Rolling Pet Toy

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1 Introduction

1.1 Objective

Owners often feel remorse leaving their pets at home for long periods of time because they get bored, get anxious and cause destruction to items around the house, and do not get enough exercise throughout the day. This is a widespread problem according to Daily Mail [1] because pet owners must leave work on average for 8 hours on Monday through Friday for work and they do not want to come home to an unhappy pet or a mess.

Our vision for a solution to this problem is a small, durable, bone-shaped cart to engage the dog throughout the day. There would be a rechargeable battery and power converter for the power supply. The control system reads in signals from input sensors and then makes decisions on how to navigate the cart based on these signals. To make the toy more interactive, custom infrared motion detectors on all sides of the ball activate movement of the car when the dog comes near it. The sounds from a custom speaker/amplifier system also attracts the pet to the toy (through doorbell or other tones) at thirty minute increments throughout the day.

1.2 Background

Dogs often have separation anxiety just as humans do. Countless research has been done on which breeds are affected most, how old dogs are when anxiety arises and what are ways to make the dog more relaxed when their owners are away. According to the American Society for the Prevention of Cruelty to Animals (ASPCA) one of the most common complaints dog owners have is that their dogs are destructive and disruptive when they are left alone. Although there are some cases where training will help with these actions, for many dogs these actions are symptoms of distress and anxiety. The key to treating these separation anxiety issues is to teach the dog to “enjoy, or at least tolerate”[2] being left in the house alone. By associating these anxious times with a treat or fun activity, the hours will go by faster and it will ease the pain of being left alone by showing them this quiet time is not all that bad.

Another common tip to help with anxious dogs, or just dogs that become bored and destructive around the house, is to be sure they are exercised directly before leaving the house for extended periods of time. This helps tire them out so they are able to sleep and relax while their owner is away. But often, pet parents must leave early in the morning and do not have time to get a long walk in before the day begins. In these situations, a toy that will both present positive entertainment to alleviate stress in anxious dogs and provide exercise throughout the entire workday will have a two fold benefit to both the furry friend and their owner.

1.3 High-Level Requirements

- The toy must have a battery life of at least 10 hours so the toy will be active for a complete work day and can be recharged overnight.

- The toy must be able to detect objects 20 cm from the edge of the chassis so it avoids walls, as well as detecting when the dog comes within 20 cm to activate movement of the car.
- The toy must be able to withstand falls from a height of 2 feet during play to guarantee durability.

2 Design

2.1 Block Diagram

As shown in Figure 2.1, this system consists of seven main sections. The power block will provide energy to each component on the cart from one rechargeable battery run through a converter. The control section determines the operation of the speaker and motor blocks depending on inputs from the sensors and the switch. The motor drives determine the motion of the cart while the speaker will output sound to attract the dog. The LEDs stay on, while the power switch can be used to conserve power while the cart is not needed. Input from the sensors determine where the cart needs to go.

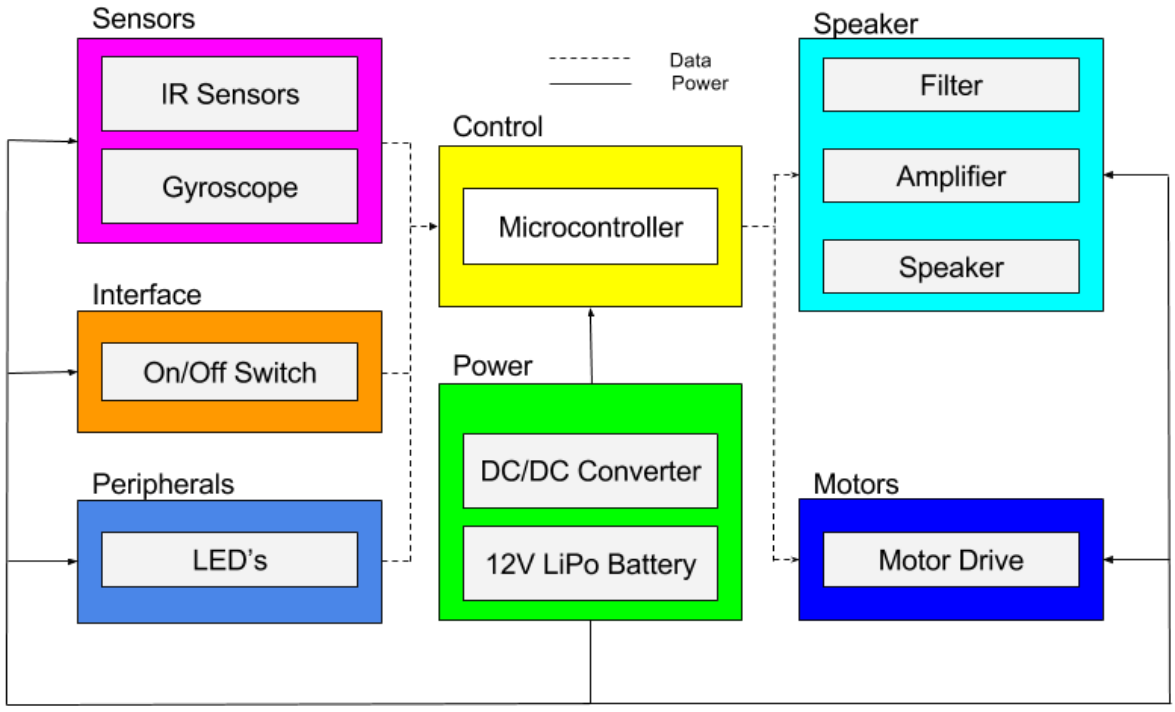

Figure 2.1: Block Diagram

2.2 Physical Design

The physical design of the cart is shown in Figure 2.2 below. The chassis resembles a Block I to represent the University of Illinois and also takes the shape of a bone that a dog can carry throughout the house during play. On the four corners of the chassis wheels are mounted to individually driven axles cased in the chassis. There will be 3 IR sensors mounted on each the front and back of the chassis to detect approaching walls while driving as well as 2 IR sensors mounted on either side of the chassis to detect the dog approaching. The main controls unit will be in the center body of the chassis and will house the speaker, lights and microcontroller. On the bottom of the chassis will be a port to recharge the battery.

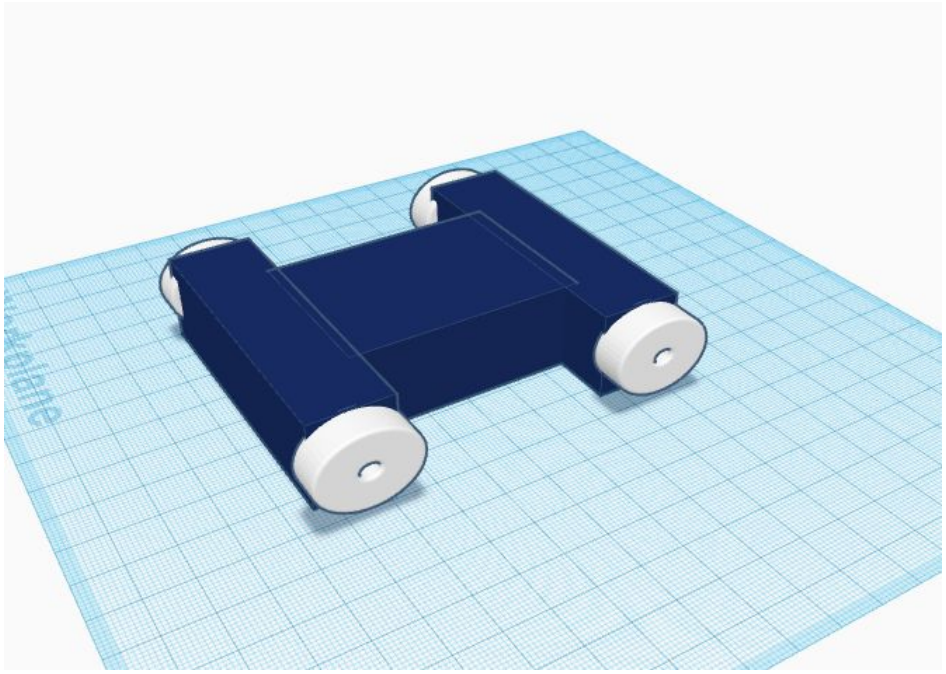

Figure 2.2: Physical Design

2.3 Functional Overview

2.3.1 Control

The control block will be entirely implemented on a group designed PCB which with house an ATmega 2560 microprocessor that will directly feed into all of the other components.

Requirement 1: The processor draws a current of 14 mA to run.

2.3.2 Power

A LiPo battery will be supply the entire system. However, the battery will be at 12V whereas all of the electronically components are at 5V. Our group will design a Buck DC/DC converter with Proportional Integral control to ensure the maximum efficiently out of the converter. This will be implemented on the PCB with the control unit.

Requirement 1: The LiPo battery must be able to power the sensors, motors , LED's and microcontroller. The main power draw will come from operating the motors which pull around 1400 mA. All together using a 6600 mAh LiPo battery will give us around 3 hours of active driving operation, while the car can last even longer as it is not always driving.

2.3.3 Speaker

A speaker with an amplifier will be mounted to the cart to provide a tone to attract the dog. The sound will come from the microcontroller and be pre-loaded.

Requirement 1: The speaker needs to be 60 dB with a frequency in 20Hz-20kHz to catch the attention of the dog from anywhere inside a house. Using a 3 watt speaker this could be achieved, with a current draw of 160 mA.

2.3.4 Motor Drive

The motor drive will be implemented with an H bridge driver connected to four stepper motors. The voltage applied will be determined by the control module which will control the speed of each motor.

Requirement 1: Four stepper motors will move the car based on signals from the microcontroller. They will be run independently to allow the car to turn fluidly. The motors we are going to use run at 350 mA and consume 4.2 watts each, for a total of 16.8 watts and 1400 mA or 1.4 A.
Requirement 2: The stepper motors will be controlled by a PWM scheme with a step angle of 1.8 degrees with a 5% error in order to properly detect its current location. The maximum holding torque is 2.3kg*cm which we expect to only use ½ to ¾ of the maximum available torque.

2.3.5 Sensors

Eight IR sensors and a gyroscope will be attached to the car. The IR sensors will be used to detect objects in the path of the cart and around it. This data will be sent to the microcontroller. The gyroscope will determine if the car is upside down or not and send this data to the control block as well.

Requirement 1: The gyroscope can run in three separate dps modes where only the least accurate of 245 dps is needed since out precision in this aspect is not as critical. Sensing three axis rotation and outputting a digital signal with a sensitivity of 8.75 mdps/sec. Typical gyroscopes to be used operate around 5 mA.
Requirement 2: The IR sensor can detect objects up to 150 cm away, with a detection accuracy of 80 cm ± 10 cm. Each IR sensor would consume around 33 mA for a total of 264 mA with an analog output.

2.3.6 Peripherals

The LED's will be on constantly to help attract the dog and allow the cart to be more visible.

Requirement 1: Only a few LED's will be needed to illuminate the car, and this was power consumption can be kept very low, in the order of 20 mA

2.3.7 Interface

The on/off switch is attached to allow the cart to be easily turned on and off.

Requirement 1: Using a SPST switch with the high being turn the car on and low being turn the car off.

2.4 Risk Analysis

The biggest risk in the project is creating a toy that is entirely autonomous and engages the dog which means the IR sensors must be functional. Without this feature, our project is simply a car that properly moves. The position of the dog is difficult to detect due to the movement of the dog. The dog will not act in a pre-predicted manner and we must set up a proper control system in order to be able to notice the dog moving from the array of IR sensors.

There could be many reasons on why these autonomous features do not work such as the control algorithm is not sensitive enough or the active IR sensors are not properly detecting the objects from the dog. The motor could also not be sensitive enough to properly stop the car from running into objects as well as braking/running the motor backwards.

3 Ethics and Safety

With the usage of electronics, there is always a possibility of danger. This device will be expected to play autonomously with dogs and cats without any human supervision. We will design the toy to have a maximum speed that will be safe if the toy were to accidentally run into furniture or the pet. We will also house all of the electronics in a safe location within the chassis to avoid anything coming loose in possible collisions. The entire toy will be designed with care in regards to the chosen materials to ensure the toy is not conductive and will electrocute the pet.

The overall circuit design will be made with as low of current as possible to maintain safety for the owner's pets. We will enclose the entire circuit in multiple layers to withstand chewing and slobber from pets. The utmost care must be given to this product to ensure people are comfortable leaving the toy alone with their pets. The overall project will follow the following IEEE Code of Ethics [3].

Conduit 1: The will be illuminated and have sound as well as the ability to detect objects and avoid them. The project is designed with the safety of the surrounding users in mind.

Conduit 2: This conduit is not as issue since we are completing this project for ECE 445 and do not have any conflicts of interests.

Conduit 3: We have not made an final claims on the product, but will build and test all of our components before making final product claims.

Conduit 4: The project is not sponsored so we will not be accepting any bribery.

Conduit 5: The product will fully improve societal knowledge of autonomous vehicles that can be used in the home and will correctly market these claims.

Conduit 6: This conduit is satisfied by the the safety procedure in the ECE 445 course.

Conduit 7: This conduit will be properly utilized in order to complete the project in a timely manner and the credit of the staff is given in the title page.

Conduit 8: This conduit will be followed strictly since we are a diverse team and will act professional in our interactions.

Conduit 9: The safety of our team and the users is our utmost important goal in mind with this project and plan to fully fully this conduit.

Conduit 10: Our group is fully committed to working together and teaching one another our expertise in order to have a fully successful project.

References

[1] Welshman, M. (2018). *Stop your dog destroying your home when you're out*. [online] Mail Online. Available at: http://www.dailymail.co.uk/news/article-3518318/Stop-dog-destroying-home-Never-guilt-leaving-pet-sense-anxious-wreak-havoc.html

[2] ASPCA. (2018). *Separation Anxiety*. [online] Available at: https://www.aspca.org/pet-care/dog-care/common-dog-behavior-issues/separation-anxiety

[3] "IEEE Code of Ethics", *ieee.org*, 2017. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html