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# Voice Integration on Smart Indoor Garden (VoISIG) Using Amazon Alexa

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## ABSTRACT

The implementation of voice integration in garden irrigation system contributes to greater comfort for those in need. In addition, it yields an effective water usage and less human involvement. Measuring the soil humidity enable the garden owner to know the water required for a plant. The accuracy of voice integration is vital for better interpretation of the commands given. The Voice Integration on Smart Indoor Garden (VoISIG) utilized NodeMCU and Amazon Alexa for data capturing, and ThingSpeak to display data. A functionality test has been conducted to test the accuracy of voice integration between male and female. The result shows that female has better accuracy rate voice integration by 13.9%. Received Signal Strength Indicator (RSSI) are measured as well to ensure stability of the network connectivity. Future research may implement additional features such as digital moisture sensor, timer and other advanced technology to cater various species of plants.

**Key words:** Home Automation System, Indoor Gardening, Internet of things (IoT), Voice Integration, Soil Moisture.

## 1. INTRODUCTION

Generally, VoISIG project is an example of Home Automation Systems (HAS). HAS has demand for the utilization of voice-controlled switches that can manage variety of appliances. With the ability to program and schedule events for an automation device on a network, the programming may include time-related commands such as to set light timers for a specific time of the day. By the year 2020, it is predicted that all web searches will be assisted by voice [1]. These systems disseminate information and commands among different devices. These systems provide a convenience way of remotely control and monitor the appliances just by voicing out commands in a reachable distance. For instance, home indoor gardening system.

The problem with manual indoor gardening lies with the situation when household members tend to forget about watering the garden due to the tight schedule ahead of them. As the living costs continue to increase over the year, these people tend to work more than staying at home. However, to decrease the living costs, many of these people began to plant herbs and own a mini vegetable farm. The Malaysian Meteorological Department (MET Malaysia) has issued a severe weather warning such as Malaysia is to face continuous extreme hot weathers, and heavy downpours [2]. Because of that fact, many of these people have shifted towards indoor gardening to avoid extreme weathers that could possibly ruin the plants if placed outside. These group of people require external assistant to look over their indoor gardens. Therefore, an automated irrigation system will be a more suitable way needed to solve this problem.

Besides, gardening is a relaxing activity that can be beneficial to whoever are interested regardless of any age. According to [3], gardening activities can boost one’s mood as well as helping to reduce psychology pressure. It is stated that by 2020, mental illness is expected to be the second biggest health problem after heart disease affecting Malaysian [4]. One of the possible solutions to the problem faced by those patients is gardening in an easy and convenient way.

Currently, there are a few gardening systems that are available in the market. However, a lot of them are outdoor based and large backyard gardens. Furthermore, the appliances used can be very expensive and not worth implementing it in indoor such as apartments or condominiums. Lack of research solution involving smart indoor gardens that purposely designed for any user who are interested in gardening and also for health patients and workaholics. Thus, the VoISIG project was piloted to explore the possibility of satisfying the real need of an indoor gardener by integrating Internet of Thing (IoT) [5,6] technology such as voice-over a smart indoor garden.

This paper will be focusing on developing an irrigation system that can be installed in homes with voice-assistance such as Amazon Alexa[7, 8] and will only explain the functionality tests result. The remaining of the paper is organized as follows: Section 2 demonstrates some previous related work on voice integration system. In Section 3, methodology is described. Result and findings are presented and discussed in Section 4. Finally, the paper is concluded in Section 5.

## 2. RELATED WORKS

Previous study in the year 2019 has implemented a voice interface for farmers to obtain and disseminate information. Automatic Speech Recognition (ASR) and Text to Speech (TTS) technologies were used to recognize uttered commands [9]. However, the recognition accuracy of ASR system is not accurate due to large variations in speech signal. If the number of words is reduced then system performance will increase.

Another study combined the use of physical and human sensors in agriculture such as Internet of Everything (IoE), where IoE is a combination of IoT and Internet of Human Sensing (IoH). The smart voice messaging system in this research has three functions [10]:
i) the user records his voice messages with related information (user ID, time, and location), ii) the system stores these messages (voice and recognized text) in a database and automatically distributes them to other users who are relevant to the messages and iii) the system visualizes messages stored in the database from several viewpoints (user, time, location, keyword). These functions will be executed in a smartphone application on Android Operating System; and a web server application on Windows Server. The result was impressive due to the combination of physical and human sensors.

Another study implements Interactive Voice Response (IVR) system to allow user to speak in native languages using collection of utterances stored in databases [11,12]. The sampling speeches are collected using Computerized Speech Laboratory (CSL). The result shows the overall accuracy of sentences passed and sentences recognized rate of the system came to be 91%. Next, another IoT-based gardening watering system implemented using mobile Bluetooth and direct current (DC) motor [13]. The temperature sensor, humidity sensor and soil sensor are connected to the Peripheral Interface Controller (PIC) microcontroller. The results of this study are displayed on the mobile device through the application as well as displaying on the LCD display which is connected to the microcontroller.

Apart from that, a work implementing Raspberry Pi 3 and Android application via Wi-Fi was developed [14].Users can monitor and control their home appliances remotely after receiving alerts signal from the smart home automation system.

## 3. METHODOLOGY

The research methodology comprises of three phases: project design, development and testing.

### 3.1 Project Design

VoISIG system was developed to be operated automatically or semi-automatically to help with the chore dealt by busy home garden tenders. It also can be used by people who enjoy gardening as relaxing activity to reduce psychological and physiological pressure that can lead them to a healthier lifestyle. A semi-automatic system provides freedom for the users to take care of their plants by voicing out commands manually to know the status of their plant and to water the plant if necessary. Figure 1 shows the conceptual design of the semi-automatic VoISIG system flow. It also highlights the hardware and software involved in the project.

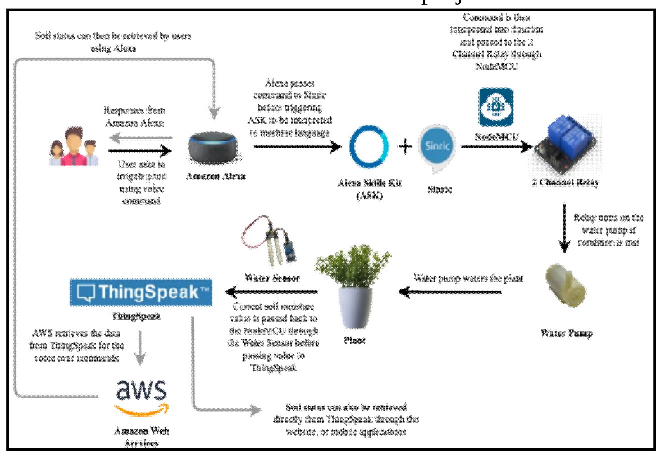


**Figure 1**: Conceptual design of the semi-automatic VoISIG system

A voice command integration with Amazon Alexa to ask for soil humidity status, as well as starting the irrigation is implemented if the automation mode is deactivated. A soil humidity chart will also be produced to check and control the soil humidity over a period of 15 seconds' time.

The Amazon Alexa [7] was configured using the ASK API to set the skills required for VoiSIG system. The function (intents), invocation name (to trigger the function), commands (utterances), and responses for the semi-automatic system using Amazon Alexa are shown in Figure 2.

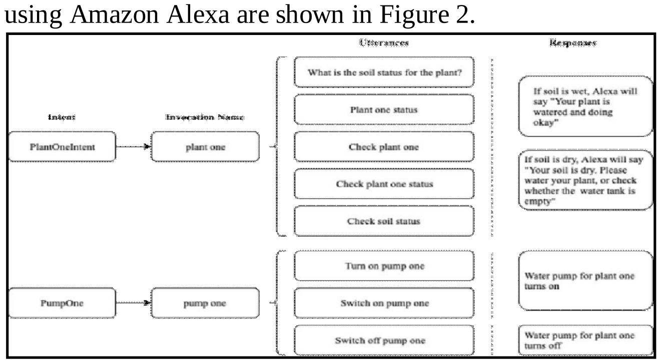


**Figure 2:**Intents of the Amazon's Alexa for the semi-automatic VoISIG system.

Once the plants are watered, the users also have the option to check the humidity of the soil for reconfirmation about the automatic watering process. The status of the plants can be accessed online through smartphones or PCs, or through the voice-over hub the Amazon Alexa, or through Amazon Alexa or ThingsView mobile applications.

### 3.2 Project Development

Project development comprises of seven phases:

**Phase 1**: Connecting moisture sensors: - To configure soil moisture sensors using Arduino IDE software on NodeMCU microcontroller board.

**Phase 2**:Installing the water pumps: -The pumps installed are controlled by a two channel DC 5V relay and the pumps will only be activated if the soil is dry.

**Phase 3**: Connecting NodeMCU to ThingSpeak for real time data transferring: -As shown in Figure 3, data on soil moisture value will be uploaded to ThingSpeak API every 15 seconds. Data can be stored and retrieved to/from any devices via WiFi connection.

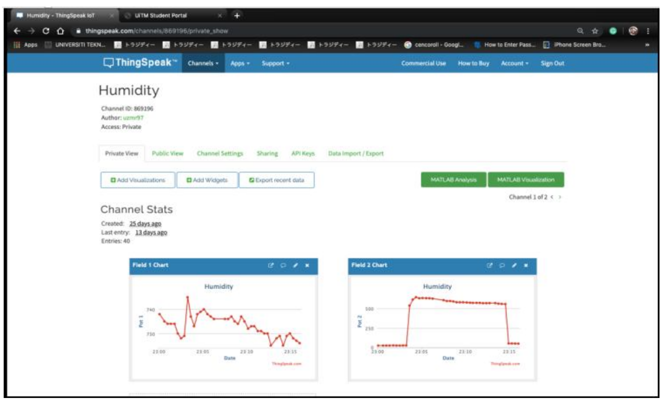


**Figure 3**: Data uploaded to the ThinkSpeak

**Phase 4**: Connecting NodeMCU to Amazon Alexa system: - This phase is device for semi-auto mode using Sinric to control the water pump. Figure 4 depicts the mobile apps,if pump1 is entered, it is to trigger the Amazon Alexa functions for Pump1 to turn on or turn off the water pump.

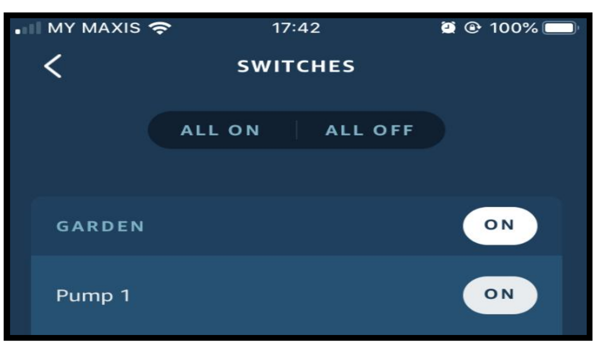


**Figure 4:**Configuring Pump 1 into Amazon Alexa mobile application

**Phase 5**: Adding button to switch from auto to semi-auto mode of the VoiSIG system. The schematic diagram of addition button switch using Fritzing software is shown in Figure 5.

**Phase 6**: Soil status retrieved using Amazon Skills Kit (ASK) and Amazon Web Services (AWS) Lambdafunction:- This phase converts the voice commands into command sets that can be sent to the NodeMCUto get requested query and transfer the information to Amazon Alexa. JSON Editor was used in the configuration of this phase.

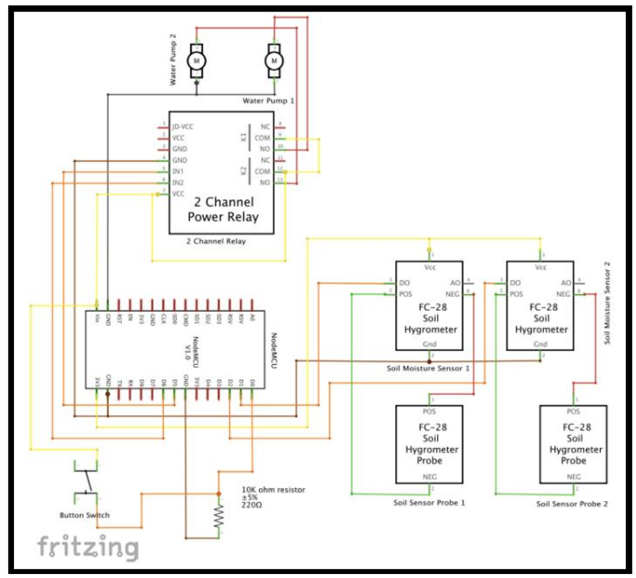


**Figure 5:** Schematic diagram of button switch

**Phase 7**: This is the last phase of the development that enable the user to retrieve the plant status in the form of voice over command via the Amazon Alexa, ThingSpeak website and mobile applications respectively:-To use the voice over command, users can say any utterances set in the ASK, and Alexa will respond with the status of the soil. As for the website (ThinkSpeak), users need to log in to their ThingSpeak account and choose the channel that monitor the plants. The plant status can be accessed via any devices that have Internet browsers. As for mobile applications, users can download and install Amazon Alexa app or ThingView mobile app. Figure 6 shows the soil status monitoring using ThingView mobile application.

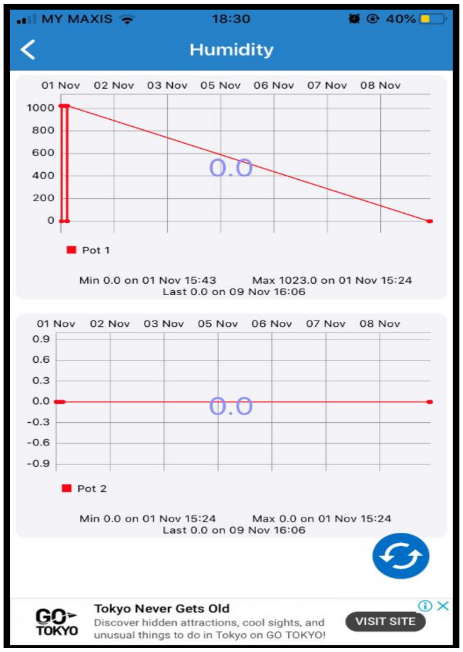


**Figure 6:** Soil status monitoring using ThingView mobile application

***Data Flow***

A graphical flow diagram is illustrated to show the data flow of the soil moisture retrieval status process of the VoISIG system using the voice command through Amazon Alexa. Each phase in the process is represented using a specific symbol. Figure 7 shows the data operation that occurs in VoISIG system.

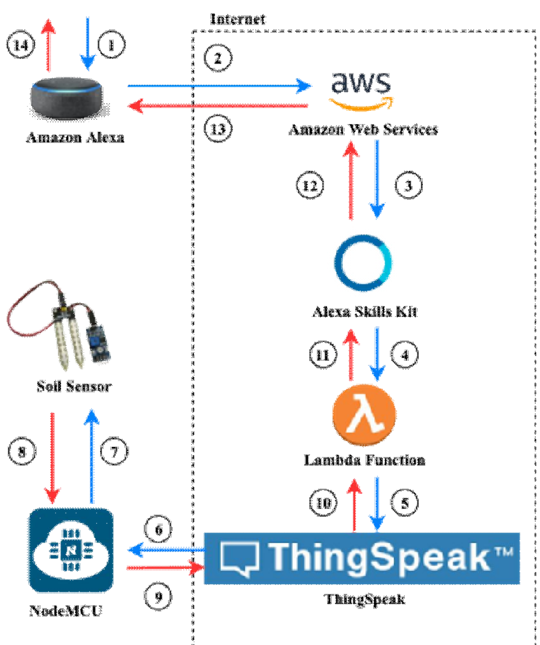


**Figure 7:** Data operation of the VoISIG system

**Legends:**

i) Blue arrow – Data Writing process
ii) Red arrow – Data Reading process

**Flow Steps:**

1) User asks for plant status using voice command through Amazon Alexa.
2) From Amazon Alexa, the voice command is sent to the AWS, a voice interfacing to communicate with the voice command sent from Amazon Alexa.
3) The interpreted commands for the data from Amazon Alexa will invoke Alexa Skills in ASK to open the skills which will then trigger AWS Lambda functions
4) The data sent and stored by AWS cloud is then retrieved by AWS Lambda. AWS Lambda will connect to AWS and Alexa Skills to get the sensor details and ID. The Alexa Skills are voice-driven Alexa capabilities. It is used to give names to the commands for the data retrieval through Amazon Alexa.
5) The AWS Lambda function will then communicate with ThingSpeak for to establish connection for soil status data retrieval.
6) On a time, interval of 15 seconds, ThingSpeak will be ready to receive data uploaded by the NodeMCU.
7) NodeMCU is connected to the soil sensor probe to receive data about the soil status.
8) In every 15 second, the soil sensor will pass soil status value to the NodeMCU.
9) The NodeMCU will then pass the data to ThingSpeak to be updated. The data in ThingSpeak will be presented in graphs.
10) The soil moisture sensor will be passed to AWS Lambda function to be manipulated logically to code the respective responses regarding the soil status.
11) The manipulated data will then be passed to ASK to be converted back to voice responses understandable by humans.
12) The responses are passed to the AWS, and to Amazon Alexa and lastly, giving out voice responses back to the users.

### 3.3 Testing

The accuracy in receiving voice commands and time taken for interpreting commands are vital in voice integration system. Two types of tests were performed; Functionality Testing and Received Signal Strength Indicator (RSSI) test.

Functionality testing refers to the process of evaluating the workable of each component. Thirty respondents participated that consists of 28 students and 2 lecturers from Faculty of Plantation and Agro-Technology of UiTM, Perlis. During the test, the respondents were asked to complete eight tasks based on the instructions given as shown in Table 1 before attending to the associated questionnaires.

**Table 1:**Functionality Test Tasks

| Task | Instructions |
|---|---|
| 1 | Check the soil moisture/ plant status through the ThingSpeak website, and ThingView app. |
| 2 | Switch to semi-automatic mode of the VoISIG mode. |
| 3 | Go to the Amazon Alexa mobile app and try to activate water pump for Plant One/ Plant Two/ both plants. |
| 4 | On the same mobile app, try to deactivate pump one through the app to stop watering for Plant One/ Plant Two/ both plants. |
| 5 | Say, 'Alexa', to wake the Amazon Alexa before saying 'turn off pump two to activate pump one to water Plant Two. |
| 6 | Say, 'Alexa', to wake the Amazon Alexa before saying 'turn off pump two to activate pump one to water Plant Two. |
| 7 | Say, 'Alexa', to wake the Amazon Alexa before saying 'Plant One' to invoke the skill from ASK. After the Amazon Alexa responds, say 'check soil status' to check the current soil moisture/ plant status for Plant One over the Amazon Alexa speaker. |
| 8 | Step 7 is repeated to check the soil status the Amazon Alexa mobile app. |

The tasks that are relevant to voice accuracy are task 5, 6 and 7. The objective of these tasks are to identify the accuracy of Amazon Alexa in receiving and interpreting commands given by different gender.

## 4. RESULT AND ANALYSIS

Voice accuracy rate has been calculated for male and female respondents. After refinement, more respondents could successfully complete the tasks given. Table 2 shows the difference in the recognition performance for accuracy rate, calculated from the functionality test tasks in Table 1. The female showed a slightly higher percentage of voice accuracy compared to male. These findings are due to the clarity and pitching of female voice.

**Table 2:** Recognition performance for accuracy

| No | Gender | Number of respondents for the gender, *g* | Total rounds of sentences spoken, *tc* | Total rounds of spoken sentences passed, *r* | Accuracy (%), $\left(\frac{r}{g \times tc} \times 100\right)$ |
|---|---|---|---|---|---|
| 1 | Male | 12 | 10 | 84 | 70.00% |
| 2 | Female | 18 | 10 | 151 | 83.89% |

A survey has been conducted and the results obtained has been divided into two sections: Section A (Perceived Usefulness) and Section B (Perceived Ease of Use). There is a total of 25 questions answered by the respondents.

In Section A (Perceived Usefulness), only Question 2 and Question 4 are related to the accuracy of the system. In Question 2,a total of 80% of the respondents agreed and strongly agreed that VoISIG enhances the accuracy on identifying the current plant status. While in Question 4, 83.3%of the respondents agreed and strongly agreed that Amazon Alexa can be interpreted successfully. Figure 8shows the bar chart of Perceived Usefulness results on accuracy of the system.

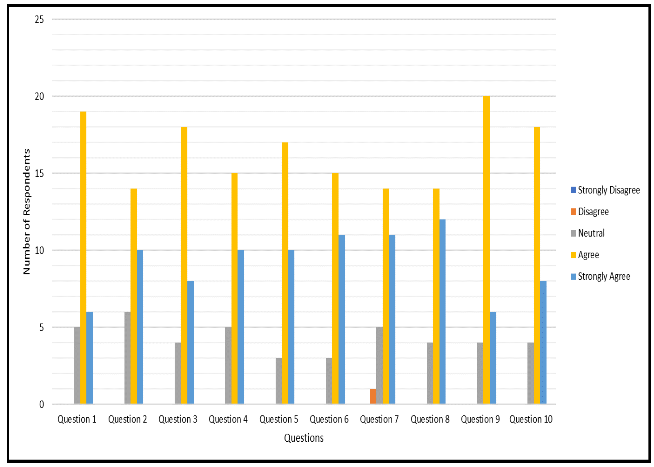


**Figure 8:** Section A: Perceived Usefulness Results

In Section B (Perceived Ease of Use), only Question 8is related to voice accuracy of the system. A total of 76.6% of the respondents agreed and strongly agreed that VoISIGwould be easy by using voice commands and mobile apps. Figure 9 shows the bar chart of Perceived Ease of Use results. The positive results obtained from the perceived ease of use will thus affect the continuance of using the VoISIG system in future. Indirectly, it represents the direct effect of users' satisfaction [12]. In addition, the IoT device user satisfaction may include using one or more heuristics for performing better service in various aspects [15].

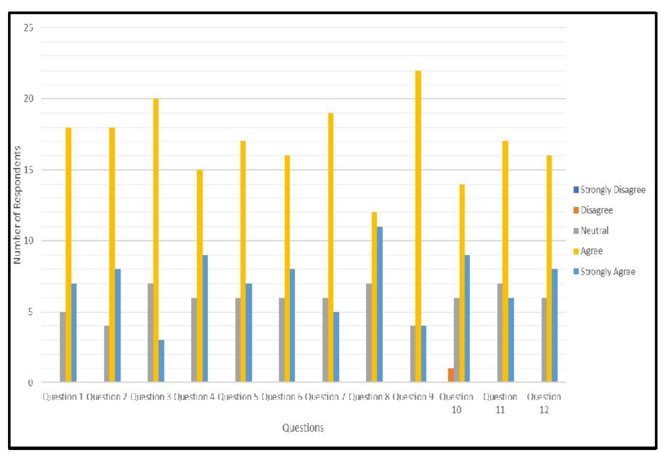


**Figure 9:** Section B: Perceived Ease of Use Results

Next test is to ensure a stable network connectivity from the access point to the plant, RSSI test is performed. This was to ensure that the voice integration is efficient for a distance. Commonly, at a larger distance gap, the received signal gets weaker, and the data will start to drop, resulting throughput degradation. This test was performed using the same interval distances set; 0 meter, 5 meter, and 10 meter. The average value of the RSSI result is calculated for every 15 minutes interval. For each distance, the command is given a total round of ten times. The result for the test is shown in Figure 10.

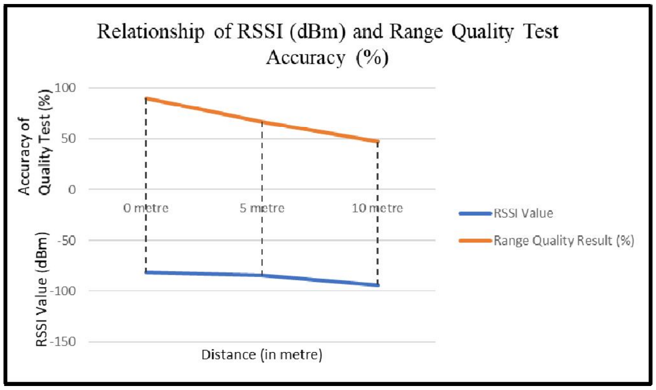


**Figure 10:** Conjoint graphs of RSSI and Range Quality Test result.

From the conjoint graphs, both RSSI value, and range quality test accuracy decreases gradually as the distance gap increases. The decreasing accuracy can also be due to the nearby obstructions and interference existence whereby it might be co-channel and adjacent channel interference.

## 5. CONCLUSION

This project was carried out to develop a smart indoor garden that utilises voice-over integration technology using Amazon Alexa on a semi-automatic and fully automatic watering system without any intervention. Then, experiments were conducted to test the functionality of the voice-over integration on smart indoor garden system in terms of accuracy and network performance in receiving voice-over commands, and time taken to interpret the command. The accuracy of the network performance is tested by performing the RSSI test. The RSSI result is then used to estimate the farthest range a voice-command can be interpreted from the Amazon Alexa speaker to find the range quality of the developed system. The project has successfullyinvestigated the effectiveness of implementing voice integration on smart indoor gardens by measuring the voice accuracy. The results showed an impressive figure from all the experiments. Some of the future recommendations are utilising advanced technologies such as implementing single voice command instead of repeating the command with different species of plants. To produce a more seamless smart gardening, the current VoISIG system could be improved by working more on the sensors and algorithm of fertigation system.In addition, this project can be enhanced for a larger scale implementation in Malaysian agriculture industry especially in green-house technology.

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