Automatic Pet Door System

ECE 445 project proposal

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Team 27

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Contents

1. Introduction

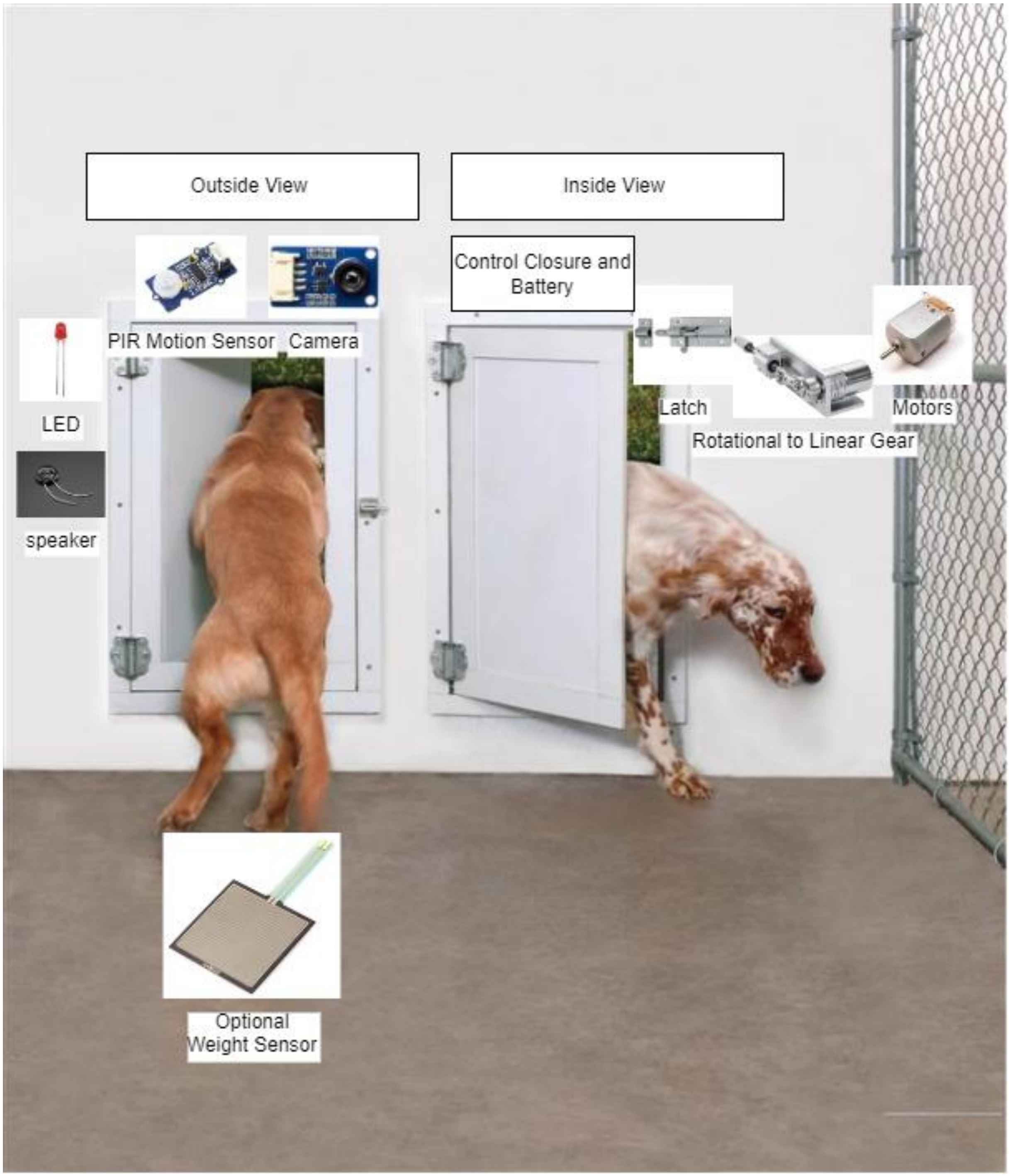
1.1 Problem

For those people living near small natural ecosystems, some small-sized wildlife animals like racoons or lizards may enter their house through pet doors from time to time. If we can design an electronic device attached on the pet door with proper sensors that can distinguish cats and dogs from non-pet animals, then when the pets attempt to enter or exit the house, the pet door will automatically unlock with the help from a latch powered by a motor, but if wildlife animals try to enter, the pet door will stay locked. The practical use of such device is not limited to pets-scenario, and any problem involved in automatically distinguishing different types of objects and taking different actions can be solved or alleviated by this device because the training sets can be easily altered to fit each problem's specific scenario.

1.2 Solution

The solution to our problem is to design an automatic pet door locking system that consists of several subsystems. The most important subsystem is a camera module to capture the image and identify the animal in front of the door. To achieve this function, a camera will be connected to a Raspberry Pi that runs pre-trained AI models. In addition to the camera, an infrared motion sensor will also be used for further verifying the animal type. A microcontroller fixed on a PCB board will receive the signals transmitted from Raspberry Pi and infrared motion sensor, process the signals, and send control out to other subsystems. After receiving the control signal, the motor in the mechanical subsystem will power the latch to lock or unlock, and the LED in the notification will turn on or off. Finally, a 3.7V battery and various converters will constitute the power subsystem to provide electricity to Raspberry Pi, infrared motion sensor, and the microcontroller. Then the Raspberry Pi and microcontroller will power the rest of the components.

1.3 Visual aid



1.4 High-level Requirements

For this project, this system is required to achieve great efficiency and accuracy in recognizing the general characteristics of pets and distinguishing pets from other objects.

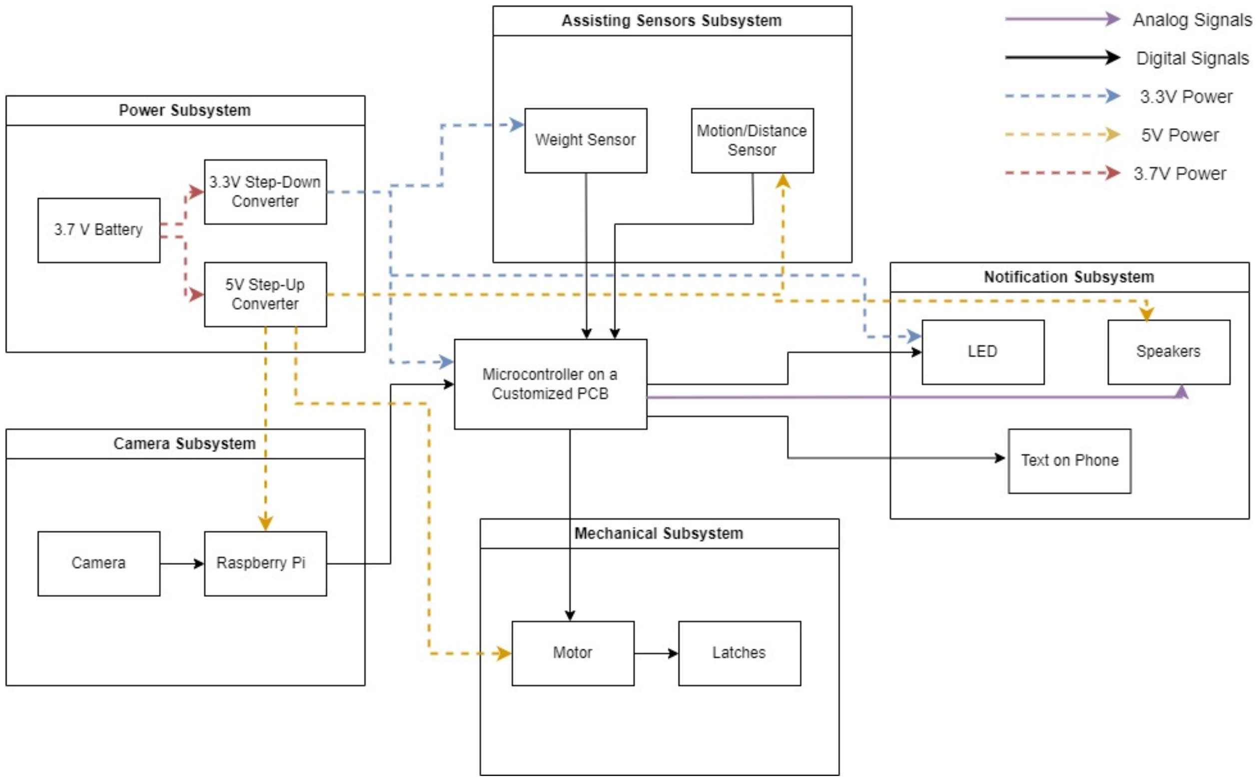
1. The latch will be locked automatically when there are no pets appearing in front of the camera. The recognition of motion and graph should be satisfied at the same time to identify the pet as the correct type. Any incorrect recognition will make the latch locked. The ideal numerical accuracy of the systems should be high enough to ensure that pets can freely enter the pet door for 99% of the time and wild animals are locked outside the pet door for 90% of the time.

2. To prevent wild animals following pets and entering the door, the locking speed needs to be fast. Pets should not wait for the unlocking process for too long, so the unlocking speed needs to be fast. Therefore, the door's response to recognition result generated by Raspberry Pi and infrared motion sensor should be quick enough to ensure that locking and unlocking process finishes within 2 seconds, and the LED turns on or off within 1 second.

3. The latch should not be immediately locked when the pets disappear from the camera because pets may need to enter. Therefore, once the latch is unlocked, it should keep the unlocking status for 5 seconds before the locking process begins even if pets disappear from the captured image.

2. Design and Diagram

2.1 Block diagram



2.2 Component Specification

Required:

- Lithium-Ion Battery Pack 3.7V:
  - 2000mAh~6000mAh. (2000mAh might be too small for a long battery) life.
- DC-DC Step-Down 3.3V Converter:
  - Convert 3.7V to 3.3V for microcontroller.
- Microcontroller:
  - Any low-power series available from the machine shop.
- PIR (Passive Infrared) Motion Sensor:
  - 5V operating voltage, detects the heat radiated from animals
  - 3 Pins: Power, GND, and Signal
- LED
- Speaker
- Raspberry Pi Camera Module 3:
  - 12-megapixel, Full HD video with autofocus at 50fps
  - Natural support by Raspberry Pi

- Raspberry Pi 4 Model B:
    - 5V 2.5A power supply would be the minimum requirement as we don't connect any USB peripherals.
    - OS, TensorFlow Lite, Python support
- MT3608 DC-DC Step-Up Boost Converter:
    - Convert 3.7V to 5V to power the Raspberry Pi
    - Can be any step-up converter or even designed in-house.
- Motor and H bridge
- Latch:
    - Design a system to translate rotational movement into transitional

3. Subsystem Overview

3.1 Camera Subsystem

An AI model on the Raspberry Pi board will be trained and tested on recognizing pets' facial images with numerous photos as training sets, development sets, and testing sets. After completing the training process and reaching the desirable successful rate during tests, the Raspberry Pi loaded with this AI will be connected to the camera to provide power and receive imagery data. The camera will monitor the outside of the door and send image data to Raspberry Pi, and then the AI will categorize the object to be pet or non-pets. After the categorization, Raspberry Pi will generate different signals to the motor and the LED accordingly.

3.2 Motion Sensors Subsystem

Required sensor:

In some scenarios, pets may be far away from the door, and they may not want to enter the house, but the camera may still capture their image and unlock the latches. To avoid this situation, this infrared motion sensor powered by 5V converter will detect whether some objects are in front of the pet door, and if this infrared motion sensor detects any object (not necessarily pets), a special signal will be sent to the microcontroller. The microcontroller will only unlock the latch and turn on the notification system if this signal and Raspberry Pi's signal are both high.

Optional sensor:

A weight sensor powered by the 3.3V converter can serve as a fail-safe: if the measured weight is lower or higher than the boundary of the expected weight range of normal cats and dogs, a signal will be generated and sent to the microcontroller. After receiving the signal, the microcontroller will ensure that latches remain locked even if the camera falsely recognizes the non-pets object as a pet. It is difficult to implement this sensor because pets may only be partially on this weight sensor, which will negatively influence the accuracy of this sensor, and some breeds of cats or dogs may have similar weight with wild animals like raccoon, so weight is probably not the most essential feature to distinguish pets from wild animals. Based on its merits and difficulty to implement, we consider this sensor as optional.

3.3 Microcontroller

The microcontroller powered by the 3.3V converter is the main control of the whole system. Specifically, it receives signals from Raspberry Pi and other assisting sensors. Then, it will generate and send signals to the motor, speakers, and the LED. The microcontroller should be fixed on a PCB board. Since these processes do not demand maximized processing power. The low-power STM32U5 is an ideal choice for both its high-power efficiency and high performance. If STM32U5 is not available, it can be substituted by other low-power microcontrollers like STM32L5 or STM32L4. Although the backup microcontrollers have a relatively inferior performance, their processing power will still be sufficient.

3.4 Notification Subsystem

Required notification device:

An LED will be lit up when the latch is unlocked; otherwise, this LED will turn off. Therefore, it should be directly controlled by the microcontroller. This LED is powered by 3.3V converters.

A speaker will make sounds whenever the latch is unlocked. Therefore, it is directly controlled by the microcontroller. This speaker is fixed on the PCB board. This speaker is powered by 5V converters.

Optional notification device:

An LCD screen will be connected to the microcontroller, and if the latch is unlocked, the word “UNLOCKED” will be displayed; Otherwise, the world “LOCKED” will be displayed. This device is very difficult to implement and may consume too much energy, which may negatively affect the performance of the whole system, so we consider the LCD screen optional.

An application on the pet's owner’s phone could remotely check the pet door status and send control signal to the pet door. This application is expected to be extremely difficult to implement on our own, so we consider this application optional. If we decide to implement this in the future, it should be wirelessly connected to the microcontroller and powered by the cellphone battery.

3.5 Power Subsystem

A 3.7V battery serves as the power source of the system. It is connected to a 3.3V converter and a 5V converter. The 3.3V converter provides power to the microcontroller, optional weight sensor, and the LED. The 5V converter provides power to the Raspberry Pi, the infrared motion sensor, the motor, and the speaker.

3.6 Mechanical Subsystem

The motor is powered by the battery and directly controlled by the microcontroller. After the microcontroller finishes processing all signals from the camera and other sensors, it will send a signal to the motor to control the motor lock or unlock the latch. Once the latch is unlocked, the pets are free to enter or leave. After the pets enter the house, the image captured by the camera should be categorized as non-pets, so the latch will be locked.

3.7 Subsystem Requirements

The output of the 3.7V battery should have an error range within ±0.1V (3.6V-3.8V).

The output of the 3.3V converter should have an error range within ±0.1V (3.2V-3.4 V).

The output of the Raspberry Pi converter should have an error range within ±0.1V (4.9-5.1V).

3.8 Tolerance Analysis

One of the risks is that the checking of our systems will vary with the moving of pets. Every sensor system, motion system, and weight system should be satisfied at the same time as unlocking the latch. However, the deviation for the same pet will also oscillate among motion, sensor, and weight systems. Those systems will vary with the movement of pets. Pets' motions are not fixed. Another limit is our camera subsystem. The AI identification is unstable if the camera cannot catch the face of pets completely and clearly. The movement of the animal will influence the operation of the camera system and the door will also be limited because of this factor.

For the power supply system, we contain a 3.7 V battery with 6000mAh.

The capacity of the battery = 3.7V* 6Ah = 22.2 Wh

The power consumption of the Raspberry Pi Camera Module 3 is between 0.4W to 1.4W.

For the DC-DC Step-Down 3.3V Converter with 300mA:

P = 3.3V* 0.3A = 0.99 W

For the PIR (Passive Infrared) Motion Sensor, its power consumption ranges from 0.5W to 8W.

The power consumption of Raspberry Pi 4 Model B is 15W

The power most of our chips and devices consume is the sum of the above devices:

Maximum: Ptotal = 1.4W + 0.99W + 8W + 15 W = 25.39W

Minimum: Ptotal = 0.4W + 0.99W + 0.5W + 15W = 16.89W

The minimum expected usage time between charging will be:

T = 22.2 Wh / 25.39W = 0.874 Hour

The maximum expected usage time between charging will be:

T= 22.2 Wh / 16.89W = 1.314 Hour

4. Ethics and Safety

Ethics and safety are the most significant factors when identifying a design. We consider every possible risk related to our subsystem components including diverse sensors, latches, power supply, and motors. It is important to prevent the pitfalls of products that cause damage. For our product, the purpose is to protect the safety of pets and prevent the disturbance of other wild animals. The electrical components in our system will be kept away from dangerous factors including water, fire, and sharp objects to prevent harm. According to the 7.8 IEEE Code of Ethics I. 1, we need to hold paramount the safety, health, and welfare of the public and it is necessary to comply with ethical design and sustainable development practices. In order to protect the privacy of others, we also need to disclose promptly factors that might endanger the public or the environment. We will set the appropriate size of the door which is suitable for the crossing of pets. Meanwhile, the door will not be allowed to let other people or wild animals enter, preventing harm to privacy.

According to the 7.8 IEEE Code of Ethics III. 10, we need to strive to ensure this code is upheld by colleagues and co-workers. We should make sure every teammate follows the code of ethics and be honest with each other. Any information related to our design will be open to each other. Each teammate in our group finishes the Laboratory Safety Training and we will keep in mind every dangerous factor when working in the lab. We will keep at least two people staying in the laboratory and be careful about the actions of soldering and wiring. Meanwhile, our power supply system contains a 3.7 V battery to supply electrical energy for the operation of our product. It will be in an isolated environment around the door to prevent unpredictable dangers.

5. Reference:

"IEEE Code of Ethics." *IEEE*, https://www.ieee.org/about/corporate/governance/p7-8.html.

Raspberry Pi. "Buy A Raspberry Pi Camera Module 3." *Raspberry Pi*, https://www.raspberrypi.com/products/camera-module-3/.

Raspberry Pi. “Raspberry Pi 4 Model B Specifications.” *Raspberry Pi*, https://www.raspberrypi.com/products/raspberry-pi-4-model-b/specifications/.