A Prototype of an IoT-Based Pet Robot with Customizable Functions (CoFiBot V2)

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***Abstract*— Nowadays, pet ownership is a rising trend. An owner may indeed regard the animal as a companion, a friend, or even a family member. The popularity of pets in the social media motivates people to own pets allowing them to show how well they can relate to pets. Owning a pet has proven to be beneficial to both physical and mental health of the owner. However, the owner's busy daily life with unpredicted schedule of activities results in the pet not being given a proper care or even being neglected. Based on the foregoing risk of owning a pet, several companies have been prompted to develop robotic pets. Possessing such robotic pets requires minimum attention but still serves the purpose of owning real pets. There are several robotic pets found in the market, but are too expensive and have little to no additional function except to serve as companions. The authors have previously proposed the first version of a robot with customizable functions (CoFiBot) allowing the user to select two modes: pet and firefighting. The need for such additional functions and the recent high demand for the integration of IoT-technology have motivated the development of the second version (V2) of CoFiBot. CoFiBot V2 is equipped with fire detection capability and customizable home monitoring functions. Simultaneously, it can roam freely within the owner's premises and provides the information on the surroundings via the internet to the owner. As an IoT-based mammal-type robotic pet, CoFiBot V2 is proven to be visually engaging and performs well under functionality and endurance tests. A comparison result between CoFiBot V2 and other research-level or market-ready robotic pets in terms of price and functionality indicates its attractiveness.**

***Index Terms*— IoT, robotics, biomimetics, pets**

I. Introduction

Pet ownership is proved to be beneficial to both physical and mental health. Pet owners enjoy interacting with their pets to relief their stress, as they perceive their pets to be entertaining. Companion-pet owners also show a strong emotional connection and attachment to their pets [1]. Research on pet-human bonding was conducted in Semarang, Indonesia [2]. The results of such research show that strong bonding between a pet and human is an important factor that offers several psychological and physical benefits, such as the opportunity to develop positive emotional interactions, a reduced risk of heart attack, and reduced blood pressure in humans [2].

Manuscript received December 1, 2020; revised April 21, 2021.

However, owning a pet may turn into a very demanding task, since an owner is required to allocate time to feed the pet, take it out of the house or interact with it. Pets are emotional creatures that need caring and loving; and enjoy spending their time with humans. If these needs are not met, pet's behavior disorder may occur causing the pet owners to be held liable for any public peace disturbance caused by such behavior disorder, according to the Indonesian Law (Penal Code) [3].

As an alternative to living pets, several companies are pushed to develop robotic pets. Robotic pets do not have to be fed or require playtime. One of such robots, Sony's Aibo robot dog, was proven to exhibit pet characteristics the way the living dogs do. In a study conducted among preschool kids, Sony Aibo was able to show pet-human interactions with kids similar to those of living dogs. The kids were also able to establish sort of pet-human bonding toward the robot dog [4].

The project reported in this paper is aimed to build a dog-like quadruped robot, which serves as a companion for human and a functional robot. The present robot is a successor of the first version of CoFiBot (customizable function robot), which is a modular pet robot [5]. Aside from an appealing look and a better locomotion, the CoFiBot V2 is equipped with the functionality and the simplicity commonly found in spider-like robots. While retaining the fire-detection procedure, the firefighting function, which is found in the previous version is dropped. This allows CoFiBot V2 to function as a playable pet when the owner is present and a mobile home monitoring system when it is left alone.

Finally, a comparison between CoFiBot V2 and other developed robotic pets are made. This is done in order to show that the former takes the lead in term of cost to functionality ratio.

II. Literature Review

A. The Advantages and Disadvantages of Pet Ownership

Pet ownership offers several advantages to the owners' physical and mental health. A study has shown that interacting with pets, even if only watching tropical a fish in a tank, can help reduce blood pressure and stress level [6]. This research results also show that in another study conducted among 11,000 German and Australian adults,

doi: 10.18178/ijmerr.10.9.510-518

there is a considerable margin of 15% fewer doctor visits made by pet owners compared to those of non-pet owners [6]. This is largely due to the tendency of pet owners to exercise more, since some pets such as dogs require physical exercise, which involve their owners as well.

However, as living organisms, pets need to be cared for, which does not mean that it is sufficient that they are fed regularly, but they also need to be checked for parasites and diseases. A study in Bangkok, Thailand showed that stray cats were identified as positive hosts of Hepatozoon canis [7]. Furthermore, most of stray animals in Indonesia are cats, which have a higher chance to be the hosts of vector-borne diseases compared to dogs [7,8].

B. The Development of Pet Robots

The development of pet robots started in 1999 when Sony released the first generation of Aibo, Sony's dog-like pet robot [9]. In the late 2000s, Tekno, the Robotic Puppy was released by ToyQuest. Tekno was considered to be a great success that it even appeared on the TIME magazine cover [10]. Tekno was intended to be a toy robot, but not a functional robot. Unlike Aibo, Tekno is not similar to living pets in terms of behavior either. Some other companies also started to develop their version of pet robots. In 2006, Innvo Labs released PLEO, an animatronic pet in form of a dinosaur [11].

The study presented in [4] also concluded that pet robots are considered to be substitutes to living pets as long as they look like living pets, just like the case that Sony Aibo is a dog-like robot. Therefore, an important role that a pet robot plays is that it can resemble living pet's like look and behavior better. This should be considered by every pet robot designer.

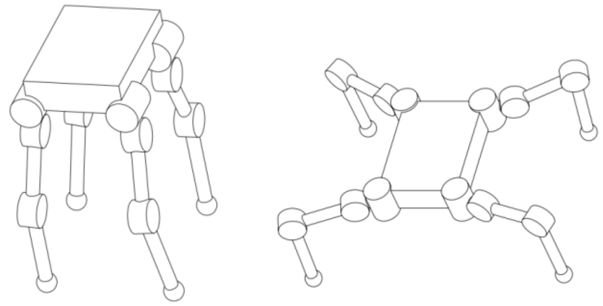
However, the cost of pet robots is not cheap. In 2020, for example, Sony Aibo was advertised on *Bukalapak* at a price of approximately IDR 103 million (equivalent to USD 7,000). It is sold in the USA at a price of USD 3,000. Tekno, the Robotic Puppy, was listed on Amazon at a price of USD 250. PLEO was listed on Ubuy at approximately USD 2,100. Although it was not intended to be a pet robot, the explorer variant of Boston Dynamics Spot is priced at USD 74,500 [12]. The comparisons among commercial pet robots can be seen in Table I.

TABLE I. THE COMPARISON AMONG COMMERCIALLY AVAILABLE PET ROBOTS

Robot	Price	Functionality
Spot	USD 74,500	Pet, gripper, heavy-duty
Sony Aibo	USD 7,000	Pet/toy
Tekno the Robotic Puppy	USD 250	Toy
PLEO	USD 2,100	Pet/toy
Petoi Nybble	USD 200	Pet/toy
Petoi Bittle	USD 225 (predicted)	Pet/toy

C. The Development of Quadruped Robots

Quadruped robots are robots, which use four legs to move. Quadruped robots offer several advantages over wheeled robots. These include better performance on steep slopes and rough terrains, omnidirectional mobility, eliminating the need for continuous ground contact path, the versatility of limbs, and an inherent redundancy [13]. There are two kinds of quadruped robots based on leg configuration: dog-like or mammal-type quadruped robots and spider-like or sprawling-type robots, as can be seen in Fig. 1 [14].



(a) (b)

Figure 1. The quadruped robots; (a) Mammal-type, (b) Sprawling-type [14]

The form of sprawling-type quadruped robots is inspired by insects or arachnoids. The leg configuration of the sprawling-type robot is similar to insects and spiders. Thus, it cannot achieve similarities in terms of looks and behavior compared to the living pets such as dogs and cats. However, sprawling-type quadruped robots are more popular and easier to build compared to mammal-type quadruped robots.

Mammal-type quadruped robots are better choice when it comes to robotic pets. The form of mammal-type quadruped robots is inspired by mammals as the name suggests. Since the most popular pets are dogs and cats, which are mammals, mammal-type quadruped robots can achieve similarities to living parts both in the look and the behavior. The leg configuration in mammal-type quadruped robots also enables these robots to pose like a real living pet.

Mammal-type quadruped robots are harder to build, since they rely on dynamic stability. A dynamic stability is a characteristic where the robots have to keep moving to achieve a stability. This is due to the fact that *dynamic gaits* are used by mammal-type quadruped robots, where two or more legs move at the same time. In a dynamic gait, the robot's center of gravity shifts every time it moves [15].

Two of the most well-known mammal-type quadruped robots in the world are the Boston Dynamics Spot robot and the MIT (Massachusetts Institute of Technology) Cheetah robot. Spot is developed as an all-terrain, heavy-duty autonomous commercial robot [16]. Boston Dynamics claimed that it can achieve the maximum speed of 1.6 m/s with 90 minutes of runtime, and is able to deliver a 14-kg of payload. Cheetah, on the other hand, is developed as an experimental robot [17]. Thus, Cheetah is more advanced in terms of locomotion compared to Spot. Cheetah is able to do a 360° backflip and reach the maximum speed of 4.47 m/s [17].

However, both Spot and Cheetah are huge robots. Spot weighs 30 kg with an arm module, while Cheetah 3 weighs 70 lbs [17]. There is a smaller version of Spot, but still weighs around 25 kg [18]. The smaller version of Cheetah, the Mini Cheetah (Fig. 2), weighs just around 9 kg, but it is unlikely to be released to the market [19]. Based on weight, dimension, and availability, neither Spot nor Cheetah can be considered as a good replacement for living pets.

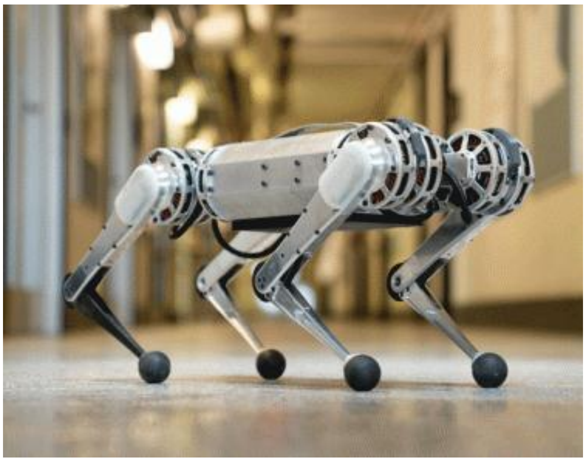


Figure 2. MIT Mini Cheetah [19]

Another pet robot project is Petoi, which is developed by Rongzhong Li. Petoi is a project that is intended to include several robots, with Nybble as the first commercially-available robot [20] and Bittle as its second robot variant [21]. Both robots serve as toys, but their respective dimensions and locomotions are not suitable for further useful functionality extension. Nybble is only equipped with a 9-gram micro servo, which can only deliver a 1.2 kg cm torque [22]. Bittle has even a smaller construction compared to Nybble, since it is marketed as a palm-sized robot dog [21].

D. The Locomotion of a Mammal-type Quadruped Robot

Two examples of the aforementioned dynamic gaits are the *trot gait* and the *gallop gait*. Both are the most popular gaits used by mammal-type quadruped robots. The trot gait is a gait in which diagonally opposite legs move at the same time. The gallop gait is a gait where three legs are moving at the same time. The leg movement ratio of each gaits can be seen on Fig. 3. The relative phase of each leg is indicated by the typical numerical value, with reference to the left hind leg.

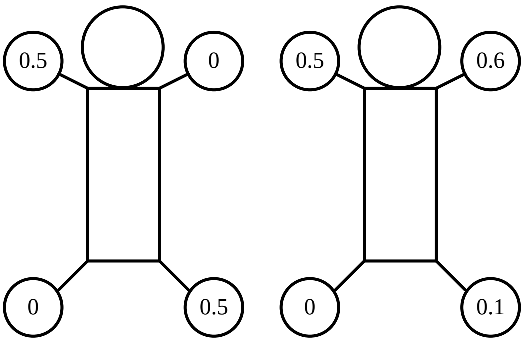


Figure 3. The movement ratio of each legs; (a) trot gait, (b) gallop gait

As shown in Fig. 3(a), the trot gait utilizes two diagonally opposite legs, which move at the same time (both 0 and 0.5). In Fig. 3(b), the gallop gait moves all legs with different phase. Both hind legs move with slight phase shifts (0 and 0.1), while the phase shifts for both front legs are 0.5 and 0.6. The more stable trot gait is mostly used as the transitional gait from a static position to the fast gallop gait.

The use of trot and gallop gaits in this research is based on a number of factors. Both gaits are the most energy-efficient ones in their respective speed classes. In quadruped animals such as rats and horses, trot and gallop gaits have an overlapping speed range, which means that these animals could perform locomotions over a wider range of speeds with a higher efficiency [23]. The authors in [15] concluded that a trot gait is more energy efficient compared to the canter and pace gaits in the medium-speed class, which is based on the Cost of Transport (CoT) versus Froude number graph. In the high-speed class, the gallop gait is also found to be more energy efficient compared to the bound gait based on similar method.

E. Compliant Leg Mechanism

One method used in order to eliminate the need for a knee servo motor for a robot's leg is the use of a compliant leg mechanism. The compliant leg mechanism utilizes a spring as a passive actuator to replace the active actuators such as DC motors or servos. Initially, compliant leg mechanism is used to reduce the energy consumption on 16-DoF robots. This reduces the number of required servos from 16 to 12. However, recent improvements showed that the compliant leg mechanism can also be implemented in 12-DoF quadruped robots. This reduces the required servos from 12 to just 8 such as in Cheetah Cub robot (leg shown in Fig. 4) made by EPFL (École Polytechnique Fédérale de Lausanne) [24].

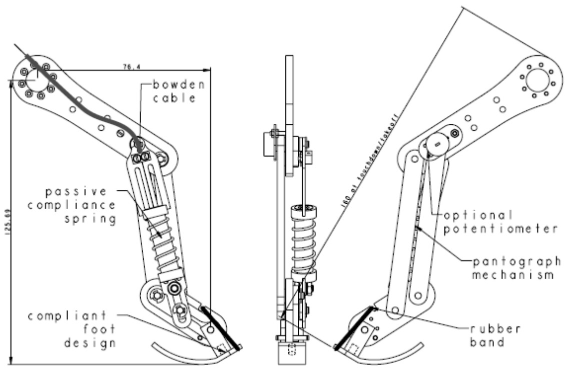


Figure 4. Compliant leg mechanism used by EPFL's Cheetah Cub [24]

The lower DoF induced by the use of the compliant leg mechanism also means simpler leg coordination, which in turn enables better transitions between stances of the gaits [15]. A simpler leg coordination enables minimal actuation due to the passiveness of the lower leg part, which contributes to the lower overall energy consumption [25]. The reduced energy consumption helps reach the desired running time without having to tweak the battery configuration.

F. CoFiBot and Improvements in CoFiBot V2

The first version of CoFiBot was built in 2018. This version features a sprawling-type body and a choice between creep and trot gaits [5]. However, this version does not look like living pets, since the configuration of the sensors resembles the robots competing in the Indonesia Firefighting Robot Contest (KRPAI) [26].

CoFiBot was designed to spray a mixture of firefighting agents by using a servo mechanism. It was concluded that the firefighting power of CoFiBot was not adequate to extinguish even a small-scale domestic fire. Thus, this function is dropped in CoFiBot V2. Instead, CoFiBot V2 operates as a mammal-type quadruped pet robot and mobile fire detector. CoFiBot V2 is intended to mimics a small dog, able to respond to the owner's gesture, detects fire, and notifies the user of the presence of a fire danger.

CoFiBot V2 is also expected to have a customizable function. This is to be done by providing a compartment at the tail part, where two additional sensors can be fitted in. The mounting of a light detector, smoke sensor, or gas sensor, for instance, increases the utilization of CoFiBot V2.

III. SPECIFICATION OF COFIBOT V2

A. Offline Part

The offline part of CoFiBot V2 regulates its walking gait, gesture detection, and fire detection mechanism. For these purposes, an offline board Arduino Nano (Fig. 5) is used.

CoFiBot V2 uses a trot gait as an initial gait when it moves around. The trot gait has a lower speed, which enables a precise control of the robot's movement. This gait resembles the way a dog walks. A transition can be made so that the robot moves with a gallop gait. Despite a less stability, the robot is able to move at a higher speed. This gait also mimics the way a dog runs.

Figure 5. An Arduino Nano microcontroller board

The pet robot is equipped with a gesture detection sensor. When the sensor detects a stroking movement of a user, CoFiBot V2 responds by sitting for a certain period of time. Afterwards, the robot changes orientation to a random direction and performs a trot gait, giving a chance for a possible next user's interaction. An obstacle avoidance sensor is also integrated into the robot. When an obstacle is detected at the distance of 10 cm, the robot randomly changes direction. When the obstacle is not detected anymore, the robot continues moving.

Starting from a resting position, CoFiBot V2 moves in a trot gait for 3 continuous cycles. Afterwards, when there is no detection of gestures, fire, or obstacles, it moves in a gallop gait fashion.

The fire detection mechanism is continuously utilized during the operation of CoFiBot V2. Two infrared (IR) sensors and one ultrasonic sensor are used for this purpose. The IR sensors are used to detect the fire as well as determine the alignment of the robot with reference to the fire. Once the left or the right IR sensor detects a fire source, the robot turns slightly to the appropriate direction until both IR sensors can detect the fire source. Then, the robot moves slowly until the separation between the ultrasonic sensor and a fire source is less than or equal to 25 cm. At this point the robot stops moving and takes a sitting position.

CoFiBot V2 waits for 5 minutes, which is considered to be sufficient length of time for the user to extinguish the fire. After a 5-minute interval has elapsed, the robot continues to probe the presence of fire again. If the fire still exists, it will wait for another 5 minutes. If the fire has disappeared, it will stand up and continue to move around.

B. Online Part

The online part of CoFiBot V2 regulates its IoT capability, connecting it via internet to the user. Through this connection, the user can perform IoT-monitoring of the measurement results and the status of various sensors. All these are to be displayed on the user's Android phone by using a Blynk application. For these purposes, an online board NodeMCU (Fig. 6) is used.

Figure 6. A NodeMCU v3 microcontroller board

Digital temperature, humidity and two IR sensors are used to support the online board NodeMCU, connecting the CoFiBot V2 via internet to the user. Thus, the air temperature and air humidity of the room where CoFiBot V2 is deployed is always monitored. The task of the IR sensors is to detect the fire independently. The measurement data and important information will be sent to the user via a display on a Blynk application. The user can be notified by blinking widgets and push notification.

As was mentioned previously, the tail of the robot can house up to two additional sensors. In this case, a light and smoke sensor, or gas sensor can be integrated, based on the user's need. The condition whether a room is bright or dark, or whether smoke or gas leak is detected, can be shown in the form of blinking widgets and push notification.

C. Block Diagram

The hardware realization of CoFiBot V2 is in compliance with the block diagram in Fig. 7. A red line indicates a power connection among components. A blue line represents a command connection.

Each board is supported by its own set of sensors allowing all sensors to run simultaneously and continuously. The separation of sensors is done in order to avoid an interrupt glitch when Arduino Nano and NodeMCU are to interact with each other.

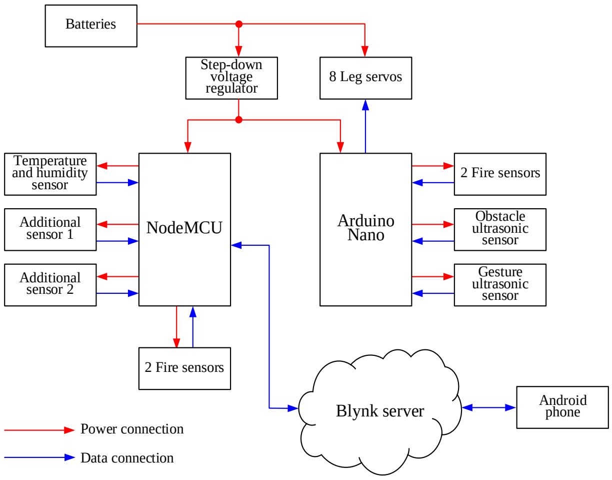


Figure 7. A block diagram of CoFiBot V2

IV. Implementation of CoFiBot V2

A. The Flowcharts of Operation

The flowcharts of the operating principles associated with CoFiBot V2 are shown in Fig. 8 for the offline part and Fig. 9 for the online part, respectively. Both the offline and online boards execute their respective tasks simultaneously and are independent of each other.

The small size of Arduino Nano allows the provision of a small robot body, and reduces the power consumption of the robot. Its 14 digital I/O pins and 8 analog pins are adequate to fulfill the need of robot's offline part [27].

NodeMCU for the robot's offline part employs a microcontroller unit with an on-board ESP-12E module [28].

MG996R servo motors are used in this project. MG996R has a metal gear construction with higher durability compared to a plastic gear counterpart. An MG996R servo operates at a running current of 500-900 mA and a voltage at 6 V [29].

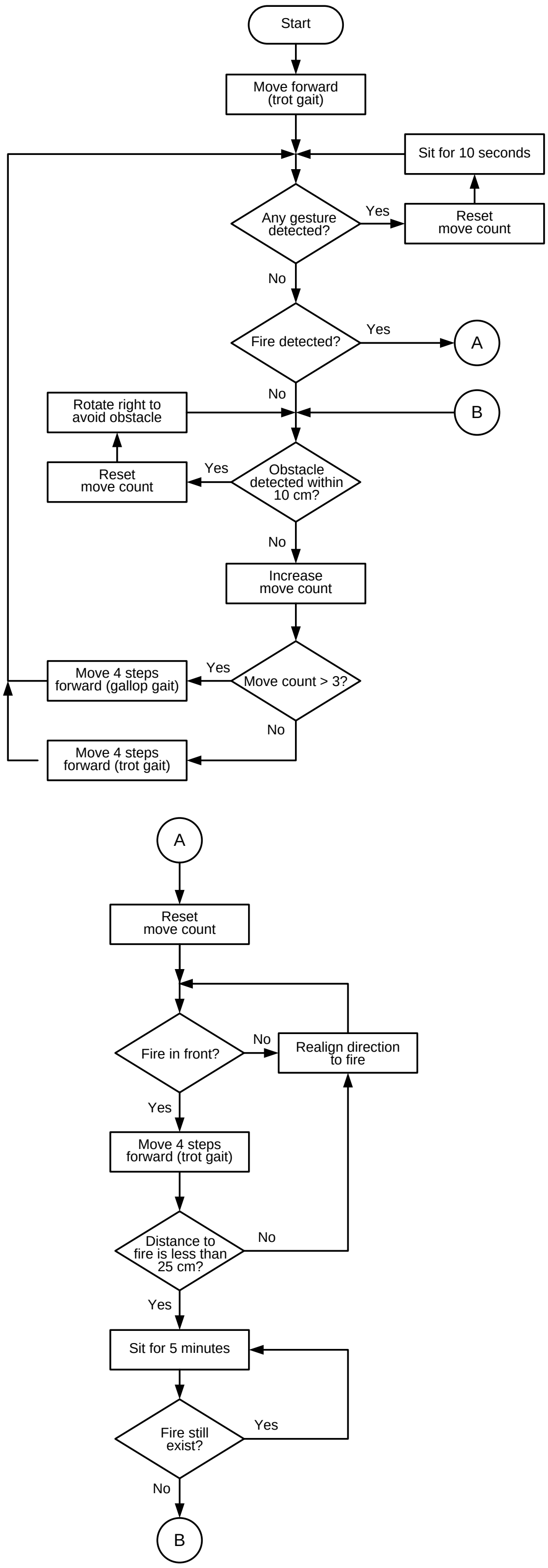


Figure 8. A flowchart of the offline part

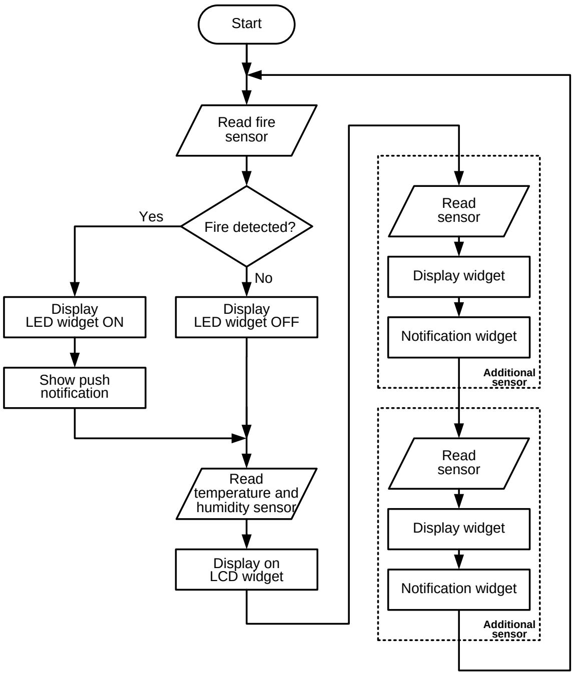


Figure 9. A flowchart of the online part

B. *Power Source and Movement Mechanism*

Starting at an initial fully charge condition, CoFiBot V2 is expected to have a long operating time. The 8 servo motors make up the biggest share of the power consumption. Due to the space limitation, the proposed configuration of the batteries for the robot is as follows: a 2s3p 18650 battery of 3.7 V and 3,500 mAh Li-ion batteries. In this configuration, the total power rating of the batteries is 7.4 V at 10,500 mAh.

Assuming that the servo motors operate at maximum drain current, not at the stall current value, the aforementioned battery configuration will be sufficient to support the operation of the robot for:

$$\text{Time} = \frac{10{,}500\ \text{mAh}}{(8\ \text{servos})\cdot\left(900\,\dfrac{\text{mA}}{\text{servo}}\right)} \tag{1}$$
$$= 1.46\ \text{hours} \ = 87.5\ \text{minutes}$$

This expected operating time is just close to the operating time of Boston Dynamics Spot, which is 90 minutes [30].

There are 4 springs used on the 4 legs, one for each leg. The springs are to replace the knee servo motors. The springs are configured so that each movement of the hip servo motors also compresses the springs, thus moving the lower part of the robot's leg. This is the implementation of the compliant leg mechanism, as has already been mentioned in the previous section.

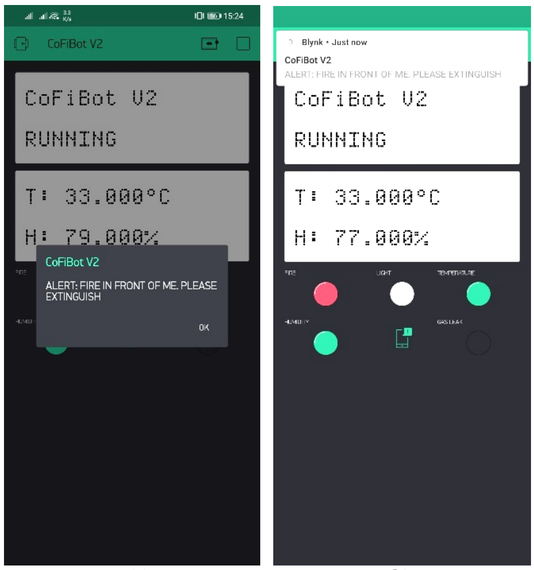
Ideally, standard compression springs are to be used, but due to unavailability, they are replaced by shock absorber springs, one of which is shown in Fig. 10.

Figure 10. A shock absorber spring mechanism for CoFiBot V2

The spring construction as mentioned above is a novel addition to the movement mechanism of the robot. Usually, a quadruped pet robot is designed as a 12-DoF robot [31]. Due to the compliant leg mechanism, the degree-of-freedom can be reduced to 8. However, this mechanism requires additional enclosures and auxiliary metal plates for the springs to be fixed at, as can be seen in Fig. 10.

C. *Blynk Application*

A Blynk application is developed to connect CoFiBot V2 via internet to an Android phone. Thus, the robot becomes an IoT-enabled after it is connected into the Blynk platform. The application serves also as a display for the robot's states and sensor outputs. The Blynk's user interface can be customized to meet the needs of the user through the use of its display widgets and push notifications. An example of a Blynk application GUI (Graphical User Interface) can be seen in Fig. 11.



(a) (b)

Figure 11. A display of CoFiBot V2 Blynk application; (a) Push notification; (b) Display widgets

Push notifications based on sensor outputs can be shown on the application screen. Fig. 11(a) shows the push notification after the fire sensors have detected the presence of fire. Fig. 11(b) shows the display widgets, in the form of numbers or an indicator.

D. Fully Assembled CoFiBot V2

Fig. 12 shows the appearance of CoFiBot V2 after the construction is finished. Including the batteries, the robot weighs approximately 3 kg. Due to this heavy weight, some adjustments are made on the movement mechanism, including the reduction of a step size to 2.5 cm. This is done in order to minimize the risk of the robot falling off due to loss of stability.

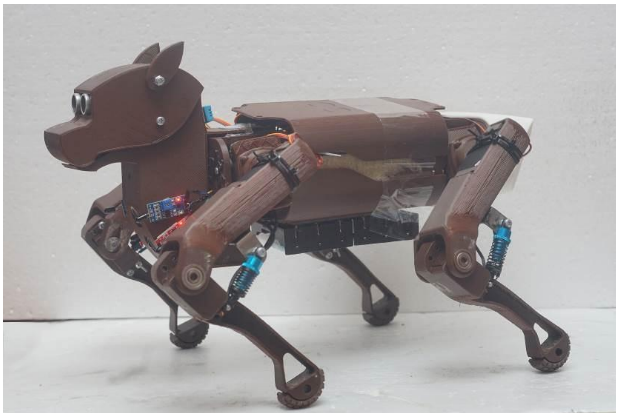


Figure 12. CoFiBot V2 after a completion of construction

The front neck houses 4 infrared sensors, 2 of them are connected to the offline board, while the other 2 to the online board. Two ultrasonic sensors are installed on the head. All ultrasonic sensors are connected to the offline board, as they are used to detect gestures and obstacles. The temperature and humidity sensor is mounted at the back of CoFiBot V2's neck.

V. Test Results and Discussions

A. Fire Detection Test

During a fire detection test, CoFiBot V2 is tested whether or not it can detect fire and execute the correct commands to handle the presence of fire (such as aligning direction towards the fire, approaching the fire, sitting at a 25-cm distance from the fire, and showing a push notification at the Blynk application).

The robot is placed 50 cm away from fire, and is expected to walk closer to the fire. As typical representatives, five cases of the fire detection tests are presented in Table II. The main problem in the execution is the repeated alignments of the robot, when the robot tries to find the position of the fire. This can be repeated until 7 times, as the robot aligns itself and approaches the fire. The Blynk push notifications are mostly fine, although some of them arrive a few seconds late, due to an internet connection delay.

TABLE II. The Results of Fire Detection Test

Test	Fire Detection	Command Execution	Time Required
1	Perfect	Perfect, 2 alignments	10.2 s
2	Perfect	Perfect, 3 alignments	11.5 s
3	Perfect	Perfect, 7 alignments	14.3 s
4	Perfect	Perfect, 6 alignments	13.8 s
5	Perfect	Perfect, 2 alignments	8.2 s

B. Gesture Response Test

In the gesture response test, a series of gesture inputs are given to the robot. The robot is expected to respond with a pose change to a sitting position and keep it for 10 seconds. The interval between two gestures is made random. In addition, the robot remains in a free operation between two consecutive gestures and is ready to respond to the presence of fire or obstacles. The results are shown in Table III.

The average response time, which is defined as the time needed by the robot to give a gesture response after a gesture is given, is also presented. In all cases, the given gestures can be detected perfectly and the robot reacts with the expected response of sitting.

TABLE III. The Results of Gesture Response Test

Test	Gesture Given	Gesture Response	Average Response Time
1	5	5	375 ms
2	6	6	382 ms
3	3	3	371 ms
4	7	7	368 ms
5	4	4	365 ms

C. Runtime Test

The runtime is used to determine the operating time of CoFiBot V2, which is the time since the batteries is fully charged until they are fully depleted. The connection from the robot to the Blynk application is taken as an indicator. When the batteries are completely empty, the robot is disconnected instantly from the Blynk application.

During the endurance test, both boards, all servo motors, and all sensors are active. Since all components are active simultaneously, the runtime can be evaluated. Besides, no fire excitation or gesture are given. This means that the robot never comes to a sit position. Less power consumption would be needed by the sit position, because for it to happen only 2 servo motors are required to operate. Thus, during the runtime test, the batteries are given the full load.

The run time of CoFiBot V2 under a full load is shown in Table IV. The average run time is 73.8 minutes, which is 84.34% of the predicted runtime, as given by Eq. (1). It is to be considered that in a normal operation, where fire excitation or gestures are present, the runtime will be higher than that of the presented result average.

TABLE IV. THE RESULTS OF RUNTIME TEST

Test	Runtime
1	71 minutes
2	75 minutes
3	76 minutes
4	73 minutes
5	74 minutes

D. A Comparison between CoFiBot V2 and Other Pet Robots

The cost of building one CoFiBot V2 is approximately USD 184, with the more details presented in Table V. The prices of other pet robots, as given in Table I, which are high or much higher compared to the price of CoFiBot V2. Besides, the proposed robot does not only function as a pet toy, but it also serves as a mobile home monitoring. The additional functions include temperature and humidity measurements, a fire detection unit, and other customizable quantities such as light intensity, smoke, and gas detections.

CoFiBot V2 is built using components that are available in the market, with all its body parts printed using a 3D printer. Should CoFiBot V2 be developed with the intention to be launched in the market, and provided that it is given specially ordered and tailored components, it will surely be able to perform much better with improved accuracy, endurance, and durability.

TABLE V. THE BILL OF MATERIALS FOR COFIBOT V2

Component	Price (USD)
MG996R Servo (9)	63.0
NodeMCU v3 board	9.4
LM2596 Step Down Module (2)	3.0
6 V 8 A UBEC	18.5
IR Fire Sensor (3)	14.0
DHT11 Module (1)	6.0
HC-SR04 Ultrasonic Sensors (2)	3.6
LDR Sensor Module	1.5
MQ-6 Sensor Module	3.5
Batteries (6)	18.0
Battery Holder	1.5
Body	40.0
Boards, Jumper Wires	2.0
TOTAL	184.0

VI. CONCLUSIONS AND FUTURE WORKS

A pet robot with customizable functions, CoFiBot V2, is proposed in this paper, as an improvement to its predecessor, CoFiBot. CoFiBot V2 is developed as a dog-like mammal-type IoT-based quadruped robot, with a fire detecting capability and a home monitoring function. As a dog-like pet, CoFiBot V2 is visually engaging, which is a key factor to fulfill its objective to give the same benefit as owning a real pet.

CoFiBot V2 utilizes a compliant leg mechanism to reduce the number of servo motors required for its locomotion. With its final state as an 8-DoF robot, CoFiBot V2 is equipped with two microcontroller boards, of which are used for offline and online engagements, respectively. The robot is connected via internet to an Android phone, enabling the use of a telephone to monitor the reading of the sensors through a GUI application.

The robot is tested to verify the functionality of the sensors, movement mechanism, response to given gestures, and operational runtime. With all design specifications fulfilled, CoFiBot V2 can operate continuously for an average of 73.8 minutes, which is 84.34% of its predicted run time, and 82.00% of the Boston Dynamics Spot runtime.

Future improvements are to be done for the following: compliant leg construction to support more poses and gaits, design of the inside compartments for ease of access, and integration of two microcontroller boards into one. With a construction costs, which is 35 times cheaper than that of pet robots available in the market, CoFiBot V2 has the potential to be mass produced as an alternative to real pets. Furthermore, it is preferable due to its additional functionality as a mobile home monitoring system, instead of just being a pet toy.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Christoforus W. D. Lumoindong contributed with the improvement ideas to be applied to CoFiBot V2, the investigation, and the implementation. Erwin Sitompul contributed with the direction and supervision. The writing and the editing of the article were conducted by both authors equally.

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