Home grocery listing hardware system and mobile application with speech recognition feature

Mohamad Faris Eizlan Suhaimi[1], Aiman Zakwan Jidin[2], Haslinah Mohd Nasir[1], Mohd Haidar Md Hamzah[3], Mohd Syafiq Mispan[1,2]

[1]Fakulti Teknologi dan Kejuruteraan Elektronik dan Komputer, Universiti Teknikal Malaysia Melaka, Durian Tunggal, Malaysia
[2]Micro and Nano Electronics (MiNE), Centre for Telecommunication Research and Innovation (CeTRI), Universiti Teknikal Malaysia Melaka, Durian Tunggal, Malaysia
[3]Hippo Techfast Sdn. Bhd., Durian Tunggal, Malaysia

Article Info

ABSTRACT

A home grocery list is a crucial aspect of household management that ensures sufficient kitchen supplies. The classic pen-and-paper grocery list is ineffective since it is time-consuming and prone to human error. Therefore, in this study, we proposed a microcontroller-based home grocery listing system using a barcode scanner and speech recognition. The proposed system consists of hardware and a mobile application. The main hardware components are the ESP32-S3 microcontroller, MH-ET barcode scanner v3.0, 20×4 LCD, and 2.4 GHz wireless keyboard. The mobile application is developed using the MIT App Inventor. Through the hardware, the system receives user input from barcode scanning or manual data entry using the keyboard. The data captured using a barcode scanner or keyboard is stored in the memory. Subsequently, the data is transmitted to the mobile application of the home grocery listing system via WiFi. Moreover, the mobile application is also equipped with user input via speech recognition and manual data entry using the keyboard. Hence, users have the flexibility to input the grocery list using four methods within the system. The developed home grocery listing system gives a new, satisfying experience to the users and a convenient way for them to make a home grocery list.

Corresponding Author:

Mohd Syafiq Mispan
Fakulti Teknologi dan Kejuruteraan Elektronik dan Komputer, Universiti Teknikal Malaysia Melaka
Jalan Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
Email: syafiq.mispan@utem.edu.my

1. INTRODUCTION

Creating and using a grocery list is a common practice to ensure nothing is overlooked while shopping. With changing consumer habits, grocery list management and inventory tracking have become key areas of study. Unplanned shopping trips can lead to multiple visits to the store, consuming significant time. Many individuals often forget intended purchases. According to Firoz and Ratnayaka [1], 40.6% of shoppers often forget planned items, sometimes leading to dissatisfaction with their purchases. These findings highlight how poor decision-making and ineffective grocery list management negatively impact consumers.

Several techniques have been proposed in the past to develop an efficient grocery listing system that mainly focuses on using sensors, smartphones, and IoT applications [1]–[10]. Studies in [2], [3], [5], [7] employed load cell sensors to measure the remaining weight of monitored grocery items. Another sensor-based

approach employed ultrasonic sensors to determine the level of stored grocery items [6], [9], [11]. However, all these methods are only suitable for specific types of groceries stored in containers such as rice, sugar, and flour. Moreover, the sensors need to be calibrated regularly to ensure accurate and reliable measurements. Elsewhere, grocery listing using a mobile application approach was also proposed in [8], [10], [12]. Although the mobile application approach offers flexibility to users, its efficiency is limited by factors such as user input dependency, processing speed, and connectivity requirements.

Elsewhere, a food tracking (i.e., expiry date) application is proposed to prevent waste of perishable food [13], [14]. The application also featured an automatic grocery or shopping list for easy and effective user management. Another study in [15] also developed a grocery list as an additional feature of the main pet monitoring application. Nevertheless, the grocery list applications above are only limited to perishable foods or cat foods. Other research focuses on developing the automated shopping cart or trolley based on the preselected grocery list using artificial intelligence (AI) or radio-frequency identification (RFID) technologies [16]–[20].

Based on all the above, the previous techniques of grocery listing systems experience major drawbacks such as sensor inaccuracies, high cost due to hardware complexity, and limited grocery selection, which depends on sensor capability. The grocery listing using a mobile application approach offers flexibility to users but still requires manual data entry. To enhance both flexibility and efficiency, hybrid approaches combining a hardware system and a mobile application are worth exploring. Therefore, in this study, we focus on developing a home grocery listing hardware system that integrates a barcode scanner and a wireless keyboard. This system is connected to a mobile application equipped with speech recognition functionality to enhance user convenience. The hardware system can be positioned at a fixed location in the kitchen for easy grocery list management. Moreover, the user has the flexibility to add or update the grocery list using the mobile application anywhere and at any time, ultimately improving the overall grocery management experience.

2. METHOD

In this section, the method to design a microcontroller-based home grocery listing system using a barcode scanner and speech recognition is described. Figure 1 illustrates the top-level block diagram of the home grocery listing system. To design the proposed system as depicted in Figure 1, this project is divided into three main parts, which are hardware development, mobile application design, and integration of hardware and mobile application. First, the hardware of the home grocery listing system is developed. Hardware components include an ESP32-S3 microcontroller, MH-ET barcode scanner v3.0, 20×4 LCD, 2.4 GHz wireless keyboard, and a USB host interface. The ESP32-S3 is chosen due to its compact size, low power consumption, and built-in Wi-Fi capabilities [21]. MH-ET barcode scanner v3.0 lets users scan items directly from the product barcodes. A USB host interface is used in our study to connect the wireless keyboard and ESP32-S3 through a USB receiver. The wireless keyboard provides user flexibility and efficiency. A 20×4 LCD is used to display the product name and its quantity when the user performs data entry using a barcode scanner or wireless keyboard.

Next, the mobile application is developed using MIT App Inventor since it offers an intuitive and visual programming environment that enables efficient Android-based application development [22], [23]. A lightweight database within the MIT App Inventor known as TinyDB is used to store the grocery data. The database ensures the grocery list remains accessible even if the application closes or the device is restarted. With the mobile application, users can view and manage (i.e., add, edit, or delete items) the grocery list. Users can perform the above actions using a keyboard or speech recognition (i.e., using a built-in mobile microphone). The speech recognition is implemented using the "SpeechRecognizer1" component in MIT App Inventor. The user must say the word "add" followed by the grocery name. "SpeechRecognizer1" is coded to receive the voice input and be able to distinguish the word "add" and the grocery name. The speech recognition features offer hands-free convenience and a satisfying experience to the users. The mobile application is also equipped with an additional feature known as "Nutrition Facts". "Nutrition Facts" gives specific information about items such as calories, protein, fat, carbohydrates, fiber, sugars, and sodium based on serving size. For data management, Google Sheet is used as a back-end database to store and retrieve nutritional information.

In the last development stage, the hardware system is integrated with the mobile application. The mobile application connects with the hardware (ESP32-S3) via a Wi-Fi connection. Data entries using product barcode or wireless keyboard are captured and processed by the ESP32-S3, formatted into JSON, and sent to the mobile application in real-time. This enables the mobile application to immediately update the list, providing a seamless and interactive experience to the user [24], [25]. Users can view and manage the grocery

list within the mobile application. Subsequently, the functionality and performance evaluation of the whole system is conducted to ensure the accuracy of data entry under various products and users.
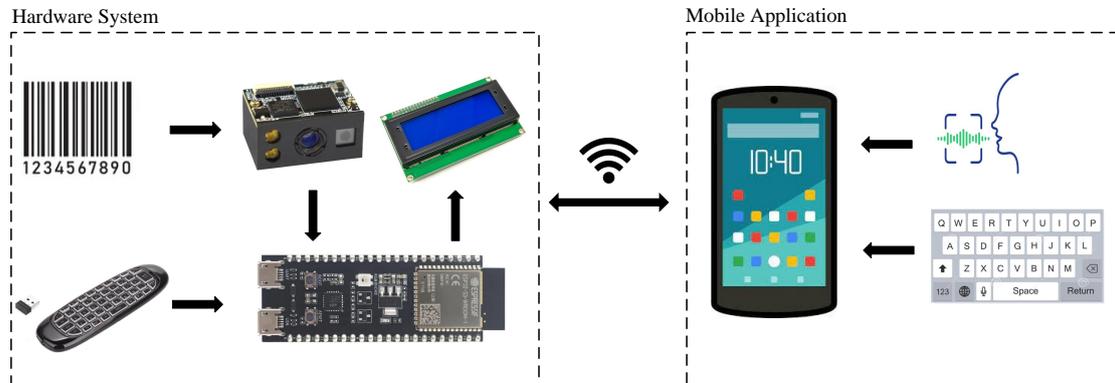

Figure 1. Top-level block diagram of the home grocery listing system

3.   RESULTS AND DISCUSSION

This section presents the results and analysis of the development of a home grocery listing system using a barcode scanner and speech recognition features in a mobile application.

3.1.   Hardware configuration

Figure 2 depicts the hardware configuration to perform the barcode scanning and manual data entry using a wireless keyboard. Four components are involved, which are the ESP32-S3, MH-ET barcode scanner v3.0, 20×4 LCD, and a USB host interface. Table 1 lists the pin connections of a barcode scanner, LCD, and USB host to ESP32-S3. The hardware configuration on the breadboard is verified using a developed program in Arduino IDE, and it successfully performs the barcode scanning and manual data entry using a wireless keyboard. Important libraries used in the program, such as *EspUsbHost.h* to enable the USB host with ESP32-S3, *map* to store barcode data in the form of key-value pairs, *WebServer.h* to configure a web server and handle HTTP requests, *LiquidCrystal_I2C.h* and *Wire.h* to print messages to an LCD screen using the I2C communication protocol. I2C is a two-wire serial communication protocol using a serial data line (SDA) and a serial clock line (SCL).
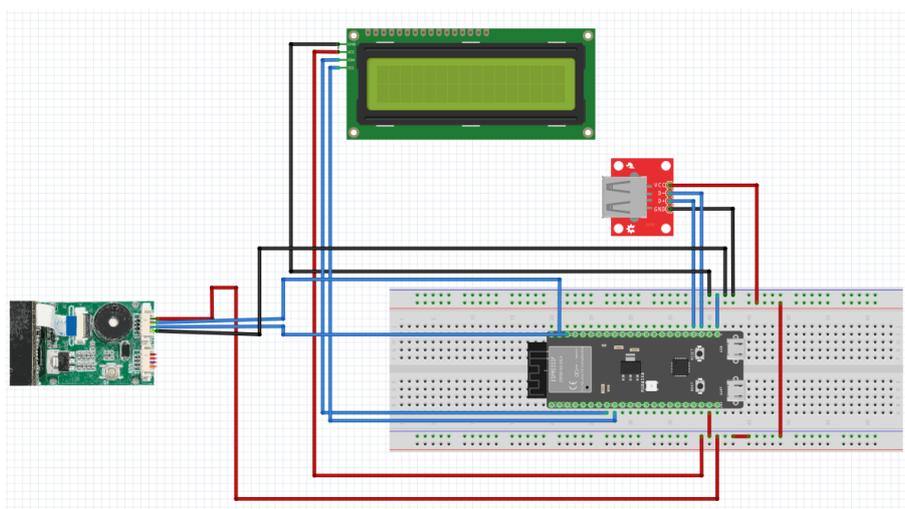

Figure 2. Circuit configuration on breadboard

Home grocery listing hardware system and mobile application with ... (Mohamad Faris Eizlan Suhaimi)

Table 1. Connectivity of barcode scanner, LCD, and USB host to ESP32-S3

Module	Module pin	ESP32-S3 pin
Barcode	RX	GPIO 16
scanner	TX	GPIO 15
LCD	SDA	GPIO 8
	SCL	GPIO 9
	GND	GND
	5V	5V
USB Host	D+	GPIO 20
	D-	GPIO 19
	GND	GND
	5V	5V

3.2. Mobile application design

As mentioned in section 2, MIT App Inventor is used to design the mobile application of a home grocery listing system. Figure 3 depicts the user interface of the home grocery listing mobile application. Figure 3(a) shows main interface. Users may add grocery items by typing the grocery names in the "Item:" and pressing the "Add" button. Users can remove the grocery items from the list by pressing the "CLEAR" button. Moreover, users can add grocery items using voice input by pressing the "Speaking Head" emoji. Once the "Speaking Head" is pressed, the user interface, as in Figure 3(b), appears and the user can speak through the built-in microphone of the smartphone to add the grocery items to the list.

"Nutrition Facts" is an additional feature in the home grocery listing mobile application, designed to provide additional functionality on a separate screen as shown in Figure 3(c). Users can navigate to the "Nutrition Facts" screen to check specific information about items such as serving size, calories, protein, fat, carbohydrates, fiber, sugars, and sodium by pressing the "NEXT" button in the main interface. Users can enter the name of an item in the search box and press the "SEARCH" button to display the nutrition details. Users can go back to the main interface by pressing the "PREVIOUS SCREEN" button.
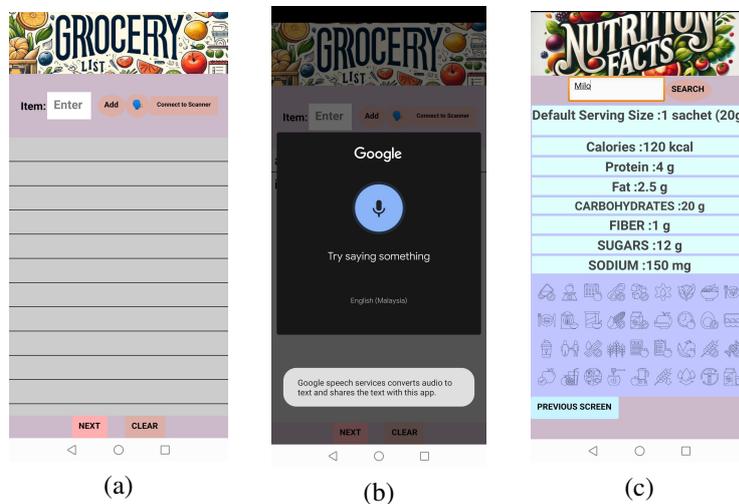

(a) (b) (c)

Figure 3. User interface of home grocery listing mobile application; (a) main interface, (b) speech recognition, and (c) nutrition facts

3.3. Functionality verification and performance evaluation

The mobile application, as discussed in subsection 3.2 was integrated with the hardware system through the ESP32's web server capabilities over a Wi-Fi network. The integration of hardware and mobile applications allows for real-time communication and data synchronization. Figure 4 illustrates the prototype of the home grocery listing system. The prototype works as follows. When a product's barcode is scanned or entered manually, the ESP32-S3 processes the information stored in its memory of ESP32-S3, and displays it

on the LCD. At the same time, the hardware system sends the data to the web server via the HTTP protocol. In the main interface of the mobile application, when the "Connect to Scanner" button is pressed, the grocery items in the web server are retrieved and populated in the grocery list.
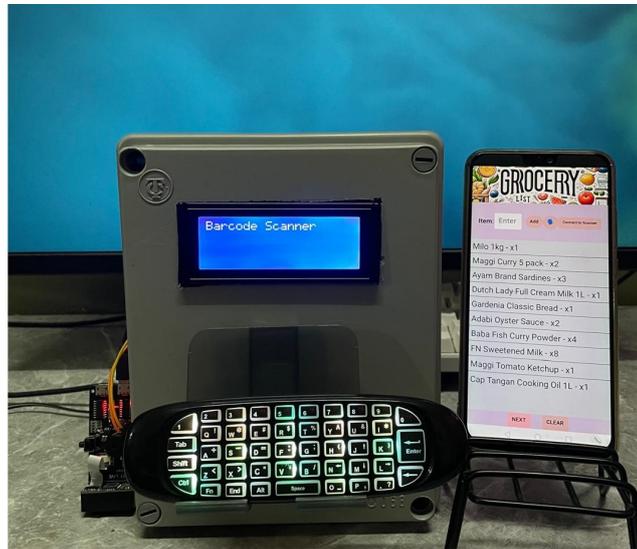

Figure 4. A prototype of home grocery listing system

Figures 5 and 6 shows screens displayed on the 20×4 LCD during barcode scanning of first time product registration and of registered product respectively. Figures 5(a) and 6(a) depict the LCD display during the barcode scanning of products. When the user scans the barcode of the un-registered product, the LCD displays "Not found" and the system requests to enter the product name and the quantity as shown in Figures 5(b)-5(d). Meanwhile, when the user scans the barcode of the registered product, the LCD displays the product name, and the previously registered quantity is automatically increased by one as shown in Figure 6(b). However, the user has the option to adjust the quantity of the product as depicted in Figure 6(c). Table 2 lists the products that were successfully scanned and registered. Five items that were previously registered are scanned and their quantity is adjusted which are Milo, Maggi Curry, Sardines, Milk, and Gardenia Bread. The other five items were unregistered and required the user to input the product name and quantity upon barcode scanning.

Figure 5. Screens displayed on the 20×4 LCD during barcode scanning of first time product registration; (a) main display, (b) product entry, (c) quantity entry, and (d) registered product
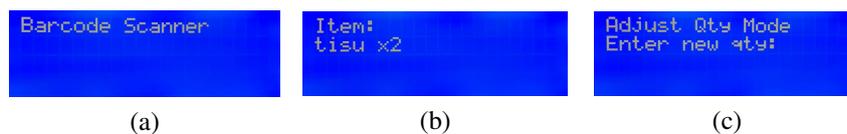

Figure 6. Screens displayed on the 20×4 LCD during barcode scanning of registered product; (a) main display, (b) registered product, and (c) adjust quantity

Table 2. Analysis of data entry for grocery items with barcode

Barcode ID	Reg.	Product name	Qty.	System action	Outcome
9556724810021	Yes	Milo 1kg	1	Displayed details on LCD, quantity adjusted manually.	Scan succeeded; inventory updated.
9557932010584	Yes	Maggi Curry 5-pack	2	Displayed details on LCD, updated quantity automatically.	Scan succeeded; inventory updated.
9551028334217	Yes	Ayam Brand Sardines	3	Displayed details on LCD, updated quantity automatically.	Scan succeeded; inventory updated.
9557124832123	Yes	Dutch Lady Full Cream Milk 1L	1	Displayed details on LCD, quantity adjusted manually.	Scan succeeded; inventory updated.
9556103456712	Yes	Gardenia Classic Bread	1	Displayed details on LCD, quantity adjusted manually.	Scan succeeded; inventory updated.
9558943127645	No	Adabi Oyster Sauce	2	Prompted user to input product name and quantity.	Product added to database; inventory updated.
9556782910314	No	Baba's Fish Curry Powder	4	Prompted user to input product name and quantity.	Product added to database; inventory updated.
9558896723419	No	F&N Sweetened Milk	8	Prompted user to input product name and quantity.	Product added to database; inventory updated.
9557819231406	No	Maggi Tomato Ketchup	1	Prompted user to input product name and quantity.	Product added to database; inventory updated.
9556128347601	No	Cap Tangan Cooking Oil 1L	1	Prompted user to input product name and quantity.	Product added to database; inventory updated.

Products without barcodes, such as meat, poultry, fish, and vegetables, require manual data entry using the keyboard. The manual data entry process is illustrated in Figure 7. Users can press the *Tab* button on the keyboard to display the main menu. To activate the manual data entry mode, the user can select the *Manual* option in the main menu as depicted in Figure 7(a). Once the manual mode is activated, the user can enter the product name and its quantity as shown in Figures 7(b)-7(e). Other main menu options such as *Clear* to clear the current grocery list, *On* and *Off* to control the system's power state, *Exit* to return to the "Barcode Scanner" main display, and *Stats* to display useful information such as Wi-Fi connection details, the number of items registered, and the memory usage.

(a)   (b)   (c)

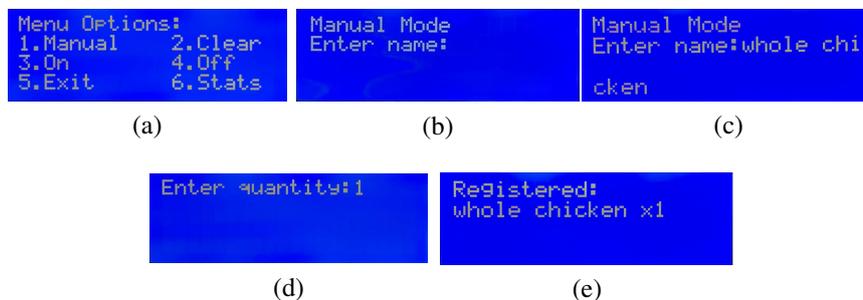(d)   (e)

Figure 7. Screens displayed on the 20×4 LCD during manual mode operation; (a) options, (b) manual mode activated, (c) product entry, (d) quantity entry, and (e) registration successful

Figure 8 shows grocery list in mobile application. Figure 8(a) depicts the grocery list in the mobile application upon successful barcode scanning and manual data entry using the hardware system. As mentioned in section 2, the mobile application is equipped with a speech recognition feature. Data entry using speech recognition has been evaluated among five different users (i.e., each with a variation in tone). Table 3 summarizes the analysis of speech recognition data entry. Data entry for each user is successfully processed, and the grocery list in the mobile application is updated as shown in Figure 8(b).

As discussed above, the developed grocery listing system in this study has four methods of data entry. By using the hardware, the user can either perform data entry using a barcode scanner or a wireless keyboard (i.e., manual data entry). Moreover, users can perform data entry using speech recognition and the "Add" feature in the mobile application. Table 4 lists the available features and compares them with the previously proposed technique of the home grocery listing system. As can be seen in Table 4, our developed grocery

listing system provides more features to the user, hence it is more efficient as compared to other systems and provides a convenient way for the user to make a home grocery list for shopping.
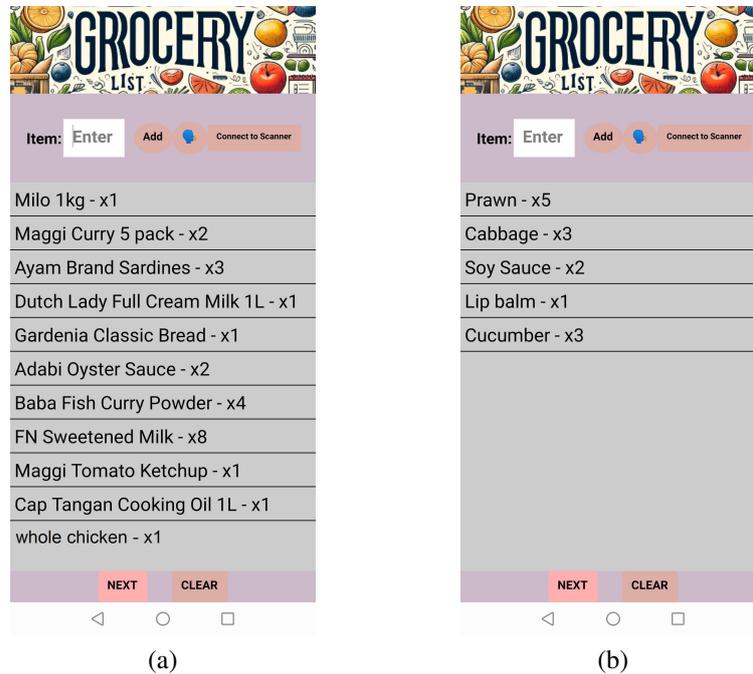

Figure 8. Grocery list in mobile application; (a) barcode scanning and (b) speech recognition

Table 3. Analysis of speech recognition data entry

User ID	Product name	Quantity	System action	Outcome
User 1	Prawn	5	Processed voice, logged details	Successful; correct product and quantity recorded
User 2	Cabbage	3	Processed voice, logged details	Successful; correct product and quantity recorded
User 3	Soy Sauce	2	Processed voice, logged details	Successful; correct product and quantity recorded
User 4	Lipbalm	1	Processed voice, logged details	Successful; correct product and quantity recorded
User 5	Cucumber	3	Processed voice, logged details	Successful; correct product and quantity recorded

Table 4. Features comparison with the previous techniques

Features	Firoz and Ratnayaka [1]	Kaur et al. [2]	Katuk et al. [10]	Rezwan et al. [5]	Patil and Pawar [9]	Our work
Mobile App	√	√	√	√	√	√
Website	×	×	×	√	√	×
Speech recognition	×	×	×	×	×	√
Barcode scanning	×	×	×	×	×	√
Dedicated kitchen hardware	×	×	×	×	×	√
Multi-input integration	×	×	×	×	×	√

4. CONCLUSION

In this paper, a home grocery listing system using a barcode scanner and speech recognition is developed. The system consists of hardware and a mobile application. Users have four methods to perform data entry. Users can use a barcode scanner or wireless keyboard within the hardware system to perform data entry. Additionally, users can use speech recognition and "Add" features in the mobile application to make a grocery list. As compared to prior works, our proposed system is considered very efficient and user-friendly, as the user has different methods to perform home grocery listing. The newly developed home grocery listing system

offers users a convenient and enjoyable way to create their grocery lists. Future research will focus on reducing the size and improving the integration of the hardware components to enhance portability and suitability for kitchen deployment.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Mohamad Faris Eizlan Suhaimi		✓		✓	✓	✓		✓	✓					
Aiman Zakwan Jidin	✓									✓				
Haslinah Mohd Nasir	✓									✓				
Mohd Haidar Md Hamzah	✓									✓				
Mohd Syafiq Mispan	✓								✓	✓		✓		✓

C	: **C**onceptualization	I	: **I**nvestigation	Vi	: **Vi**sualization
M	: **M**ethodology	R	: **R**esources	Su	: **Su**pervision
So	: **So**ftware	D	: **D**ata Curation	P	: **P**roject Administration
Va	: **Va**lidation	O	: Writing - **O**riginal Draft	Fu	: **Fu**nding Acquisition
Fo	: **Fo**rmal Analysis	E	: Writing - Review & **E**diting		

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [initials: MSM], upon reasonable request.

REFERENCES

[1] A. Firoz and G. Ratnayaka, "ShopLister - A grocery list management application," in *2020 International Conference on Image Processing and Robotics (ICIP)*, Negombo, Sri Lanka, 2020, pp. 1–6, doi: 10.1109/ICIP48927.2020.9367367.

[2] L. Kaur, S. Shah, M. Gupta, and R. Bhadoriya, "Smart grocery monitoring system using smart sensors and IoT," *International Journal of Recent Development in Engineering and Technology*, vol. 11, no. 5, pp. 1–5, 2022.

[3] J. K. Kiruthika, S. Manikandan, U. Nithya, M. Preethika, and S. Poorna, "IoT-based smart inventory management system," in *2023 International Conference on Computer Communication and Informatics (ICC)*, Coimbatore, India, 2023, pp. 1–6, doi: 10.1109/IC-CCI56745.2023.10128211.

[4] D. Singh, N. Desai, and R. R. Nair, "Design of portable IoT based grocery tracking system via Wi-Fi module for home automation," *International Research Journal of Engineering and Technology*, vol. 7, no. 7, pp. 5469–5473, 2020.

[5] S. Rezwan, W. Ahmed, M. A. Mahia, and M. R. Islam, "IoT based smart inventory management system for kitchen using weight sensors, LDR, LED, Arduino Mega and NodeMCU (ESP8266) Wi-Fi module with website and app," in *2018 Fourth International Conference on Advances in Computing, Communication & Automation (ICACCA)*, Subang Jaya, Malaysia, 2018, pp. 1–6, doi: 10.1109/ICACCAF.2018.8776761.

[6] T. S. K. Sakthisudhan, S. Mohanraj, and T.V.P. Sundararajan, "A smart kitchen automation and grocery management system using IoT," *International Journal of Recent Technology and Engineering*, vol. 8, no. 1, pp. 2368–2373, 2019.

[7] H. Desai, D. Guruvayurappan, M. Merchant, S. Somaiya, and H. Mundra, "IoT based grocery monitoring system," in *2017 Fourteenth International Conference on Wireless and Optical Communications Networks (WOCN)*, Mumbai, India, 2017, pp. 1–4, doi: 10.1109/WOCN.2017.8065839.

[8] W. A. H. Jayawilal and S. Premeratne, "The smart shopping list: An effective mobile solution for grocery list-creation process," in *2017 IEEE 13th Malaysia International Conference on Communications (MICC)*, Johor Bahru, Malaysia, 2017, pp. 124–129, doi: 10.1109/MICC.2017.8311745.

[9] C. S. Patil and K. N. Pawar, "Smart grocery management system using Internet of Things (IoT)," *International Journal of Research in Engineering and Technology*, vol. 5, no. 7, pp. 2321–7308, 2016.

[10] N. Katuk, T. Jayasangar, and Y. Yusof, "Design and development of smart list: A mobile app for creating and managing grocery lists," *Baghdad Science Journal*, vol. 16, no. 2, pp. 462–476, 2019, doi: 10.21123/bsj.2019.16.2(SI).0462.

[11] D. Sharma, H. Lakhera, I. Bakshi, and S. Chauhan, "IoT based cloud kitchen optimization using fuzzy intelligence and advanced

signal processing," in *2024 4th International Conference on Sustainable Expert Systems (ICSES)*, Kaski, Nepal, 2024, pp. 285–291, doi: 10.1109/ICSES63445.2024.10762978.

[12] T. Fatema, A. E. Khan, M. Shams, M. G. S. Hossain, and S. Momen, "Bazaar mind: A virtual shopping assistant," in *2019 International Conference of Computer Science and Renewable Energies (ICCSRE)*, Agadir, Morocco, 2019, pp. 1–5, doi: 10.1109/ICCSRE.2019.8807446.

[13] S. Miniaoui, S. Atalla, and K. F. Bin Hashim, "Introducing innovative item management process towards providing smart fridges," in *2019 2nd International Conference on Communication Engineering and Technology (ICCET)*, Nagoya, Japan, 2019, pp. 62–67, doi: 10.1109/ICCET.2019.8726900.

[14] M. Pajpach *et al.*, "Exspiro-mobile application for food sustainability," in *2023 International Conference on Modeling, Simulation & Intelligent Computing (MoSICom)*, Dubai, United Arab Emirates, 2023, pp. 77–82, doi: 10.1109/MoSICom59118.2023.10458770.

[15] A. Sanctorum and B. Signer, "A unifying feference framework and model for adaptive distributed hybrid user interfaces," in *2019 13th International Conference on Research Challenges in Information Science (RCIS)*, Brussels, Belgium, 2019, pp. 1–6, doi: 10.1109/RCIS.2019.8877048.

[16] P. Kaushik, A. Sharma, and G. S. Bhathal, "Revamping supermarkets with AI and RSSi," in *2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS)*, Coimbatore, India, 2021, pp. 53–59, doi: 10.1109/ICAIS50930.2021.9395814.

[17] A. Paul, R. Ferdaush, and T. Islam, "Revolutionizing retail: An automated shopping trolley for effortless customer experience," in *2023 26th International Conference on Computer and Information Technology (ICCIT)*, Cox's Bazar, Bangladesh, 2023, pp. 1–6, doi: 10.1109/ICCIT60459.2023.10441104.

[18] B. L. Prasanna, M. P. P. Reddy, S. S. Kumar, and S. Mareddy, "RFID-enabled smart shopping cart for enhancing shopping efficiency and preventing theft," in *2024 5th International Conference on Recent Trends in Computer Science and Technology (ICRTCST)*, Jamshedpur, India, 2024, pp. 485–490, doi: 10.1109/ICRTCST61793.2024.10578386.

[19] S. Sah, E. Deswal, and S. Annamalai, "RFID infused IoT shopping system," in *2024 10th International Conference on Advanced Computing and Communication Systems (ICACCS)*, Coimbatore, India, 2024, pp. 1223–1227, doi: 10.1109/ICACCS60874.2024.10716996.

[20] J. N. V. R. S. Kumar, B. K, L. G, C. Ch, N. K, and T. K, "IoT based smart shopping cart integrated with payment gateway," in *2024 International Conference on Recent Advances in Electrical, Electronics, Ubiquitous Communication, and Computational Intelligence (RAEEUCCI)*, Chennai, India, 2024, pp. 1–6, doi: 10.1109/RAEEUCCI61380.2024.10547971.

[21] T. Pfitzinger and H. Wohrle, "Embedded real-time human activity recognition on an ESP32-S3 microcontroller using ambient audio data," in *2023 IEEE 12th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS)*, Dortmund, Germany, 2023, pp. 459–464, doi: 10.1109/IDAACS58523.2023.10348926.

[22] S. Sajimon, V. Msr, P. V. Manitha, and M. Nithya, "Implementation of accelerometer controlled robot using MIT Inventor App and Arduino," in *2023 2nd International Conference on Automation, Computing and Renewable Systems (ICACRS)*, Pudukkottai, India, 2023, pp. 100–104, doi: 10.1109/ICACRS58579.2023.10404505.

[23] R. Kawchale, S. Deshpande, K. Patil, A. Wajed, and Vaibhav Somvanshi, "Home automation system by Android application and voice control," in *2024 8th International Conference on Computing, Communication, Control and Automation (ICCUBEA)*, Pune, India, 2024, pp. 1–6, doi: 10.1109/ICCUBEA61740.2024.10774849.

[24] W. Song, X. Wang, T. Wang, Z. Li, Z. Zhang and L. Yang, "Design of factory environmental monitoring system based on ESP32," in *2023 5th International Conference on Frontiers Technology of Information and Computer (ICFTIC)*, Qiangdao, China, 2023, pp. 311-314, doi: 10.1109/ICFTIC59930.2023.10456317.

[25] N. Nikolov and D. Gotseva, "Make a prototype of IoT connected diagnostic tool using ESP32 and MQTT for reading data from car CAN Bus OBD2," in *2024 59th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST)*, Sozopol, Bulgaria, 2024, pp. 1-4, doi: 10.1109/ICEST62335.2024.10639614.

BIOGRAPHIES OF AUTHORS

Mohamad Faris Eizlan Suhaimi ⓘ 🔡 🆂🅲 ♻ received a Diploma of Electronic Engineering (Control) from Malacca Polytechnic, Malaysia and Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours from Universiti Teknikal Malaysia Melaka in 2025. He is currently working as NPI Engineer in Venture Pintarmas Sdn. Bhd. He can be contacted at email: mfaris.suhaimi@venture.com.sg.

Aiman Zakwan Jidin ⓘ 🔡 🆂🅲 ♻ is recently completed his Ph.D. in Electronic Engineering at Universiti Malaysia Perlis, Malaysia. His research topic focuses on creating a new low-complexity memory testing algorithm for optimum static fault coverage in SRAM. Previously, he obtained his M.Eng. in Electronic and Microelectronic Systems from ESIEE Engineering Paris, France, in 2011, before working as an FPGA IP Core Design Engineer at Altera Corporation Malaysia (now part of Intel). He is a full-time lecturer and researcher in Electronic and Computer Engineering at Universiti Teknikal Malaysia Melaka (UTeM). His research interests include DFT, VLSI, and FPGA system design. He can be contacted at email: aimanzakwan@utem.edu.my.

Haslinah Mohd Nasir ⓘ � SC ◌ received her Bachelor Degree in Electrical-Electronic Engineering (2008) from Universiti Teknologi Malaysia (UTM), M.Sc. (2016) and Ph.D. (2019) in Electronic Engineering from Universiti Teknikal Malaysia Melaka (UTeM). She had 5 years (2008-2013) experience working in industry and currently a lecturer in UTeM. Her research interest includes microelectronics, artificial intelligence, and biomedical. She can be contacted at email: haslinah@utem.edu.my.

Mohd Haidar Md Hamzah ⓘ 🔶 SC ◌ completed his Bachelor of Engineering with Honors in Electrical Engineering in 2007 from Universiti Teknologi MARA (UiTM) and went on to earn his Master of Engineering in Electrical (Computer and Microelectronic System) in 2010 from Universiti Teknologi Malaysia (UTM). He has accumulated extensive experience in the industry, having worked as a Physical Design Engineer, RF Modelling Engineer, PV Engineer, and Design Automation Engineer. He is an expert in physical layout design and proficient in programming languages such as Python, Perl, Java, HTML, and Dart Flutter. Currently, he is the founder of Hippo TechFast Sdn Bhd, where he focuses on machine learning, artificial intelligence, and app development. His diverse expertise and entrepreneurial spirit drive the company's mission to deliver innovative technological solutions. He can be contacted at email: hippotechfast@gmail.com.

Mohd Syafiq Mispan ⓘ 🔶 SC ◌ received B.Eng. Electrical (Electronics) and M.Eng. Electrical (Computer and Microelectronic System) from Universiti Teknologi Malaysia, Malaysia in 2007 and 2010 respectively. He had experienced working in the semiconductor industry from 2007 until 2014 before pursuing his Ph.D. degree. He obtained his Ph.D. degree in Electronics and Electrical Engineering from University of Southampton, United Kingdom, in 2018. He is currently a senior lecturer in Fakulti Teknologi dan Kejuruteraan Elektronik dan Komputer, Universiti Teknikal Malaysia Melaka. His current research interests include hardware security, CMOS reliability, VLSI design, reconfigurable computing, and electronic system design. He can be contacted at email: syafiq.mispan@utem.edu.my.