). Firebase is a mobile and web application development platform which provide the function of the database, messaging and reporting. Thus, the authors apply Firebase to store data such as type of vegetable planted, date of planted and duration needed. Firebase also allows Arduino to connect with it and send the notification to the mobile phone.

To detect humidity and the temperature of the planting environment, DHT11 sensor (Figure 6) was used. This sensor is made of two parts, a capacitive humidity sensor and thermistor. DHT11 sensor. can easily to be read by using any microcontroller. YL-69 (Figure 7) is a soil moisture sensor and it is used to detect the humidity of the soil. The sensor is set up by 2 pieces which are electronic board and 2 pads. The pads function is to detect the water content. The output of the sensor is voltage. The voltage will change according to soil water content.

Figure 5. Arduino Microcontroller

Figure 6. DHT11 Sensor

Figure 7. YL-69 Sensor

In this project, the authors had chosen a full spectrum grow light (Figure 8). The temperature of the light is 6300K which appearance is white color. According to Lalge et al. (2017), the plants grown under white light were having bigger leaf area compare to the plants grown under blue light. The ideal distance to install is 12 to 24 inches above the crops as shown in Figure 9. It also recommended not to leave the lights on 24-7, the plants need at least 6 hours of darkness for “resting”. ESP8266 as a Wi-Fi module (Figure 10) was used which is suitable for IoT project that is requiring network connection. This module is compatible with Arduino microcontroller and allows to be integrated with the sensors and other application with minimal development up-front and minimal loading during runtime. To communicate with Arduino microcontroller, codes are written using Arduino IDE and loads Arduino module while Java language was used in developing the system (Figure 11).

Figure 8. Grow Light

Figure 9. Grow Light

Figure 10. ESP8266 Wi-Fi module

Figure 11. Auto Setting Control

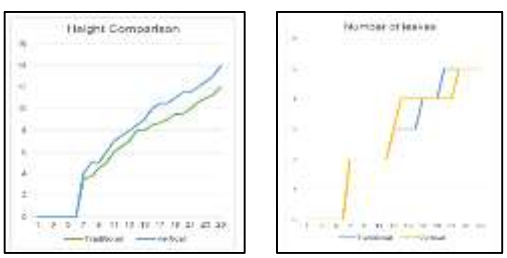
Testing

The implemented system was tested in terms of hardware integrated with developed Android application functionality. The authors carried out various hardware testing which are: Arduino and ESP8266 Wi-Fi Module; Temperature and Humidity Sensors; Soil Moisture Sensors; Ultrasonic; Water Valve; Cooling Fan; and Artificial Light. For Android application, the following module was tested: Retrieve Temperature, Humidity, Soil Moisture Level and Auto Control Details; Save, Edit and Delete Type of Vegetables from database; Summary of Previous Month Production; Test whether the mobile application can control the connected components; Plant New Vegetable; Update Auto Control Details; Notification; and lastly Control the Components. During the testing stage, the authors have identified some errors and able to rectified.

The developed SVFS was tested against traditional farming method by planting white stem choy sum and Chinese choy sum. The vegetable height and number of leaves will be evaluated through growing period. The authors also have conducted usability acceptance evaluation of SVFS by interviewing a farmer (Madam Ng Cui Yi) and a housewife (Madam Wong). The results of this testing were discussed in the following sections.

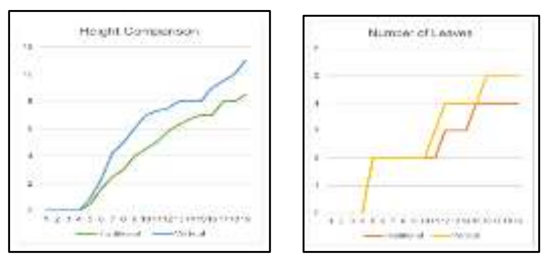
Results and Discussion

Figure 12 and 13 shows the comparison of choy sum growth between traditional farming and SVFS for 19 days. The result shows that the vegetables grown under SVFS could grow faster (Figure 12a and 13a) and produce more leaves (Figure 12b and 13b). The results obtained in this study are also consistent with Haris et al. (2019).



(a) (b)

Figure 12. White stem choy sum Comparison



(a) (b)

Figure 13. Chinese choy sum Comparison

Based on usability acceptance evaluation, the overall system user interfaces are accepted. Still, it will be better if user manual was included and supported with multi language. For the hardware, some suggestion was given which are timing should be adjusted, reduce the water pressure, and implement a camera to monitor the vegetables. However, the over SVFS was accepted and the interviewees are willing to implement this system in their farm in the future. It can be said that SVFS is much better compare to traditional farming.

Conclusion

In conclusion, the proposed SVFS had been considered fulfilling the project's objective. The authors had developed the IoT based prototype and an Android application in this project. The user able to control the components connected to the prototype by using the designed mobile application. Besides, the user also able to monitor the temperature, humidity, and soil moisture level from the mobile application. The auto control mode allows the user to control the farm automatically based on the condition set by the user. This had helped the user reduce the workload in growing the vegetables.

References

Al Jazeera English, TechKnow - The farmers growing vegetables with LED lights, Published 28 November 2015. 2016. Available at: https://www.youtube.com/watch?v=LrOADvRHRlw

CCTV English, Singapore urban farming provides sustainable solutions Published 17 November 2016. Available at: https://www.youtube.com/watch?v=hrQulNptLXA

Chuah, Y. D., Lee, J. V., Tan, S. S., & Ng, C. K. (2019, June). Implementation of smart monitoring system in vertical farming. In IOP Conference Series: Earth and Environmental Science (Vol. 268, No. 1, p. 012083). IOP Publishing.

Discovery Channel, Growing Roots - This Farmer Is Taking Root On Your Rooftops, Published 30 June 2016. Available at: https://www.youtube.com/watch?v=vPRySy3Qtvs

Fong, F. and Lokman, T. (2019). Labour shortage in Cameron Highlands. [online] Nst.com.my. Available at: https://www.nst.com.my/news/exclusive/2018/01/327205/labour-shortage-cameron-highlands

Haris, I., Fasching, A., Punzenberger, L., & Grosu, R. (2019, June). CPS/IoT Ecosystem: Indoor Vertical Farming System. In 2019 IEEE 23rd International Symposium on Consumer Technologies (ISCT) (pp. 47-52). IEEE.

Lopez, B. (2019). Food security is - Letters | The Star Online. [online] Thestar. Available at: https://www.thestar.com.my/opinion/letters/2019/06/05/food-security-is-important

Nuvvula, J., Adiraju, S., Mubin, S., Shahana, B., & Valisetty, V. (2017). Environmental Smart Agriculture Monitoring System Using Internet of Things. International Journal of Pure and Applied Mathematics, 115(6), 313-320.

Shamsudin, M. (2016). Food safety and food security. New Straits Times.

Solehudin, A., Heryana, N., & Cahyana, Y. (2020). Designing and Building Client-Server Based Student Admission Applications. Buana Information Technology and Computer Sciences (BIT and CS), 1(1), 16-18.

Talib, A. (2019). Urban youth going into agriculture. [online] New Straits Times. Available at: https://www.nst.com.my/opinion/columnists/2019/04/476869/urban-youth-going-agriculture

Zulqarnain, N. M., Sharifuddin, J., Roslan, M., & Hassan, S. (2020). Factors Influencing Attitude towards Technology Adoption among Permanent Food Production Park (PFPP) Program Participants in West Malaysia. Journal of Agricultural Science and Technology B 10 (2020) pg. 89-97.