Fertigation Technology Meets Online Market: A Multipurpose Mobile App for Urban Farming

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***Abstract*—In a world where smartphones dominate the market and provide opportunities to a vast population, this work introduces an innovative application that enables users to order irrigated vegetable crops from urban farmers. The application utilizes simple fertigation system technology, which can be easily implemented in small areas such as homes. Currently, consumers and sellers rely on traditional methods like paper or other means to place orders for vertical farming. However, research shows that these methods are unreliable and only offer temporary relevance. Additionally, the traditional agriculture supply chain diminishes the appeal of urban farming as its benefits do not outweigh the disadvantages. The primary objective of this application is to promote the concept of urban farming by creating an online marketplace that bypasses traditional methods. This allows consumers to directly order from the farmers themselves, serving as an alternative to the agricultural supply chain. Furthermore, a monitoring system has been integrated into the application as an additional tool, enabling farmers to remotely monitor and control their farms. This feature is particularly beneficial for urban farmers with farms in multiple locations who may lack the time to physically visit each one.**

***Keywords*—Vertical farming; mobile application; online market; farm monitoring; urban farmer; agriculture supply chain**

I. Introduction

Mobile applications have had a significant impact on today's world, exerting a large influence on the way communities think and on their goals and standards. In the economy, mobile applications have opened up numerous new opportunities for individuals to successfully earn money online. A catalyst for this success has been the emergence of M-commerce mobile applications. M-commerce mobile applications provide a platform where sellers can offer their products, allowing customers to browse and make purchases. Despite the growing popularity of M-commerce mobile applications, the agriculture sector has yet to fully embrace this tool to enhance farmers' profitability.

The agricultural sector requires significant improvements. Although farmers' income has steadily increased over the years [1] [2] [3] [4], they are often limited to selling their crops through middlemen. This traditional approach to connecting farmers with consumers makes it difficult for newcomers or individuals interested in farming to enter the agricultural sector. New farmers must find middlemen to ensure profitability from their farms, as they lack a direct marketplace to sell their crops to consumers. Additionally, the agriculture supply chain has proven to be unreliable, particularly during the COVID-19 pandemic, which has caused disruptions and restrictions on movement [5]. As a result, crops have gone to waste due to the lack of middleman services for distribution. However, the challenges associated with crop distribution could be mitigated through widespread adoption of urban farming. Urban farming has the potential to improve access to healthy and nutritious food [6]. Urban farmers operate at various scales, ranging from small gardens to large-scale operations that incorporate systems like hydroponics for indoor farming. Currently, urban farming is not popular due to inefficiencies in farming practices within urban areas. Many medium to large-scale urban farmers do not reside near their farms, leading to inconvenience as they need to frequently travel to their farms located at a distance from their homes. However, constant monitoring is necessary for efficient crop production, leaving farmers with no choice but to visit their farms regularly. The trade-off between a farmer's time and crop production efficiency makes the concept of urban farming less appealing to urban dwellers.

Hence, the main goal of this work is to promote the idea of urban farming. To achieve this objective, an easy and approachable marketplace needs to be built. An online marketplace is perfect as it allows farmers to sell their crops without the need to meet anybody or be physically present. The concept of anyone being able to start farming indoors or in their garden and sell their produce through a mobile application makes urban farming more appealing to urban dwellers. Therefore, this project involves the creation of a mobile application that can host a marketplace for urban farmers to sell their crops. Additionally, a monitoring system is included in this application to reduce the frequency of farmers needing to be physically present at their farms. This saves a tremendous amount of time, especially for urban farmers. With these two functionalities in the application, along with the ability to generate profit, the concept of urban farming will become more and more popular. One significant advantage of urban farming is that it encourages people to buy fresh crops since the purchased crops are farmed near their location. This eliminates the need for preservatives used to prolong the shelf life of crops in traditional agricultural supply chains. In such chains, some crops may no longer be fresh, resulting in waste as they lose their appeal for sale.

The remainder of this paper has been organized as follows: Section II discusses the background of the study. Then, Section III described the system implementation and testing. Section IV describes the results and discussion meanwhile the conclusion is described in Section V. Lastly, future works is mentioned in Section VI.

II. Background of the Study

In an article published on January 13, 2020, in The Malaysian Reserve, former two-time Finance Minister Tun Dr. Daim Zainuddin emphasized the importance of making agriculture more profitable and attractive to younger people. He highlighted that such a transformation would have significant benefits for Malaysia, including reducing the country's import bill, creating employment opportunities, and boosting federal revenue [7]. The consistent growth in demand for food supplies and vegetables further supports the viability of the agricultural sector as a solution for Malaysia's economy [8] [9] [10] [11]. In this context, vertical farming has emerged as a promising technology for sustainable food production in urban areas. With 80% of the global population residing in urban areas, where the demand for food supply is expected to become critical in the next 50 years, vertical farming offers a compelling solution [12]. By utilizing vertical spaces such as tall buildings and skyscrapers that are abundant in urban areas, this innovative approach enables the cultivation of crops. Vertical farming not only creates job opportunities in the agriculture and related industries but also addresses the issue of unemployment in urban areas. Additionally, it generates indirect employment through local distribution, community outreach, logistics, and delivery services [13] [14].

m-Commerce, also known as Mobile Commerce, has gained significant popularity as a method of conducting business and shopping using mobile devices [15]. The widespread use of mobile devices and the diverse intentions of users have contributed to its success. Demographic factors such as age, gender, and education play a crucial role in influencing consumers' inclination to use m-commerce applications. Overall, there is a positive consumer intention to utilize m-commerce, indicating that the development of mobile applications can attract younger generations to participate in agriculture by leveraging IoT technology [16]. Fig. 1 provides examples of mobile commerce applications that can be easily installed on smartphones. Moreover, there is a plethora of platforms and applications available that entrepreneurs can leverage to establish their own online businesses, even within the agricultural sector [17].

Fig. 1. Example of m-Commerce application in smartphone [17].

Moreover, various factors such as climate change, the overconsumption of Earth's resources [18], and population growth have emphasized the importance of adopting more sustainable agricultural practices. Traditional farming methods often face challenges due to their vulnerability to adverse weather conditions and a lack of technological advancements and marketing investments [19]. Despite efforts to enhance greenhouse farming, vertical farming still relies on manual order management systems, which are prone to errors and time-consuming mistakes [20]. By integrating a mobile application using m-commerce, these errors can be minimized by providing a backup system and a comprehensive order history, reducing the need for farmers to engage in face-to-face interactions with customers. Additionally, the m-commerce application enables the acceptance of a diverse range of crops, ensuring efficient fulfillment of food supply demands.

Moreover, the utilization of monitoring devices in agriculture is becoming increasingly prevalent and offers numerous advantages over manual monitoring methods. The industry is transitioning from traditional farming to modern, smart farming, which incorporates various technologies such as sensors, computing cores, machinery, and equipment. The integration of the Internet of Things (IoT) and cloud computing is driving this modernization, enabling farming operations with minimal human presence [21] [22]. This combination of technologies allows for real-time monitoring of crucial parameters such as temperature and soil moisture [23] [24]. Farmers can now remotely monitor their farms without the need for physical presence, which is particularly advantageous for those who reside far from their agricultural lands. Long-distance trips to check on farm conditions are no longer necessary. The monitoring system also assists farmers in maximizing crop production while utilizing the same inputs as conventional farming methods [25] [26].

Lastly, with all the benefits come to building mobile application around farming; numerous farming applications are available today, each with its unique functions tailored to specific farms or crops. For instance, there are applications designed to calculate the growth period of corn. However, these calculators are typically specific to corn and cannot be used to determine the growth of other plants.

A. The Implementation of Smart Farming Application based on the Microcontroller and Automatic Sprinkler Irrigation System of Agricultural Land

Hasiri et al. [27] developed an Android-based application aimed at managing an automatic sprinkler system and monitoring the farm. The application consists of six pages, each offering different user interface (UI) functions. These functions include displaying the average temperature, moisture level, weather information, historical sensor data, scheduling activities such as watering and fertilization, manual watering mode, IoT setup, and application settings. The temperature and moisture levels are categorized into three conditions, and the watering activity can be either automated or manually controlled. Additionally, the application provides a settings page with options to enable or disable the automatic watering system and fertilization activities.

B. Development of an Android Application for Smart Farming in Crop Management

The research involves the utilization of unmanned aerial vehicles (UAVs) and an Android application to monitor paddy fields in Kampung Lundang Paku, Kereteh, Kelantan [28]. The Android application processes the images captured by the UAVs, analyzes them, and presents the information as a Normalized Difference Vegetation Index (NDVI) map, which helps monitor the health of the crops and assess the weather conditions. The application also provides the farmer with information regarding rice cultivation, planting schedules, field issues, and supplier details. The application is installed on a smartphone and requires an internet connection to update data in real time. The user interface is designed with user-friendly buttons that allow easy access to the information collected by the drones, and the NDVI map segments the paddy fields to indicate their health using an index ranging from -1 for unhealthy to 1 for healthy conditions.

C. Mobile Application Development of Hydroponic Smart Farm using Information Flow Diagram

The objective of this work is to develop an application for managing a hydroponic farm and visualizing data collected by sensors connected to a Raspberry Pi [29] [30] [31] [32]. The sensors are responsible for collecting various parameters such as temperature, humidity, sunlight, pH level, water level, and electrical conductivity. The system utilizes MongoDB as its database system and employs Message Queuing Telemetry Transport (MQTT) for seamless communication between the sensors, Raspberry Pi, and other devices. To access the farm status data, users are required to log in to the application. New users have the option to sign up and provide their Raspberry Pi's Wi-Fi information. The application comprises multiple pages, including a login page, as well as a dedicated page that displays the average values of the sensor data. Additionally, users can obtain further information by clicking on specific data points.

D. Development of Soil Moisture Monitoring by using IoT and UAV-SC for Smart Farming Application

The project utilizes both IoT and UAV technology to collect information about farmers' farms and present it through an application [33]. Ground sensors are deployed to gather data, such as soil moisture, which is then transmitted to a UAV drone. The UAV collects the data and stores it in a database. To avoid the need for lengthy cables, the sensor is powered by a solar panel. The UAV has a flight time of approximately 20 minutes. The application allows farmers to access real-time data and supports multiple users, ensuring that each farmer can only view information relevant to their own farm. The application provides detailed sensor data, including soil moisture levels categorized into three stages: "Dry" for moisture levels below 45%, "Humid" for moisture levels between 45% and 79%, and "Wet" for moisture levels exceeding 80%.

E. Ma-Ease: An Android-based Technology for Corn Production and Management

A mobile application has been developed specifically for corn farmers to conveniently manage and access information using their smartphones [34]. The application is built using Java on Android Studio and is designed to be user-friendly. One of its key features is the ability to function without Wi-Fi, which is particularly beneficial for farmers operating in areas with limited internet connectivity, as it can be used offline. The application offers a simple and intuitive user interface (UI) with clear labeling and includes weather forecasts to assist farmers in making informed decisions. It also provides a calculator to estimate crop yield, enabling farmers to plan their farming activities effectively. Additionally, a pest control feature has been integrated into the application, allowing farmers to quickly contact pest control services in case of infestations, thereby helping to prevent crop loss.

The past related works are compared to the purposed method using these feature criteria: -

a) Application displays sensor reading.

b) Application is not limited to certain crops.

c) Application can control device/automation.

d) Application can work in long range scenario.

e) Application provides general information about farming.

f) Application allow user to monitor farm visually.

g) Application can handle multiple users.

h) Application has additional feature that have not been mentioned from a – g.

All the applications from the past related works will undergo a checklist to identify the presence of the mentioned criteria. If an application meets a specific criterion, it will be marked as 'Y'; otherwise, if the criterion is not present, it will be marked as 'N'. Next, the Y-Score will be calculated to determine which application has the highest number of 'Y' marks, using formula (1).

$$Y - Score(\%) = \frac{Amount\ of\ Y}{8} \times 100\% \qquad (1)$$

The aim of the comparison table is to identify which application offers the most functionality that can effectively address the challenges faced by farmers, particularly those in urban areas. The table will allow for a comprehensive evaluation of the applications based on their features and capabilities, enabling the determination of which application is better suited to accommodate the specific needs of farmers.

TABLE I. COMPARISON BETWEEN EXISTING WORK

Feature / REF	a	b	c	d	e	f	g	h	Y-Score
[27]	**Y**	**Y**	**Y**	N	N	N	N	N	37.5
[28]	**Y**	N	N	**Y**	N	**Y**	N	**Y**	50.0
[29]	**Y**	**Y**	**Y**	**Y**	N	N	N	N	50.0
[33]	**Y**	N	N	**Y**	N	N	**Y**	N	37.5
[34]	N	N	N	**Y**	**Y**	N	**Y**	**Y**	50.0
Purposed Work	**Y**	**Y**	**Y**	**Y**	N	N	**Y**	**Y**	75.0

Table I shows the feature comparison between previous works and this work. Based on the comparison table, it is evident that this work offers 25% more features compared to the highest percentage of features available in the previous works. However, to ensure the application remains streamlined and user-friendly, some features have been omitted. Despite this compromise, the application is still able to accommodate most of the needs of farmers, including those in urban areas. By providing a comprehensive set of features, it aims to address the challenges faced by farmers effectively.

III. The System Implementation and Testing

A. Hardware Implementation

The necessary hardware components for developing this work include an ESP-32, an Electroconductivity (EC) sensor, and a temperature sensor. These components will be connected as depicted in Fig. 2. The hardware setup will be implemented in a selected hydroponic farm situated at Pertubuhan Kebajikan Villa Harapan in Taman Desa Molek, Melaka. The ESP-32 will be responsible for collecting data from the sensors and calculating the EC value, which will then be transmitted to the database. The formula (2), (3) and (4) is used to calculate the EC value.

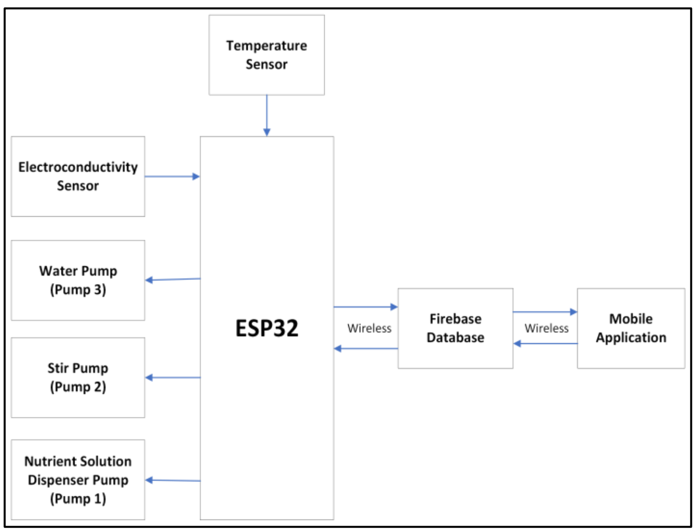


Fig. 2. Block Diagram of hardware system.

$$tempCoefficient = 1.0 + 0.0185 \times (temperature - 25.0) \quad (2)$$

* ‘temperature’ is the reading of temperature sensor

$$voltageCoefficient = \frac{Voltage}{tempCoefficient} \quad (3)$$

* ’Voltage’ is the reading of EC sensor

$$ecCurrent \begin{cases} voltageCoefficient \leq 448; 6.84 \times voltageCoefficient - 64.32 \\ voltageCoefficient \leq 1437; 6.98 \times voltageCoefficient - 127 \\ else\ ; 5.3 \times voltageCoefficient + 4322 \end{cases} \quad (4)$$

*ecCurrent’ is the EC value that will be sent to the database

The EC value is crucial for monitoring the health of hydroponic crops, as it determines the conductivity and nutrient levels in the water-nutrient solution. Maintaining the appropriate EC value is vital to ensure optimal growth and development of the plants. In the case of hydroponic farming, if the EC value of the water-nutrient solution is too high, it indicates a high concentration of salts or nutrients. This can lead to an imbalance in osmotic pressure, causing the water-nutrient solution to draw water from the roots of the crops. As a result, the plants may suffer from water stress and eventually wilt or die due to inadequate water supply. On the other hand, if the EC value is too low, it suggests a deficiency of salts or nutrients in the water-nutrient solution. In this scenario, the roots of the plants will primarily absorb water but not enough nutrients, leading to nutrient deficiencies and poor growth. For the selected hydroponic farm, maintaining a desirable EC value of 12.8 mS/cm is important. This value ensures an appropriate concentration of salts and nutrients in the water-nutrient solution, providing optimal conditions for the hydroponic crops to thrive and grow healthily. Regular monitoring and adjustment of the EC value will help maintain the desired nutrient balance and support the overall success of the hydroponic farming system.

The hardware system will operate in fully automatic mode, where the EC value will determine the functionality of the pumps, as shown in Fig. 3. Furthermore, to test the hardware, it has been run at various EC values to observe the intended operation of the ESP-32. The results of all the tests will be tabulated in a table to analyze the occurrences when different scenarios are presented to the hardware.

B. Software Implementation

The marketplace hosted in the application will utilize Firebase database to store all the information related to the crops, including price, pictures, descriptions, and more, for sale within the application. Firebase database also provides real-time functionality, allowing the mobile application to receive and display real-time data. Additionally, Firebase Authentication will be used to authenticate users who sign up or sign in to the application. The mobile application will be developed in Android Studio using Java as the programming language. The interface of the mobile application is designed according to Fig. 4. Farmers will have a slightly different interface where they can view their farm conditions and control the pumps and automation systems. On the other hand, customers will not be able to view the farm conditions to respect the privacy of the farmers, but they will have the ability to contact the farmers using the built-in interface within the application. To test the application and database, a series of simulations have been conducted to verify if the application interface is working as intended and if the monitoring interface updates the values of temperature and EC (Electroconductivity) accurately. During the simulations, different scenarios were presented to evaluate the performance of the application. The interface was tested to ensure that it accurately displays the temperature and EC values retrieved from the database in real time. The goal of these tests was to confirm that the monitoring interface effectively tracks and updates the data, providing farmers with up-to-date information about their farm conditions. Additionally, the functionality of the application's interface was thoroughly tested to ensure that all features, such as crop information, pricing, pictures, and descriptions, are properly stored and retrieved from the Firebase database. This testing aimed to ensure that the application operates smoothly and offers a user-friendly experience for both farmers and customers. By conducting these simulations, any potential issues or discrepancies were identified and addressed, ensuring that the application and database perform reliably and meet the intended objectives.

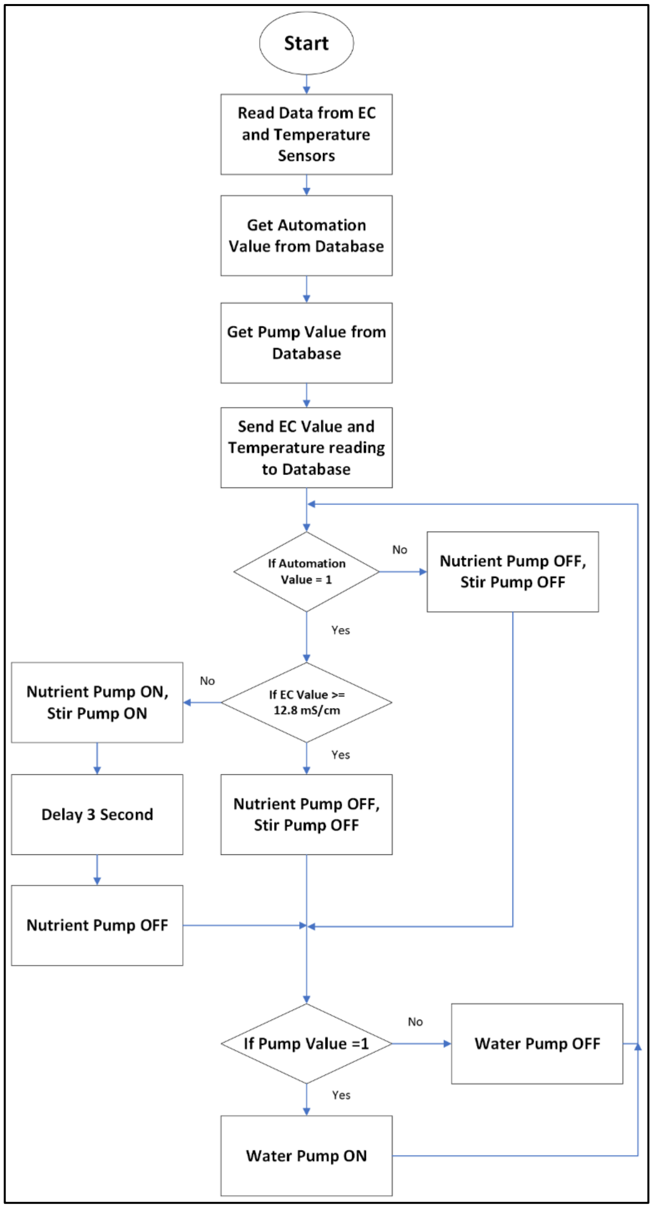


Fig. 3. Flowchart of automatic nutrient pump and monitoring system.

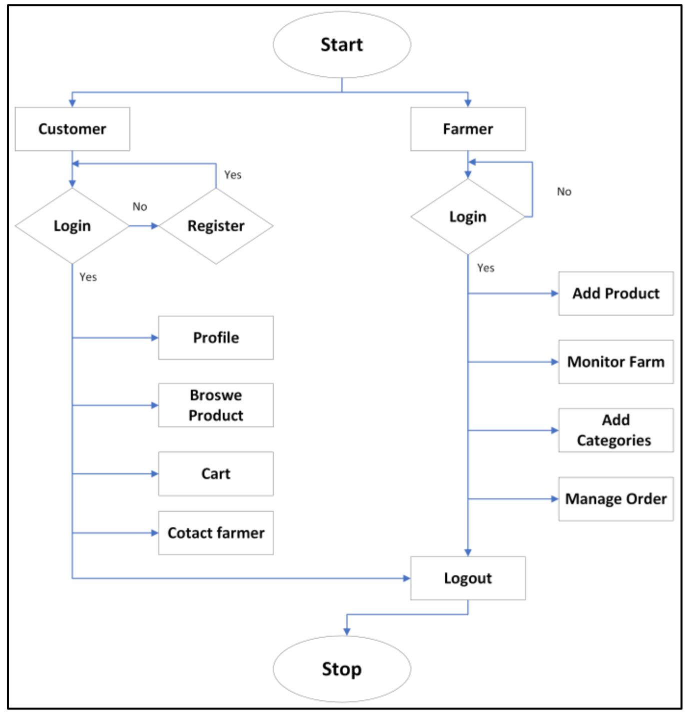


Fig. 4. Flowchart on function available in the mobile application for each type of user.

IV. Result and Discussion

A. Hardware Test Result

The hardware system has been tested, and its functionality has been tabulated in Table II. The ESP32 is capable of controlling the pumps based on the predetermined conditions set during the upload of EC and Temperature values to the Firebase Database. Additionally, the interval at which the mobile application updates the values has been captured and tabulated in Table III to determine any correlation between the distance between the mobile application and ESP-32 and the interval of information updates.

B. Hardware Result Discussion

Based on the test results, we can conclude that the fully automated system with monitoring is functioning as intended. The hardware successfully passed all the tests, achieving a 100% success rate. Thus, the farmer in Villa Harapan can trust the automation system to work as intended and allow them to not be needed in vicinity of their farm, majority of the time. The amount of time saved by not needing to be at their farm will make the concept of urban farming gain attraction.

TABLE II. AUTOMATIC NUTRIENT PUMP AND MONITORING SYSTEM HARDWARE TEST RESULT

Test ID	EC Value in Apps	Fully – Automate Switch in Apps	Pump Switch in Apps	Pump 1	Pump 2	Pump 3	Result
01	<12.8 mS/cm	OFF	Not Relevant	OFF	OFF	Not Relevant	Pass
02	<12.8 mS/cm	ON	Not Relevant	ON	ON	Not Relevant	Pass
03	>12.8 mS/cm	OFF	Not Relevant	OFF	OFF	Not Relevant	Pass
04	>12.8 mS/cm	ON	Not Relevant	OFF	OFF	Not Relevant	Pass
05	Not Relevant	Not Relevant	OFF	Not Relevant	Not Relevant	OFF	Pass
06	Not Relevant	Not Relevant	ON	Not Relevant	Not Relevant	ON	Pass

TABLE III. INTERVAL OF THE APPLICATION UPDATE THE INFORMATION AT DIFFERENT RANGE

Range (m)	Interval 1 (s)	Interval 2 (s)	Interval 3 (s)
5	1.54	1.45	1.37
10	3.47	3.05	3.83
20	2.74	3.38	1.48

Furthermore, the data gathered in Table III indicates that the range of the mobile phone to the farm does not have a significant impact on the time interval of information updates in the mobile application. The main factor causing the inconsistent time intervals is the stability of the network internet connection. The farm is located approximately 30m away from the internet router, which can result in intermittent connection issues for the ESP32, leading to inconsistent data updates in the database. Similarly, the mobile phone also requires a stable internet connection to ensure reliable and instant updates of the latest data in the application. In conclusion, to achieve a more consistent time interval for information updates in the mobile application, it is crucial for both the farm and the mobile application to be in close proximity to the network router or in a location with a stable and reliable internet connection. This will minimize the chances of the ESP32 experiencing connection losses and ensure a smooth and uninterrupted flow of data.

C. *Software Test Result*

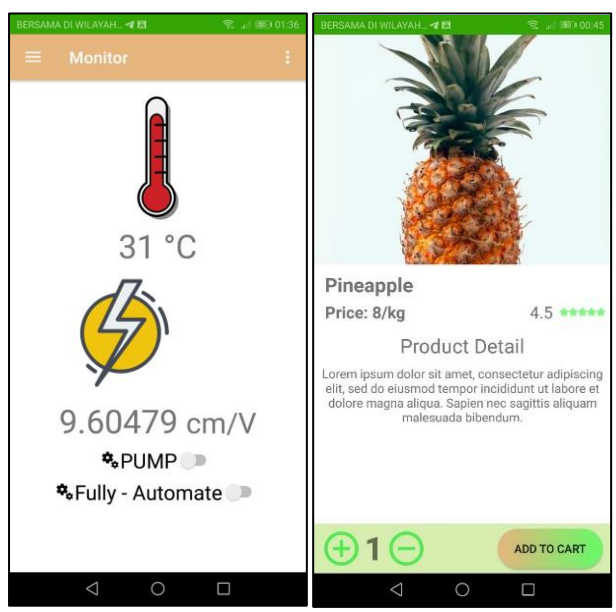
The software was subjected to testing, and the results have been compiled and presented in Table IV. The mobile application demonstrated its ability to handle multiple users simultaneously, enabling a marketplace where customers can search, browse, and purchase products. Additionally, customers have the option to contact the farmer to inquire about the status of their orders. The mobile application also provides access to farm information and allows users to control automation and pumps, as depicted in Fig. 5. Moreover, the application offers several other interfaces to enhance the user experience. This includes an interface where users can view product details such as descriptions, ratings, and prices. The home interface allows users to browse and search for desired products, while the sign-in interface enables registered users to log in to their accounts. Overall, the software has proven its capability to facilitate a user-friendly and feature-rich mobile application that accommodates multiple users and supports various functionalities, including marketplace access, farm information, and control of automation systems.

TABLE IV. BASIC NAVIGATION FOR APPLICATION SOFTWARE TEST RESULT

Test ID	Test Condition	Result
07	The user sign up customer account.	Pass
08	The user sign in into their account.	Pass
09	User search item in search bar.	Pass
10	User add item into the cart.	Pass
11	User check cart for the item	Pass
12	User buy the product.	Pass
13	User Delete Item in cart	Fail
14	User contact seller	Pass
15	Sign In using admin/farmer account	Pass
16	User Monitor farm	Pass

D. *Software Result Discussion*

Based on the test results, it can be concluded that the mobile application is functioning mostly as intended. The application successfully passed 9 out of 10 tests, accounting for 90% of the overall testing process. Thus, the consumer can reliably browse the application and successfully create an order to purchase the crops from Villa Harapan. Since this application is still in development/testing stage, bug is expected, hence the failure one of the features. But with now option to generate profit on using the mobile application, the concept the urban farming surely getting more popular as the urban farmer can start their farm anywhere.



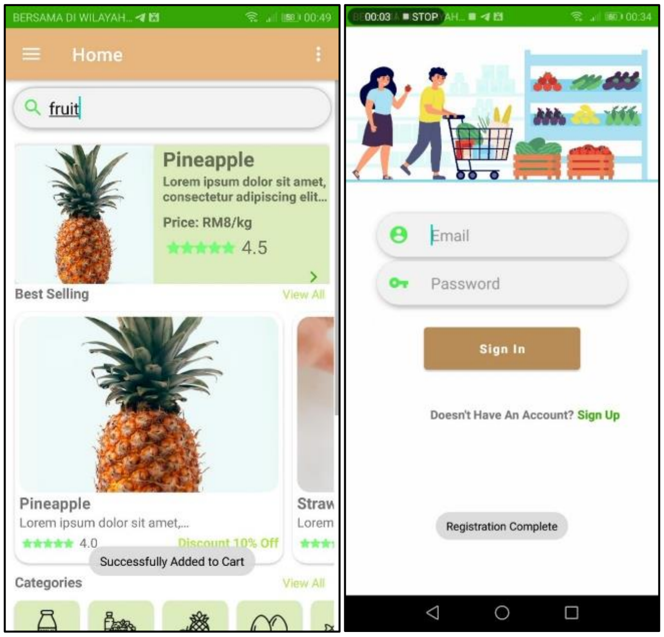


Fig. 5. Mobile application page for monitoring the browse item interface, home interface and sign in interface.

V. Conclusion

This work was developed to help urban farmers to easily sell their crops directly to the customer without relying on traditional method of agriculture that is soon to be rendered obsolete. Furthermore, the work also developed to help urban farmers to monitor their farm wirelessly using the mobile application. With the implementation of IOT, farmers can anywhere check their farm condition even if they have their farms in multiple locations. By not needing to be in vicinity of their farm, it opens many opportunities especially for people in urban area to venture into agriculture sector, hence promoting the idea of urban farming. The chosen farm for testing and implementing this innovation has also reaped the rewards of state-of-the-art, fully automated pump system that can be easily controlled and monitored through a mobile application. Interestingly, according to Table III, the proximity of the farmer to the farm holds no bearing on the latency between updates in the interface, which varies greatly. This can be attributed to the fact that the farm is stationary and therefore, internet quality remains consistent. Essentially, the principal factor contributing to the latency between update intervals is the quality of the farmer's internet connection. The better the internet quality, the shorter the latency period between updates, enabling farmers to remotely control their farm from anywhere with a decent internet connection. Upon the crops reaching maturity, farmers can conveniently sell their produce through the in-built marketplace feature in the application. The introduction of this innovative application provides a practical solution to the growing need for sustainable urban farming and healthy food consumption. With the increasing use of smartphones and mobile applications, this technology offers a convenient and reliable platform for consumers, farmers, and other stakeholders to engage in indoor vertical farming. By incorporating features such as remote farm monitoring, the application enhances the efficiency and productivity of urban farming, promoting sustainability and self-sufficiency. As more individuals turn to urban farming to address the challenges of food security and limited resources, this application provides a promising step towards a sustainable and equitable future.

VI. Limitation and Future Works

This works has a limitation that can be improved with future works. The monitoring system built is tailor made to the selected farm in this work. So some monitoring features may not be of any use to other farms and thus some may request that feature is missing for other farm. For future work, more research can be conducted to gather data on the most common requested features in farm monitoring mobile application so that the feature can be widely used by variety of farmers especially urban farmers. Besides that, this approach of promoting the concept of urban farming also has a limitation where the user needs to be knowledgeable in technology to set up their online shop and monitoring system. This work only comes with mobile application since we assume user of this application already has his own monitoring system set up. So, if the users don't have the monitoring system set up, and they don't know how to, then the monitoring system feature will be useless to them, making the mobile application and urban farming less appealing in general. Next, the user interface can be improved much better to attach more consumers to use the application boosting the popularity of the application, simultaneously promoting the concept the urban farming to urban people. In future works, more appealed color scheme and modern design in user interface can be built. Lastly, the transaction for purchase in this application is still not diverse compared to other m-commerce applications in the market. In future work, the application can be built with more diverse options to complete the transaction making it more appealing to both consumer and seller. With improvement to this work, the goals to promote the concept of urban farming can achieve greater success.

Acknowledgment

The authors would like to thank Centre for Research and Innovation Management (CRIM) for the support given to this research by Universiti Teknikal Malaysia Melaka (UTeM).

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