MTSFB TR 010:2022

TECHNICAL REPORT

SMART URBAN FARMING FOR VEGETABLES (V-SUrF)

MTSFB TR 010:2022

Preface

Malaysian Technical Standards Forum Bhd (MTSFB) has awarded Universiti Teknologi MARA the Industry Promotion and Development Grant (IPDG) to implement the Proof of Concept (PoC) for the Smart Urban Farming for Vegetables (V-SUrF). The duration of this PoC is for a period of 18 months starting May 2019. The PoC is implemented at Pangsapuri Baiduri, Shah Alam, Selangor.

This Technical Report outlines the objectives, benefits, scope of work, methodology and findings.

Prepared by:

Universiti Teknologi MARA

In collaboration with:

Pangsapuri Baiduri Shah Alam Residents

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Malaysian Communications and Multimedia Commission (MCMC) Centre of Excellence
Off Persiaran Multimedia, Jalan Impact, Cyber 6
63000 Cyberjaya, Selangor Darul Ehsan
Tel : (+603) 8320 0300
Fax : (+603) 8322 0115
Email : admin@mtsfb.org.my
Website : www.mtsfb.org.my

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Abbreviations

ADC	Analogue Digital Converter
CSS	Cascading Style Sheets
DC	Direct Current
DSS	Decision Support System
DHT	Digital Humidity Thermistor
HTML	Hypertext Markup Language
IoT	Internet of Things
IP	Internet Protocol
LED	Light Emitting Diode
MQTT	Message Queueing Telemetry Transport
pH	Potential of Hydrogen
SPI	Serial Peripheral Interface
SQL	Structured Query Language
UI	User Interface
V-SUrF	Smart Urban Farming for Vegetables
WiFi	Wireless Fidelity

SMART URBAN FARMING FOR VEGETABLES (V-SUrF)

Executive summary

This project aimed to propose and perform Proof of Concept (PoC) to demonstrate the application of Internet of Things (IoT) to automate the monitoring and reporting of plants management called Smart Urban Farming for Vegetables (V-SUrF).

V-SUrF is a fully automated smart plantation system that is able to monitor critical data such as temperature, moisture, illumination and nutritional value. Utilising sensing technology over an IoT platform, V-SUrF enables smarter farming by controlling vital functions that impact overall production quantity and quality.

For this project, 10 users from different houses contributed to this project. The users were equipped with 3 different types of V-SUrF kits namely Beginner (3 users), Intermediate (3 users) and Advanced (4 users). Each Beginner V-SUrF kit is able to maintain one plant, whereas Intermediate V-SUrF kits can cater for 2 plants. Advanced V-SUrF kits is designed to maintain 4 plants. The plants chosen for this project are the commonly consumed vegetables, which are okra, chilli, eggplant and basil.

V-SUrF project was successfully developed and deployed where the Decision Support System (DSS) was running as planned to maintain the plants automatically. The DSS implemented for water measurement from soil moisture triggered output Direct Current (DC) water pump when the reading is less than 80% daily (7.30 am & 5.00 pm). Another DSS implemented was when users were alerted via web based and mobile application to notify user when the water tank level is lower than the threshold (30%).

As a summary, this project focused on providing a cloud IoT-based urban farm that is applying DSS and smart scheduling. V-SUrF showed the availability and functionality to handle high-rise farming automation. The use of IoT technology, DSS and light as power source in V-SUrF can be upscaled for landed urban farming.

1. Background

This project aims to optimise IoT utilisation in urban farming by helping urban citizen to grow their own vegetables and fruits for daily consumption.

Water, temperature and humidity are the three main parameters that need special attention in farming, especially urban farming. However, these three parameters might not be monitored automatically. To overcome this limitation, this project has implied capability of IoT in urban farming where the system is able to observe the changes in the sensors' data and react according to the plants' requirements efficiently.

The V-SUrF plant kits were integrated with sensors where the sensors read the plants' data such as soil moisture, pH level and humidity level. The data then were collected and transmitted via internet to IoT cloud system and were analysed by the DSS for planned action. Application of smart scheduling has been added to ensure plants grow is controlled. Besides that, users are also able to remotely control and monitor their farm accordingly.

2. Target groups and benefits

Target groups are communities of high rise building who are interested to grow vegetables, urban farmers and home gardeners.

Benefits of this project in term of results chain are:

a) input

   i) plants and kit with sensor reading capabilities;

   ii) solar powered kit for self-sustainability;

   iii) Message Queueing Telemetry Transport (MQTT) communication between kit and V-SUrF IoT cloud system;

   iv) internet communication for data collection and output motor triggering; and

   v) DSS and scheduling capability for automated plants maintenance.

b) activities

   i) daily plants data collection; and

   ii) watering motor triggering based on auto scheduling and data analysis.

c) output

   A more efficient monitoring on home growth plants as well as encouraging healthy farming process that is supported by automation.

d) outcomes

   Facilitates V-SUrF users in terms of reducing the time needed for plant observation and care while helping to generate optimal plant growth through planned care.

e) impact

   IoT technology is able to improve current monitoring on urban farm and encouraging production of safer and healthier vegetables and fruits. This solution can be customised to a landed and bigger scale urban farming resulting to a controlled farming environment.

3. Objectives

The project objectives are as follows:

a) to analyse data captured through urban farm sensors via cloud platform;

b) to develop DSS that automatically trigger urban farm sensors; and

c) to integrate the DSS with mobile application.

4. Scope of work

The scope of work for this project are as follows:

a) preliminary study which involves understanding the significant problem in smart urban farming especially on common type of vegetables such as okra, eggplant, chilli and basil. The parameters of study are water consumption, air temperature, soil type and alkalinity;

b) IoT cloud system setup for monitoring and managing the sensors and output for the kits;

c) data collection from various type of sensors;

d) web and mobile apps development for monitoring and controlling the kit outputs;

e) DSS which involve constructing the rules for smart urban farming decision making;

f) software and hardware efficiency testing; and

g) design of V-SUrF kit

  i) Beginner, designed for first-timers in vegetable growing consisting of single plant, water consumption monitoring module and motored water sprinkler;

  ii) Intermediate, designed for experienced vegetables grower consisting of two plants, water consumption monitoring module, motored water sprinkler soil and Potential of Hydrogen (pH) monitoring; and

  iii) Advanced, designed for seasoned vegetables grower consisting of four plants, water consumption monitoring module, motored water sprinkler soil, pH monitoring indoor garden light and web camera.

5. Methodology

The methodology are as follows:

a) methodological approach

   The qualitative type of approach was used to verify the workability of V-SUrF system which are tested at Pangsapuri Baiduri. This is to justify and observe the differences between research data in preliminary study compared to contextual real-world behaviours of the plants and the system.

   Pangsapuri Baiduri which is located in Seksyen 7, Shah Alam is chosen as it is located in the middle of the city. The high-rise building and the city-centred location of the apartment are coinciding of the objective of this project. The project has been done in several houses with different level to see the environmental effect on the plant so that different data analysis of the sensors can be done.

b) data collection method

   The selected method for data collection is by collecting plants information via sensors such as soil humidity, soil nutrient, temperature and illumination continuously via MQTT telemetry. MQTT is a standard messaging protocol for the IoT. It is designed as an extremely lightweight messaging transport that is ideal for connecting remote devices with a small code footprint and minimal network bandwidth. The collected sensors data will be stored in cloud database for analysis.

c) analysis method

The selected method for analysis is by analysing change of the metrics in the collected data. Data from the overall collection for each plant type from different houses will be compared and measured in order to set the output triggering threshold and populating the average plant health status.

6. Preliminary study

Water, temperature and humidity are the 3 main requirements for plants to grow properly. Most of the available solutions are focusing on timer setup as a tool to automate the plant management process. Timer setup will trigger the output motor based on set times**.** Therefore, timer-based solution is not taking soil and humidity into consideration.

The moisture of the soil for the plants needed to be managed to obtain better yield.

In term of the basic plant needs, the requirements are as tabulated in Table 3.

Table 3. Plants requirement

No	Plant	Daily water consumption	Temperature	Soil
1	Chili	20 mm	15.56°C to 21.11°C	Sandy loam, deeper than 400 mm and pH between 5.5 to 7.0
2	Lady finger (okra)	25 to 38 mm	23.89°C to 32.22°C	Rich, sandy loam soils and pH between 6.0 to 7.0
3	Eggplant	4 mm	21.00°C to 30.00°C	Sandy loam or alluvial soils that are deep and free draining. pH between 6.0 to 7.0
4	Basil	2.98 to 4.87 mm	15.56°C to 21.11°C	Well drained sandy loam with average to rich composition and pH between 5.5 to 6.5

7. System architecture

The system architecture is divided into 2 main categories, which are hardware and IoT cloud system. Figure 1 shows the overall V-SUrF system architecture.

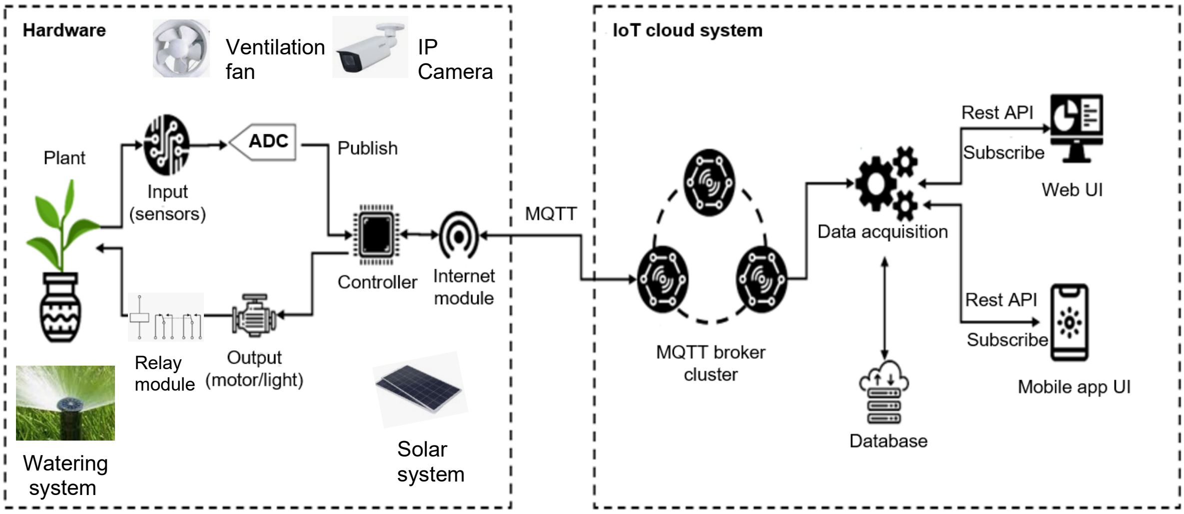

Figure 1. Overall V-SUrF system architecture

V-SUrF consists of the development of a smart urban farming monitoring system and a cloud-based DSS. Users are provided with web and mobile applications with dashboards that they can use anytime and anywhere to monitor and maintain their urban farms. The urban farms are auto-managed by cloud-based system.

7.1 V-SUrF components

The functions of each of the components in the respective categories are explained in Table 2.

Table 2. Overall V-SUrF system architecture components

Category	Component	Function
Hardware	Input sensors	Input sensors will detect and read the physical parameter such as soil moisture, pH level and humidity level.
	Output (motor/light)	Responsive to the instruction from controller to feed the plant requirement.
	Analogue Digital Converter (ADC)	ADC (ADS115) is a 4-channel ADC module that converts analogue electrical signal from sensors into a digital signal to controller through Serial Peripheral Interface (SPI) communication.

Category	Component	Function
	Controller	Controller is a programmable micro-computer that will receive the signal from ADC, then will feed the collected data to IoT Cloud system using Message Queuing Telemetry Transport (MQTT) protocol via internet access. The controller is also used to trigger the output such as pump, fan and also LED light when necessary.
	Internet Module	Is a module that is used to connect the non-network part of the V-SUrF to the network system.
	Solar system - Solar panel - Solar charger controller - Battery	Solar panel collect clean renewable energy in the form of sunlight and convert that light into electricity which can then be used to provide power for V-SUrF system. The collected electricity will be stored by using battery. This module is basically a voltage and/or current regulator to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery.
	Watering system - Water tank - Direct Current (DC) water pump	Water tank were used to store the water needed for plants usage. The water will be pump by using DC water pump. DC water pump will pump the water from tank for the purpose of watering the plant. This DC pumps will be controlled by controller via relay module.
	Ventilation fan	This fan is used to provide ventilation to plants where it will bring in fresh air and carbon dioxide to give plants what they need for photosynthesis. It also removes old air that could lead to an imbalance of carbon dioxide and oxygen.
	Relay module	This power module is to trigger and control the output motor, fan and lamp.
	Internet Protocol (IP) camera	IP camera is used to monitor the growth of the plants. The image will be automatically captured by system every 10 minutes.

Category	Component	Function
IoT cloud system	Data acquisition	Data collector system that implies set of functions to control the whole system based on the set rules and schedules. These processes are also known as the backend system which is written in Golang language. For the DSS, a set of rules has been set for the water pump trigger as below: a) DSS1 Plants water pump scheduler based on soil moisture output. -Morning (7.30 am) -Evening (5.00 pm). If the soil moisture is less than 80%, the water pump will be triggered. Else, the pump remains idle. b) DSS2 Web based and mobile application alert for notifying user when the water tank level is lower than the threshold (30%). Else, the reminder will not be triggered.
	MQTT broker cluster	A broker cluster that is responsible for receiving all messages, filtering and publish the message to the subscribers. MQTT broker will receive the data from the controller and channel it to the data acquisition processes
	Database	Responsible to store all entities and telemetry of the whole system in Structured Query Language (SQL) database. This database will store the collected MQTT devices data and support user and devices management. The database use for V-SUrF system is PostgreSQL.
	Web UI	Web interface that extends the control of the system to admins and users. For V-SUrF, the web front end is developed using Bootstrap framework which includes Hypertext Markup Language (HTML), Cascading Style Sheets (CSS) and Jquery.

Category	Component	Function
	Mobile app UI	Mobile application for the user to manage their own devices. This application is similar to web UI (customer) functions, but it is in the form of application (Android & Apple) that are able to be download and install on customer mobile devices. The mobile application is developed using Flutter framework. The types of users created in the system can be divided into 2 categories, which are customer and admin.

A micro services-based system was developed by leveraging on containerisation technology such as Docker for its lightweight footprint in terms of infrastructure resources as well container orchestration capabilities from Kubernetes to enable scalability and reliability of the overall system of the V-SUrF kit.

7.2 Type of V-SUrF kits

The details of different V-SUrF kit types are summarised in Table 1.

Table 1. Types of V-SUrF kits

Kit type	Plants	Sensors	Controller	Output
Beginner	1 plant (chilli)	a) Capacitive humidity sensor and thermistor (Digital Humidity Thermistor (DHT) sensor) b) Temperature humidity pressure sensor c) Moisture sensor d) Ultrasonic sensor	TTGO ESP32 model	DC water pump
Intermediate	2 plants (chilli & eggplant)	a) Temperature humidity pressure sensor (BME 280) b) Moisture sensor c) Ultrasonic sensor d) pH sensor	TTGO ESP32 model	DC water pump
Advanced	4 plants (okra, chilli, eggplant and basil	a) Temperature humidity pressure sensor (BME 280) b) Thermistor c) Moisture sensor d) Ultrasonic sensor e) pH sensor f) Light sensor	Raspberry Pi 0 WH module	a) DC water pump b) IP camera c) Ventilation fan d) LED light

8. Results and findings

The summary of average sampling 1-hour data from 7.30 am until 8.30 am for beginner kits are as shown in Table 15. Table 15, 16 and 17 are showing the results immediately after watering.

Table 15. Summary of average 1 hour data for beginner kits

Average Reading at 1:00 am to 2:00 am					
No	**Kit Number**	V-SUrF-1	V-SUrF-2	V-SUrF-3	Average data for 1 hour
1	**Water Level (%)**	90.15	91.14	92.37	91.22
2	**Temperature (°C)**	28.31	29.73	27.77	28.60
3	**Soil moisture sensor 1 (%)**	70.53	71.66	68.39	70.19
4	**Soil moisture sensor 2 (%)**	71.42	71.73	69.55	70.90
5	**Humidity**	83.11	83.42	85.23	83.92
6	**Water pump trigger (frequency)**	0	0	0	0
Average Reading at 7:30 am to 8:30 am					
No	**Kit Number**	V-SUrF-1	V-SUrF-2	V-SUrF-3	Average data for 1 hour
1	**Water Level (%)**	88.72	88.71	89.73	89.05
2	**Temperature (°C)**	31.70	31.69	31.71	31.70
3	**Soil moisture sensor 1 (%)**	82.14	82.13	81.90	82.05
4	**Soil moisture sensor 2 (%)**	81.12	81.14	81.83	81.36
5	**Humidity**	69.55	69.55	69.52	69.54
6	**Water pump trigger (frequency)**	1	1	1	1
Average Reading at 5:00 pm to 6:00 pm					
No	**Kit Number**	V-SUrF-1	V-SUrF-2	V-SUrF-3	Average data for 1 hour
1	**Water Level (%)**	84.58	84.41	84.83	84.61
2	**Temperature (°C)**	30.15	30.74	30.63	30.51
3	**Soil moisture sensor 1 (%)**	81.53	82.14	81.95	81.87
4	**Soil moisture sensor 2 (%)**	82.34	81.87	82.35	82.19
5	**Humidity**	63.92	61.54	62.87	62.77
6	**Water pump (frequency)**	1	1	1	1

Table 15. Summary of average 1 hour data for beginner kits *(concluded)*

Average Reading at 9:00 pm to 10:00 pm					
No	**Kit Number**	V-SUrF-1	V-SUrF-2	V-SUrF-3	Average data for 1 hour
1	**Water Level (%)**	84.58	84.41	84.83	84.61
2	**Temperature (°C)**	29.73	28.94	29.48	29.38
3	**Soil moisture sensor 1 (%)**	78.45	78.37	79.14	78.65
4	**Soil moisture sensor 2 (%)**	77.98	79.64	78.88	78.83
5	**Humidity**	75.65	76.66	79.23	77.18
6	**Water pump (frequency)**	0	0	0	0

Table 16: Summary of average 1 hour data for Intermediate kits

Average Reading at 1:00 am to 2:00 am					
No	**Kit Number**	V-SUrF-4	V-SUrF-5	V-SUrF-6	Average data for 1 hour
1	**Water Level (%)**	91.91	92.73	81.29	88.64
2	**Temperature (°C)**	28.31	27.73	27.77	27.93
3	**Soil moisture sensor 1 (%)**	71.53	71.36	67.39	70.09
4	**Soil moisture sensor 2 (%)**	71.42	71.73	68.54	70.56
5	**Soil moisture sensor 3 (%)**	69.99	72.88	71.09	71.32
6	**Pressure**	1005.56	1005.56	1005.56	1005.56
7	**pH Level**	7.34	7.34	7.33	7.34
8	**Humidity**	83.13	83.42	85.73	84.09
9	**Water pump trigger (frequency)**	0	0	0	0
Average Reading at 7:30 am to 8:30 am					
No	**Kit Number**	V-SUrF-4	V-SUrF-5	V-SUrF-6	Average data for 1 hour
1	**Water Level (%)**	87.72	87.73	77.72	84.39
2	**Temperature (°C)**	31.69	28.68	31.67	30.68
3	**Soil moisture sensor 1 (%)**	82.26	82.24	82.08	82.19
4	**Soil moisture sensor 2 (%)**	81.27	81.24	81.08	81.28
5	**Soil moisture sensor 3 (%)**	84.26	84.25	84.08	84.19
6	**Pressure**	1005.56	1005.56	1005.56	1005.56
7	**pH Level**	7.35	7.34	7.33	7.34

Table 16: Summary of average 1 hour data for Intermediate kits *(concluded)*

Average Reading at 7:30 am to 8:30 am					
8	**Humidity**	69.55	69.55	69.52	69.54
9	**Water pump trigger (frequency)**	1	1	1	1
Average Reading at 5:00 pm to 6:00 pm					
No	**Kit Number**	V-SUrF-4	V-SUrF-5	V-SUrF-6	Average data for 1 hour
1	**Water Level (%)**	84.12	83.75	74.39	80.75
2	**Temperature (°C)**	29.72	28.94	29.48	29.38
3	**Soil moisture sensor 1 (%)**	81.24	82.94	84.08	82.75
4	**Soil moisture sensor 2 (%)**	82.34	81.87	82.35	82.18
5	**Soil moisture sensor 3 (%)**	81.25	84.35	83.98	83.19
6	**Pressure**	1005.56	1005.56	1005.56	1005.56
7	**pH Level**	7.35	7.34	7.33	7.34
8	**Humidity**	63.92	61.54	62.87	62.77
9	**Water pump trigger (frequency)**	1	1	1	1
Average Reading at 9:00 pm to 10:00 pm					
No	**Kit Number**	V-SUrF-4	V-SUrF-5	V-SUrF-6	Average data for 1 hour
1	**Water Level (%)**	84.12	83.75	74.39	80.75
2	**Temperature (°C)**	29.73	28.94	29.48	29.38
3	**Soil moisture sensor 1 (%)**	77.36	79.55	78.05	78.32
4	**Soil moisture sensor 2 (%)**	75.21	77.94	78.72	77.29
5	**Soil moisture sensor 3 (%)**	78.45	78.37	79.14	78.65
6	**Pressure**	1005.56	1005.56	1005.56	1005.56
7	**pH Level**	7.35	7.34	7.33	7.34
8	**Humidity**	69.55	69.55	69.52	69.54
9	**Water pump trigger (frequency)**	0	0	0	0

Table 17. Summary of average 1 hour data for Advance kits

Average Reading at 1:00 am to 2:00 am						
No	Kit Number	V-SUrF-7	V-SUrF-8	V-SUrF-9	V-SUrF-10	Average data for 1 hour
1	Water Level (%)	93.76	93.44	89.73	89.73	91.67
2	Temperature (°C)	28.21	27.73	26.76	27.93	27.66
3	Soil moisture sensor 1 (%)	67.48	68.23	67.56	67.93	67.80
4	Soil moisture sensor 2 (%)	65.43	67.80	68.91	69.52	67.92
5	Soil moisture sensor 3 (%)	69.79	68.56	68.77	69.61	69.43
6	Soil moisture sensor 4 (%)	69.55	69.55	69.52	69.52	69.54
7	Pressure	1005.56	1005.56	1005.56	1005.56	1005.56
8	pH Level	7.43	7.31	7.37	7.29	7.35
9	Light level (Lux)	23.82	22.99	22.79	23.47	23.27
10	Humidity	83.42	82.90	83.87	83.77	83.49
11	Water pump trigger (frequency)	0	0	0	0	0
Average Reading at 7:30 am to 8:30 am						
No	Kit Number	V-SUrF-7	V-SUrF-8	V-SUrF-9	V-SUrF-10	Average data for 1 hour
1	Water Level (%)	91.71	91.72	81.71	83.73	87.22
2	Temperature (°C)	31.70	31.69	31.71	31.71	31.70
3	Soil moisture sensor 1 (%)	82.28	81.84	81.87	82.04	82.01
4	Soil moisture sensor 2 (%)	81.26	80.86	82.57	81.03	81.43
5	Soil moisture sensor 3 (%)	84.23	83.85	81.52	84.01	83.40
6	Soil moisture sensor 4 (%)	84.29	83.85	84.30	84.02	84.21
7	Pressure	1005.56	1005.56	1005.56	1005.56	1005.56
8	pH Level	7.43	7.31	7.37	7.29	7.35
9	Light level (Lux)	176.43	184.13	194.14	184.13	184.71
10	Humidity	69.45	68.35	69.11	69.94	69.21
11	Water pump trigger (frequency)	1	1	1	1	1

Table 17. Summary of average 1 hour data for Advance kits *(concluded)*

Average Reading at 5:00 pm to 6:00 pm						
No	**Kit Number**	V-SUrF-7	V-SUrF-8	V-SUrF-9	V-SUrF-10	Average data for 1 hour
1	**Water Level (%)**	88.72	88.71	79.13	81.43	84.50
2	**Temperature (°C)**	29.16	29.42	29.32	29.28	29.30
3	**Soil moisture sensor 1 (%)**	82.14	82.13	81.90	81.90	82.05
4	**Soil moisture sensor 2 (%)**	81.12	81.14	81.83	81.83	81.36
5	**Soil moisture sensor 3 (%)**	82.57	81.03	82.18	81.99	81.94
6	**Soil moisture sensor 4 (%)**	81.26	80.86	82.57	81.03	81.43
7	**Pressure**	1005.56	1005.56	1005.56	1005.56	1005.56
8	**pH Level**	7.43	7.31	7.37	7.29	7.35
9	**Light level (Lux)**	234.39	232.44	241.15	238.75	236.68
10	**Humidity**	62.87	63.47	63.89	63.16	63.35
11	**Water pump trigger (frequency)**	1	1	1	1	1
Average Reading at 9:00 pm to 10:00 pm						
No	**Kit Number**	V-SUrF-7	V-SUrF-8	V-SUrF-9	V-SUrF-10	Average data for 1 hour
1	**Water Level (%)**	85.45	84.98	77.14	79.57	81.79
2	**Temperature (°C)**	28.91	28.88	29.54	29.11	29.11
3	**Soil moisture sensor 1 (%)**	77.23	76.63	74.89	75.31	76.02
4	**Soil moisture sensor 2 (%)**	76.55	74.79	75.61	75.39	75.59
5	**Soil moisture sensor 3 (%)**	74.97	73.44	74.76	77.71	75.22
6	**Soil moisture sensor 4 (%)**	72.87	71.29	75.44	77.17	74.19
7	**Pressure**	1005.56	1005.56	1005.56	1005.56	1005.56
8	**pH Level**	7.43	7.31	7.37	7.29	7.35
9	**Light level (Lux)**	26.62	25.42	26.89	26.28	26.30
10	**Humidity**	69.52	67.94	68.35	68.80	68.65
11	**Water pump trigger (frequency)**	0	0	0	0	0

The average of the soil moisture sensors was above 80% after the water pump were activated. It indicates that the soil is already watered. For data sampling and analysis purpose, the data were captured every 1 hour for 7 days. Please refer to the Table 18 for the cumulative sample data 7 days' test period. This data is presented to show that the pumps are activated when the soil moisture are below 80%.

The implemented scheduling to activate the water pump was working as planned. The DSS implemented is the system to verify soil moisture sensors every day at 7.30 am and 5.00 pm. The timing priority was set by considering the nature of plant that has its own suitable time for watering. Plant is usually watered during morning and evening. The soil moisture must not be less than 80% or the pump will be activated. Therefore, this system was set to trigger the water pump at 7.30 am and 5.00 pm only. If the soil moisture falls below 80% during other times, the water pump will not be triggered.

Based on the observation during data sampling activities, the water pumps are triggered twice a day. Sample was provided is based on normal dry week where there is no rain impacting the pump activation. The soil moisture data that were provided to the system will decide when not to water the plants based on soil water sensor level reading. If the water measurement in soil moisture exceeds 80%, the instruction will not be sent to water pump.

User alerts is implemented in web based and mobile application to notify user when the water tank level is lower than the threshold (30%). User also able to view the pump activation in the system log for verification and manually trigger the pump, ventilation fan and LED light as and when required. Figure 2 shows the sample for user alert on the water tank level drop below threshold. Figure 3 shows the sample for user alert on the water tank level drop below threshold.

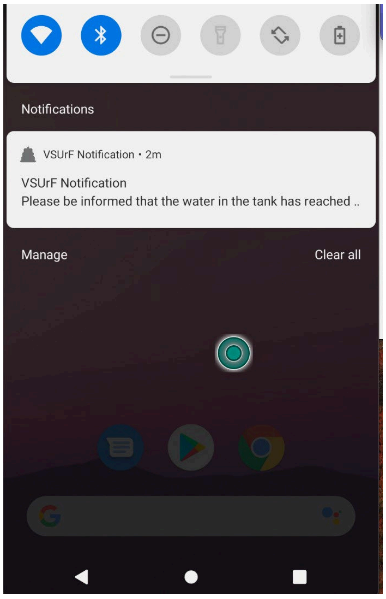

Figure 2. Mobile user alert on the water tank level drop below threshold

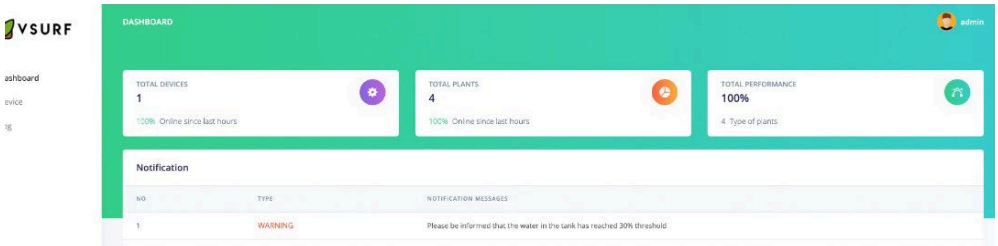

Figure 3. Web User alert on the water tank level drop below threshold

Overall, the architecture is partitioned into hardware (i.e. shelf, sensors, controllers, solar and 3G sim card), and software (cloud, web applications and mobile application). First of all, the input sensor will detect and read the physical parameter.

Then, the analog digital converter (ADC) converts the analog electrical signal into a digital signal. A micro-computer that will publish the signal received from ADC and react according to the instruction received from IoT cloud system. In the cloud programming, an infrastructure is created that consists of Kubernetes and database clusters. The A protocol is used to send data from all the devices to the cloud which is MQTT protocol that is based on publish or subscribe (pub/sub) model. All of the data received are stored in a database.

In the cloud, a MQTT broker is ready to receive the sending data of the devices to be filtered and published to the subscriber. Then, data acquisition system is used that implies set of functions to control the whole system based on the set rules and schedules. A web interface that extends the control of the system to admins and users and mobile application for the user to manage their own devices is also created. The database cluster is separated from the Kubernetes cluster to avoid single point of failure.

Based on this PoC, some of the conditions that need to be considered for the smoother functionality of V-SUrF such as internet connection stability, hardware functionality, sensors calibration and cloud applicability. For the internet connection, it is preferable to use Wireless Fidelity (WiFi) instead of GSM.

In addition, the sensors that are used must be checked and calibrated before installation to avoid hardware malfunction.

9. Conclusion

In conclusion, this project has successfully addressed the needs of communities of high rise building who are interested to grow vegetables, urban farmers and home gardeners. The project demonstrated the availability of real-time plants data and automation that can be implemented to maintain plants for farming in high rise buildings.

The gathered data in this project were captured through sensors and were able to be analysed and used in the DSS. The DSS that is integrated with mobile application was also successfully implemented. The kits were self-maintained using light as a power source to run the system, DSS to automate the plants' requirement and internet as the communication medium.

From this PoC, it is evident that IoT technology is able to improve current monitoring on urban farm and encourage production of safer and healthier vegetables and fruits. The ability to identify real-time reading and automation leads to operational efficiencies and can be customised to a landed and bigger scale urban farming resulting to a controlled farming environment.

This PoC can therefore be a use case in formulating standards in IoT-based urban farming.

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Malaysian Technical Standards Forum Bhd (MTSFB)

Malaysian Communications and Multimedia Commission (MCMC)
Off Persiaran Multimedia, Jalan Impact, Cyber 6
63000 Cyberjaya, Selangor Darul Ehsan
Tel: (+603) 8320 0300
Fax: (+603) 8322 0115

Website: www.mtsfb.org.my

In collaboration with

Malaysian Communications and Multimedia Commission (MCMC)
MCMC Tower 1
Jalan Impact, Cyber 6, 63000 Cyberjaya
Selangor Darul Ehsan
Tel: (+603) 8688 8000
Fax: (+603) 8688 1000

Website: www.mcmc.gov.my