February 23, 2019

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S8

DoggyGo Inc.

Re: ENSC 405W/440 Design Specification for an Automatic Animal Ball Launcher

Dear Dr. Rawicz,

The document attached with this letter is our design specification document for our Automated Pet Entertainment Toy as described in our design specification. The goal for this Capstone Project is to create a product that will entertain our pets when we are not able to accompany them by providing them with a game to play indoors and outdoors. To achieve all these designed features and to make them work properly and harmoniously, DoggyGo will require many systems and components.

The objective of the design specification document is to outline the design details and determine a method to implement and integrate all components to form subsystems that will be closely connected to each other. We will first detail DoggyGo's system components individually and will describe the interactions between each system. This document will include the following systems: Motion System, Feedback System, Remote System, Power System and Output System.

DoggyGo Inc. consists of 5 outstanding and creative senior engineering students: Hongbin Lin, Junchen (Steven) Wang, Curtis Cheung, Manci (Maggie) Song and Danfeng (Sherlock) Sheng. Coming from 3 different engineering concentrations, our team has extensive hardware and software experience to aid us in realizing this proposition.

Thank you for taking the time to review our design specifications. If you have any inquiries regarding the document, please contact our Chief Communications Officer, Junchen (Steven) Wang, by phone (778-321-1907) or by email (junchenw@sfu.ca).

Sincerely,

Danfeng (Sherlock) Sheng
Chief Executive Officer
DoggyGo Inc.

Enclosed: Design Specification for an Automatic Animal Ball Launcher

DoggyGo Inc.

Design Specification

Automatic Animal Ball Launcher

Solo Carnival for Pets

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Submitted to: William Craig Scratchley (ENSC 405W)

Dr. Andrew Rawicz (ENSC 440)

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Issue Date: February 23, 2019

Abstract

This document specifies and defines the design specifications of the automatic animal ball launcher, DoggyGo. First, the design specifications for each of DoggyGo's independent subsystems are presented. Their individual design is described separately by outlining the functionality of components within the system (along with their dimensions and specifications) and will focus on the core design specifications to satisfy DoggyGo. The document will then outline the high-level descriptions of each subsystem along with interactions between each of them. DoggyGo will have all subsystems connected to an Arduino Uno, a microcontroller capable of accepting analog and digital input/output data.

DoggyGo's 5 subsystems are outlined as follows:

1. **Motion System**
   Ability for DoggyGo to adjust launch angle and strength of a launched ball.

2. **Feedback System**
   Use sensors to detect surroundings, whether the ball is returned or ready to be launched and determine if the ball is safe to launch. Once a ball is returned, the system will release treats for the animal to enjoy.

3. **Remote System**
   Allow user to select the strength level and launching angle using a remote and control the launch operation and treat release.

4. **Power System**
   Outlines the power requirements necessary for DoggyGo to operate.

5. **Output System**
   Activates alarm, launcher, or treat release based on the feedback system.

The Arduino Uno will work as the top-level platform to implement the subsystems above.

DoggyGo's user interface design will contain the following components: a power button for DoggyGo itself and a portable wireless remote with launch strength level adjustment, launch angle adjustment, and the ability to launch the ball or release treats manually. A speaker shall be used to provide informational and error feedback to pets and end-users that are around DoggyGo.

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Glossary

ABS	Acrylonitrile butadiene styrene, or ABS, is a common type of plastic used for 3D-printing. Lego is an example of ABS plastic.
ANSI	American National Standards Institute
Arduino	An open-source hardware and software company which allows users to develop digital devices that are able to accept sensor inputs and outputs.
Brushed DC Motor	A motor driven using direct current and uses carbon brushes and magnetic fields to rotate a coil, thus creating a motor "spin"
Buzzer	An integrated electronic loudspeaker powered by a constant DC voltage that produces a "buzz" sound when powered
CSA	Canadian Standards Association
ISO	International Organization for Standardization
IR	Also known as infrared. Produces light that is invisible to a human eye and is able to transmit a specific sequence of pulses to transmit a message.
NFPA	National Fire Protection Association
PBT	Polybutylene terephthalate, or PBT, is another type of common plastic that is stronger than ABS and is more susceptible to wear and tear.
Proximity Sensor	A sensor that can detect presence of an object without any physical contact with an object.
PWM	Also known as pulse width modulation. A method to control the speed of DC motors and electronic signals by sending direct current in pulses
Relay	An electrical switch having the ability to control high-powered devices using a low-powered device and is able to be operated using low voltage to produce an electrical field for the switch to conduct.
Servo Motor	A motor that can perform precise control of motor rotation through the use of position feedback circuit.
Time Stepper	A time counter which is used to record the idle pulse and sending the command when the function is called
Ultrasonic Sensor	A sensor that uses an ultrasonic transmitter and detector to detect the distance of an object based on the time between transmission and reception of the transmitted ultrasonic signal.

1 Introduction

In the past few years, the popularity of pet keeping have been cultivated as a universal trend. It is true that an abundant of researchers has indicated that people who keep pets will be healthier in both physical and mental activities compared to those who do not live with pets. Pet keeping is a very effective way to allow people who are under stress to relax. Therefore, in the recent years, there are more and more households willing to raise pets. However, with full-time day shifts for most people, keeping the pets entertained will be very difficult.

DoggyGo aims to make friends with dogs and their owners while they are out at work. DoggyGo combines several similar products that are found on the market into a single system. DoggyGo can fire a tennis ball from the launcher and provide treats to dogs. This system has the ability to be controlled in both automatic mode and manual mode. The most attractive feature of DoggyGo will be its great sustainability and high safety standards. To accomplish this goal, DoggyGo will have a complete detection system constructed with sensors to inspect the surrounding launching zone. If there are objects that are obstructing the launcher path, DoggyGo will stop its launch sequence. Users also can control the launcher and treat system manually as opposed to automated launch and dispense operation sequences. This will allow the user to adjust the angle, strength and direction of the launched ball. A high-level behavioral diagram description of functionalities is shown in Figure 1.1.

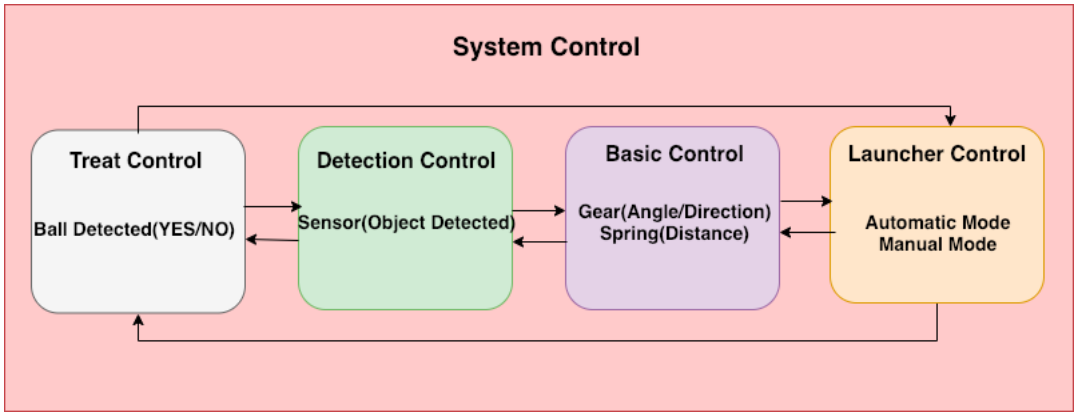

Figure 1.1: Basic Behavioral Overview

This design document will provide a detailed introduction and design specifications for achieving the above functionalities. These specifications will include several components: Power, Speaker, Ball Launcher, Treat Dispenser, Sensors & Buttons, Remote Controller and Arduino Uno.

1.1 Intention

We will specify the subsystems of DoggyGo as well as introducing how they form our final product. DoggyGo's prototype details will be detailed in depth and will contain descriptions of other design phases. At the end of the document, some other important appendices will be included such as product time plan, functional test plan, and user interface design. The design specifications will

allow readers to be more familiar with DoggyGo.

1.2 Audience

This document will provide information of DoggyGo to the DoggyGo Inc. members, supervisors and potential clients: William Craig Scratchley (ENSC 405W), Andrew Rawicz (ENSC 440), Nic Zilinski (TA), and Bakhtiar Azim (TA). The functionalities and requirements will be clearly defined in this documentation. Further revisions and future documentation will base on this framework and workflow.

1.3 Requirement Classification

The following table indicates the design stages with their corresponding code names.

Table 1.1: Design Classification

Code Name	**Design Stage**
C	Proof of Concept
P	Prototype
F	Final Production Product

The specific requirements and functionalities in this document and further versions will adopt the form:

Des (Section Number). (Subsection Number). (Design Number) - (Design state).

For example, the first design specification of the fifth section's first subsection as the final production product can be shown as Des 5.1.1 - F.

1.4 System Overview

DoggyGo will include two modes of operation: automatic and manual mode. Both of these modes will be comprised of three subsystems: launcher system, detection system and treat system. The launcher system will contain a launcher with two motor-driven wheels to adjust the shooting strength along with gears that will allow the launcher to adjust the horizontal and vertical launch angle. The launcher system will also include a speaker that will sound a warning before launching the ball. The detection system is formed by several types of sensors: proximity sensor and ultrasonic sensors. In the treat system, DoggyGo will consist of several proximity sensors to detect whether the ball is returned. In automatic mode, the treats in the treat system will be dispensed when a ball is returned to the launcher. In manual mode, users can use a remote control to control the launcher strength and angle along with the ability to manually dispense treats. Figure 1.2 provides a workflow diagram of DoggyGo.

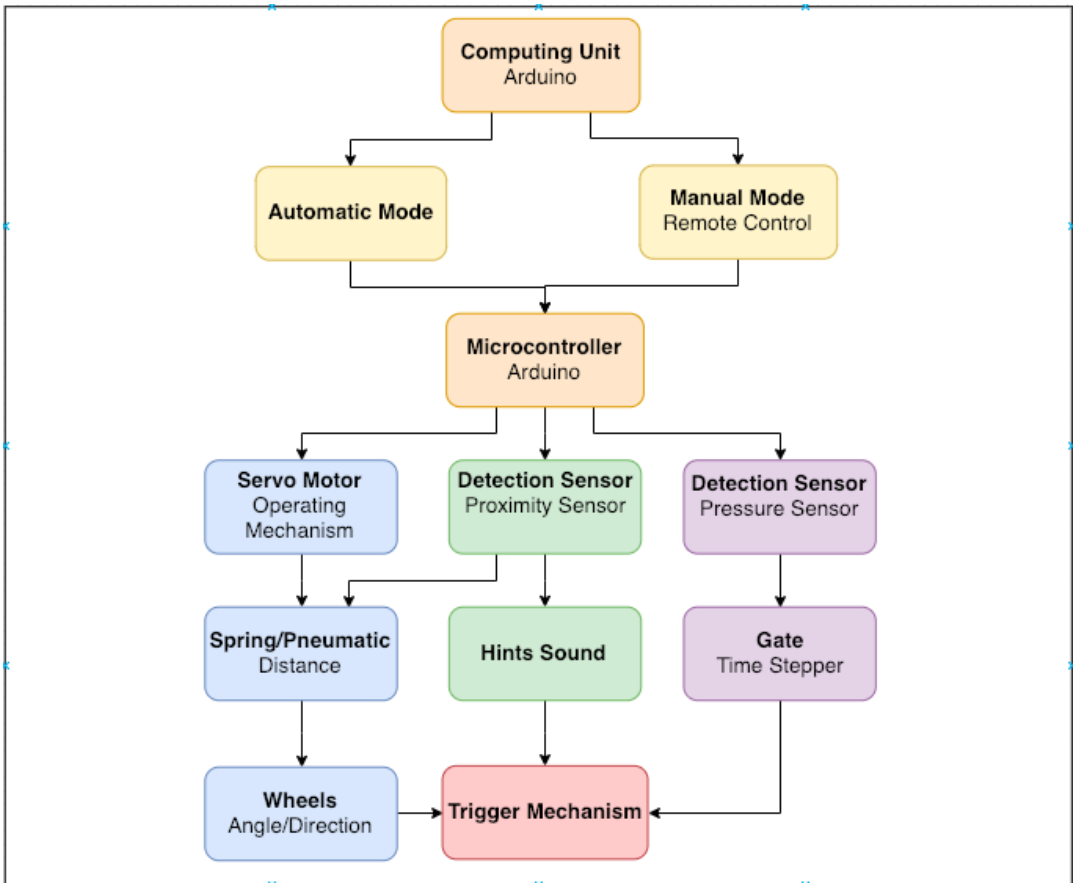

Figure 1.2: DoggyGo's System Overview

The high-level design specifications will be mainly divided into three subprojects: the ball launcher system, the environmental detection system and treat system. Table 1.2 and Table 1.3 show the general and overall requirements which we will detail further in the subsequent chapters.

Table 1.2: General Requirements

Des 1.4.1-P	Adjust the angle, direction and strength to a certain value.
Des 1.4.2-P	Be able to dispense treats when the dog returns the ball.
Des 1.4.3-F	Reliably recognize the objects before activating the ball launcher mechanism.
Des 1.4.4-F	Ability for DoggyGo to be configured both automatic and manual mode.

Table 1.3: Overall Performance

Des 1.4.5-C	Adjust the launcher angle/strength to achieve a relatively accurate distance for shooting.
Des 1.4.6-C	Adjust to achieve a correct angle for shooting as specified.

Des 1.4.7-C	Adjust to achieve a correct direction for shooting as specified.
Des 1.4.8-C	Sound a voice from the speaker to warn the surrounding people before a ball is launched.
Des 1.4.9-P	Launch a ball based on the adjusted distance, angle and direction.
Des 1.4.10-P	Provide a treat when the launcher detects that the ball is returned.
Des 1.4.11-P	Ability to open the treat container to allow treats to dispense.
Des 1.4.12-P	Ability to close the treat container to prevent further treats from dispensing.
Des 1.4.13-F	Detect surrounding objects in the launch zone.
Des 1.4.14-F	Pause launch sequence if objects obstructing the launch path are detected.
Des 1.4.15-F	Available to choose either automatic mode or manual mode
Des 1.4.16-F	Controlled by a remote control in the manual mode

2 Motion System

The motion system of DoggyGo will feature a servo system with a pan and tilt feature using two gears, which will be controlled by the by the feedback system. The material used for the base must be sturdy to support the weight of the gear and the launch tube This will allow DoggyGo to handle the recoil force experienced on DoggyGo when launching the ball. The following sections will describe the design of the motion system.

2.1 Servos

Table 2.1: Servos Requirements

Des 2.1.1-C	The servos is controlled based on feedback from the microcontroller to ensure accurate rotation of the motors.
Des 2.1.2-P	A center gear (located on the base) is attached with the vertical gear located in the center axis to rotate the launcher vertically in increments of 15° to provide a vertical launcher angle adjustment.
Des 2.1.3-P	The gear located on the base on the DoggyGo rotates along the horizontal axis and is connected with another gear that contains a servo that rotates DoggyGo horizontal in increments of 15°.
Des 2.1.4-P	The gears attached on DoggyGo shall have barriers to limit the maximum vertical

and horizontal rotation.

Des 2.1.5-F All servo motors used shall provide enough torque to perform their given task.

Power consumption and torque of motors are two key constraints to keep in mind when selecting the appropriate motors. DoggyGo will be powered from a battery source in the final product, thus frequent recharging will be needed if the motors consume too much power. This consideration must be balanced with DoggyGo's need for reliable, accurate, and smooth angular displacement. The cross-section design diagrams for the gear construction along with specifications of are shown below:

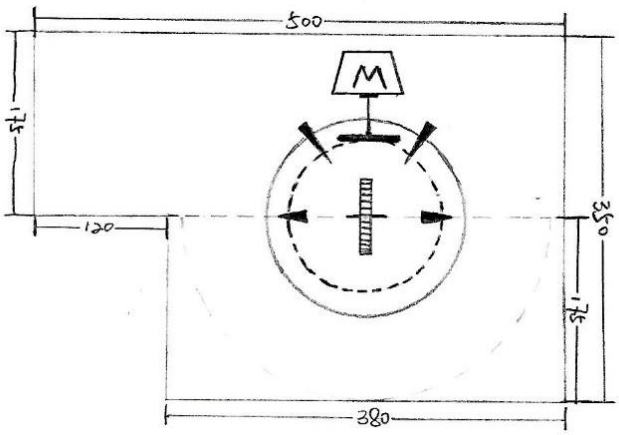

Figure 2.1: Top View of Horizontal Rotational Gear

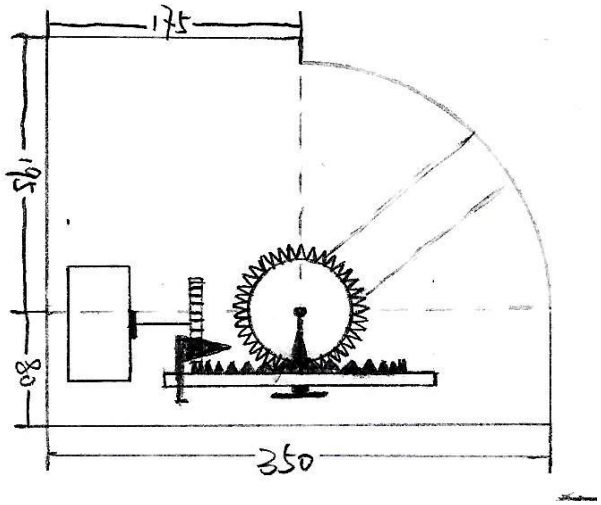

Figure 2.2: Side View of Ball Launcher Rotational Gears

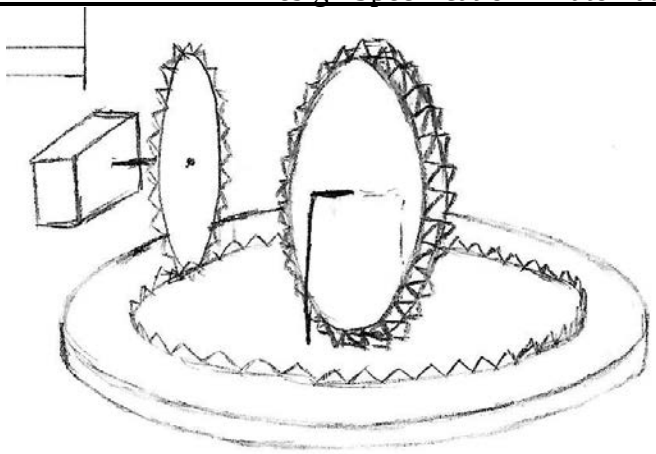

Figure 2.3: Overview View of the Gear System

Table 2.2: Motion System Parameters

Parameter	Value
Mass of Product	*5 kg*
Rotating Angular Speed	*π/12 rad/s*
Unit Step Angle	*15°*
Rotating Range (Horizontal)	*-60°~+60°*
Gear Teeth (Horizontal)	*36T*
Gear Radius (Horizontal)	*10 cm*
Rotating Range (Vertical)	*30°~60°*
Gear Teeth (Vertical)	*24T*
Gear Radius (Vertical)	*5 cm*
Motor Torque	*3 Nm @ 5V*
Gear Teeth (Motor)	*24T*
Gear Radius (Motor)	*4 cm*

2.2 Base

Table 2.3: Base Requirement

Des 2.2.1-C The base shall be made from PBT plastic.

Des 2.2.2-C The base shall be smooth inside-edge to hold the quarter-sphere cover of the motion system.

Des 2.2.3-P	The base shall be capable of providing sufficient support the prototype with mass of 5 kg (base on estimate) and able to support recoil force of launching.
Des 2.2.4-P	The base shall be 350mm x 380mm in size.

To ensure that DoggyGo will not injure others when handling the product, the corners and edges must be adequately smooth and free of sharp edges. The gear located on the base shall be adequately separated from the exterior to prevent any injuries from occurring to animals or to the end user. These gears will be built inside the base around the geometric center.

3 Feedback System

3.1 Sensors

Table 3.1: Sensors

Des 3.2.1-C	Two ultrasonic sensors shall detect distances up to 3 meters.
Des 3.1.2-C	One proximity sensor shall detect the ball in launcher pocket.
Des 3.1.3-C	Three proximity sensors shall detect the amount of balls contained in the launcher.
Des 3.1.4-P	Ultrasonic sensor has minimum sensing distance of 0.1 meters and a detecting range up to 3 meters.
Des 3.1.5-P	Ultrasonic sensor shall have a resolution up to 5 mm.
Des 3.1.6-P	Proximity sensor shall have a resolution up to 1 mm.
Des 3.1.7-F	The ultrasonic sensor shall have a detection in range [0.1m - 3m] away from an animal as a safety area.

3.1.1 Ultrasonic Sensor

For the ultrasonic sensors, we will be using the HC-SR04 ultrasonic sensor. Each of the ultrasonic sensors consists of 4 pins: VCC, Trigger, Echo and Ground. DoggyGo will use ultrasonic sensors to detect the safety distance between the launcher and object. If an object is detected within 3 meters from the front of DoggyGo, the launcher will abort its launch sequence and will sound an error to indicate that the launch sequence has stopped. The ultrasonic sensors work with the formula:

$$Distance = Speed * Time$$

The design diagram and specifications for the ultrasonic sensor detection is shown below:

Figure 3.1: HC-SR04 Ultrasonic Sensor [1]

Table 3.2: Ultrasonic Sensor Parameter [2]

Parameter	**Value**
Operating Voltage	*5V*
Current Consumption	*15 mA*
Detection Range	*2~400 cm*
Range Accuracy	*3 mm*
Measuring Angle	*15°*
Dimensions (Length*Width)	*45 x 20 x 15 mm*

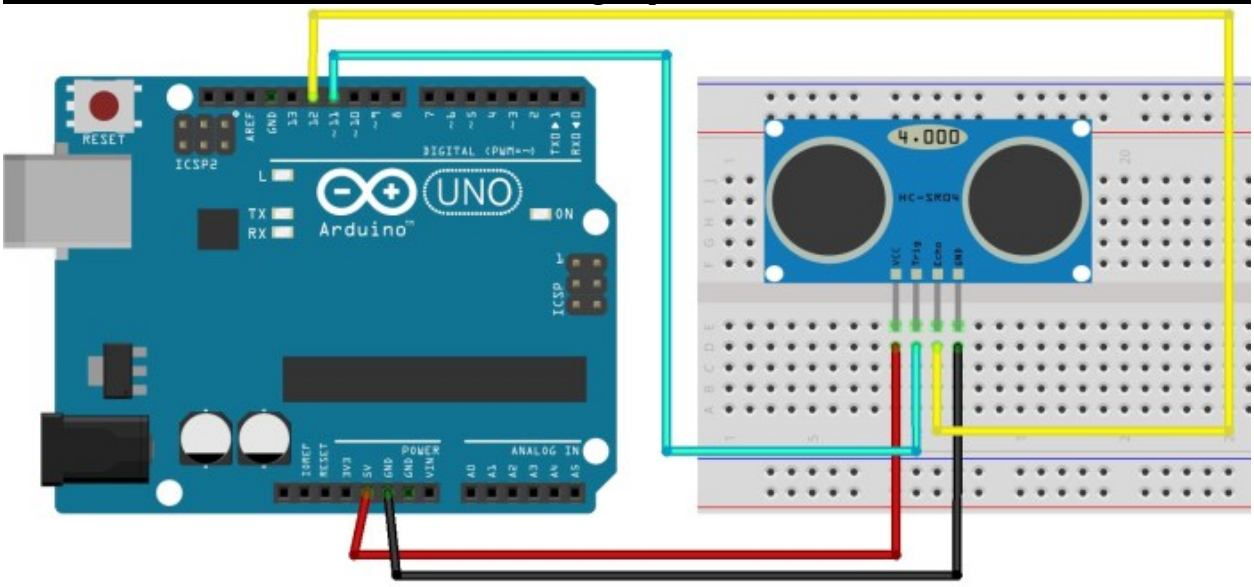

Figure 3.2: Ultrasonic Sensor Wiring Layout [3]

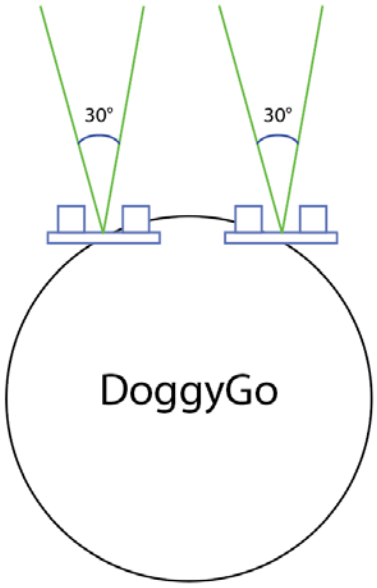

Figure 3.3: Placement of Ultrasonic Sensors

3.1.2 Proximity Sensor

Proximity Sensor will be used to detect if the launched ball is returned by the pet. DoggyGo will use three mini SPST (single-pull-single-throw) momentary N/O (normally-open) off-on push

button sensors (one of each ball) to detect whether the ball is in the launcher. When the ball pushes the button, it will detect that the ball is in the launcher. When there is no ball, the button will be disconnected, and Arduino will be able to determine that there is no ball on a specific slot by reading the state of the power button.

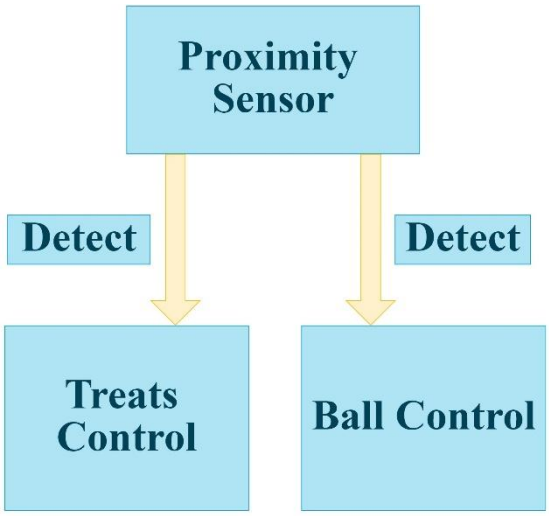

Figure 3.3: Proximity Sensor Introduction

Figure 3.4: Proximity Sensor [4]

Table 3.3: Specification of Proximity Sensor

Parameter	**Value**
Mounts	*In 1/4 inches; diameter hole*
Dimensions	*1 1/16 inches; long x 3/8 inches; diameter*
Diameter and maximum current rate	*10 mm 125V 6A, 250V 3A*

3.2 Buttons

Table 3.4: Buttons

Des 3.2.1-C	There shall be two buttons on DoggyGo, one (A) shall be used to turn on/off the power and one (B) shall be used to change the mode of operation (Auto or Manual) of DoggyGo
Des 3.2.2-C	There shall be one remote to control the distance, angle, and treat/ball launch in manual mode of DoggyGo
Des 3.2.3-P	The buttons on DoggyGo shall be highly visible and easily accessible for an end-user

3.2.1 Switch Button

We will use mini SPDT slide switch to change the mode of operation—Auto or Manual. When the slide switch is in its “up” state”, Auto mode will be activated. When the slide switch is in its “down” state, Manual mode will be activated, allowing the user to control the launcher using the remote.

The figures below show the actual switch along with dimensions for the mini SPDT power switch. We can see that the length and width of the switch button are less than 1.2 cm.

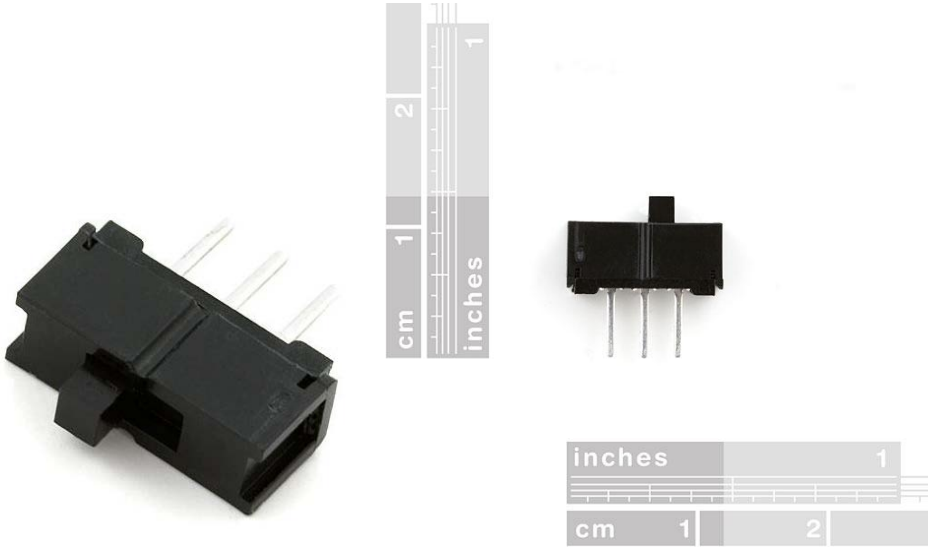

Figure 3.5: Switch Button Overview and Dimension [5]

3.2.2 Power button:

We use DS-412-Red SPST button to control the power (on/off).

Below is the figure for the DS-412-Red SPST button:

Figure 3.6: Power Button [6]

Table 3.5: Parameters of Power Button

Parameters	Value
Contact Form	*SPST*
Switch Function	*OFF-(ON)*
Contact Rate	*3A @ 125V, AC*
Dimensions	*0.82" Depth x 1.0" Total length*
Mounting Hole Diameter	*0.500*
Number of Pins	*2*

3.3 Motors & Gears

Table 3.6: Motors & Gears

Des 3.3.1-C	There shall be four gears to rotate the angle for semi-circular launcher pad both horizontally and vertically
Des 3.3.2-C	The motors for semi-circular launcher pad shall control and rotate the orientation of two gears to adjust with a high accuracy to any desired angle
Des 3.3.3-C	One motor shall release the treat when the returned ball is detected by proximity sensor.
Des 3.3.4-P	The circular pitches and the face width of driving gears should perfectly match those of the engaged gears
Des 3.2.5-P	The angular displacement of the semi-circular launcher pad must be accurately determined based on input angles and launch strength

To drive the motors that we will be using for the launcher and treat dispenser, we will use the L298N module to driver the motors. The motor driver will have 14 pins: Pin 1 and 2 will allow the user to attach the “+” and “-” terminals respectively of the first DC motor onto the module. Pin 3 is a 12V jumper - this jumper will be removed if the supply voltage to the motor driver is greater than 12V DC. Pin 4 is where one connects the power source for the motor driver with a maximum input voltage of 35V DC. Pin 5 will be ground. Pin 6 will supply a 5V DC output if the 12V jumper in place. Pin 7 is a DC motor 1 enable jumper, leave this in place when using a stepper motor, this will be connected to the PWM output on the Arduino for DC motor speed control. Pin 8 to 11 are IN1, IN2, IN3, and IN4, which are connected to the Arduino PWM pins to control the speed of the motors. Pin 12 is DC motor 2 enable jumper, leave this in place when using a stepper motor. Pin 13 and 14 will allow the user to attach the “+” and “-” terminals respectively of the second DC motor onto the module.

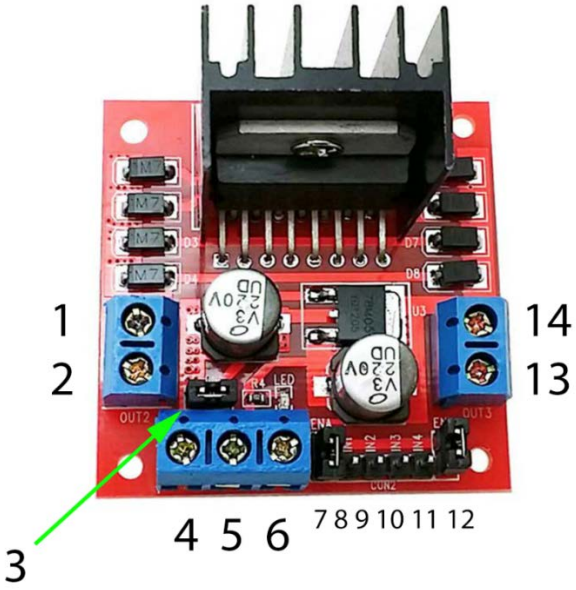

Figure 3.7: L298N Pinout

Table 3.6: IC Design Parameters [7]

Parameters	Value
Main Control Chip Name	*L298N*
Logical Voltage	*5 V*
Drive Voltage	*5 V ~ 35 V*
Logical Current	*0 mA~36 mA*
Maximum Power	*25 W*
Peripheral Dimensions	*43*43*27 mm*

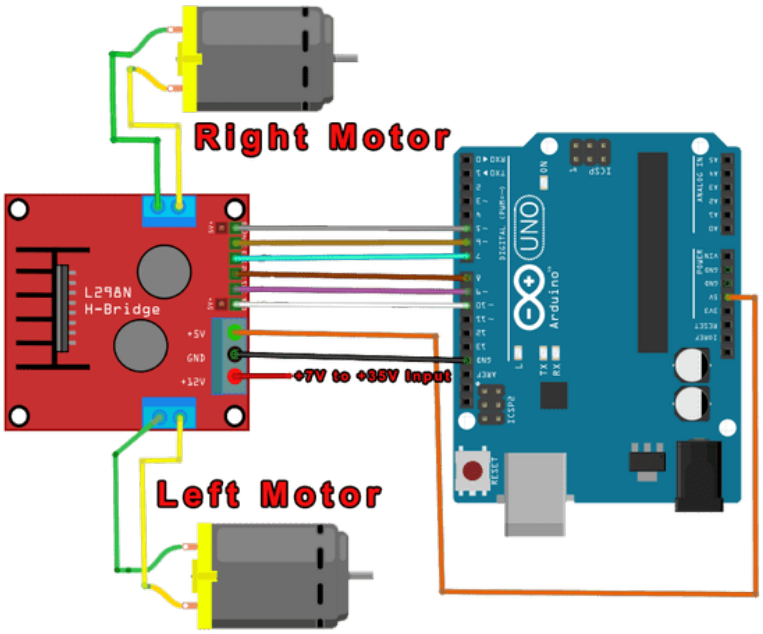

Figure 3.8: Wiring Design [8]

4 Remote System

4.1 Remote Controller

Table 4.1: Remote Controller on Hardware

Des 4.1.1-C	The remote shall be enclosed in a plastic enclosure weighing under 2 kilograms
Des 4.1.2-C	The remote shall contain two sets of switches to control the angle (vertical and horizontal) of the launcher along with a slider ON-OFF switch to turn the remote on or off
Des 4.1.3-C	The remote will contain a switch to select the strength of the launched ball
Des 4.1.4-C	The remote shall have two push buttons to fire the launcher and dispense treats

For our proof of concept, the remote controller communication protocol will be through infrared, or IR. Often used on television remotes, infrared beams are a common method in communicating with a device wirelessly. Infrared communication usually involves two components, a transmitter and a receiver. The transmitter consists of a light emitting diode, or LED, which produces a specific sequence of light “pulses” for an instruction. The receiver consists of a photodiode, where the pulses of light from the infrared LED are received and converted to an instruction which is read using a microcontroller such as an Arduino Uno. The remote controller will be responsible for controlling DoggyGo in manual mode. The remote features will consist of rotating and selecting

the launch distance of the launcher, dispensing treats, and launching the ball. The mock-up and dimensions of the remote controller in Table 4.2.

Table 4.2: IR Transmitter and Receiver Technical Specifications [9] [10]

IR LED (IR323) (Transmitter)		**IR Photodiode (KSM-603LM) (Receiver)**	
Diameter	*5mm*	**Dimensions**	*7.4*7.9*5.2 mm*
Peak Wavelength	*940 nm*	**Peak Wavelength**	*940 nm*
Pin Spacing	*2.54 mm*	**Max Receiving Distance**	*10 m*
Continuous Forward Current	*100 mA*	**Pin Spacing**	*2.54 mm*
Peak Forward Current	*1 A*	**Current Consumption**	*1.2~2.5 mA*
Operating Temperature	*-40~85 °C*	**Output Voltage**	*0.1V~5V*

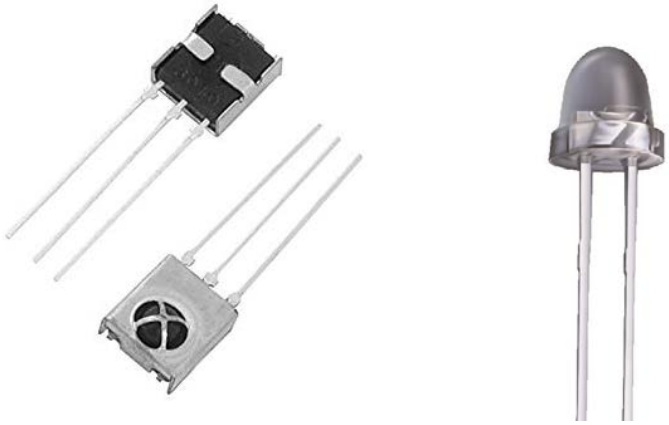

Figure: 4.1: Receiver and Transmitter [11] [12]

5 Power System

5.1 Power Specifications

In this chapter, we will specify the power supply for DoggyGo. In order to achieve safety and sustainability goals, we will use rechargeable batteries in our final product. To reduce development time and power, we will use an in-wall DC power supply for our proof of concept. Table 5.1 lists the power supply requirements below:

Table 5.1: Power Supply Requirements

Des 5.1.1-P	The power source provides 600~2750 mAh.

Des 5.1.2-P The power source provides 12V DC voltage.

Des 5.1.3-F The power source provides Max. energy at nominal voltage 12 Wh.

Des 5.1.4-F The power source is rechargeable.

Table 5.2 lists the parameters for motors power consumption in the product:

Table 5.2: Motor Power Parameters

Parameter	Value
Motor Internal Resistance	*25 Ω*
Maximum Current Draw	*0.6 A*
Maximum Input Voltage	*12V DC*

In DoggyGo, at most five motors will be activated. So, as a result, a conservative estimate for typical power is given below:

$$P_1 = 5 * R * I^2 = 5 * 25 * 0.6^2 = 45\,W$$

In addition to motor power calculations, the main system to control DoggyGo functionality, the Arduino Uno, must be also included in estimating the maximum power consumption of DoggyGo. The power consumption parameters for the Arduino Uno are shown in Table 5.3:

Table 5.3: Arduino Uno Board Parameters

Parameter	Value
Arduino Uno pin output voltage	*5 V*
Arduino Uno maximum current output	*0.3 A*

The maximum estimated power for the controller can be given:

$$P_2 = V * (I_1 + I_2) = 5 * (1.2 + 0.3) = 7.5\,W$$

Totally, the overall estimated power for whole system will be:

$$Ptotal = P_1 + P_2 = 45 + 7.5 = 52.5\,W$$

This power supply will offer both 12V DC voltage for the DC motors and 5V DC voltage for the Arduino Uno. Based on the above calculations, we will choose to use a suitable power supply that will be able to supply more than out maximum required current, voltage and power in order to avoid overcurrent on our power supply. With the maximum power consumption determined, we are able to calculate the appropriate battery required to power DoggyGo for a minimum of 2 hours. Table 5.4 summarizes our power consumption calculations and provides the power supply specifications.

Table 5.4: Power Supply Specifications

Parameters	Value
12V Maximum current	*3 A*
5V Maximum current	*2 A*
Total Maximum Power	*60 W*
Energy Capacity	*80 Wh*
Height, Width, Depth	*150*75*50 (mm)*
Mass	*1.10 kg*

5.2 Wiring

We will connect the 12V DC voltage source to our DC motors and connect a 5V DC voltage source to the Arduino on the other hand. The Table 6.5 provides a requirement summary of our wiring. In order to debug our system easier, different coloured wires will be used and organized in order to easily identify which wires are connected to which component.

Table 5.5: Wiring

Des 5.2.1-C	All wiring shall be insulated using PVC insulation.
Des 5.2.2-P	The 12V DC power shall be distributed to different components on the system using a terminal block.
Des 5.2.2-F	Wiring shall be organized using braided sleeving and zip-ties.

5.3 Safety and Sustainability

DoggyGo will be focused on safety in addition to finding the best solution for sustainability. Based on the above-mentioned configuration and specifications, DoggyGo will achieve a high safety rating. The wiring method discussed in section 6.2 will allow us to isolate power wires from signal wires to ensure safety. In order to achieve sustainability, we decide to use the AA rechargeable batteries in DoggyGo. The team at DoggyGo believes that we can offer a safe and sustain circumstance for users and will keep working on the better solutions.

6 Output System

6.1 Launcher

Table 6.1: Ball Launcher Requirement

Des 6.1.1-C	The torque of motor shall be able to shoot the ball to the maximum required distance of 9m at a vertical angle of 30°.
Des 6.1.2-P	The launcher vertical angle shall allow adjustments from +30° to +60° in 10° increments.
Des 6.1.3-P	The vertical angle of launching shall be adjusted gradually and accurately.
Des 6.1.4-P	The ball projectile shall be consistent and easily determined based on the configured parameters (angle/distance).
Des 6.1.5-F	The components used (motors, gears, springs etc.) shall operate effectively over a reasonable operational lifetime.

Based on the research of similar products, the most common tennis ball used for dog's toy is a mini tennis ball. The mini tennis ball is suitable for any size of dogs and it can be used both indoor and outdoor. The diameter of a mini tennis ball is 5 cm and the weight of the ball is 30 g.

From our requirement, the maximum distance of shooting the ball is 9 meters at a vertical angle of 30°. The projectile motion diagram is shown in fig 6.1.

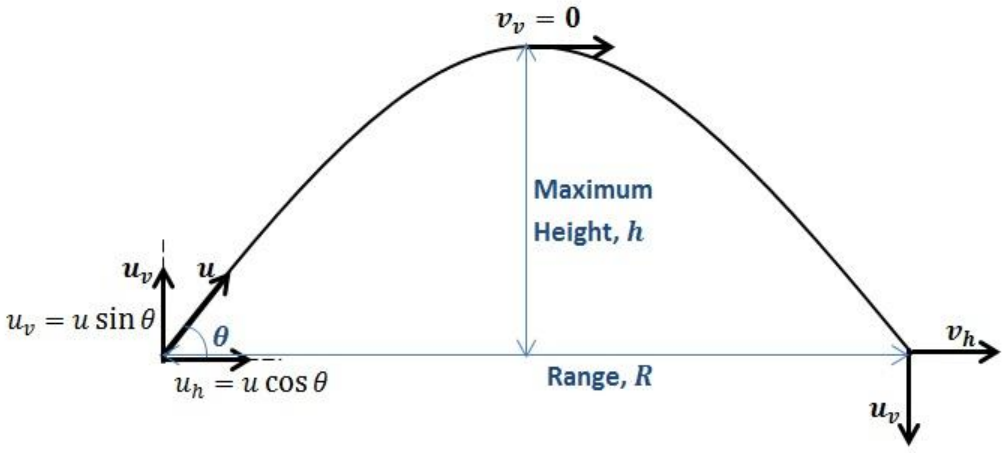

Figure 6.1: Projectile motion [13]

To calculate maximum initial speed v_0, we use $\theta = 30^o \; and \; R = 9m$. Using formula $R = \frac{V_0^2 sinsin\, 2\theta}{G}$, the maximum required initial velocity is $10m/s$.

Figure 6.2 shows the mechanism of ball launcher. The ball launcher uses two independent rotating wheels between which a tennis ball is held. When the rotating wheels are activated through the use of motors, the tennis ball will be squeezed between the rotating wheels and will be launched using a frictional force created by the contact between the ball and the rotating wheels. With DoggyGo's horizontal angle adjustment, the launcher will be able to shoot the ball at the angle we have

specified.

The launching distance can be changed by changing the rotational speed of the wheels using our motor driver.

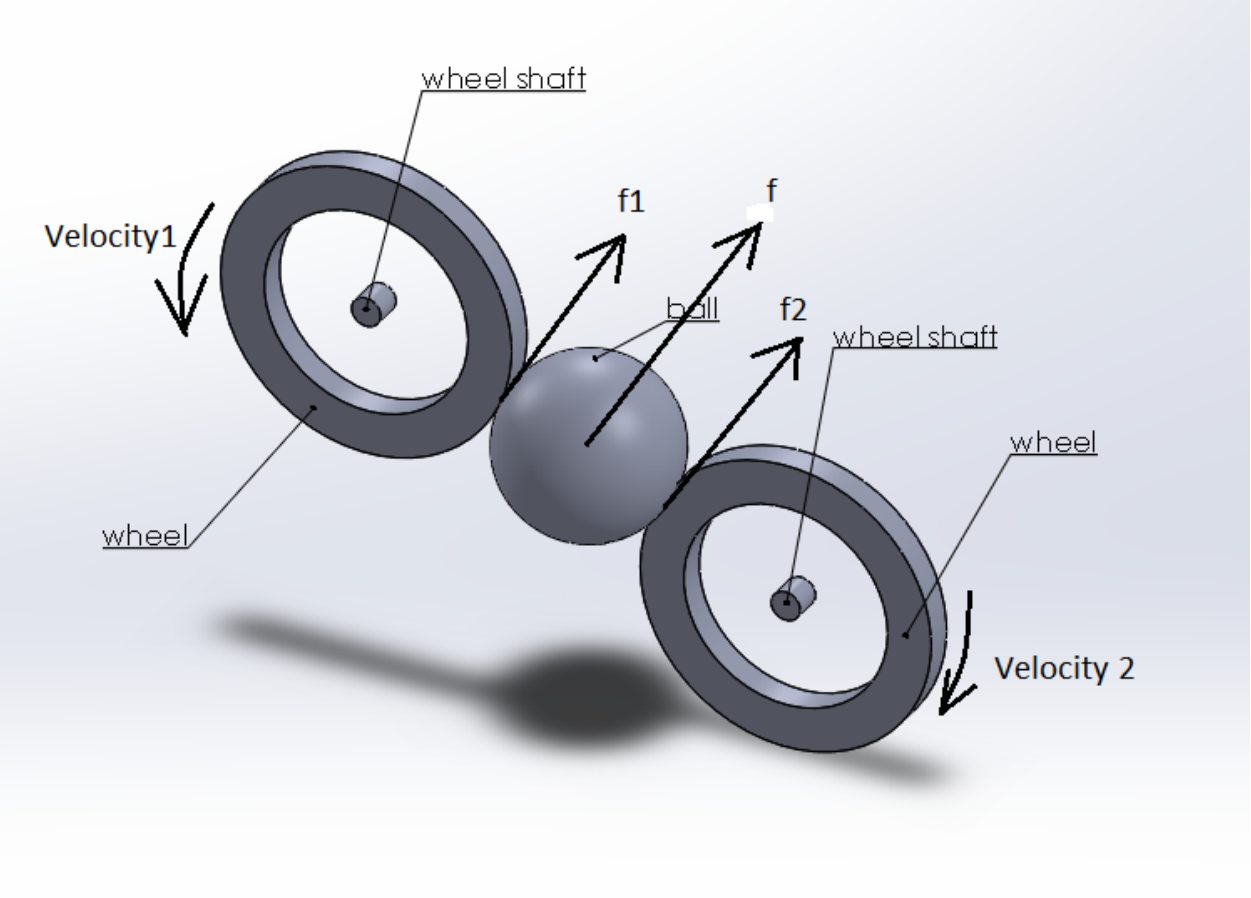

Figure 6.2: Launcher Dynamic Design

To achieve maximum power efficiency and space efficiency, we will connect a motor directly on the wheel shaft. In order to provide enough frictional force on ball, the motor must have enough torque and power. After researching and comparing, we choose to use Banebots First Cim Brushed DC Motor shown in Figure 6.3, and which parameters are listed in Table 6.2.

Figure 6.3: Banebots First Cim Brushed DC Motor

Table 6.2: Banebots First Cim Brushed DC Motor [14]

Specification	Value
Nominal Voltage	*12 V*
Stall Torque	*343 oz*in*
No-load Speed	*5280 rpm*
Diameter	*6.2 cm*
Length	*11.2 cm*

6.2 Treat Dispenser

Table 6.3: Treat Dispenser Requirement

Des 6.2.1-C	The treat dispenser shall work in both automatic and manual mode
Des 6.2.2-C	The dispenser shall dispense at least one treat each time
Des 6.2.3-P	The dispenser shall be able to accept treats up to a size of 3cm*3cm*3cm
Des 6.2.4-P	The dispenser shall be able to dispense any shape of treats.
Des 6.2.6-F	The treats shall be easy to load into treat container.

Figure 6.4 depicts the mechanism of treat dispenser. Every time a dog places a ball back in automatic mode, or when the ‘treat’ button is pushed in manual mode, the slotted rotor will rotate 90° to drop treat/treats in one slot. During this process, treats will be loaded into the next slot through the top of the rotor. A servo motor will be used to rotate the rotor to achieve an accurate 90° rotation. The radius of the slotted rotor will be 4~6 cm to make sure passing at least on treat with maximum size of 3cm*3cm*3cm.

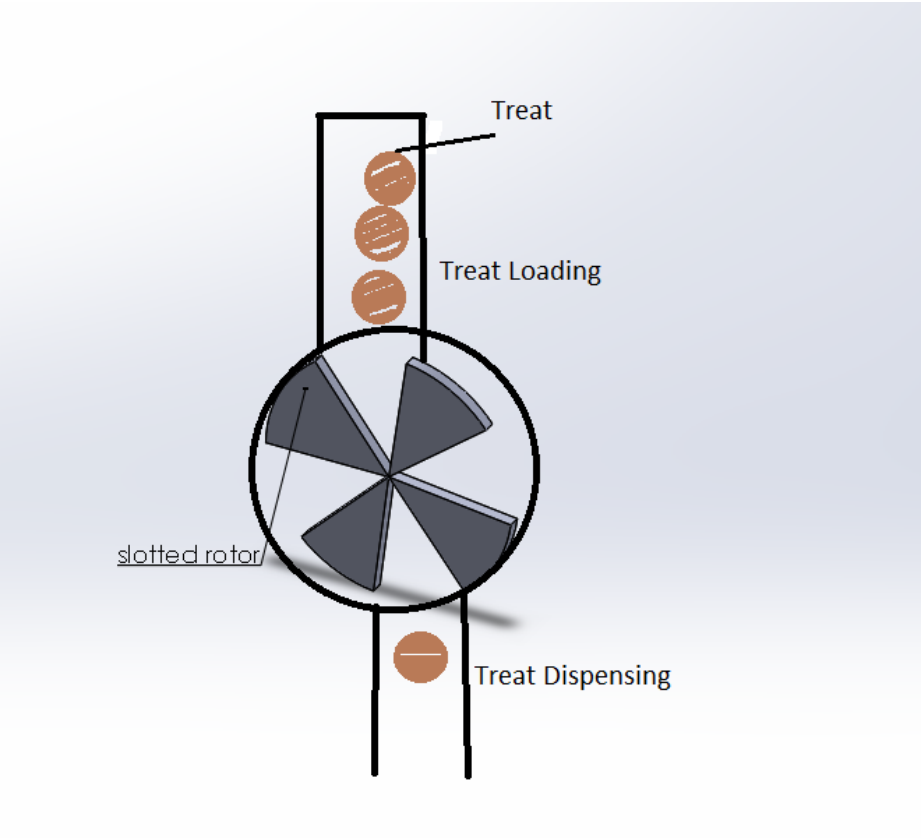

Figure 6.4: Treat Dispenser Mechanism

A SG90 servo motor is used in order to perform the rotational aspects of the treat dispenser. It's main purposes will be to ensure the proper dispensing angle, and to ensure that dispensed treats reach the correct destination. The specifications of a servo motor can be found in Table 6.3.1:

Figure 6.4.1: SG90 Servo

Table 6.3.1: SG90 Servo Motor Specifications [15]

Specification	Value
Operating Voltage	*5 V*
Torque	*1.80 kg*cm*
Speed	*500 degree / sec*
Weight	*9g*
Dimensions	*23 * 12.2 * 29 mm*
Number of Connections	*3 - pin*

6.3 Relay & Buzzer

6.3.1 Relay

A relay is a kind of electrical control device. When the current draw of a device exceeds the maximum available current from the power supply, it will damage the power supply by drawing too much power form the power supply. By using a relay, it will protect the circuit allowing a microcontroller to control a device through a signal to switch the device on and off instead of supply power to the device directly. It will be used as an electronic switch which turns on a device with a low power signal input. In summary, a relay performs a role of controlling high powered devices using low powered devices through the use of a relay. Therefore, it plays the role of ensuring the safety of our circuit by isolating high powered components from low powered components. Some examples of relays are shown on Figure 6.5:

Figure 6.5: Ordinary appearances of relays

Due to our requirement specification, we choose to use normal but high quality-guaranteed DC electromagnetic relays. With Arduinos being able to only supply 20 mA per pin, a relay is used as an electronic switch to turn on and off high-powered devices. The relay module shall contain two 5V DC relays. The specifications of the relay used are shown below. The VCC pin on the relay will be used to receive 5V DC from the Arduino in order to power the relay coils. IN1 and IN2

pins will be connected to the digital pins on the Arduino. When the Arduino sends a high signal (5V) into one of the IN pins, the relay module will turn on the relay, which in turn will turn on the device connected to the relay. When the relay module receives a low signal (0V) into one of the IN pins, the relay will turn off the connected device. On the terminal side, 2 out of 3 pins will be used: GND, NC, and NO. We will be using GND and NO as attaching in this configuration will result in a normally-open switch, which will turn on whenever a high signal is received from the Arduino. The dimensions and specifications of the relay module are shown below:

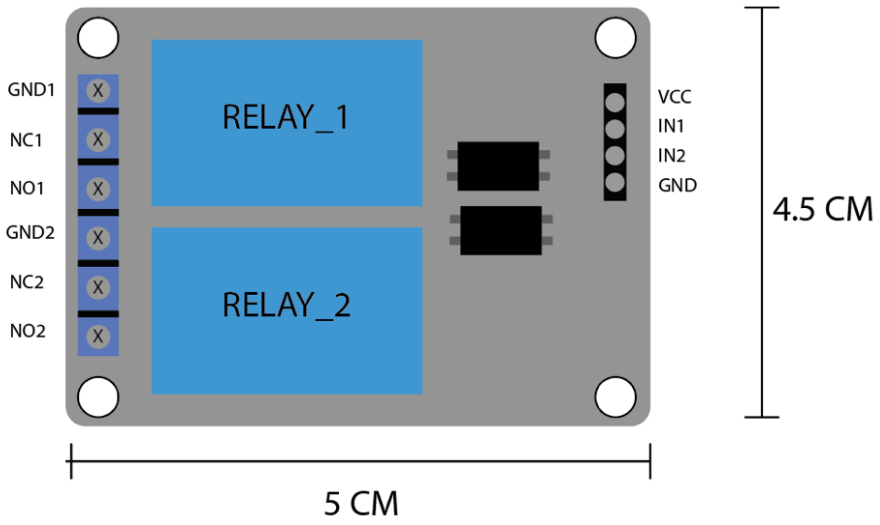

Figure 6.6: Dimensions and relay pinout diagram of 5V module

Table 6.4: Relay System Parameters [16]

Specification	Value
Operating Voltage	*5 V*
Maximum Power Rating (Volts / Amps)	*30V DC / 10A*
Relay Switching Technology	*Opto-isolated*
Dimensions (Length*Width)	*45*50 mm*

6.3.2 Buzzer

Buzzer is an integrated electronic loudspeaker powered by a constant DC voltage. The buzzer is mainly divided into two types: piezoelectric buzzer and electromagnetic buzzer. A buzzer will always have markings with the letter letters “H” or “HA” for easy identification. For the buzzer, we will be using an electromagnetic buzzer. Electromagnetic buzzer is constructed using an oscillator, an electromagnetic coil, a magnet, a vibration diaphragm, and all is encased in a plastic

shell. When the power is supplied to the device, the buzzer will generate an input current from the oscillator and will pass it through the electromagnetic coil, producing a magnetic field. The vibrating diaphragm will vibrate periodically and make a buzzer sound due to the magnetic field generated by the coil. The general electromagnetic buzzer from the market we choose is listed in the Figure 6.7:

Figure 6.7: General Electromagnetic Buzzer

Table 6.5: Buzzer Parameters [17]

Specification	Value
Operating Voltage	*3~24V DC*
Maximum Sound Level	*85 dB*
Maximum Current Consumption	*12 mA*
Mounting Hole Distance	*30 mm*
Physical Dimensions	*35*23*12 mm*

6.3.3 A Combination of Relay and Buzzer

We will connect the relay and buzzer in a series circuit. The relay will play a role as automatic switch to control the ON/OFF of the buzzer. In DoggyGo, the buzzer will make the sound when the sensors in the detection system detected the objects surround the launcher. After the launcher is all set and ready to shoot the ball, it can also make a sound to alert the surrounding for a couple of second before firing. The Figure 7.3 shows the overall specifications of Relay and Buzzer system.

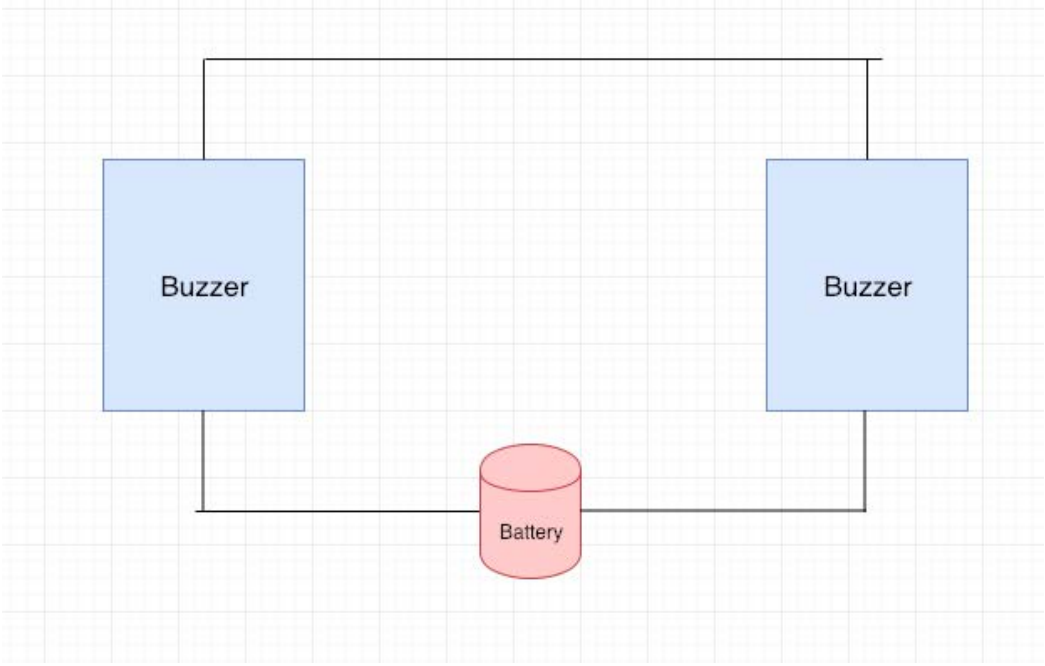

Figure 6.8: Overall Relay and Buzzer System

7 Top-level Controller

7.1 Arduino Uno

The Arduino Uno is a small computer that is built on an integrated circuit and is able to perform automated tasks on analog and digital inputs and outputs. The Arduino Uno will be responsible for controlling the ball launcher and movements involved with DoggyGo. DoggyGo will use the analog pins on the Arduino Uno to process distance data for our two ultrasonic distance sensors. The remaining components will be driven on the digital input and output pins. The Arduino Uno also contains a few PWM pins, which will be useful when driving motors. The wiring diagram and specifications of the Arduino Uno are shown in Figure 7.1 and Table 7.1 respectively.

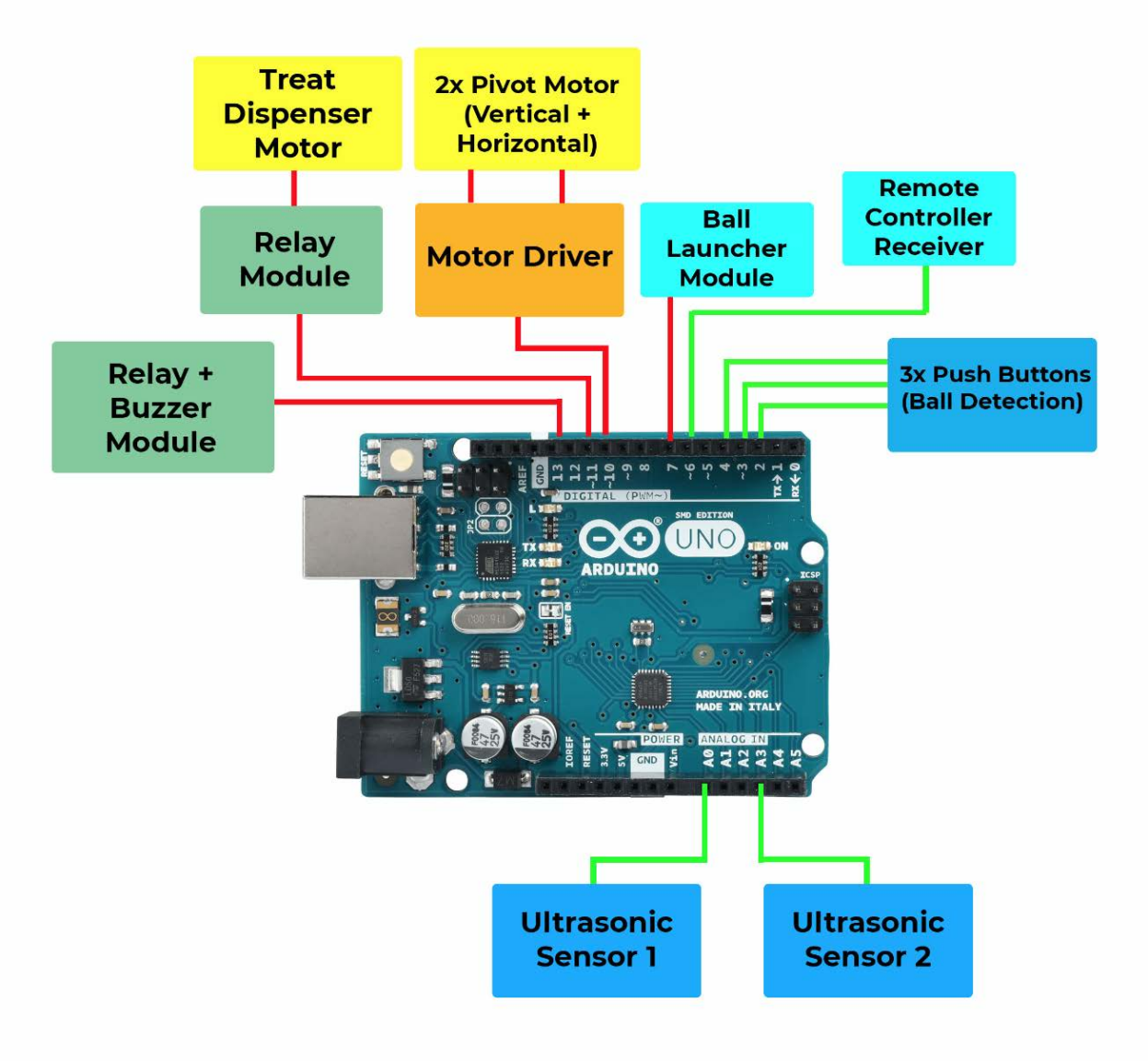

Figure 7.1: Arduino Uno Hookup Diagram

Table 7.1: Arduino Uno Technical Specifications [18]

Name	Value
Operating Voltage	*5 V*
Input Voltage	*6~20 V*
Number of Digital I/O Pins	*14 (6 pins are PWM)*
Number of Analog I/O Pins	*6*
DC Current Output Per Pin	*20 mA*

Clock Speed	*16 MHz*
Flash Memory Size	*32 KB (31.5 KB useable)*
Dimensions (Length*Width)	*68.6 mm*53.4 mm*

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A Test Plan

The main purpose of DoggyGo is to make friends with dogs and their owners, therefore having high-quality standards are necessary to meet the consumers' need. In order to ensure that DoggyGo will not cause any potential injury and property damage, DoggyGo Inc. members will maximize the efficiency and validity of DoggyGo through the use of test cases to verify those functionalities throughout the design process. The following tables illustrate the test plan:

Mechanical Testing		
Test Case	Result	Comment
1. Drive System - Horizontal Rotation	Pass/Fail	
Ability to vary the horizontal rotation (driven by servos) of DoggyGo using the remote.		
Expected Outcome		
The base shall be able to rotate at least ±60° horizontally in clockwise and counterclockwise direction around the geometric center of the launcher, in increments of 15°. The angle of rotating must be adjusted gradually and accurately.		
2. Drive System - Vertical Adjustment	Pass/Fail	
Ability to vary the vertical rotation (driven by servos) of DoggyGo using the remote.		
Expected Outcome		
The launcher vertical angle shall allow adjustments from +30° to +60° in 10° increments. The vertical angle of the launcher must be adjusted gradually and accurately.		
3. Drive System - Launch Strength	Pass/Fail	
Turn on the DC motors and vary the launch distance based on rotation speed of wheels controlled by the remote.		
Expected Outcome		

The torque of motor shall be able to shoot the ball to the maximum required distance of 9m at a vertical angle of 30°. The launch strength must be adjusted gradually and accurately.		
4. Treat System - Treat Dispenser	Pass/Fail	
When an animal returns the ball back to the launcher, the proximity sensor will detect the returned ball and the treat dispenser will provide treat to the animal.		
Expected Outcome		
1: The treat dispenser shall work in both automatic and manual mode (controlled using a remote). 2: The dispenser shall provide at least one multiform treat each time without being stuck in the dispenser.		

Electrical Testing		
Test Case	Result	Comment
1. Power Supply - Operating Conditions & Safety	Pass/Fail	
Turn on the power supply and measure the voltage and current at the output on both delivery system and microcontroller.		
Expected Outcome		
1: The power draw from DoggyGo shall not exceed a maximum of 12V DC at 3 Amps. 2: The input voltage to the microcontroller must be between 3-12 V DC.		
2. Power Supply - Sustainability	Pass/Fail	
The battery on DoggyGo is able to be recharged and able to last for a certain period of time.		
Expected Outcome		
The batteries must be rechargeable, providing a minimum of 4 watt-hours.		
3. Wiring		

Check that all wires are appropriately insulated in PVC insulation and organized in a safe manner.	Pass/Fail	
Expected Outcome		
1: All wiring shall be insulated using PVC insulation. 2: The 12V DC power shall be distributed to different components on the system using a terminal block. 3: Wiring shall be organized using braided sleeving and zip-ties.		

Hardware Testing		
Test Case	Result	Comment
1. Feedback System - Sensors	Pass/Fail	
Check that all sensors are successfully working with specific and suitable detection range.		
Expected Outcome		
1: Ultrasonic sensors shall detect distances up to 3 meters. 2: One proximity sensor shall detect the ball in launcher pocket. 3: Three proximity sensors shall detect the amount of balls contained in the launcher.		
2. Feedback System - Buttons	Pass/Fail	
Push the ON/OFF button to activate the launcher. Push the mode button to switch mode between manual mode and automatic mode.		
Expected Outcome		
1: Once DoggyGo is turned on, it will be operate based on the selected mode. 2: It can switch between manual mode and automatic mode. 3: The buttons shall be easy to change states and should not contain any intermediate states.		
3. Motors & Gears		

Check that the motors and gears can achieve the goals of rotation and launch strength without exceeding the motor and gear specifications.	Pass/Fail	
Expected Outcome		
1: The launcher vertical angle shall allow adjustments from +30° to +60° in 10° increments. 2: The launcher horizontal angle shall allow adjustments from -60° to +60°. 3: Maximum required distance of 9m at a vertical angle of 30°.		
4. Remote Controller - Adjustment	Pass/Fail	
1: Check that users can adjust the angle, direction, launch strength and provide treats by remote.		
Expected Outcome		
The angle, direction, launch strength and treat system are adjustable by remote.		
5. Remote Controller - Notifications	Pass/Fail	
1: Check that the indicator LED will illuminate if the detection system works. 2: Check that the indicator LED will illuminate if the remote is low on battery.		
Expected Outcome		
1: The indicator LED will prompt users if the detection system has detected the objects. 2: The indicator LED will prompt users if the remote is low on battery.		

B User Interface Design

B.1 Introduction

DoggyGo Inc. strives to create a pet toy, namely DoggyGo, which automates the entertainment procedure for lonely pets at home and have the ability to operate in manual mode to allow the owner to interact with their pets in more ways. This design gives rise to a User Interface (UI) which is simplistic in nature and requires only a few input parameters from users.

DoggyGo's prototype iteration will contain the following main UI components:

1. **Power Button**

   Once DoggyGo is positioned in place, user will press this button (Red) to turn DoggyGo on/off.

2. **Mode Switch (Auto <-> Manual)**

   As DoggyGo has the ability to operate in two different modes for different conditions, the user is able to select the desired mode by sliding the switch to their desired mode.

3. **Remote Controller (Manual Mode)**

   Once DoggyGo is set in manual mode, all behaviours (launch angle, treat dispense, launch ball) of DoggyGo can be controlled by a portable wireless remote.

4. **Speaker**

   If the ball is ready to launch or some errors or problems are detected, the speaker will be sound to notify the user.

5. **Dispenser Box**

   DoggyGo will contain a removable cover for the user to refill the treats and the cover will be clear to allow the user to see the remaining treat amount.

B.1.1 Purpose

This document aims to aid potential users in understanding DoggyGo's main features and how to utilize them through its simple UI design. To achieve this, diagrams illustrating key UI design related concepts and component placements will be presented. These diagrams will be followed by brief descriptions explaining the reasoning behind each UI design choice.

B.1.2 Scope

As DoggyGo is in its early design stages, this document will focus on its Proof of Concept (PoC) and Prototype iterations. As the result, the following key topics will be discussed:

1. **User Analysis (B.2)**

   Looks into the required user knowledge for safe operation procedures. Additionally, this section will clearly state any restrictions or limitations of DoggyGo which the user may need to be aware of.

2. **Technical Analysis (B.3)**

   Presents crucial elements of any UI design/interaction, namely Discoverability, Feedback, Conceptual Models, Affordance, Signifiers, Mappings and Constraints.

3. **Engineering Standards (B.4)**

   Lists specific engineering/safety standards that DoggyGo's UI must be adhere to in order to be a marketable product.

4. **Usability Testing (B.4)**

   Details both the analytical (designer perspective) and empirical (client perspective) usability testing/scenarios that DoggyGo Inc. members need to consider.

B.2 User Analysis

DoggyGo's primary intended consumers are all pet keepers. With the product designed for lonely pets as home (when operated in automatic mode), DoggyGo's main goal is to avoid any unexpected injuries for pets and users and to avoid any damage on surrounding objects that exists in a home environment. Therefore, the product shall be placed at somewhere is relatively open. The prototype or product shall not have any sharp edges and corners, and it shall be enclosed to avoid pets damaging the internal components.

As mentioned above, DoggyGo aims to automate the entertainment procedure for lonely pets at home. This drastically simplifies the UI components, making DoggyGo simple to understand and useful for many potential users who have minimal or no prior experience in operating robotic equipment.

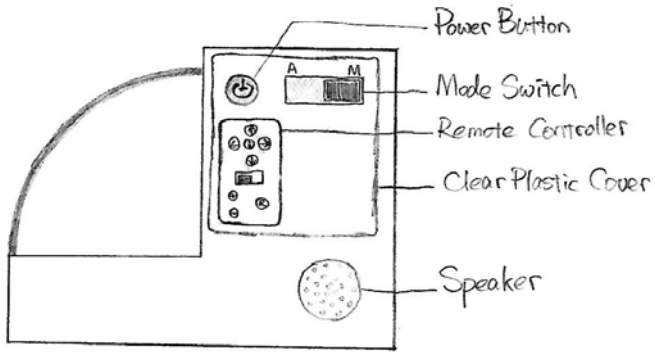

Figure B.2.1: Control Panel Interface

The figures above and below show the interface design on DoggyGo. Figure B.2.1 represents the control panel of DoggyGo. The control panel contains the power button and mode switch along with a place to hold the remote. The remote used to operate DoggyGo in manual mode is shown in in Figure B.2.2. All of the components described above will be covered by a clear plastic cover to avoid pets from damaging the components on DoggyGo.

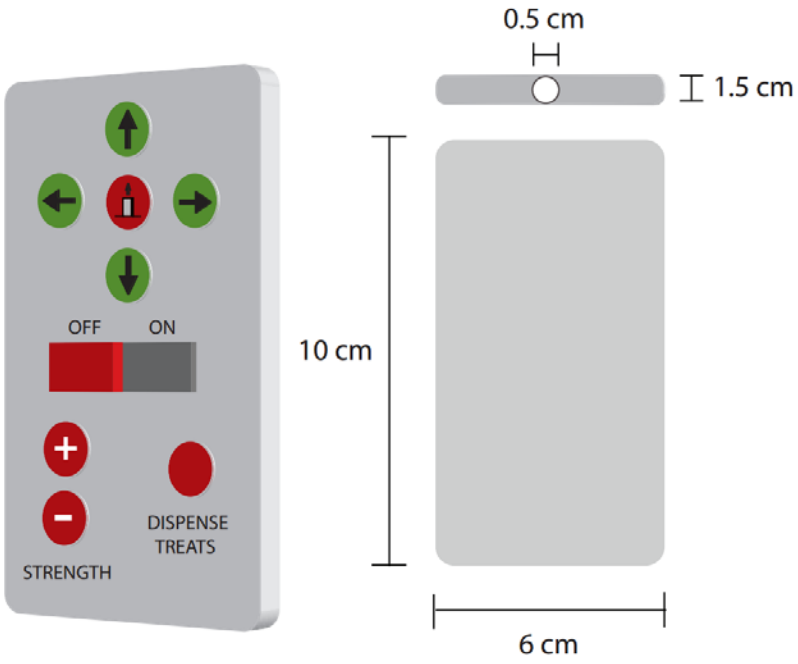

Figure B.2.2: Remote Controller Interface

Figure B.2.3 represents the other side of DoggyGo. The dispenser gate is located on the top, which will be used to refill the treats and will contain a clear window below the dispenser gate to check the remaining number of treats.

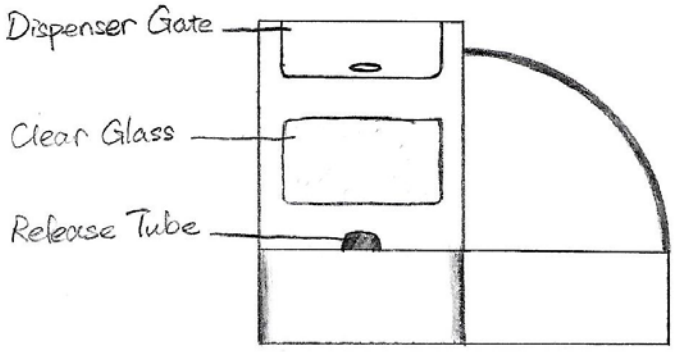

Figure B.2.3: Dispenser Box Interface

B.3 Technical Analysis

The following section outlines how DoggyGo will comply to UI standards based on Don Norman's "Seven Elements of UI Interaction" describe in the book The Design of Everyday Things: discoverability, feedback, conceptual models, affordances, signifiers, mappings, and constraints.

B.3.1 Discoverability

Discoverability describes the ability for a user to determine the actions that are able to be applied on a device based on their initial observation. For instance, when a user receives a phone, a first initial action they would attempt would be to turn on the device, which most people would intuitively determine the button will be on the top or the side of the device.

DoggyGo aims to achieve the highest discoverability to reduce the time required for a user to learn the operation of the device by maintaining a low count of user interface objects (switches or buttons) on DoggyGo's UI elements and clearly labeling each object.

On DoggyGo itself, the device shall only have (insert the details of switch and button on DoggyGo) with labels regarding each function clearly described above each user interface. For instance, the power plug shall only allow one orientation to allow the user to easily connect DoggyGo to a power source.

The remote controller shall contain large buttons as shown in Figure B.2.2 and are clearly labeled. The space between buttons shall be separated with adequate space to avoid activating a wrong button and affecting the user experience.

B.3.2 Feedback

With a ball launcher device, feedback is important to ensure the safety of the device in addition to the overall enjoyable experience.

The dog ball launcher will be driven on a feedback system consisting of sensors. Through the use of two ultrasonic sensors, DoggyGo will be able to determine whether or not the area is free of obstacles before the ball is launched. As shown in Figure B.3.1, DoggyGo will have a wide detection range to ensure the safety of animals.

By using a buzzer on DoggyGo, the system is able to provide feedback to the user. Before the ball is launched, an audible sound will be produced to warn any users within the surroundings that a ball will be launched from the launcher. When the launch sequence for the ball launcher is aborted, DoggyGo will produce a unique error sound to notify the user that the ball launching sequence has been aborted due to an obstacle detected in the surroundings. The feedback system is shown in Figure B.3.1.

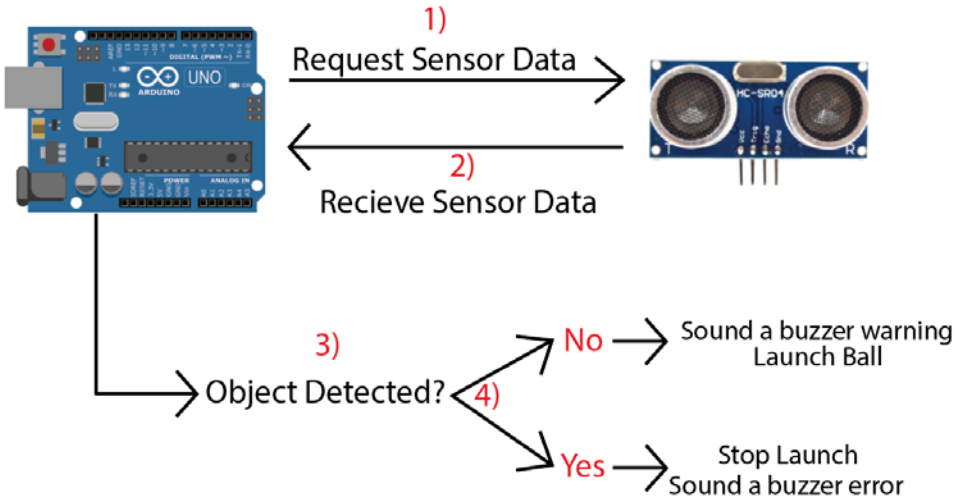

Figure B.3.1: Feedback System

In DoggyGo, a light emitting diode, or LED, will be placed beside the power input to let the user know that the device is properly powered and ready to be used when the light is illuminated.

B.3.3 Conceptual Models

Conceptual models are important to allow the user to understand the functionality of a device that is not usually noticed when using the device. Figure B.3.2 shows a conceptual model between DoggyGo and the remote controller:

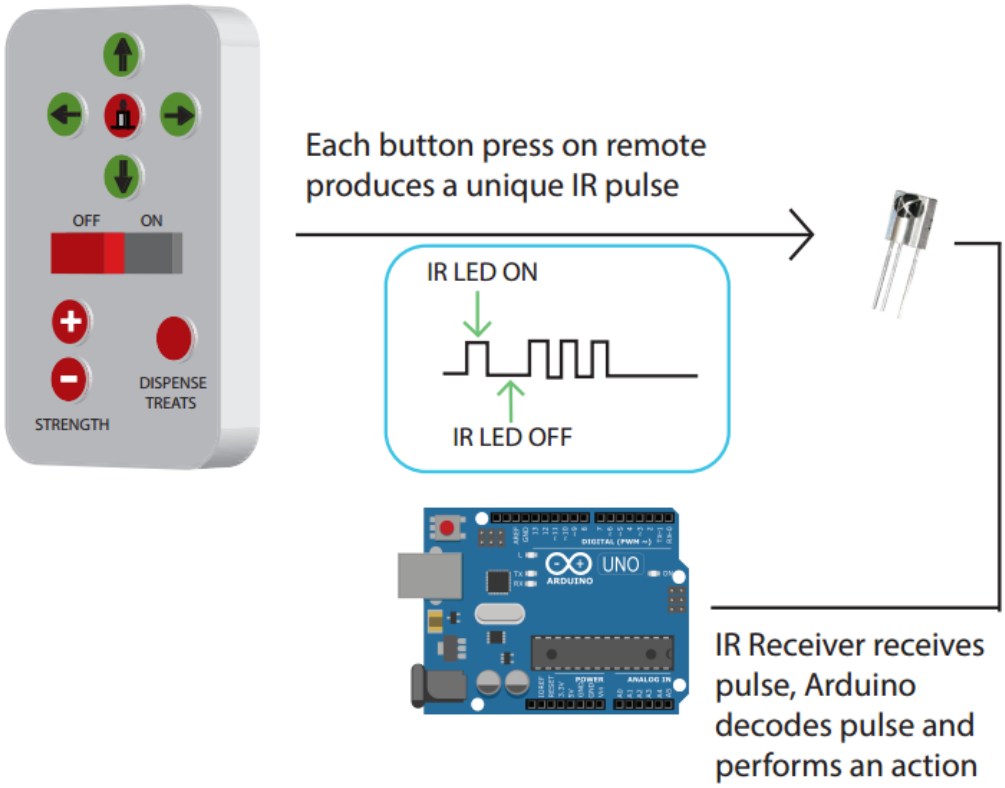

Figure B.3.2: Conceptual Model Interaction

B.3.4 Affordances

Affordance uses physical characteristics to describe possible actions a user can perform on a device. With DoggyGo, minimal user interaction is required as the ball launching and treat dispensing is all automated in automatic mode, minimizing user interaction. By activating a switch on DoggyGo, a user is able to use the provided remote in order to control DoggyGo's treat dispensing and ball launching parameters. DoggyGo also features a remote holder to allow the user to store the remote when the remote is not in use.

B.3.5 Signifiers

In addition to affordances, signifiers are an important aspect in producing a good user interface. As described in the feedback system, DoggyGo will have an LED on the device to indicate whether or not the device is on. The treat storage location for the treat dispenser and battery compartment

for the DoggyGo remote will be clearly labeled and will have an arrow on the lid indicating the correct direction to open the lid, as shown in Figure B.3.3.

Figure B.3.3: Treat Storage

B.3.6 Mappings

Mapping describes the positioning on UI elements on a device to control various actions on the device. The power button will clearly be labeled on DoggyGo making it easily understandable. On the remote controller for DoggyGo, the layout shown in Figure 2.2 will be similar to a TV remote with the action button being surrounded with directional arrows, making it easy to understand for users who have used similar remotes before. To minimize any understandings, the strength selection and dispense treats button will be labeled and adequately spaced apart to avoid any mis clicks from the user.

B.3.7 Constraints

Constraints in UI are implemented features in a device to prevent a product from being used in an incorrect way. In DoggyGo, all the electrical components in DoggyGo shall be properly enclosed to protect from being damaged during transit. The treat box lid shall be pet-resistant to prevent the pet from obtaining treats when the device is not in use. All wiring including signal and power wires shall be securely attached to a mounting point and will not expose any bare wires. In the final product, the battery charging port shall be protected using a port cover to prevent any metal objects from shorting the port and potentially become a fire hazard.

B.4 Engineering Standards

B.4.1 General Considerations

To appeal to the market and offer optimal end user experience for all of the main interactions, such as activation and deactivation, DoggyGo's UI design will be built by and tested against the following engineering standards:

1. **IEEE 1621-2004**

   IEEE Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments [19].

2. **IEEE 1012-2012**

   IEEE Standard for System and Software Verification and Validation [20].

3. **ISO 9241-161-2016**

   Ergonomics of human-system interaction – Part 161: Guidance on visual user-interface elements [21].

B.4.2 Safety Considerations

Safety is the most significant aspect of any product UI design. The team at DoggyGo Inc. has considered various potential hazards that may impact the user, such as electrical shock while handling the batteries. To maximize user safety, DoggyGo design stages shall meet the following standards:

1. **ANSI C 18.2M**

   Part 1-2013 American National Standard for Portable Rechargeable Cells and Batteries - General and Specifications [22].

2. **C22.2 NO. 0.23-15**

   General requirements for battery-powered appliances [23].

3. **NFPA (Fire) 70**

   Temperature thresholds for the electrical components [24].

B.5 Usability Testing

Usability testing is important for company to gain further information about the potential problems that users may face when they use company's products. According to this information, DoggyGo Inc. can improve their products' defects before the products go to market. Below is the usability testing performance for DoggyGo.

B.5.1 Analytical Usability Testing

One stage of usability testing is analytical usability testing. In the analytical usability testing stage. DoggyGo will start a series of product tests to determine the problems and inconvenience that the company overlooked when designing the user interface for the products. The list below are the principles for testing that DoggyGo Inc. will refer to.

1. **Buttons**

   The on/off buttons will provide physical feedback when it is pressed. The switch button contains a small bar for user to control the state of the switch. All buttons on DoggyGo as well as the remote controller are labeled with their corresponding functionalities and shall be clearly visible.

2. **Angle Scale**

   The angle scale will be indicated on DoggyGo itself with the angle increments labeled. The angles drawn on DoggyGo shall be drawn to scale to allow the user to determine the launch angle.

3. **LED Display**

   The LED shall illuminate red when it is charging. The LED shall illuminate green when the power button is in an "on" state. The LED shall not be illuminated when the power button is in an "off" state. The LED shall be located at highly visible area.

4. **Track Size**

   The size of ball track must be adequately large to fix the size of the ball. The size of the ball's entrance must be larger than the size of the ball to ease use. The output for the treat dispenser must be larger than the treat size to avoid jams. The size of the launch port is larger than the size of the ball.

5. **Remote Control**

   The remote control contains eight buttons. Four buttons for adjusting the horizontal and vertical angle, one for power on/off, two buttons to change the launch distance, and one button for dispensing treats.

6. Edges and Corner

The edges around DoggyGo will be smooth and every corner of the product will be cambered and smooth.

B.5.2 Empirical Usability Testing

Another usability testing is empirical usability testing. In empirical usability testing stage, Members in DoggyGo will contract dog owners to use DoggyGo with their dogs. Users will be asked to conduct a series of simple and functional operations. The members in DoggyGo will document the feedback that the users provide about their experience and suggestions for potential improvements on the product. The information below will describe the safety and functional user guides along with questions for users to exercise in order to minimize potential errors during testing.

For button and remote control, users will be asked to use every button to determine

- If the functional names are labeled correctly
- If the LED display matches the button states, such as the LED being illuminated green when user turns on DoggyGo using the power switch
- If the functional name labels on the switches matches the actual button functions. Examples include such as the ball will launch automatically (suppose it's safe) when DoggyGo is set in automatic mode from the user.
- If the product's actions match the actions that the remote requested.
- If all the buttons are visible and easy to find when user uses the product.

For track size, users will be asked to put the specific ball into the ball entrance and then launch the ball to see if the ball can be launched successfully. If the track size is designed correctly, the ball shall be able to be launched out from DoggyGo consistently without any jams occurring.

For the angle adjustment, users will be asked to change the launcher angle horizontally and vertically before launching the ball. If the launch angle matches the angle the user set, this will mean that DoggyGo angle adjustment is working as expected and the rotation system in functioning properly.

For the edges and corners on DoggyGo, users will be asked to analyze the product and determine if there are any edges or corners that can lead to injuries to pets or surroundings.

Once all of the tests are completed, members in DoggyGo will review all the feedback and suggestions. There will be some reasonable improvements to our product based on feedback and suggestions. After revising the product, the latest version of the product will be tested again to confirm everything is work good before releasing this product.

In conclusion, the goal of DoggyGo is to ensure the users and their dogs have a safe experience when they use the product. The usability testing is necessary and important to improve the product.

B.6 Conclusion

User interface is very important to make a product that is easy to operate. Through the use of the seven elements of UI interaction, DoggyGo is able to achieve a high user interface standard.

For DoggyGo's proof of concept stage, the UI design will mainly be focused on the button and switch placement. The main purpose of the proof of concept is to setup and verify the functionality of DoggyGo. Each button or switch shall be spaced adequately between each other to prevent any misclicks.

In DoggyGo's prototype stage, labelling of buttons, switches, and lids will be performed to further clarify the user interface. As shown in Figure B.2.2, similar buttons for similar actions will be labeled as the same color to allow the user to easily find buttons that perform similar actions. In addition to labelling, calibration to the object detection feedback system shall be performed to increase the accuracy of object detection.

DoggyGo's final product shall be consist of design features to protect the device. A cover shall be added on the power plug to protect the battery charger from any damages. The treat dispenser cover shall be constructed in a pet-resistant design to prevent pets from opening the cover when the device is not in use.

With user interface design, continuous improvements are necessary as the product is distributed to a wider range of users. DoggyGo aims to maintain the highest level of UI design using a feedback system from users to ensure that the device is easy to use.