Autonomous Dog Entertainment

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Contents

1 Introduction

1.1 Objective

Dogs are often left at home alone for periods of time when their owner needs to leave the house. According to the American Humane Society, this can cause a dog to become anxious or bored while left alone. This can lead to the dog acting out and chewing on the furniture or causing some other damage throughout the house[1].

Our goal is to develop a device that will provide a stimulating source of entertainment for the dog while its owner is out of the house. Furthermore, it will keep the dog's attention for the length of its attention span in order to keep it from becoming bored or anxious. We want to create a device that will drag one of the dog's toys around the house in order to stimulate the dog's interest and provide entertainment. The device will be able to navigate throughout the house by using IR sensors on the vehicle in order to avoid obstacles. The navigation will be autonomous and require no user control. The device will be durable such that it is not damaged by the dog playing with the device and must be safe for a dog to play with. Finally, the device will be able to move around for 20 minutes so that it will keep the dog's attention for its full 15 minute attention span[2].

1.2 Background

Most current dog toys on the market rely on human interaction to stimulate the dog's attention. This makes them ineffective when humans are not around to play with the dog. Some dogs are still willing to play with toys without human interaction, but this often involves throwing or flinging the toy with potentially destructive results. Our system will not require human interaction and will minimize harm to its surroundings by actively avoiding obstacles.

Some dog owners choose to send their dog to doggy daycare or hire someone to walk the dog during the day. This method, while effective in entertaining the dog, can be costly. Some dog owners cannot afford to spend $20-$40 a day on entertainment for their dog. Our goal is to provide a more affordable way for dogs to be entertained when their owners are unable to play with them.

1.3 High-level Requirements

- The device will be able to detect and avoid potential obstacles at least 80% of the time.
- The device operates in a manner that could attract a dog for a duration of 20 minutes.
- The device can continue to operate effectively when dropped on any side.

2 Design

2.1 Block Diagram

The block diagram shows that there are four main modules to our device: External, Power Supply, Control, and Motors. The external portion of the device contains a charger that is used to recharge the power supply, battery, within the device. The power supply contains a battery as well as converters and voltage regulators to allow for multiple voltage supply levels to various parts of the control and motors. The control utilizes power to operate various parts that are used for the internal operation of the device. The control collects inputs from the environment, such as button clicks and potential obstacles, and uses the information to send data to the motors module. Furthermore, internally, the control operates a display and speaker for use by the dog and owner. Finally, the motor drive takes power and data inputs, which it then uses to operate the two rear-wheel motors.

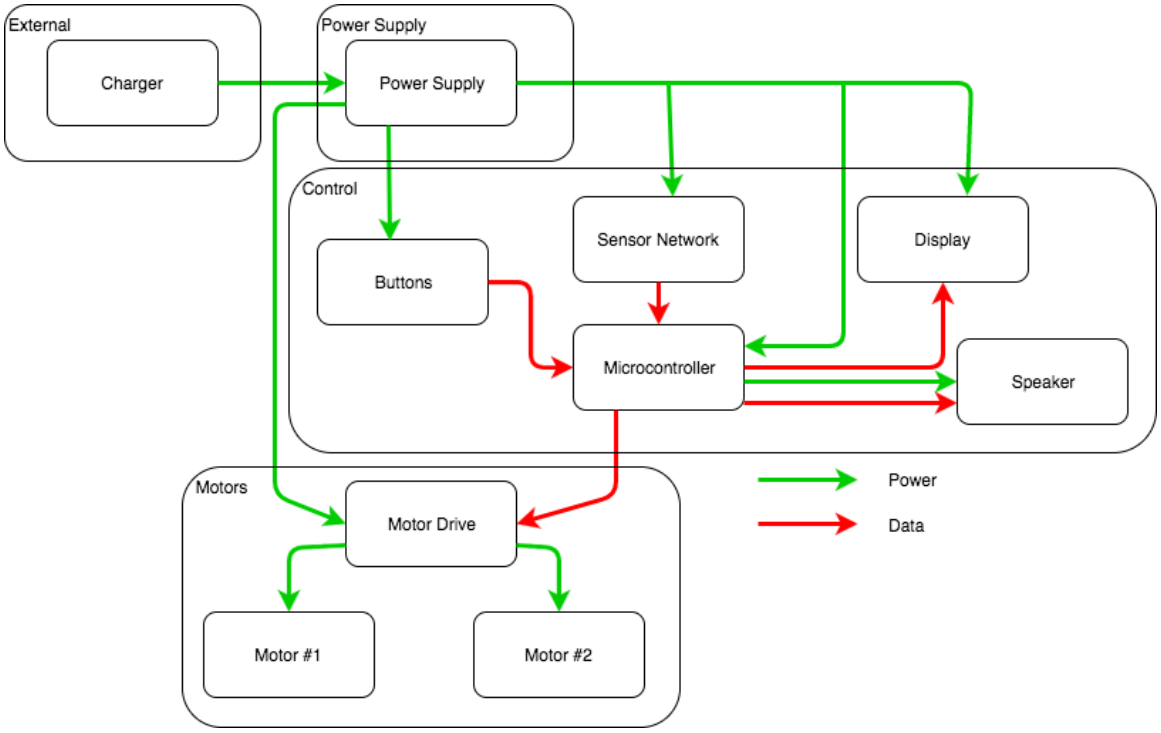

Figure 1: Block Diagram

2.2 Physical Design

The physical design of our device will be durable such that it can continue to operate if dropped in any orientation. This will be achieved by the use of hemispherical shaped wheels (Figure 2). The shape of the wheels will allow the device to be dropped on its side without it staying flat on its side, making the cart immobile. The location of the sensors are shown in red in Figures 3 and 4. Each sensor was chosen to be in the center on each side in order to better detect obstacles in the path of the vehicle. The display and buttons were placed in the front in order to minimize the potential risk for damage. The dog is least likely to bite on the front face due to the length and placement of the wheels. Furthermore, the wheels extend forward in order to act as a buffer between the display and objects. The back has a short cord with a latch that forms a hangmans noose around whichever toy the owner decides to attach to the back. Measurements in Figures 3 and 4 show the minimum dimensions required. Minimum width is 6 inches, minimum height is 4 inches, and minimum length is 9 inches. The wheels have been chosen to have a diameter of 6 inches so that the diameter of the wheels is larger than the height of the device.

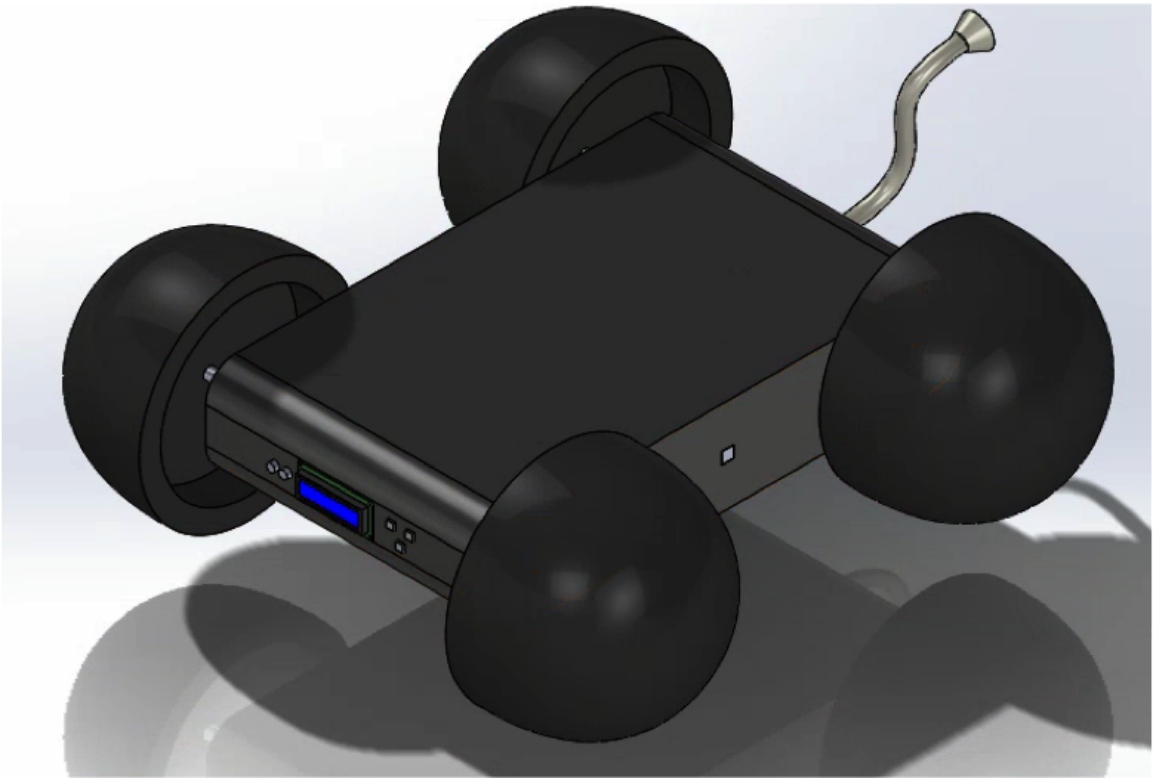

Figure 2: CAD Drawing of Design

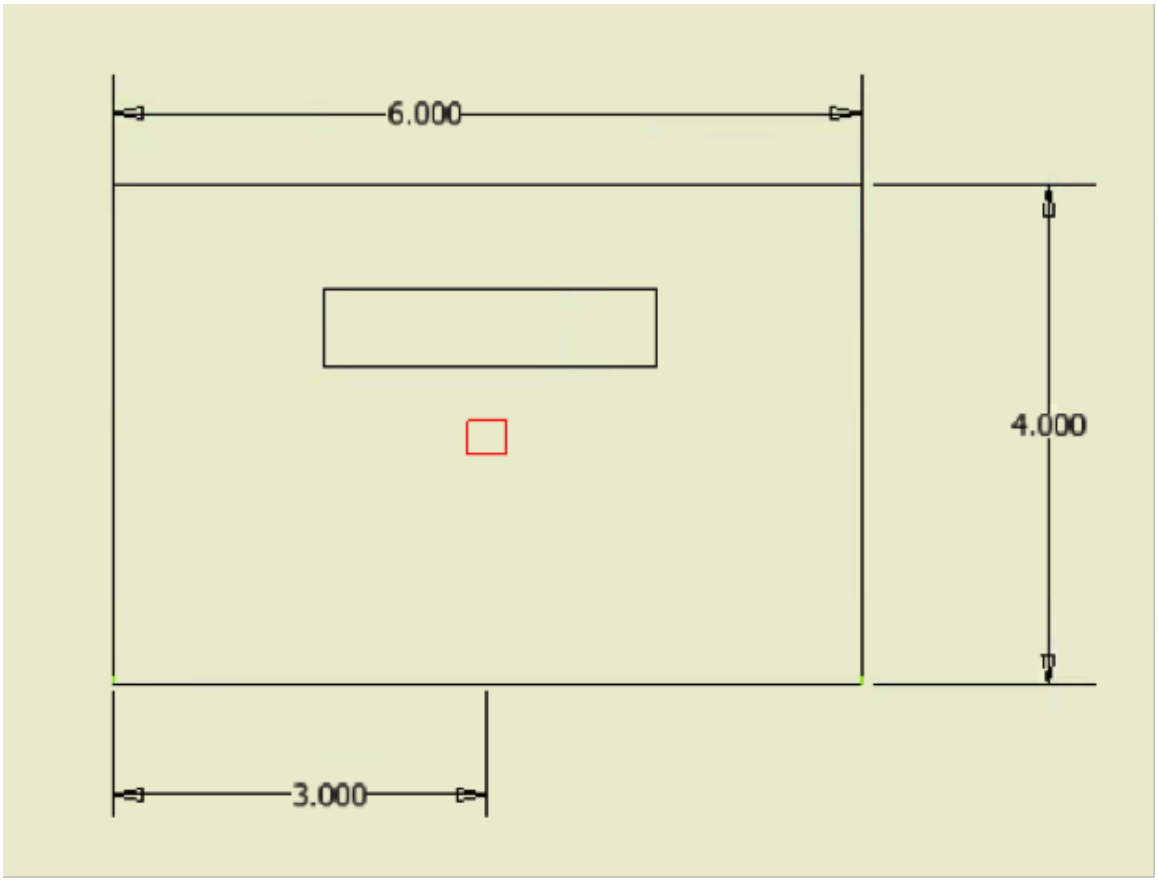

Figure 3: Front View (Measurements in Inches)

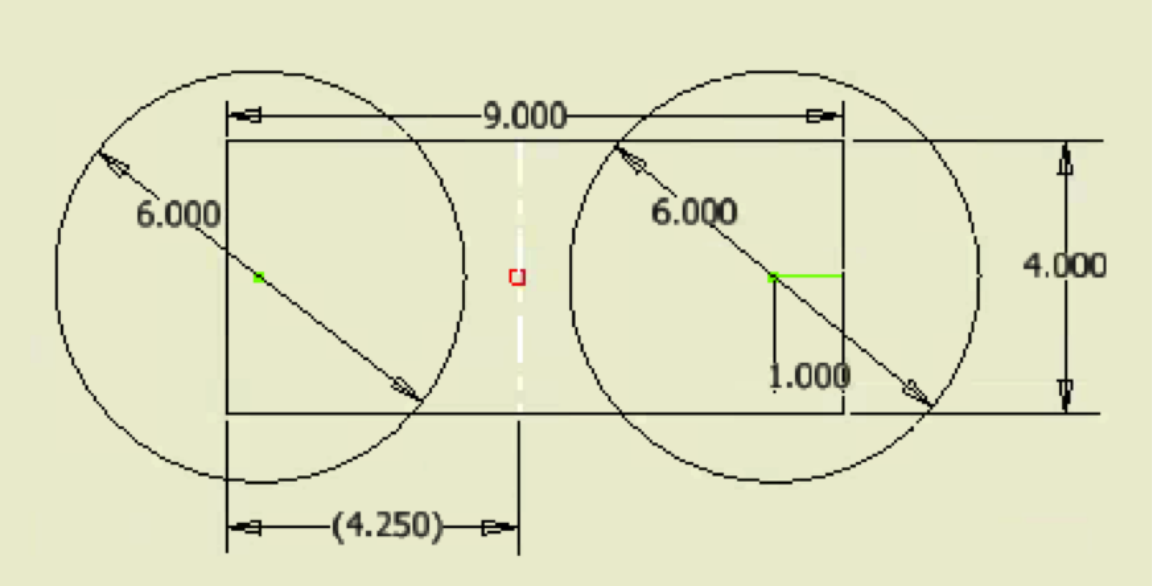

Figure 4: Side View (Measurements in Inches)

2.3 Block Descriptions and Requirements

2.3.1 Charger

This block is used to recharge the battery that will be used as the power source. This block will convert a standard 120VAC wall outlet input into a DC source that will be able to charge the 12V battery.
Requirement 1: The charger must be able to fully charge a 12 volt battery.

2.3.2 Power Supply

The power source will be used to power each of the components of the device. A DC-DC converter will be used to step down the voltage to the 5 volts for the required components. Furthermore, potentiometers will be used to adjust the voltage being supplied to the IR receivers, and therefore will be used to control the range.
Requirement 1: The device ia able to operate at full functionality for a minimum of 20 minutes.

2.3.3 Buttons

The design utilizes three buttons that connect from the power supply to pins on the microcontroller. One button is the power button, which is used to tell the system to start operating. The power button is between the battery and the powered devices. It remains activated for as long as the device is on and turns off after a second press. The other two buttons are used for increasing time on the timer. One button is for adding additional hours while the other is for incrementing the timer by ten-minute intervals. They are only on while pressed and provide digital data to microcontroller I/O pins.
Requirement 1: The power button must turn on the device.
Requirement 2: The hour button must add an additional hour to the timer every time it is pressed.
Requirement 3: The minute button must add an additional 10 minutes to the timer every time it is pressed.

2.3.4 Sensor Network

There are four IR emitters and receivers in the sensor network that are mounted on the front, back, right, and left of the device. The IR sensors will have a range of at least one meter. If there is an object that becomes present in front of the vehicle, the sensor will send a digital high signal. Then, based on the signals being returned from the side and back sensors, the vehicle will turn, switch directions, or stop. Furthermore, an accelerometer will be used to determine which side of the device is facing upward. Digital signals will be sent to the microcontroller to determine orientation.
Requirement 1: The device will correctly detect which side is facing upward at least 90% of the time.
Requirement 2: The device is able to detect an obstacle within a minimum of one meter at least 80% of the time.

2.3.5 Display

The display consists of a hexadecimal display as well as two LEDs. The hexadecimal display is a four-digit clock display that shows the amount of time that is left on the timer that counts down to device activation. The hexadecimal display receives digital data from the microcontroller. On the other hand, the LEDs are used to indicate that the device is fully charged and that the device is low on battery, below 25 percent of its full charge. The LEDs are controlled by separate circuits that determine the voltage level of the battery. An op-amp is used to determine if the voltage of the battery is above the set threshold voltage value to turn on

the full battery LED. A second op-amp is used to determine if the voltage level of the battery is below 25% of its full charge, which will turn on the low battery LED. The full battery LED circuit is located between the battery and power switch so that the LED will indicate a full charge without the device being on.
Requirement 1: The correct value of the timer is displayed on the screen.
Requirement 2: The full charge LED turns on whenever the battery charge is above 90%.
Requirement 3: If the battery voltage level drops below 25%, the LED turns on.

2.3.6 Speaker

The speaker is connected to the microcontroller and emits a sound whenever it receives a digital high signal from the microcontroller. Due to the operation of the speaker, it is powered directly from the microcontroller.
Requirement 1: The speaker emits a frequency of 25 to 30 kHz, which is appealing to most dogs[3].

2.3.7 Microcontroller

The microcontroller is the central hub of the system where all the data goes through. It will receive power from the DC-DC converter and takes data inputs from the buttons and the sensors placed throughout the body of the device. The input data from the sensors are used to determine what signals should be sent to the motor drive. Furthermore, the microcontroller outputs a PWM signal to the motor drive. The input data from the buttons is used to determine the time until the device will activate. It then outputs the current time left on the counter to the hexadecimal display.
Requirement 1: The microcontroller is able to output the correfct PWM to operate the motors.
Requirement 2: The microcontroller must provide enough power to operate the speaker with the use of an amplifier.
Requirement 3: The microcontroller must be able to correctly receive inputs from various buttons and sensors.
Requirement 4: The controller must output the correct signals to count down with the counter.

2.3.8 Motor Drive

The motor drive consists of a dual H-bridge motor driver that regulates the power to the motor by using a PWM digital signal that is provided by the microcontroller. Furthermore, the motor drive utilizes signals from the microcontroller to determine whether the motor receives power to operate in forward or reverse. The output of the motor drive is power to the motors. The motor drive module also consists of a current limiter to avoid damage from stall current spikes.
Requirement 1: The current limiter in the module must be able to prevent damage from current spikes due to motor stalling.

2.3.9 Motor 1

The first motor will be on the right rear wheel of the cart and will be used in conjunction with the other motor to move forward, or will be used by itself to turn the cart. It is controlled using an H-bridge motor driver that provides power to the motors in a manner that can operate the motor in forward or reverse. The motors being used will be gear motors in order to increase torque without drawing too much power.
Requirement 1: The motor must provide enough torque to move the device as well as a dog toy with a maximum weight of half of a pound.

2.3.10 Motor 2

The second motor will be on the left rear wheel of the cart and will be used in conjunction with the other motor to move forward, or will be used by itself to turn the cart. It is controlled using an H-bridge motor driver that provides power to the motors in a manner that can operate the motor in forward or reverse. The motors being used will be gear motors in order to increase torque without drawing too much power.
Requirement 1: The motor must provide enough torque to move the device as well as a dog toy with a maximum weight of half of a pound.

2.4 Risk Analysis

The microcontroller poses the greatest risk to the successful completion of the project. It must be able to interface with sensors and motors in order for the device to function properly. The main mechanism used to attract the dogs attention is movement. The microcontroller must output PWM signals to the motor drive in order for the cart to move. It must also interface with the IR sensor network in order to avoid obstacles by taking input from all sensors and determining which directions are free of obstacles. The specific PWM signals must then be sent in order to move the cart in a safe direction. Finally, the microcontroller must interpret data received from an accelerometer to determine which side of the device is facing upwards. This will affect the direction in which the wheels must turn in order to go forward. If the microcontroller fails to communicate with any of these components, the device will not be able to function as desired. Microcontrollers can be broken fairly easily if they receive an excessively high voltage or current. In order to protect the microcontroller, its power supply must not exceed 5.5V. Any signals entering the microcontroller must not exceed the maximum values for their respective pins as specified in the microcontroller datasheet.

3 Ethics and Safety

Our project adheres to the IEEE code of ethics[4]. The following rules were especially taken into consideration during the course of this project. The first rule was taken into account because the project has some potential health and safety issues that we have addressed and disclosed for future users to view. An example is the potential for the dog to bite through the casing over time. Furthermore, the third rule is adhhered to as there are limitations to the capabilities of our project, such as the casing being subject to wear and tear that causes circuitry exposure after a large amount of use. We have been upfront about any potential limitations. We have also adhered to the fifth rule and attempted to maintain a project that was within the scope of our combined abilities,which included limiting the capabilities of the device in order to make it a trustworthy device. Besides that, there are several safety steps that we have taken to minimize damage to the operator, property, and pets. Some safety considerations include:

- The motors and other electrical devices are located inside of a hard plastic casing so that the dog can safely bite the device without harming itself. We avoided the use of foam or sponges as they have been proven to be potentially harmful[5].
- The display is on the front to decrease the likelihood of the dog causing damage to buttons or displays.
- The torque of the motors is enough to allow for the cart to move without causing harm to the dog.
- The torque of the motors and sensor ranges are enough to allow for the device to turn without damaging potential obstacles.

- The size of the cart is large enough that the dog wont be able to lift the cart for an extended period of time and can be utilized by large dogs[5].
- The wheels are semi-spherical so that the device cant land on its side.
- The battery is able to be oriented in any direction, except inverted, which is avoided by placing the battery on its side so that it is never continuously inverted.
- The battery is leak-free so that dogs and humans are not exposed to toxic chemicals.
- The cord used for attaching the toy is short in order to avoid tangling around the dog or furniture.
- The parts of the toy that are accesible to the dog are large enough to avoid a potential choking hazard[5][6].
- The parts that contain chemicals are stored within a container that will be subject to a use and abuse test[6].

Furthermore, there are several steps that users can take in order to ensure the maximum level of safety while operating the device. These steps include:

- Only plugging the charger into a 60 Hz, 120 VAC outlet.
- Removing the charger once the battery indicates a full charge.
- Checking the device on a semi-regular basis to ensure that wear and tear has not exposed circuitry.

Finally, before any lab work takes place, the team will be certified in lab safety protocols as well as electrical safety protocols.

References

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