2022 IEEE 2nd International Conference on Mobile Networks and Wireless Communications (ICMNWC)

A Multifunctional Automatic Dog-Feeder with Bluetooth and Wi-Fi Connectivity

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***Abstract*—The prevalence of household pets has grown in recent decades. Dogs are the most common, and they provide companionship and protection. Averagely, dogs need to eat at least twice a day. Monthly tablet administration is also required to protect them against infectious pests. It is important to remember that the keeper's hours wasted on these tasks, increases proportionally with the number of pets they care for. Owners may spend far less time on tedious tasks like: feeding, providing water, and medicating pets – by utilizing dispensers. However, there are many important features modern pets need, that are absent from the market's selection of antiquated dispensers. In this work, we present the methodology behind the development of an automated food dispenser. The ESP32 served as the central microcontroller. This automated system essentially dispenses food to dogs, with voice command/ button control, using MIT App Inventor II. It also hydrates pets at predetermined intervals and secretly injects medications into their food. Three different types of monitoring software have been included into the system [Gmail, ThingSpeak and a Database website]. This helps users observe pets' food and water levels. The final product is a combination of the technical hardware and software components.**

Keywords—Automation, PHP, MySQL, MIT App, ESP32.

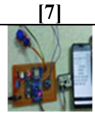
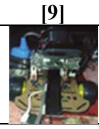
I. Introduction

Dogs, according to a recent survey, are the best-loved pets in history. Their importance is backed up by a plethora of numbers. Healthline reports that having a dog in the home can lessen feelings of isolation by 60% [1]. As a result, almost 33% of Americans explored adopting dogs (with high daily needs), during the Covid-19 outbreak [2]. Their relevance remains [3] even if we ignore the story of a caring owner. Those that temporarily acquire these pets, sell them to make a profit – making as much as $395 for one sold pup [4]. It is only natural that they would wish to ensure the wellbeing of their pets. An automatic pet feeder is a novel, time-saving device, for pet owners. Time limits in providing for dogs are becoming a concern, as their numbers continue to rise in households [3]. These pets have stringent daily requirements that must be met, or they rapidly get ill. Because of this, owners often have to pay several hundreds of dollars for their rehabilitation. The scope of this project is restricted to developing an IoT-based automatic dog feeding system. The system will have a food, water, and pill dispenser. Finally, a pet-tracking component will be added. Together, these components form the embedded system's hardware and software.

II. Related Work

Although various efforts have been made to address the issues associated with pet-provision, many of these solutions have been inadequate [5]. Some of the problems with modern designs are as follows: (1) no provision of an autonomous pet-calling system; (2) inability to provide both wet/dry food to dogs; (3) no power-saver option; (4) failure to give set temperature foods; and (5) the inability to properly preserve dog food. The new dog-feeder system will address these shortcomings. It will make it possible for users to produce a variety of safe pet foods, all the while keeping their pet's food fresh. In order to understand and assess the work done in this field, a survey of existing pet-feeder designs was conducted. With this newfound information, we can create a stronger prototype. As shown in Table I, the past models' design decisions are ranked and recorded – all these projects were found on the IEEE Xplore database. The goal was to compare the performance of the old pet feeders to the performance of the new, more adaptable design. Using Table II, we will take into account all of the earlier models' distinctive features, and solve all of their shortcomings. These selected criteria will also lead the system requirements in Section III.

TABLE I. Pugh chart of related models

Description		**MA [6]**	**MB [7]**	**MC [8]**	**MD [9]**
Sketch					
Criteria	***Weight***	***Model A***	***Model B***	***Model C***	***Model D***
Automated	5	+	+	+	+
Robust	4	0	– –	0	–
Power Saver	3	0	0	0	– –
Accurate	4	+	+	0	– –
Preserves food	4	– –	– –	– –	– –
Stores copious volumes of food and water	5	+	–	+	– –
Delivers feedback	4	+	+ +	+	+ +
+		18	17	14	13
0		7	3	11	0
–		8	21	8	36
Net Score (out of 29)		10	–4	6	–23

2022 IEEE 2nd International Conference on Mobile Networks and Wireless Communications (ICMNWC) | 978-1-6654-9111-2/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICMNWC56175.2022.10031807

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TABLE II. SUMMARY OF RELATED MODELS OF AUTO DOG-FEEDERS

	Unique Aspects	Limitations
MA	-Be able to recognize an individual dog through the use of a Radio-Frequency Identification (RFID) tag. -Stunning design. -The waiting period can be adjusted using a mobile app [6].	-Receiver for radio frequency identification (RFID) has accuracy issues. -There is no way to reduce power consumption, as it utilizes a simple USB plug-in. -Only dry food is served. -No provision for refueling water supplies. -There's a chance that pets will show up once the selected amount of time has passed. -Bad decision concerning the type of microcontroller.
MB	-Advanced RISC Machine (ARM) microcontroller, used for greater efficiency [7].	-Weak design/construction. -No defined motor choices. -Device easily pushed across floor by pets (not durable). -Unjustified utilisation of microcontroller.
MC	-Attractive design. -Can store large amounts of food [8].	-Food preservation technique is flawed, and may lead to pet illness. -Poor design and construction (uses solderless breadboard). -Can only hold small food pallets.
MD	-Has access to a video camera, to record the condition of the pet. -A feeding system that is both portable and trackable, so it may be delivered to the dog wherever it may be [9].	-There is a severe restriction on the amount of food/ water that can be carried. -No self-regulation; human input is required to operate the robot. -The onboard power supply drains rapidly. -It is possible that water will flow onto electronics. -No use of sensors (blind product).

III. METHODOLOGY

Several components work together to form the automatic machine. As one unit, they will be able to complete the project goals successfully. The major components are the cooling/heating system, the mixing system, the dispensing and pet calling system, and the monitoring component. The design will incorporate a number of different motors and sensors. This is for moving consumables like food or water from one area to another without risk.

A. System Justification

Understanding the needs of the target audience is crucial. This had to be done before proceeding with the device's sub-system integration. These specifications will be extremely helpful during the building process, component selection, and software development. The necessary specifications for the system and their explanations are shown in Table III.

B. System Design

Table IV shows the Pugh matrix for communications technology selection. Data came from 'Communication' articles [10]. For performance, the ESP32 microcontroller was chosen. Other factors used in the decision, included: memory, architecture, speed, and direct Wi-Fi and Bluetooth availability. Next, a block and contextual diagram of all electronic components was created (Figure 1 and Figure 2). These components will meet system requirements.

TABLE III. SYSTEM REQUIREMENTS FOR NEW AUTO PET-FEEDER

No.	System Requirement	Specification	Justification
1	Food must be hot.	Wet food should have a temperature between 35 – 40 °C.	So that the dog does not get sick from eating cold food. However, it should not be too hot, or the dog could get burned.
2	Device should be able to store food.	Food must be stored between temperatures of 24 – 27°C.	For the pet food to stay fresh for longer.
3	The device must present food, at certain times.	There must be a minimum delay of less than 3 minutes.	To provide a reliable and easy-to-use device for pet owners, into which feeding times need only be entered.
4	Serve cool water.	Water delivered to the pet must be 24°C (on average).	Users want their canine companions to feel cool and refreshed even on hot days.
5	Deliver de-wormers as appropriate.	At the end of every month, de-wormer tablets are given to the pet.	The many health benefits and the convenience with which medication can be administered to dogs, would be much appreciated by owners.
6	A feature that enables power-saving.	The cooling system must be shut off by a temperature range, and restarted at 28°C.	A machine with a high-power need is both inefficient and costly.
7	Technology that can be operated from afar.	The user must be able to operate the gadget by speaking commands into it, or pressing buttons from no more than 5 meters away.	It is possible that pet owners might like to alter feeding schedules via a mobile app without leaving their houses; they will not need to approach the machine.
8	Monitor success in terms of pet's diet, remotely.	Online pet feeding must be available. Therefore, timely data analytics will be provided.	Users receive pet eating habits. That is, how often and whether they eat.

TABLE IV. PUGH MATRIX FOR CHOOSING COMMUNICATION TECHNOLOGY

Basis	Wi-Fi (80211B)	Weight (Out of 5)	GSM	Bluetooth (802.15.1)	Zigbee (802.15.4)
Range	0	5	– 1	– 3	+1
Data Rate	0	5	– 1	– 1	– 2
Expense	0	5	– 2	+1	– 1
Availability	0	5	– 1	0	– 2
Power Consumption	0	5	+1	+1	+3
TOTAL	0	25	– 4	– 2	–1

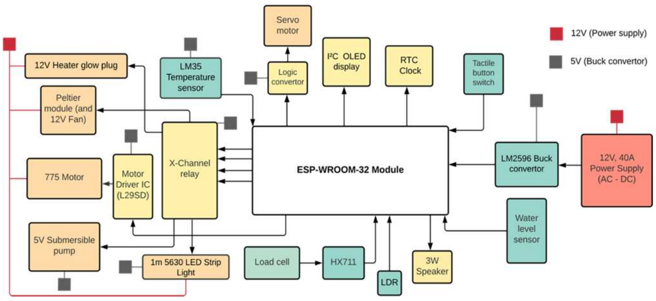

Fig. 1. Block diagram of hardware system

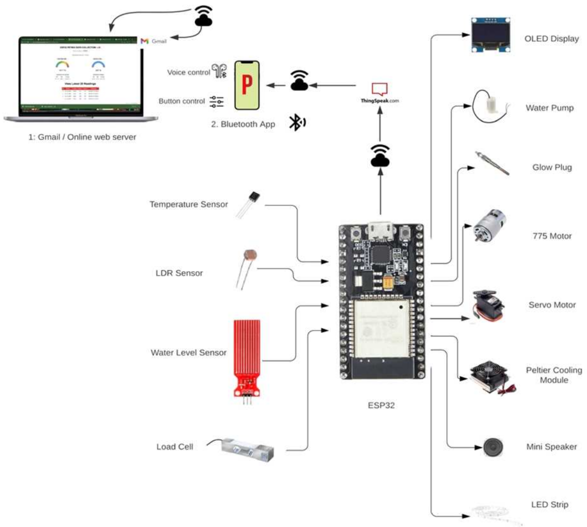

Fig. 2. Contextual diagram for automatic dog-feeder

Bluetooth will be used to connect the smartphone app, since it does not require Wi-Fi and is suitable for short distances (less than 10m). Additionally, it is far less expensive than other communication methods and has a minimal energy footprint. In the meanwhile, Wi-Fi will be utilized to transmit data to online monitors. The ESP32's outstanding Wi-Fi and Bluetooth capabilities will make it an ideal device for its intended application. No new connecting hardware would need to be purchased. For example: a $5 Wi-Fi module (ESP8266). Integration with a second microcontroller increases both cost and hardware space, which is a significant negative. Also, ESP8266 has but a single analog input pin. In contrast, the ESP32 is available for $8.81, which is only $1.26 more expensive than an Arduino Uno. A Bluetooth module (HC-05 or 06) that costs an additional $5 would not be required. Moreover, based on the block and contextual diagrams, 6 PWM (Pulse Width Modulated) pins will be required; 4 for controlling the servos, 1 for controlling the buzzer sound, and 1 for the L293D driver. Three analog input pins will be allocated to the water sensor, temperature sensor, and Light-dependent Resistor (LDR) sensor. Real Time Clock (RTC) and Organic Light-Emitting Diode Display (OLED) require 2 sets of Inter-Integrated Circuit (I2C) pins: SDA and SCK. Ten additional GPIO (General Purpose Input/Output) pins will be required (for the control of the 4-channel relay and connection to the HX711). Wi-Fi and Bluetooth are required, along with 21 GPIO pins. The ESP32 meets all of these requirements. The gadget will require three types of voltage as well: 3.3V (for the OLED display, water sensor, and LDR sensor), 5V (for the servo motors and ICs), and 12V (for the 775 motor and relay).

C. Electronic Components

The block and contextual diagram helped to determine which materials would be required to complete the project. To guarantee the device's optimal performance, it is necessary to properly pick both the passive and active components through rigorous evaluation. Here is a rundown of the 18 main parts:

1) ESP32 chip - The central microcontroller is the brain of the entire product. It is equipped with Bluetooth, Wi-Fi, and the required GPIO pins.

2) *10kg load cell with HX711* - The load cell is utilized to determine the weight of the pet dish (this value is monitored and displayed to users). The HX711 is an analog-to-digital converter (ADC) that is connected to the load cell.

3) 12V Heat glow plug - It provides dependable cold starting and a brief pre-heating time of 5 to 7 seconds after the required power source is attached. This component serves as a source of heat for moist foods.

4) LM35 module - This module is used to determine if the acceptable temperature range (for the pet's food) has been reached.

5) Real time clock DS3231 - The RTC is utilized for accurate timing of food and water dispensing. It has its own battery, allowing it to operate independently from the system to which it is connected.

6) ST-L293D Integrated Circuit (IC) - The L293D push-pull 4-channel driver with diodes controls the speed and direction of the dc motor. This motor is attached to food-mixing blades and works as a mixer.

7) 4-Channel 5V relay - The relay module regulates the activation and deactivation of four vital components (the water pump, LED strip, glow plug and cooler module).

8) 5V dc submersible pump - This was utilized to pump water from a holding tank to the pet bowl.

9) 1m, 5630 led - Used to brighten the pet feeder during the night.

10) Light-dependent resistor - The LDR is a light sensor. It causes the LED to turn on and off as required.

11) LM2596 dc to dc buck converter - This is a step-down controller able to drive a 3A load. It is used to reduce the 12V of the power source to 5V. Consequently, with a single buck converter to step down the voltage from 12V dc to 5V dc, all 5V devices will need to split the 2-3A provided by the buck, which is insufficient. It was agreed that two buck converters would be used for 4A-6A output.

12) Water level sensor - This analog sensor measures the level of water in the water bowl. The device must deliver water to pets if a low level is registered.

13) I2C OLED - Used to show bitmap pictures and the most up-to-date, and precise time.

14) MG995 servo motor - These motors will be affixed to metallic strips that will serve as food distribution hatches.

15) 775 dc motor - When supplied with 12V, the 775 dc motors have close to 3000rpm. Before the dog food is delivered, it is employed as a mixing agent.

16) 5V active buzzer - A tiny buzzer used to emit high frequency noises (17 - 20kHz) to notify dogs of their meals. In lieu of the unavailable speaker, a buzzer was deployed.

17) Semiconductor cooling module - this is a high-quality semiconductor cooler with exceptional durability. It has a 12V, 10A rating and is utilized to cool the food. This is intended to preserve food, as well as to cool the water for pets.

18) Power supply - The SP-xx0-12 is a single-output ac-dc power supply with an enclosed design. This component will supply 12V to the entire system.

D. Circuit Schematic

Electronics Design Automation (EasyEDA) was used to design the pet-feeder circuit.

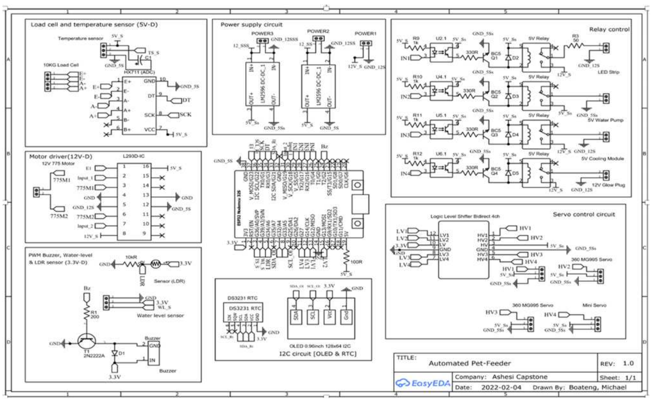

Fig. 3. Circuit schematic

E. Design of Software

The 'Petmix' Bluetooth app lets consumers program their automatic pet-feeder. App Inventor-2 (AI2) was used to generate 5 unique screens. Images, labels, switches, and horizontal/vertical layouts were artfully mixed. The app's Bluetooth connectivity is set to automatically connect users to the ESP32 when accessed. An Arduino code read the ESP32's Bluetooth address. After setting up the user interfaces and app outline, it was connected to the C++ code via keywords/text entering. The first screen is the intro. It lets users connect instantly to the ESP32 or choose another device. The app is connected to Google Assistant, which is contacted when the button is hit. Owners can feed their pets by saying "feed now," or cancel a scheduled program by saying "cancel program." The app is then sent a speech-to-text. A dog bark tune is heard when users start their eating plan. Screens 2 and 3 follow; screen 2 explains why users must enter data; screen 3 considers the pet's gender, age, and breed. By entering this information into the app, pet feeding amounts will be determined. Screen 4 allows customers to select dog food and medicinal alternatives. Screen 4's links to significant pet-monitoring sites. Section IV shows the finished app. In the second and third stages of the software design, an online monitoring website to display auto-feeder statistics, and an emailing feature to message users about their dog, were built. Figure 4 shows the web monitor and Gmail notifier design context. The microcontroller sends 'HTTP POST' request to the PHP script, which inserts data into 'MySQL' database. 000webhost was used as the free web host. All .php codes were in my webhost's public html folder (See Figure 5). Including the website's .css file. The color, padding, height, etc. was included. In the esp-readings.php, the heading, gauges, and tables were added. One gauge shows the dog's bowl water level, and the other the preservation tank's temperature. An 'HTTP POST' request and 'notification.php' script were used to deliver email notifications. The email, API key, and sensor reading variables were stated. The following code sent an email [containing the recipient's email, the topic, and the message]: mail ($**********@gmail.com, "Petmix Alert," $email msg);

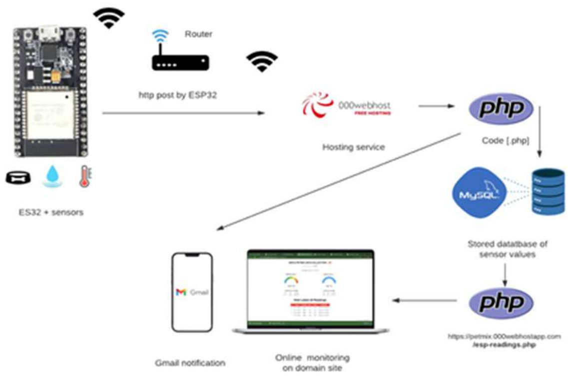

Fig. 4. Online web monitor and Gmail notifier using MySQL, PHP, HTML and CSS

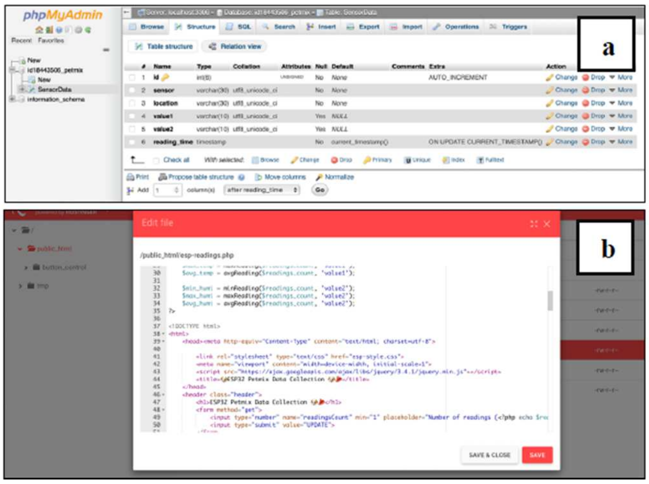

Fig. 5. (a) phpMyAdmin database. (b) Petmix online monitor. php file

IV. IMPLEMENTATION

A. Hardware Implementation

Figure 3's circuit was used to design a PCB. The trace width was calculated carefully (in respect to the high and low voltage tracks). As calculated, 0.6mm was left for wire routing, to avoid errors. The PCB was 140 x 140cm. Two-layer PCBs were chosen for their lower size. Component wiring was rearranged on the two-layer board's top and bottom sides. Equations (1) and (2) determined the 12V power supply's rating. Total power from all electronics was calculated.

NB: The datasheets for the electronics listed in section III, were used to get all current and voltage ratings.

$$V = IR \tag{1}$$

$$P_T = IV \tag{2}$$

$$\begin{aligned} P_T = [&(3.6 * 5) + (1.28x10^{-4} * 5) + (1x10^{-2} * 5) + (3 * 12) \\ &+ (8x10^{-2} * 5) + (2.2x10^{-1} * 5) \\ &+ (1.6x10^{-3} * 5) + (3.2x10^{-2} * 3.3) \\ &+ (6x10^{-5} * 5) + (0.2 * 12) + (0.25 * 5) \\ &+ (500x10^{-9} * 3.3) + (30 * 12) \\ &+ (0.0207 * 3.3) + (0.125 * 3) + 0.5]W \end{aligned}$$

$$= 420.3\ W \text{ (Total power)}$$

$$I_T = 37.4A \text{ (Total current)}$$

Therefore, the selected power source must be capable of delivering current more than 37.4A, ideally in the 40A range. Providing both 480W and 40A, the SP-480-12 power supply is a viable solution.

B. *Software Implementation*

Every one of the four software components for this project turned out well, both in terms of concept and implementation. The auto-feeder process was simplified with the help of a custom app built in App Inventor II (AI2). The app featured five screens, and utilized Bluetooth. The app's voice command features were effective, with an 89% rate of success. All input elements (button, checkbox, input text) were successfully associated with a search term in the ESP32 program. Around 1.6 seconds was the average time it took for a button to respond. Following voice command activation of a meal, a Gmail alert will be sent with the cooler's current temperature and the amount of water remaining in the water tank. The dog's preferences and eating schedule must be taken into account while deciding on a typical meal. The ThingSpeak dashboard will alert consumers on the status of their food's weight when the time for that update approaches. The gauges and table on the PHP-based monitor, are constantly updated to reflect the most recent measurements of water level and temperature. Calibrating with ADCs of the microcontroller, measurements were averaged. For example:

Voltage = readADC_Cal(watersensor_Raw_Sensor1);
 watersensor _Water_level_Sensor1 = Voltage / 10;

C. *Integration of Software and Hardware*

Integrating hardware and software solutions, as shown in the contextual diagram, allowed for a more complete perspective. With this in place, we can rest assured that no part operates in isolation from the others. You can access the PHP and ThingSpeak sites from within the Petmix app (See Figure 6), by tapping on their corresponding buttons. Consequently, the entire suite of programs is found in one app. Following this, the finished hardware for the project could be packaged appropriately.

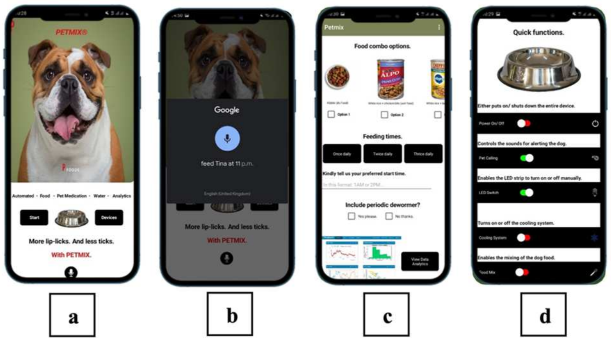

Fig. 6. (a) Home page. (b) Voice command option enabled. (c) 4th screen for feeding times. (d) 'Quick functions' screen

The automatic pet feeder's soldered circuitry is shown in Figure 7a. Figure 7c shows the ThingSpeak data, whereas Figure 7b displays the PHP web page. The printed circuit board incorporated appropriate labels. These helped make sure the parts got soldered in the correct places. Positive and negative connections were represented by red and black wires. The feeder's hardware have been combined into a single unit (electronics via PCB). The product's exterior shell was the next stage in the production process. The finished product is shown in Figure 8. To this end, we have an embedded system that combines hardware and software. Details on the mechanical construction will be provided in section V. The prototype has fully functional versions of all subsystems. An actual product was used as inspiration for the prototype. The water container is on the right side of the top compartment, while the food container is on the left.

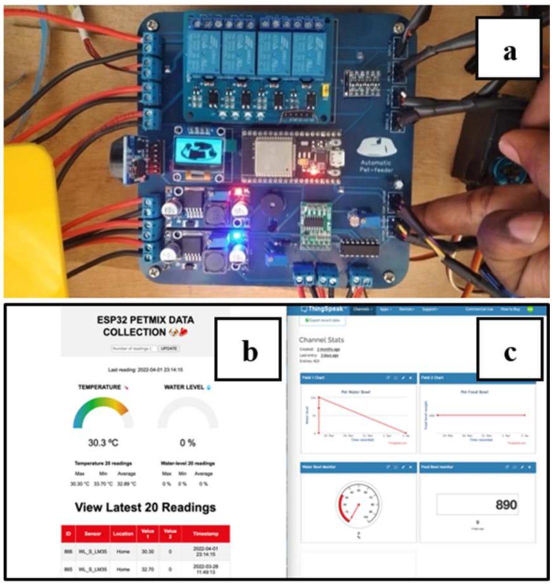

Fig. 7. (a) Soldered PCB. (b) Online webpage (water level and temperature). (c) ThingSpeak data collection

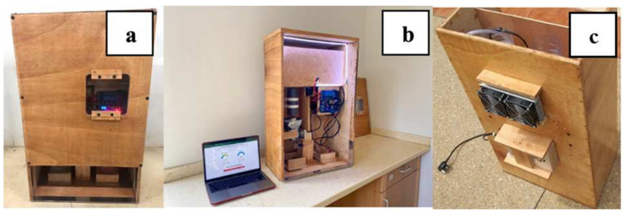

Fig. 8. (a) Completed pet-feeder (fore view). (b) Cross-section of auto pet-feeder. (c) Completed pet-feeder (rear view)

V. RESULTS AND DISCUSSION

A. Prototype Test

The prototype had to be tested in three major categories, i.e. the complete assessment of: the app, the device, and finally, the online monitors.

1) App: Voice/ Button Control

The Petmix Bluetooth app worked well, with a 1.6s average latency. Upon the voice command of "feed now," the machine fills the empty water container – if the level was read as being 70% or lower. Afterwards, the metallic blade on the servo displaces by ¾ in the anticlockwise direction, to allow food to come out. Food falls through the PVC pipe and into the bowl. All buttons worked as planned, and was able to manually control light levels, trigger pet-calling, shut-down the machine, and switch on/off the water pump.

2) Device: Food, Water, And Medicine Dispensation

The food, water and medication, dispensed at the particular time that the user selected (e.g.: '07:00am'). All the other sub-systems were also tested in this phase, as they combined to form the entire product. The buzzer sent out a pitch sound when meals were presented. The heater and the cooler maintained their proposed functionality when testing. The cooler kept the food and water at the top refreshed. It also was made to go off at around 28 °C. The heater and the mixer went together; the food entered a metallic funnel, at the select time, then the glow plug heated up the funnel with the food contained within it. Finally, the mixer-motor was attached to a small set of blades that spun and turned the food. The last servo hatch then opens to dispense the meal. The output temperature of the food was within the range of 32-40 °C – ideal for dogs. The water temperature remained at a cool temperature, between 24-27 °C. The medicinal tablet was dropped into the food at pre-set times, using the app (See Figure 9).

Fig. 9. (a) Gmail notification using PHP (temperature and water level). (b) Food, water, and medicine dispensation

VI. CONCLUSION AND FUTURE WORK

A. Conclusion

The technology functions well according to the test results. The superiority of the new product over past versions was established. The previous best version received a 10/29 score, while this one received a high 25/29 score (from Table I). To achieve a perfect score of 29, some modifications will need to be made – this will be elaborated on in the future work section. Important reaction times and latency results are shown in Table V. It is observed that using voice command is more responsive, on average, than button control.

B. Future Work

Further calibration of the servo motor is required, in order to acquire an accurate minimum and maximum range. This will improve the accuracy of the food hatches. Furthermore, the Petmix makes use of Bluetooth, which has a restricted range. A better option will be to use a website to maintain a database of GPIO pins on the ESP32. As a result, it can be operated from anywhere on the planet.

TABLE V. Response Times and Latency for Software

No.	Response time for voice command (s)	Response time for button control (s)	Latency for PHP site update (s)	Latency for ThingSpeak site update (s)
1	1.62	1.65	1.20	2.50
2	1.65	1.67	1.30	2.60
3	1.62	1.64	1.20	3.00
4	1.52	1.68	1.00	2.20
5	1.57	1.71	1.20	2.30
6	1.55	1.69	1.40	2.40
7	1.61	1.62	1.20	2.20
8	1.63	1.62	1.00	2.56
9	1.52	1.67	1.40	2.40
10	1.62	1.63	1.50	2.40
11	1.54	1.65	1.30	3.00
12	1.53	1.68	1.20	2.30
13	1.53	1.65	1.00	2.30
14	1.52	1.64	1.50	2.40
15	1.55	1.66	1.50	2.40

C. Link to Official Automatic Dog-Feeder Video:

https://www.youtube.com/watch?v=khQmykFBtg4

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