March 16, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 440W Design Specifications for a Motion Sensing Cat Toy

Dear Dr. Rawicz,

Please accept the following document as design specifications for our Motion Sensing Cat Toy. We aim to design and implement a cat toy that is more interactive and lively for cats to have an enjoyable and fun chase. Our design consists of an ellipse shape toy that will sense motion and roll to attract the cat's attention.

The purpose of this design specification is to describes different subsystems of the project in detail and outlines the performance specifications of each component. Wherever possible, we have included diagrams to further explain the functionality. The document also includes a detailed test plan that we will use to ensure that our subsystems are functioning as expected, prior to integration.

CatStone consists of four motivated, innovative, and talented fourth-year engineering students: Jjay Chen, Genevieve Wong, Xiang Wu, and Jason Xu. If you have any questions or concerns about our proposal, please feel free to contact me by phone at 778-889-0830 or by e-mail at gsw5@sfu.ca.

Sincerely,

Genevieve Wong
Chief Executive Officer
CatStone

Enclosure: Design Specification for a Motion Sensing Cat Toy

Design Specifications
for a Motion Sensing Cat Toy

Project Team: Junjie (Jjay) Chen
Genevieve Wong
Xiang Wu
Chunhuan (Jason) Xu

Contact Person: Genevieve Wong
gsw5@sfu.ca

Submitted to: Dr. Andrew Rawicz – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science
Simon Fraser University

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Abstract

As living quality enhances with technology, more and more cat owners are willing to invest on better quality cat toys to enhance their cat's living quality as well. Although cats are known to equip the skills of turning everything, such as newspaper strips, paper bags, and milk ring, into their toy, they still desire for something more interactive, lively, and safe.

Cats are very fond of all sorts of ball shaped toys. The movement of a ball along a surface mimics the movement of scampering mice or other prey animals, which will entice cats to chase. Furthermore, some of these toys allow owners to insert treats or catnip into them to make the experience for their cats more rewarding and exciting. Others have bells, small objects, or LED lights inside them to make noise or lights to attract the cat's attention. Some common types of ball toys are wadded-up paper balls, Mylar balls, Ping-Pong balls and sponge balls. The disadvantages of these products are that they will remain motionless until cats approach them. This makes these toys less attractive and the cats will eventually lose interest in playing with them.

This document lists the design specifications that have been created for the motion sensing cat toy - Purrsuit. These design specifications were created following the guidelines set forth in our previous document, Functional Specifications of the Motion Sensing Cat Toy. All functional specifications have been strictly adhered to in order to ensure a quality product.

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List of Figures and Tables

1. Introduction

Purrsuit is the purr-fect toy for your furry little friend. It is a cat toy that can detect a cat's approach and react to roll towards the opposite direction, mimicking a fearful escaping prey for the cat to pursuit. Unlike most cat toys, Purrsuit will deploy into action without the need of the cats' initiation. Its unique ellipse shape makes the toy wobble when rolling away, increase its attractiveness. In addition, an ellipse shape makes the toy impossible to 'tip over' and become unable to move. Thus, giving cats an unlimited amount of fun chase. The requirements for Purrsuit, as proposed by CatStone, are described in this design specification.

1.1. Scope

This document outlines the detailed design specifications of Purrsuit. It explains how the design meets the functionality of the system including the shell, offset weights, sensors, microcontrollers, and the overall system functionality. Furthermore, requirements listed in this document will be used as guidelines for the design, development, and testing of Purrsuit to ensure safety and reliability.

1.2. Intended Audience

This design specification is intended for use by all members of CatStone. Our team will refer to this document as overall design goals through development. This document will also be used to justify any design decision as well as serve as a template for future modification, if any issues are encountered during the testing and quality assurance stage before finalizing the product.

2. System Overview

Our product, Purrsuit, is designed for detecting the cat approaching direction in a proper range and responding as a motion in an opposite direction. After sensor receive the direction information from the cat, it will create a digital signal and transmit it to our microcontroller. The microcontroller will output an electronic activate signal to each of the four sensors to control specific rotating speed of each motor, which enable the toy keep distance with our animals.

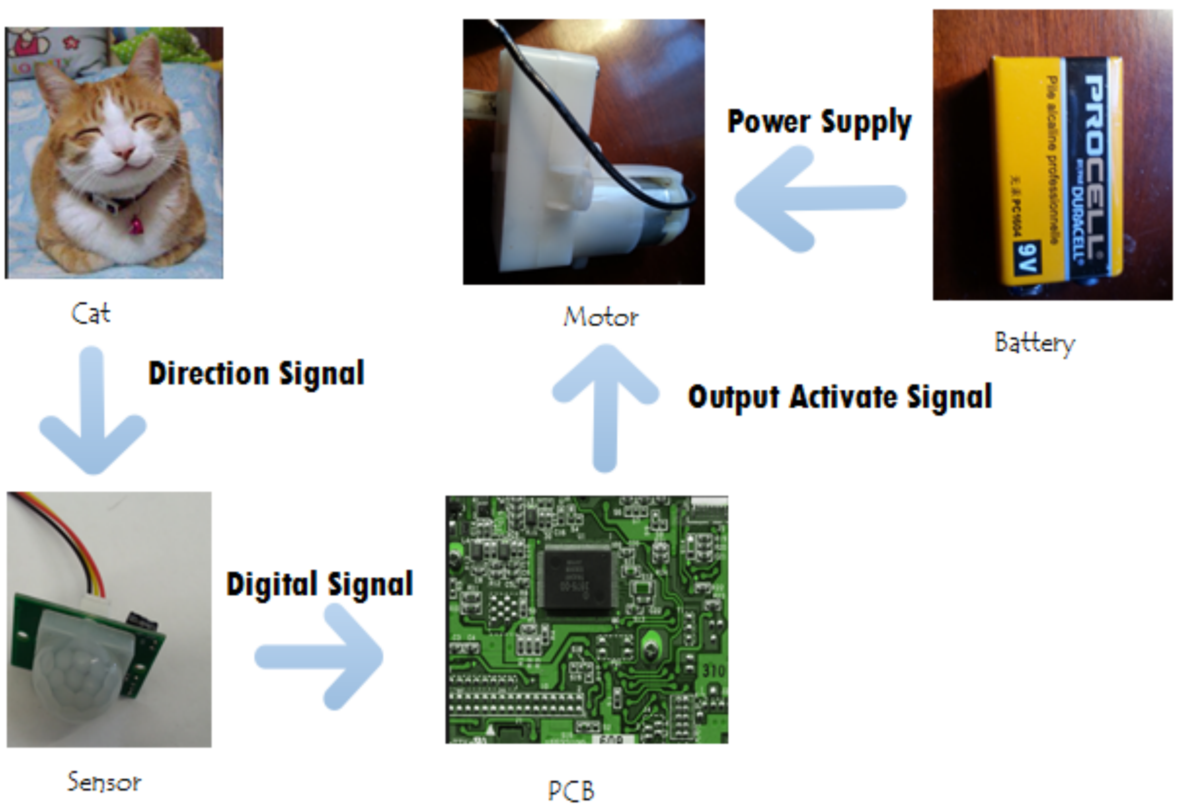

Figure 1: System Specific

3. Motion Sensor Unit[1]

Our motion sensors main function is to detect if the cat has entered an area range from the cat toy. We do not need to know the actual distance of the cats or how many cats are presences. With such, PIR sensors are the best and simplest option. They are small but have a wide lens range, low power, low cost, easy to use, and do not wear out.

3.1 Detecting Area

We do not want a big rectangular sensing-area, but rather a scattering of multiple small areas. PIR sensor has a lens that splits up the lens into multiple sections, each section of which is a Fresnel lens. The radiation range of PIR sensor is 2.4 meters in horizontal direction and 5 meters in width.

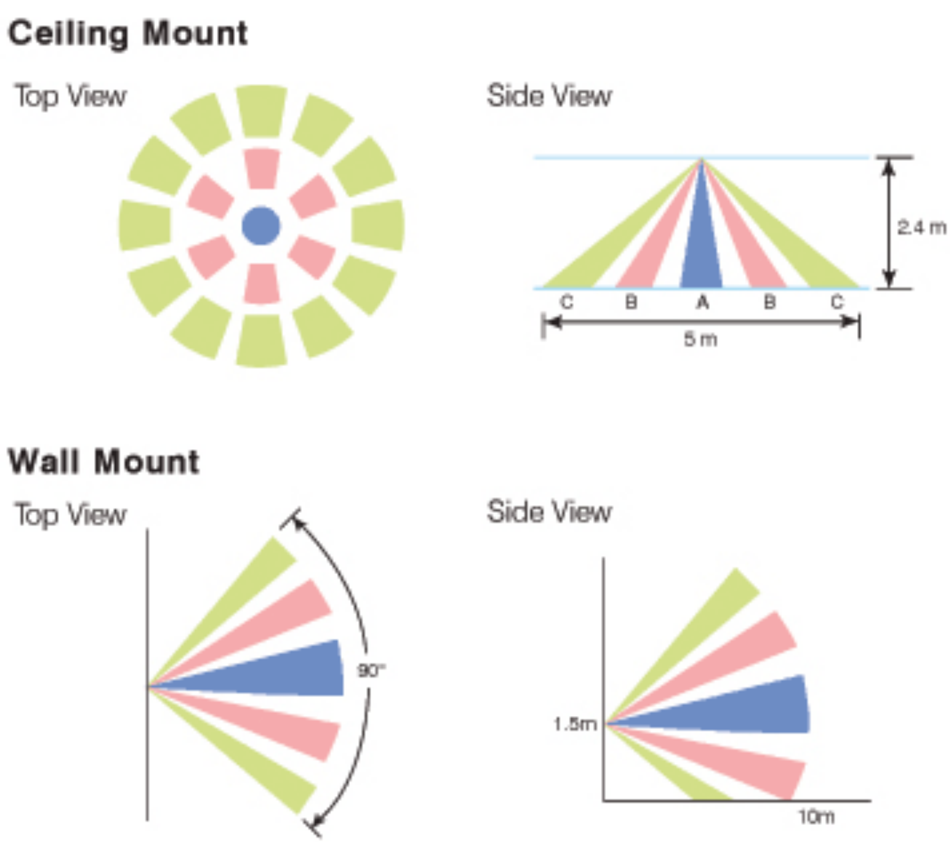

Figure 2: Lens Cutting and Sensing Range

3.2 PIR connection

PIR sensors have a 3-pin connection, which are power, ground, and output respectively. Power is usually 3-5V DC input but may be as high as 12V. When the PIR detects motion, the output pin will go "high" to 3.3V. Connecting PIR sensors to a microcontroller is really simple. The PIR acts as a digital output, so all it need to do is waiting for the pin to flip between high (detected) and low (not detected). Power the PIR with 5V, which uses the microcontroller’s voltage regulator, and connects to the ground. The output of PIR connect to a digital input pin 3 which shown as below.

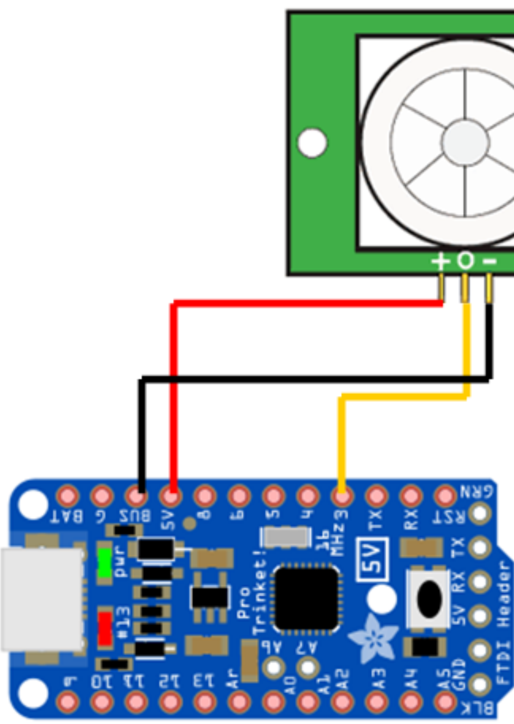

Figure 3: Sensor and Microcontroller Connection

4 Microcontroller (Pro Trinket) Unit[2]

Microcontroller module is the major unit of our cat toy. It analyzes the motion sensor input and outputs motor operations to rotate the cat toy. The microcontroller we selected is Pro Trinket from Adafruit. Pro Trinket has 28K flash memory and 2K RAM with high speed processing performance.

With limiting space inside the cat toy, the microcontroller we are selecting must be as small as possible. In addition, we need at least 8 I/O pins for receiving signal from PIR and transmitting signal to motor driver. By researching various kinds of mini microcontrollers, the adequate one is Pro trinket.

The Pro Trinket uses the Atmega328P chip, which is the same core chip in the Arduino UNO/Duemilanove/Mini/etc. It's the 'classic' Arduino chip, and the control logic is written in C++ language under the integrated development environment of Arduino.

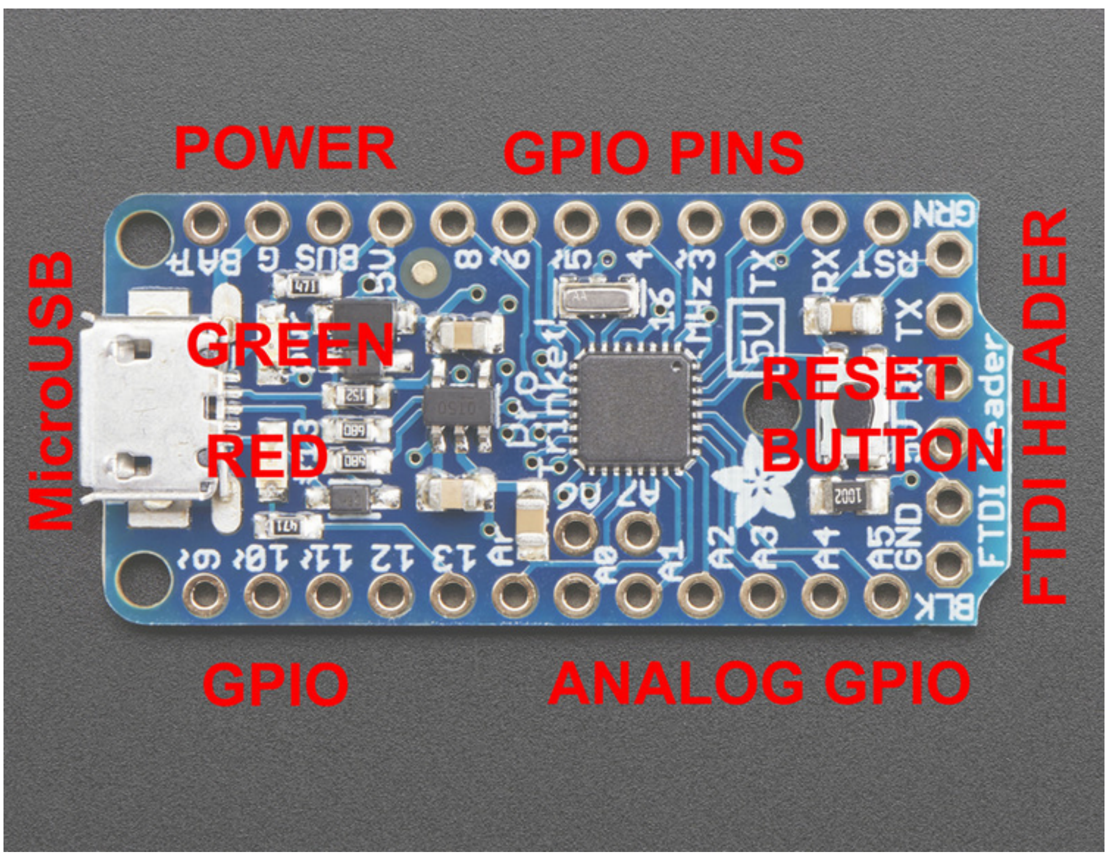

Figure 4: Microcontroller (Pro Trinket) Layout

5. Motor Unit[3][4]

The motor unit controls the entire motion of the cat toy, and is operated by the microcontroller through the motor driver. In our project, we need two independent motors side by side in the product to allow the toy makes turns. Depending on the signal received from microcontroller to motor driver, the two motors will both spin clockwise, counter-clockwise, or opposite direction against each other.

5.1 Motor

We need a motor that has fix rotating shaft, therefore after several complete rotations cycles, it will stops at the same position as it starts. The main reason we need this feature is that we want the offset weights always be at the bottom of the product while at rest to maintain the balance and the position of the product. We are selecting the gear motor with 30 rpm and 9 V input voltage.

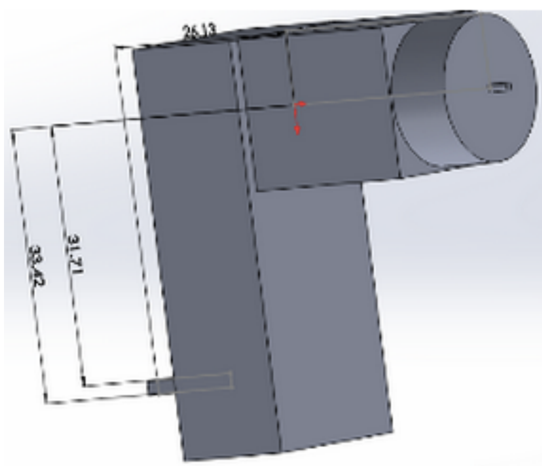

Figure 5: Gear motor

5.2 Motor Driver

The motor driver is used to control the two motors using four outputs from the microcontroller. This driver allows the microcontroller to output either a high or a low signal, thus controlling the spinning directions of two motors. The motor driver we are selecting is L293D, each IC can handle two motors at nominally 600mA each, with spikes up to 1.2 amps, at a voltage range between 4.5 and 36 volts. The circuit schematic of L293D application is shown as below

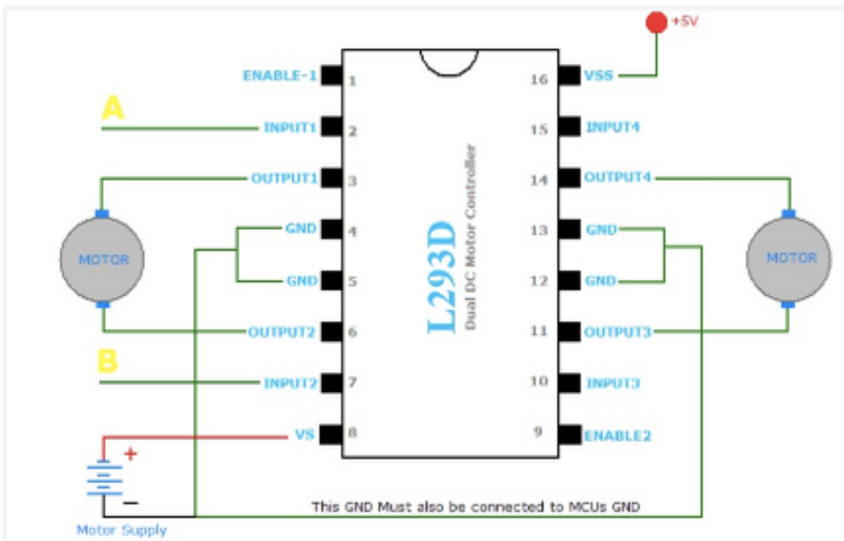

Figure 6: Motor Driver Circuit

5.3 Offset Weight

In order to achieve the rotating action of the ellipsoid shaped cat toy without installing wheels on it, the only way we can do this is to change the center of mass of the toy by using offset weights installed motors. We fabricated two semi-circular disk offset weights with 40 mm in radius and 4 mm in thickness out of steel as shown below.

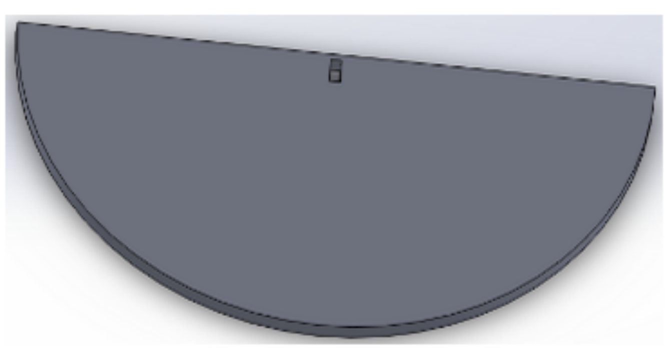

Figure 7: Semi Disk Offset Weight

6. Electronic Design

For our electronic design, it consists of various parts: control system, circuit, programming instruction, and PCB. These are very crucial to the internal design. The control system and the programming instructions build the function of the cat toy, while the circuit and the PCB allows us to minimize the wires and capacity.

6.1 Control System

In order to activate the motor operation by receiving signals from motion sensors, we brainstorm our idea into a flowchart shown as below:

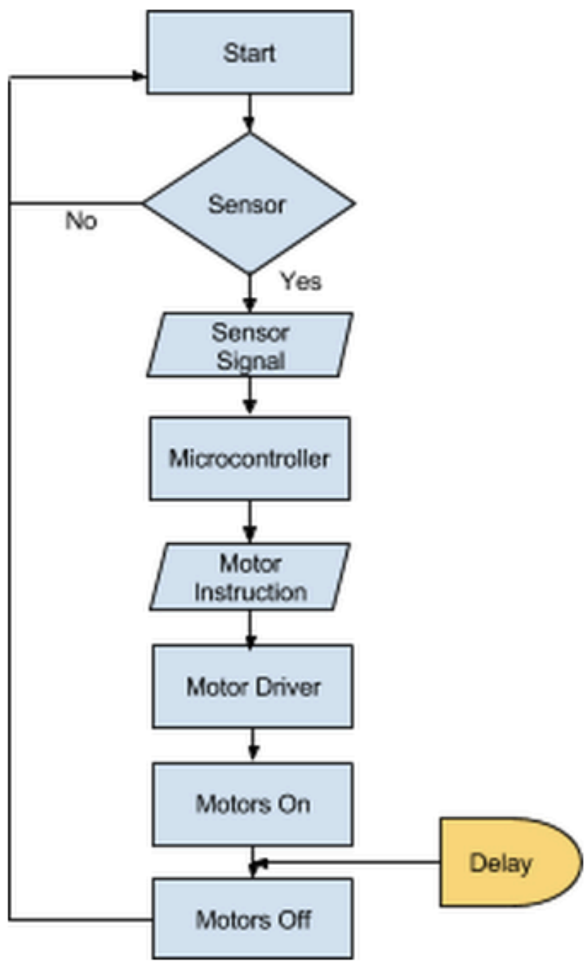

Figure 8: Control System Flowchart

6.2 Circuits Design

By checking the datasheets of Pro Trinket, we selected pin A0, A1, A2 and A3 as digital outputs, which can only execute the **digitalWrite()** operation, thus connecting these outputs to motor driver inputs. And by testing the Pro Trinket GPIO pins, we selected pin 3, pin 5, pin 8 and pin A4 as digital inputs for sensor signals. We are using single 9V battery to power Pro Trinket and the motors. The power sensors and motor driver could be generated from 5V regulator of Pro Trinket. Thus we constructed the circuit on breadboard shown as below:

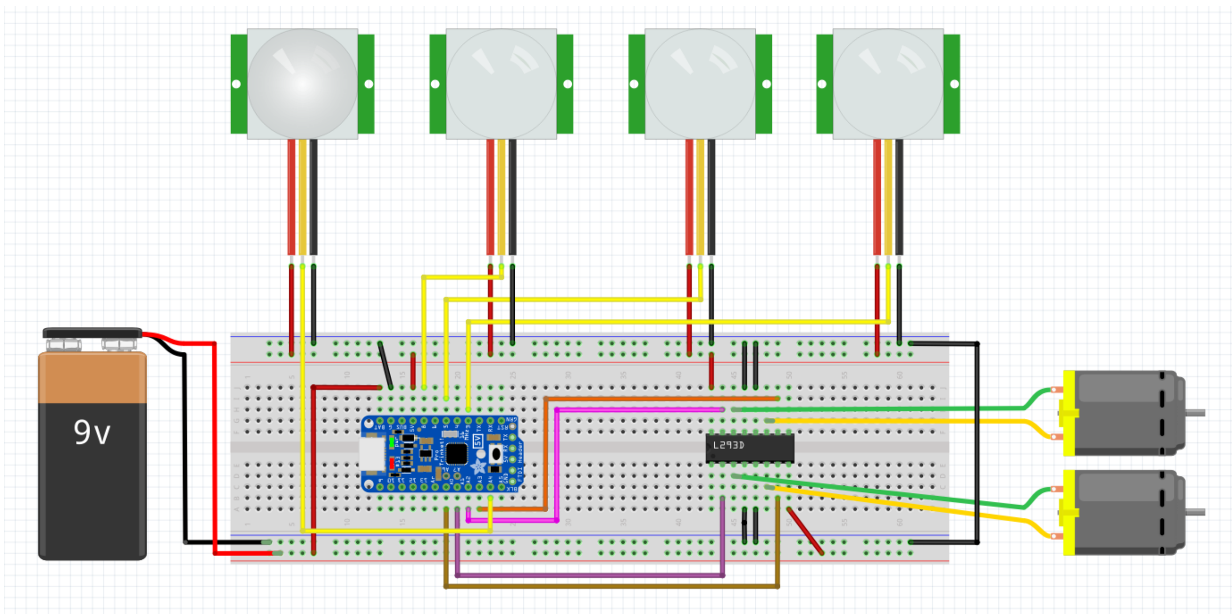

Figure 9: Circuit Construction

6.3 Programming Instruction

The control programming is a series of decision-making process that determines a course of action depending on different inputs from the sensors, which can be concluded as four cases.

	Input	Output		
Sensor 1	Pin3 (High)	PinA0 (High) PinA2 (High)	PinA0 (Low) PinA2 (Low)	
	Detected	Motors in same direction Toy rotates away	Toy stops	
Sensor 2	Pin5 (High)	PinA0 (High) PinA3 (High)	PinA3 (Low) PinA2 (High)	PinA0 (Low) PinA2 (Low)
	Detected	Motors in opposite direction Toy makes turns	Motors in same direction Toy rotates away	Toy stops
Sensor 3	Pin8 (High)	PinA1 (High) PinA3 (High)	PinA1 (Low PinA3 (Low)	
	Detected	Motors in same direction Toy rotates away	Toy stops	
Sensor 4	PinA4 (High)	PinA1 (High) PinA2 (High)	PinA2 (Low) PinA3 (High)	PinA1 (Low) PinA3 (Low)
	Detected	Motors in opposite direction Toy makes turns	Motors in same direction Toy rotates away	Toy stops

Table 1: Programming Design Table

6.4 PCB Design[5]

After all the circuit testing, code writing and mechanic designing, we decided to design a PCB for our final product construction. To avoid wires across, we exchange several pins for PCB layout, we can modify the pin declaration part of the programming to match up. The total area of our PCB is only 27.24cm2.

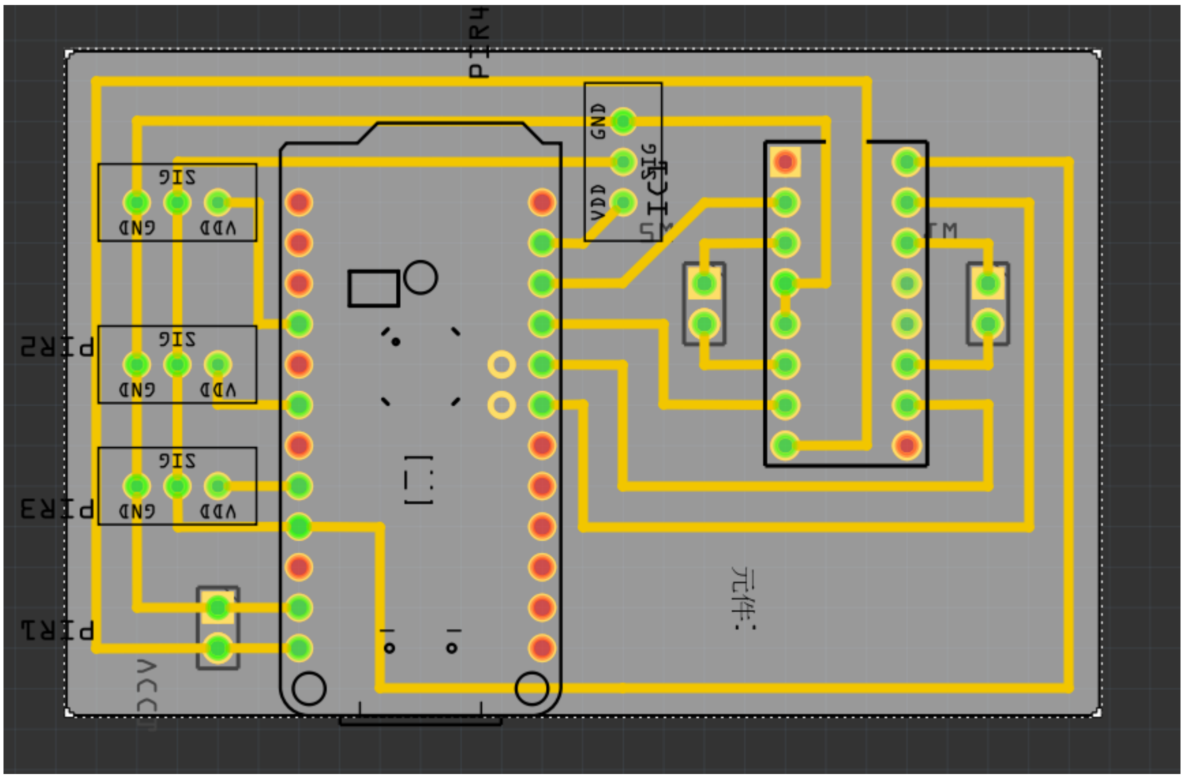

Figure 10: PCB

7. Mechanical Construction

As the final construction of our shell, it needs to be a lightweight, small, and smooth container. We designed our outer shell as a plastic ellipsoid with maximum height of 130mm and maximum length of 220 mm. For safety, the material that we used for the outer shell would be robust, which would contain less toxic substance that would affect the health of cat.

The following figure shows the inner construction of our prototype. Two motors will be placed in the center of the model that account for one third of the shell's total length (about 80mm), with a PCB board laid on the top, and the battery set in the bottom. The four sensors will be placed on the four corners of the outer shell.

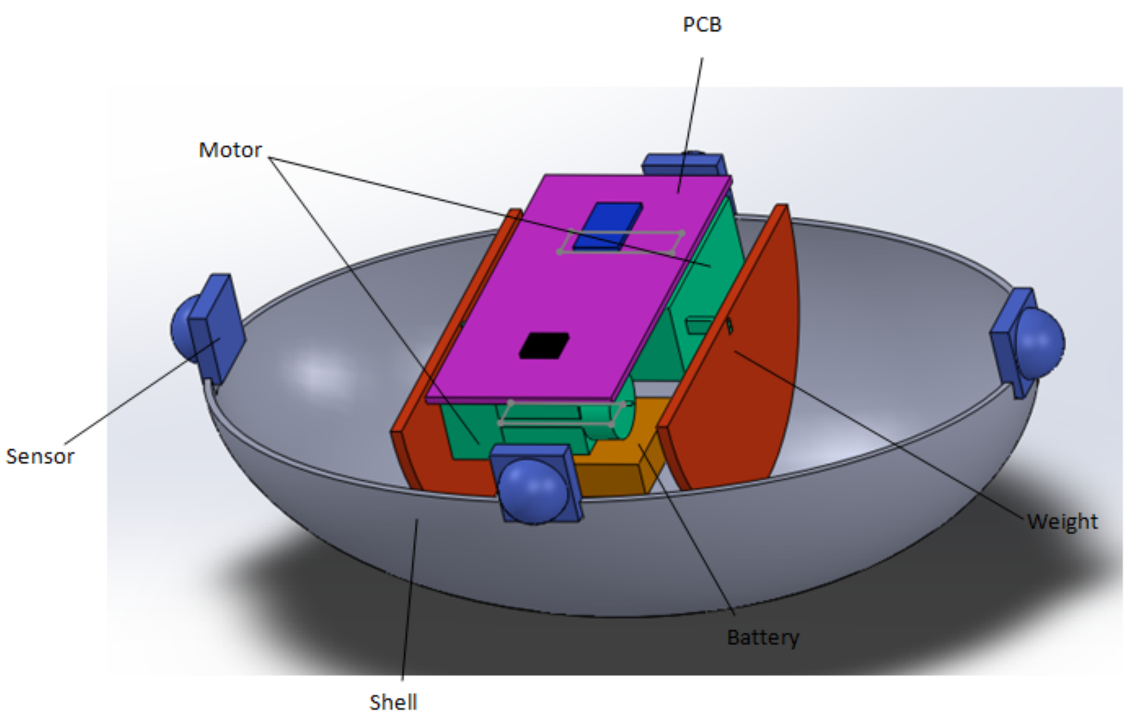

Figure 11: Half Shell Construction Overview

8. Test Plan

In order to get the best performance of Purrsuit, test scenarios must be conducted. We will have two different sets of test plans: unit test plan, where each unit is tested separately; and system test plan, where the product will be tested as a whole system.

8.1 Unit Test Plans

8.1.1 Motion Sensors and Motor Unit Test

The sensors unit and motor units are to be tested together. For each sensor, there are two test cases:

1. When out of sensors' range, motors do not respond.
2. When within sensors' range, motors activated.

8.1.2 Microcontroller Unit Test

Since to test the Microcontroller Unit, we have to connect the sensors and motors in order to have visual input and output, this unit testing has to be done after the Sensors and Motor Unit testing. The following figure shows how the sensors and motors are positioned.

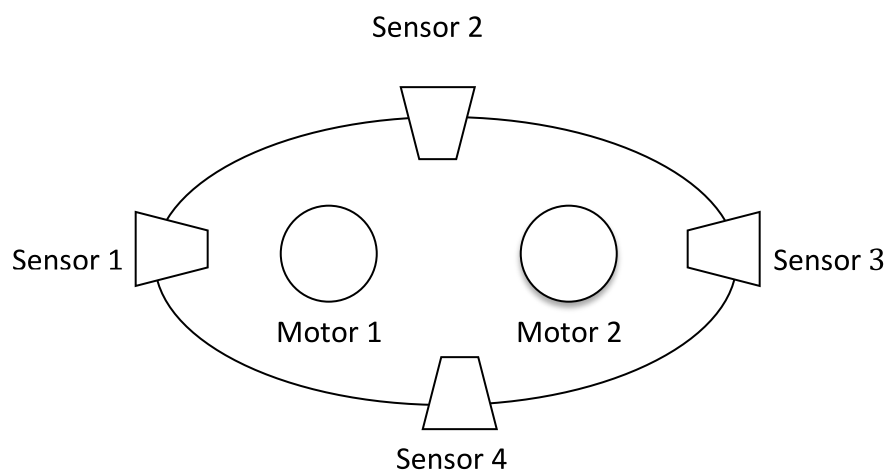

Figure 12: Sensors and Motors Positions

With this setting, we can construct the following test cases listed in the table below to test if the Microcontroller Unit is working as expected.

Active Sensor	Output
0	No movement
1	Motor 1 will spin in the direction towards sensor 2 and motor 2 will spin in the opposite directions. After a delay, motor 2 will spin in the same direction of motor 1.
2	Both motors spin in the direction towards sensor 4
3	Motor 2 will spin in the direction towards sensor 4 and motor 1 will spin in the opposite directions. After a delay, motor 1 will spin in the same direction of motor 2.
4	Both motors spin in the direction towards sensor 2

Table 2: Microcontroller Unit Test Cases

8.2 System Test

After all the internal units are tested and assembled, we can conduct the system testing. The following figure shows how the sensors are positioned, and a direction guide.

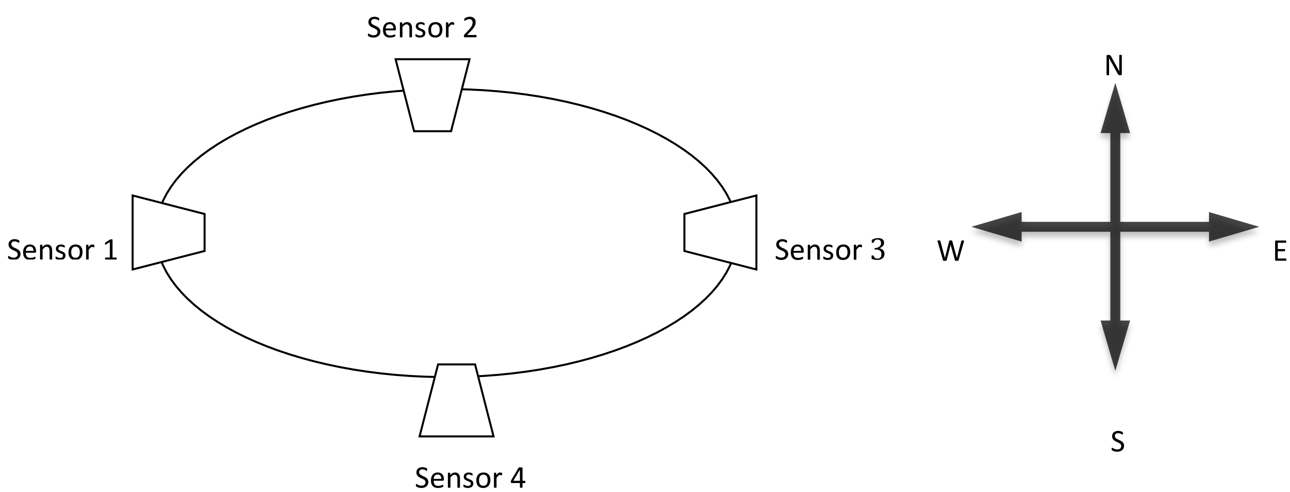

Figure 13: Sensors Positions and Directions

With this setting, we can construct the following test cases listed in the table below to test if the system reacted as expected.

Active Sensor	Expected Behaviour
0	No movement
1	Purrsuit will turn South, then roll towards East
2	Purrsuit will roll towards South
3	Purrsuit will turn North, then roll towards West
4	Purrsuit will roll towards North

Table 3: System Test Cases

9. Conclusion

This documentation provides the design specifications for Purrsuit to meet the functional specifications of Purrsuit. These specifications include: Motion Sensor Unit, Microcontroller Unit, and Motor Unit. We have also included details of the Electronic Designs and Mechanical. Furthermore, unit and system test plans are also provided to ensure the quality and functionality of each unit and the overall system. By following to the requirements in this document, CatStone is confident that Purrsuit will be designed to the highest of quality.

10. References

[1] PIR Motion Sensors. Adafruit, 2014. 6 March 2015
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[2] Introducing Pro Trinket. Adafruit, 2014. 6 March 2015
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http://www.electroons.com/8051/electroons/dc_motor_control.html

[4] L293D Datasheet. Datasheet 360, 2015. 6 March 2015
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[5] Fab. Fritzing, 2014. 6 March 2014
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