AUTOMATION OF PET BEHAVIOR IMPROVEMENT AND SERVICE TRAINING USING ARTIFICIAL INTELLIGENCE AND COMPUTER VISION

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ABSTRACT

Owning a dog brings with it a multitude of responsibilities, chief among them being the essential task of dedicating ample time to training [1]. While the specific time commitment may vary, effective training necessitates steadfast dedication and effort. Unfortunately, many dog owners struggle to allocate sufficient time, leading to untrained canine behavior [2]. Research indicates that approximately 75% of dogs worldwide lack proper training. Effective training serves as the bedrock of a harmonious human-canine relationship, fostering mutual understanding and safety [3]. Despite its paramount importance, training demands patience, consistency, and perseverance, qualities often underestimated by dog owners. Addressing this issue requires a shift in owners' perspectives, underscoring the significance of prioritizing training through professional guidance and obedience classes. Ultimately, investing in training not only enhances the quality of life for dogs but also strengthens the bond between owners and their cherished companions, showcasing the dedication necessary to ensure canine well-being in an ever-changing world.

KEYWORDS

Dog Training, Artificial Intelligence, Human-Canine Bond

1. INTRODUCTION

Owning a dog comes with a lot of responsibilities, and one of those responsibilities is to spend the appropriate amount of time training your dog. Now, the specific time can vary from person to person, but it without a doubt takes time and commitment. Sometimes people aren't able to commit that much time to training their dogs, which results in the dog's behavior being untrained. On average 75% of the world's dogs aren't properly trained [4].

The significance of training cannot be overstated. It forms the cornerstone of a harmonious relationship between a dog and its owner, fostering mutual understanding and respect. Through training, dogs learn vital skills such as obedience, socialization, and appropriate behavior in diverse environments. Moreover, a well-trained dog is safer, both for itself and for those around it.

However, training demands patience, consistency, and perseverance. It is a gradual process that requires regular practice and reinforcement. Many dog owners underestimate the time and effort required, leading to a staggering number of untrained dogs globally.

Addressing this issue necessitates a shift in perspective regarding the responsibilities of dog ownership. Owners must recognize the importance of training and prioritize it accordingly. Seeking professional guidance or enrolling in obedience classes can provide valuable support in this endeavor.

Ultimately, the commitment to training not only enhances the quality of life for dogs but also fosters stronger bonds between owners and their beloved companions. It is a testament to the dedication and care required to ensure the well-being of our canine companions in an ever-evolving world.

The proposed solution to address the challenge of insufficient time for dog training is the development of a revolutionary device: the AI Pup Trainer [8]. This innovative technology aims to alleviate the burden on dog owners by streamlining the training process with minimal effort required from them. The AI Pup Trainer serves as a reliable assistant, enabling dog owners to effectively train their pets even when they are unable to dedicate extensive hours solely to training.

What sets the AI Pup Trainer apart is its advanced capabilities in detecting and interpreting the actions of dogs. Through sophisticated algorithms and sensors, the device can analyze the behavior of the dog and provide tailored training feedback based on specific commands. This autonomous functionality empowers dog owners by automating aspects of the training process, thus mitigating the challenges posed by time constraints.

By leveraging artificial intelligence, the AI Pup Trainer offers a dynamic approach to dog training, adapting to the unique needs and behaviors of individual dogs. Its ability to provide real-time feedback and reinforcement enhances the learning experience for both dogs and owners, fostering a more efficient and rewarding training journey.

The AI Pup Trainer represents a paradigm shift in the realm of dog training, offering a solution that is not only effective but also accessible and user-friendly [9]. With this innovative device, dog owners can embark on a transformative journey towards nurturing well-trained and disciplined canine companions, enriching the bond between humans and their beloved pets.

The dog detection experiment has proven its reliability in detecting the presence of a dog with a high degree of confidence. Through rigorous testing and analysis, the experiment consistently demonstrates its ability to accurately identify dogs in various conditions and environments. Its dependable performance instills confidence in its outcomes, making it a valuable tool for tasks requiring precise dog detection.

The current dispensing mechanism operates with a fail rate of 20%, indicating that one out of every five attempts may encounter issues such as jams or malfunctions. However, this rate presents an opportunity for improvement through redesigning the mechanism. By implementing adjustments and enhancements, the dispensing system can mitigate the occurrence of jams significantly. Redesigning may involve optimizing the internal components, refining the feeding mechanism, or employing more durable materials to enhance reliability. These modifications aim to streamline the dispensing process, ensuring smoother operation and reducing the frequency of disruptions or errors.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. The Image Detection

The image detection aspect, pivotal yet prone to significant issues, might encounter challenges if it doesn't perform optimally. Utilizing YOLO V8 for image detection, I could enhance accuracy by incorporating additional images of both sitting and non-sitting dogs [10]. This strategy aims to refine the software's capability and improve overall detection precision.

2.2. The Servo Motor

Another major component that could cause some problems is the servo motor not being able to dispense the treat correctly. This could be due to the python code on the raspberry pi not rotating the right amount to dispense the treat properly. It can be fixed just by inputting the correct amount into the python code to make the motor spin in a 180° angle.

2.3. Raspberry Pi Hardware

Achieving seamless integration of Raspberry Pi hardware with our app poses a potential challenge [11]. Establishing effective communication channels between them entails exploring diverse options, including Bluetooth connectivity, configuring the Raspberry Pi as a local hotspot, or equipping it with cellular capabilities. Each approach brings forth distinct considerations, ranging from range and reliability to data usage. Optimal selection among these methods depends on various factors such as intended usage scenarios, user preferences, and technical limitations. The paramount objective is to ensure robust connectivity between the Raspberry Pi and our app, thereby delivering a user experience that is both seamless and dependable.

3. SOLUTION

My program seamlessly integrates three key components: an Image detection model, a treat dispenser program, and a command-giving program [12]. The program flow operates as follows: Initially, the camera captures an image to detect the presence of a dog. If a dog is detected, it proceeds to execute the "sit" command. Conversely, if no dog is detected, the program waits for one minute before capturing another image. Following the "sit" command, another image is captured to verify if the dog is sitting. If the dog is sitting, treats are dispensed; otherwise, the program returns to the initial stage to detect the presence of a dog. Subsequently, after dispensing treats, the program waits for approximately 20 seconds before initiating the process anew, effectively restarting the cycle.

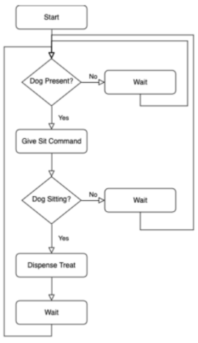
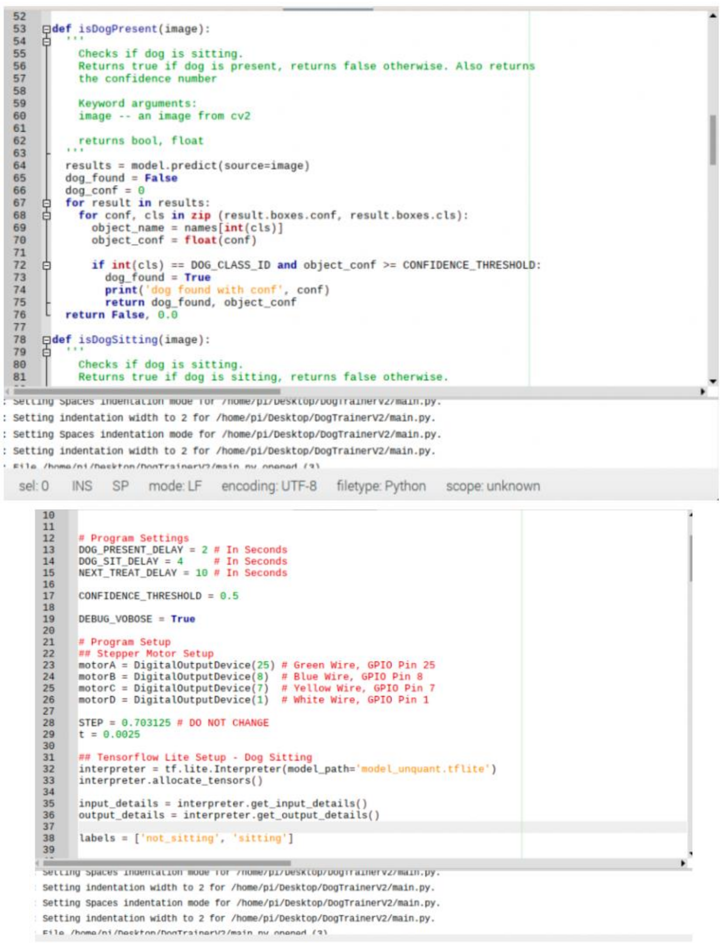


Figure 1. Overview of the solution

One component is the image detection model, its purpose is to detect whether or not there is a dog in the image. To implement this system I used the YOLO V8 model to specifically train it to detect whether there is a dog present or sitting [13].



```python

def isDogPresent(image):
  '''
    Checks if dog is sitting.
    Returns true if dog is present, returns false otherwise. Also returns
    the confidence number

    Keyword arguments:
    image -- an image from cv2

    returns bool, float
  '''
  results = model.predict(source=image)
  dog_found = False
  dog_conf = 0
  for result in results:
    for conf, cls in zip (result.boxes.conf, result.boxes.cls):
      object_name = names[int(cls)]
      object_conf = float(conf)

      if int(cls) == DOG_CLASS_ID and object_conf >= CONFIDENCE_THRESHOLD:
        dog_found = True
        print('dog found with conf', conf)
        return dog_found, object_conf
  return False, 0.0

def isDogSitting(image):
  '''
    Checks if dog is sitting.
    Returns true if dog is sitting, returns false otherwise.
```

```
: Setting Spaces indentation mode for /home/pi/Desktop/DogTrainerV2/main.py.
: Setting indentation width to 2 for /home/pi/Desktop/DogTrainerV2/main.py.
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: File /home/pi/Desktop/DogTrainerV2/main.py opened (3).
```

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```python


# Program Settings
DOG_PRESENT_DELAY = 2 # In Seconds
DOG_SIT_DELAY = 4     # In Seconds
NEXT_TREAT_DELAY = 10 # In Seconds

CONFIDENCE_THRESHOLD = 0.5

DEBUG_VOBOSE = True

# Program Setup
## Stepper Motor Setup
motorA = DigitalOutputDevice(25) # Green Wire, GPIO Pin 25
motorB = DigitalOutputDevice(8)  # Blue Wire, GPIO Pin 8
motorC = DigitalOutputDevice(7)  # Yellow Wire, GPIO Pin 7
motorD = DigitalOutputDevice(1)  # White Wire, GPIO Pin 1

STEP = 0.703125 # DO NOT CHANGE
t = 0.0025

## Tensorflow Lite Setup - Dog Sitting
interpreter = tf.lite.Interpreter(model_path='model_unquant.tflite')
interpreter.allocate_tensors()

input_details = interpreter.get_input_details()
output_details = interpreter.get_output_details()

labels = ['not_sitting', 'sitting']

```

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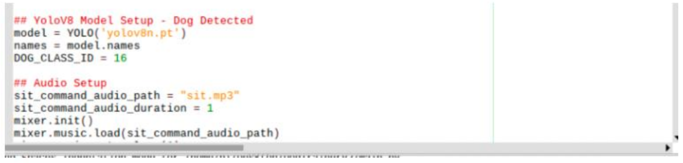
File /home/pi/Desktop/DogTrainerV2/main.py opened (3).
```

Figure 2. Screenshot of code 1



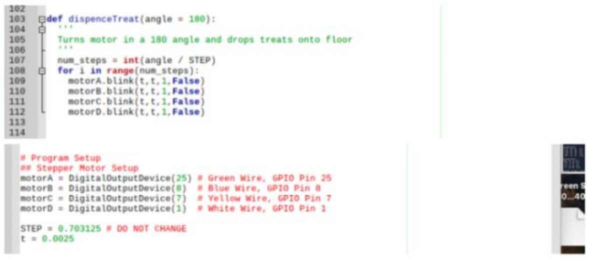
```
## YoloV8 Model Setup - Dog Detected
model = YOLO('yolov8n.pt')
names = model.names
DOG_CLASS_ID = 16

## Audio Setup
sit_command_audio_path = "sit.mp3"
sit_command_audio_duration = 1
mixer.init()
mixer.music.load(sit_command_audio_path)
```

Figure 3. Screenshot of code 2

The YOLO V8 model is imported into the Raspberry Pi and then is called upon when the camera takes a picture to detect whether the dog is there or not. The variable model is created to import the Yolo v8 model correctly into the code. The variable DOG_CLASS_ID is made to identify the correct index in which the detection of the dog is. This is because the YOLO V8 model is also trained on identifying a lot of objects and putting them into a numbered list, specifying each object as an index, this makes it so that if you wanted to single out an object you would have to specify the specific index it is listed as. With the dog then being detected the model will wait until the program itself is repeated to run again.

The treat dispenser program is run by a servo motor that is programmed to rotate at specific intervals. The rotation of the motor is decided by my python program that will only run it on a conditional. This motor is attached to a 3D printed model of a dispenser to help it dispense the treat [14].

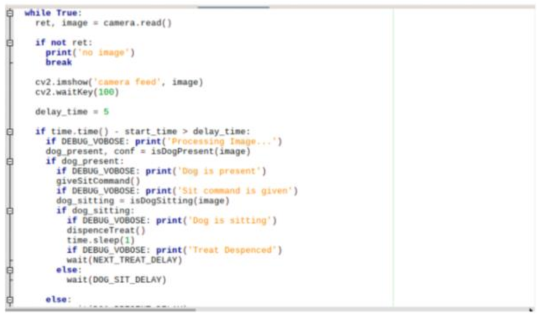


```
def dispenceTreat(angle = 180):
    '''
    Turns motor in a 180 angle and drops treats onto floor
    '''
    num_steps = int(angle / STEP)
    for i in range(num_steps):
      motorA.blink(t,t,1,False)
      motorB.blink(t,t,1,False)
      motorC.blink(t,t,1,False)
      motorD.blink(t,t,1,False)
```

```
# Program Setup
## Stepper Motor Setup
motorA = DigitalOutputDevice(25) # Green Wire, GPIO Pin 25
motorB = DigitalOutputDevice(8)  # Blue Wire, GPIO Pin 8
motorC = DigitalOutputDevice(7)  # Yellow Wire, GPIO Pin 7
motorD = DigitalOutputDevice(1)  # White Wire, GPIO Pin 1

STEP = 0.703125 # DO NOT CHANGE
t = 0.0025
```

Figure 4. Screenshot of code 3



```
while True:
  ret, image = camera.read()

  if not ret:
    print('no image')
    break

  cv2.imshow('camera feed', image)
  cv2.waitKey(100)

  delay_time = 5

  if time.time() - start_time > delay_time:
    if DEBUG_VOBOSE: print('Processing Image...')
    dog_present, conf = isDogPresent(image)
    if dog_present:
      if DEBUG_VOBOSE: print('Dog is present')
      giveSitCommand()
      if DEBUG_VOBOSE: print('Sit command is given')
      dog_sitting = isDogSitting(image)
      if dog_sitting:
        if DEBUG_VOBOSE: print('Dog is sitting')
        dispenceTreat()
        time.sleep(1)
        if DEBUG_VOBOSE: print('Treat Despenced')
        wait(NEXT_TREAT_DELAY)
      else:
        wait(DOG_SIT_DELAY)

    else:
```

Figure 5. Screenshot of code 4

In the first image it shows the function that calls the servo motor to rotate in a 180-degree angle in order to dispense the treat. In the second image below, it shows the pins that each stepper motor wire is connected to.

The program begins by defining a function called dispenseTreat. This function is responsible for dispensing treats using a motor. When called, the motor turns precisely 180 degrees, causing treats to drop onto the floor. The function calculates the number of motor steps required based on the specified angle. Four GPIO pins (motorA, motorB, motorC, and motorD) control the motor’s movement. The STEP constant is set to 0.703125 (a critical value for motor control). A delay of 5 seconds occurs before processing the next image.

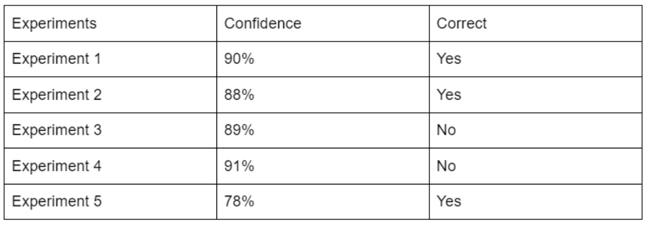
In the program setup section, GPIO pins are assigned to each motor (e.g., motorA corresponds to GPIO pin 25). The t variable is set to 0.0025. The program enters an infinite loop (while True) to continuously process camera images.

During image processing, the code reads an image from the camera feed. If an image is successfully retrieved, it briefly displays it (cv2.imshow) and then proceeds to analyze it. The isDogPresent function (not shown here) evaluates whether a dog is in the frame and the isDogSitting function determines if the dog is sitting. If a dog is detected and meets the specified conditions, the dispenseTreat function is invoked.

4. EXPERIMENT

4.1. Experiment 1

To set up this experiment I can have a dog run across the camera as it is taking an image. This is to test the accuracy of its identification and make sure that no matter the frame the AI will be able to detect it. It is important that this works well as it is the basis of my design and without accurate detection the program won’t run as well as it should be. The experiment is set up this way to determine if the detection model is good enough to detect a dog that is blurry in the image.



Experiments	Confidence	Correct
Experiment 1	90%	Yes
Experiment 2	88%	Yes
Experiment 3	89%	No
Experiment 4	91%	No
Experiment 5	78%	Yes

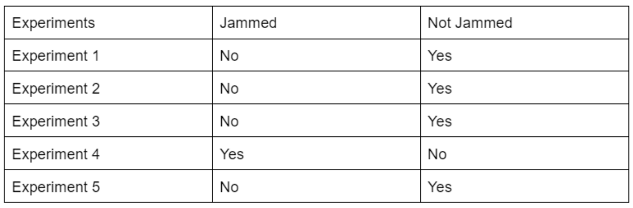
Figure 6. Figure of experiment 1

While high confidence scores may instill trust, they don't always guarantee precision, as evidenced in Experiments 3 and 4. Conversely, Experiment 5, despite lower confidence levels, managed to produce a correct outcome. These outcomes underscore the nuanced nature of model assessment.

In evaluating experimental data, it's imperative to weigh both confidence and correctness. A model's confidence score serves as a valuable indicator but must be contextualized within the broader framework of accuracy. Researchers and developers must navigate this trade-off carefully, understanding that optimal performance isn't solely dictated by confidence levels. By considering both dimensions, we gain deeper insights into the model's behavior and its implications for real-world applications.

4.2. Experiment 2

Another potential blind spot lies in the dispensing mechanism of the treat. Due to the treats funneling through a glass jar positioned at the top of the design, there is a risk of treats getting stuck in the dispenser, leading to machine breakage and jamming. To address this issue, I plan to simulate real-world conditions by setting up an image of a dog in front of the design and running it through the program multiple times. This experiment aims to quantify the frequency of jamming incidents and assess the reliability of the device under operational conditions. By systematically testing the device's performance in a controlled setting, we can identify potential weaknesses in the dispensing mechanism and implement necessary improvements to enhance its durability and functionality.



Experiments	Jammed	Not Jammed
Experiment 1	No	Yes
Experiment 2	No	Yes
Experiment 3	No	Yes
Experiment 4	Yes	No
Experiment 5	No	Yes

Figure 7. Figure of experiment 2

The experiment findings reveal that the dispensing mechanism of the treat dispenser exhibits a failure rate of 20%. This failure rate signifies a notable proportion of instances where the dispenser does not effectively dispense treats as intended. Such occurrences pose significant implications for the reliability and functionality of the treat dispenser system.

Implementing a redesigned rotating mechanism that addresses these underlying issues can significantly reduce the failure rate and improve the overall functionality of the treat dispenser. This may involve optimizing gear ratios, enhancing motor torque, incorporating anti-jamming mechanisms, or redesigning component geometries to promote smoother rotation and reliable treat dispensing.

5. RELATED WORK

The article titled "Dog behavior classification with movement sensors placed on the harness and the collar" utilizes motion sensors positioned on the harness and collar to discern a dog's behavior [5]. In contrast, our approach employs a camera initially to detect if a dog is sitting, with the potential to extend our technology for identifying other dog behaviors in the future.

Similarly, in the article "Dog Sit! Domestic Dogs (Canis familiars) Follow a Robot's Sit Commands," the focus is on determining if dogs respond to commands from a robot and loudspeaker [6]. Conversely, our research aims to ascertain whether dogs can be trained using our method, thus testing its efficacy on untrained dogs.

Furthermore, in the article "Dog Behavior Recognition Based on Multimodal Data from a Camera and Wearable Device," the authors utilize Yolo to identify dog behaviors, resembling AI Pup Trainer [7]. However, our approach diverges as we focus on training dogs, while their methodology primarily monitors general dog behavior and health.

6. CONCLUSIONS

Transitioning from Raspberry Pi 3 to Raspberry Pi 5 presents a viable solution to address constraints in speed and accuracy associated with the dog detection model. The enhanced capabilities of Raspberry Pi 5 allow for accommodating heavier models, thereby facilitating higher accuracy in dog detection. This upgrade not only accelerates processing times but also enables the deployment of more sophisticated algorithms, contributing to improved performance and precision in the detection process.

However, an ongoing challenge with Raspberry Pi devices lies in their connectivity to the internet for data uploads to the database and subsequent transmission to the app. Current procedures typically require users to connect the device to their home Wi-Fi using a monitor, mouse, and keyboard, lacking the user-friendliness crucial for seamless IoT device integration into home networks. Simplifying the connectivity process is imperative for enhancing user experience and promoting widespread adoption of IoT technology in various settings.

Despite these challenges, the AI Pup Trainer device and app exhibit high accuracy in detecting dogs and assessing their sitting behavior. While the training of dogs may require additional evaluation time, the AI Pup Trainer device functions effectively and merely needs to address the jamming issue, which can be easily overcome.

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