Pet Selective Automated Food Dispenser

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1 Introduction

1.1 Objective

A lot of pet owners lead busy lives and sometimes neglect their pets' health. This includes problems like improper and untimely feeding habits and decreased physical activity for the pets. There is a growing trend towards multi-pet households, which only heightens the problem [2]. **The goal of this project is to regulate the feeding habits of the owners' pets while taking into consideration that pets may eat each others food.**

A lot of times one pet eats the other pet's food causing problems to their health. This device will properly identify which pet is approaching the dispenser and consequently dispense the right amount of food at a previously set time. In case the wrong cat tries to eat the food, the dispenser will restrict access to the food. The system can be applied to a wide variety of animals but for simplification purposes we will be building a dispenser for cats.

1.2 Background

Inspiration to create this device came from one of our friend, who was facing a "fat-cat-skinny-cat" situation at home. One of the cats would finish its food quickly and proceed to eat the other cat's food as well. This caused one cat to be obese, while the other cat lacked necessary nutrients. A recent report showed that 24% of the cats owned as pets in the US are overweight [1].

Currently the pet ownership in US households stands at 55%. About 59 million Americans own cats and about 50% of cat households own multiple pets; two or more cats, cats and dogs. The increasing trend in multi-pet households creates a demand for a wholesome food scheduling system [2].

Available products in the current market that address this problem are mainly of two types. Type one, these products are basically food dispensers that can be timed so your pet is fed only at a particular time. While this does not solve the multi-pet problem it helps busy pet owners to feed their pets in a timely fashion. Type two, these are pet food bowls that come with a closing-lid mechanism. If the right pet comes to the bowl, the door opens and the pet can eat its food. If the wrong pet come to the bowl, it cannot access the food. This solves the other half of the problem but the pet-owner has to pre-place the food in the bowl. Our solution will combine these two features.

1.3 High-Level Requirements

- The food dispenser must be able to distinguish between two or more different cats using RFID/Microchip from a distance of at least up to 5 cm with an accuracy of at least 90%.
- The food dispenser must be able to dispense pre-programmed amounts of food at specified times for each cat using feedback from a weight sensor.
- Using an OLED screen, the food dispenser must notify the owner when the food in the dispenser storage is lower than 100g (approximately three meals).

1.4 Aspirational Goals

- The food dispenser must be able to monitor how much food each cat is eating and communicate wirelessly with the owner by sending weekly updates on the cat's food intake.
- The food dispenser must include a sound feature that can grab the pets' attention during meal time.

2 Design

2.1 Block Diagram

Our design is divided into six modules which are further subdivided into smaller modules that perform certain functions. The RFID tag in the sensory module is attached to the cat and sends signals to the RFID receiver module. The RFID receiver module can differentiate between the two cats. The antenna of the receiver will be designed to extend the range of the receiver to meet our requirements. The bowl load cell is a weight sensor that provides feedback to the microcontroller to dispense a pre-programmed quantity of food. The dispenser load cell measures the weight of the food in the dispenser and will send an alert (using an LED) to the owner when the food is running low. The microcontroller will process the information from the sensors and control the motors using a motor driver. The I/O unit will allow for the user to input appropriate quantities and times for the food of the cats. The multiple voltage regulators will supply power to the different modules as shown.

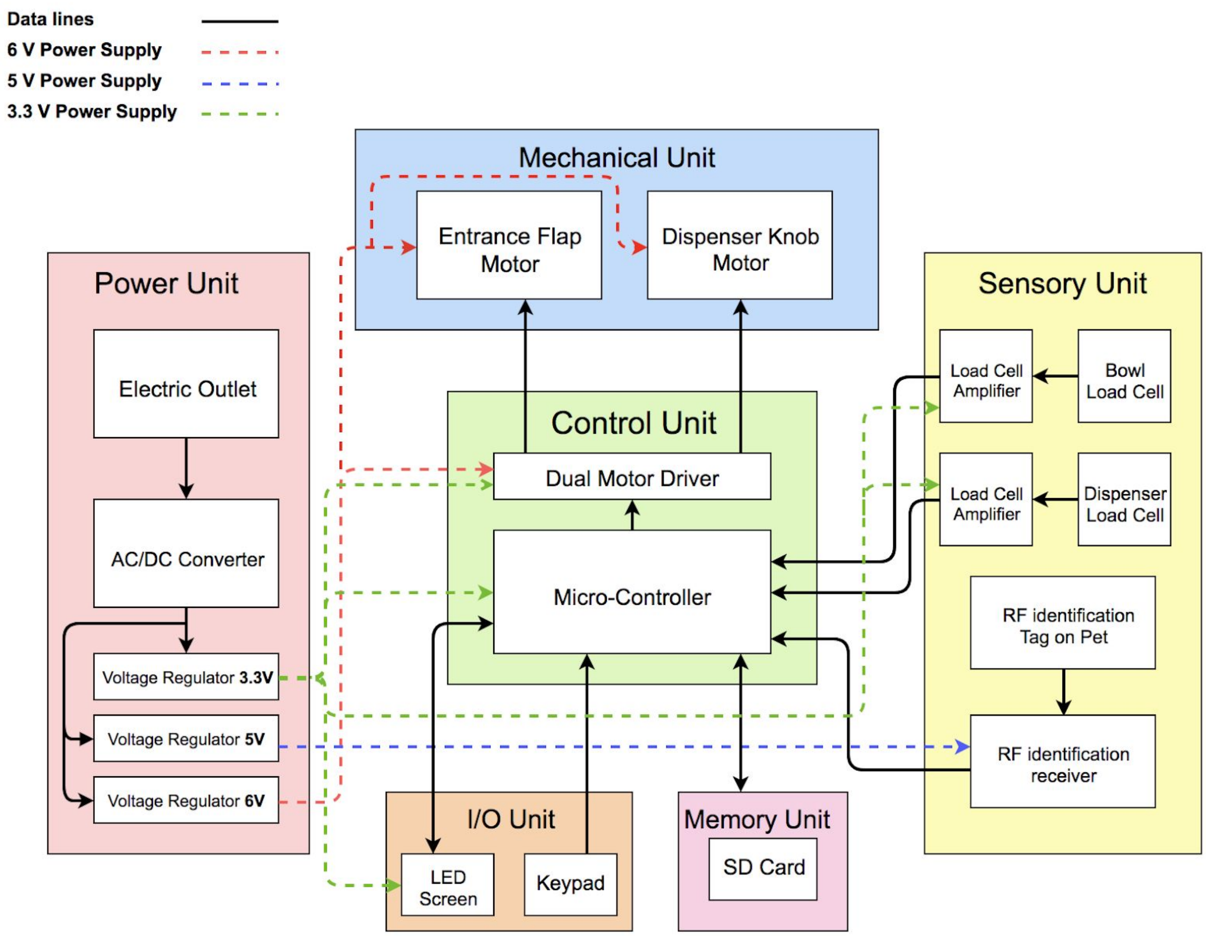

Figure 1: Block Diagram of the Pet Selective Food Dispenser

2.2 Physical Design

Physically, the main goal of our device's design is to be able to withstand moderate amounts of force in order to prevent it from toppling onto the pets. Our mechanical structure will emphasize on sturdy design and will use materials like plastic and metal, prohibiting the pet from being able to move it around or break it. We will also use a counterweight to ensure that the device does not topple over because of the tantrums of an angry and hungry cat. Another major concern regarding the pet feeders in the market is that they contain rubber parts that are not durable and also cause pets to choke. Our design will properly seal away all small, hazardous and chewable parts to avoid this. The tentative design for the dispenser is depicted below. Dashed blue encirclements indicates where the location of the specific part would be in our design.

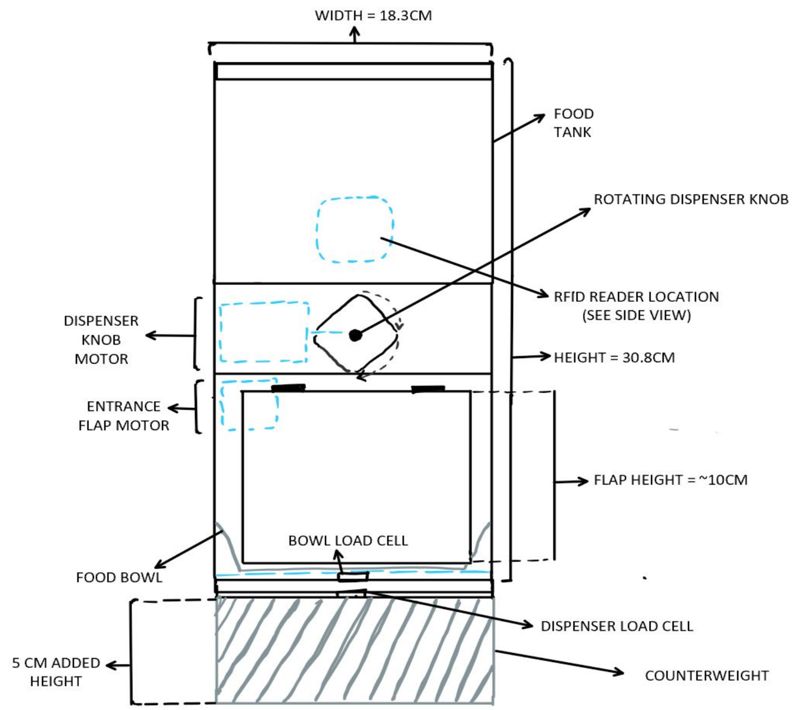

Figure 2: Front View of the Pet Selective Automated Food Dispenser

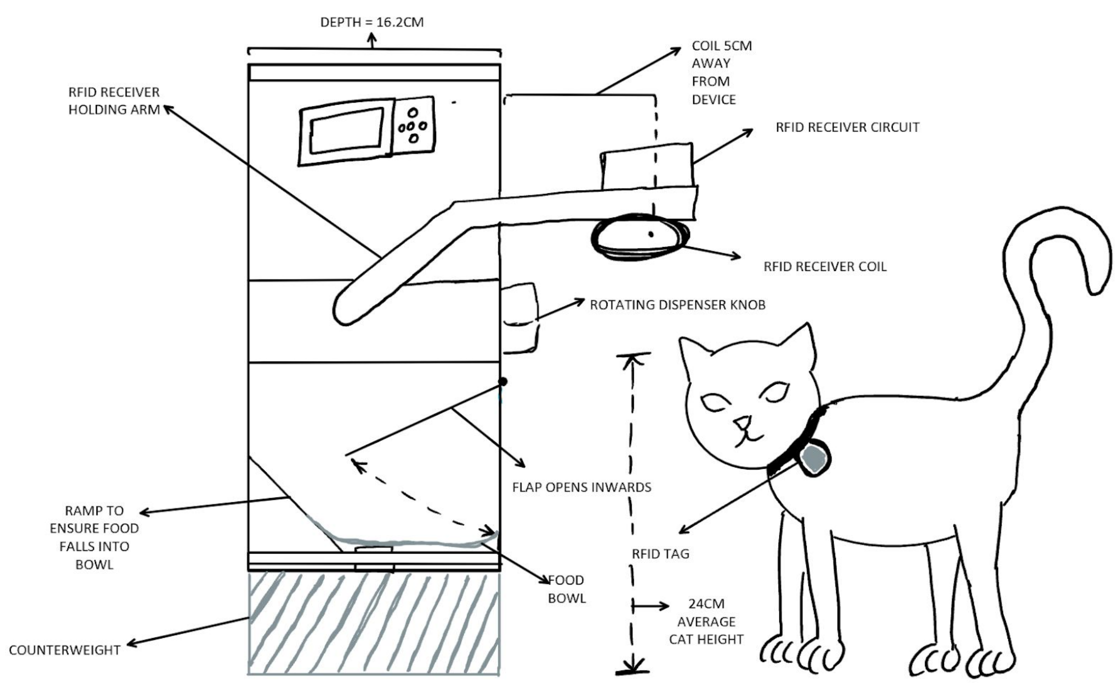

Figure 3: Side View of the Pet Selective Automated Food Dispenser

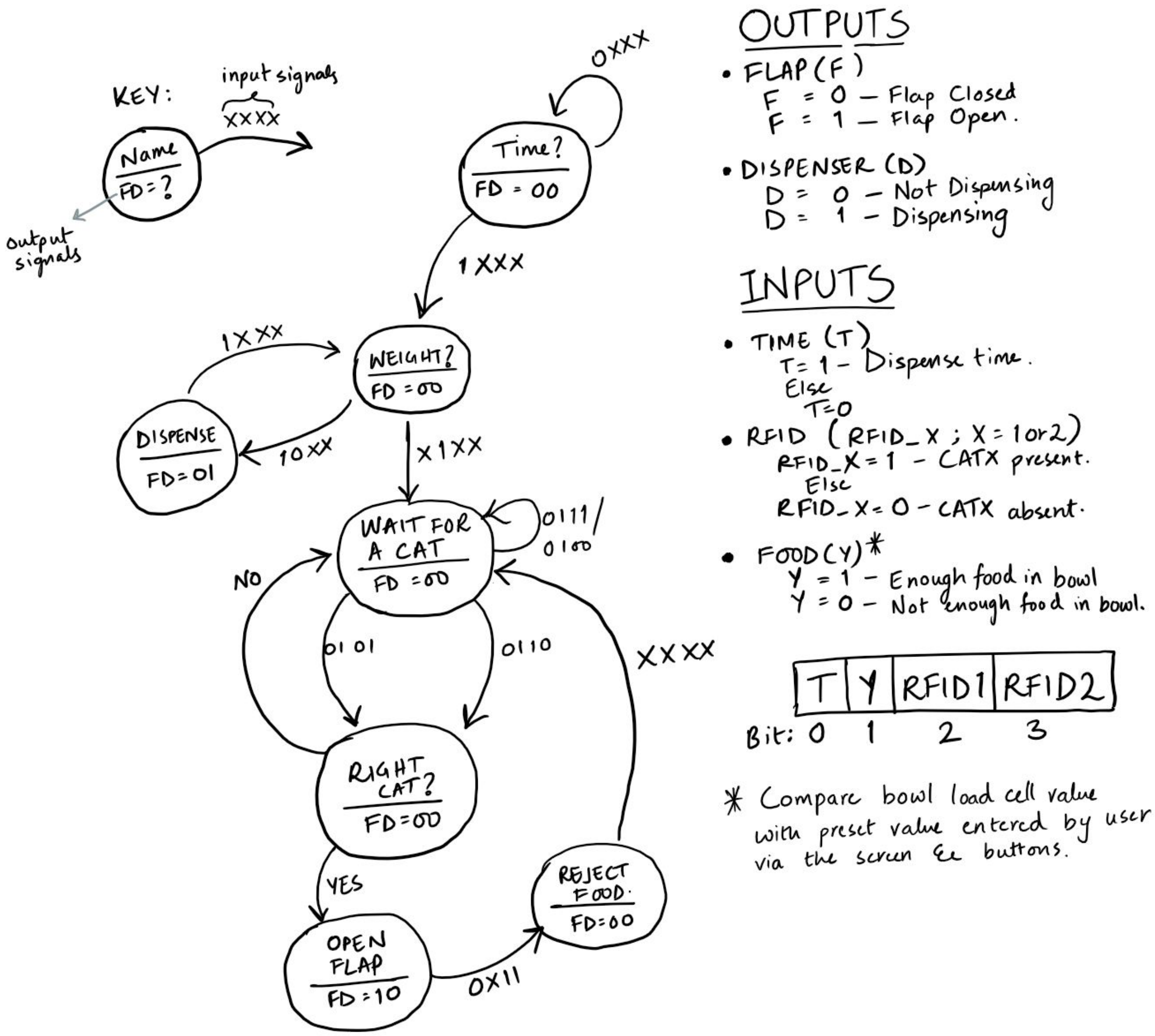

Figure 4: State Machine showing the Functional Process of the Device

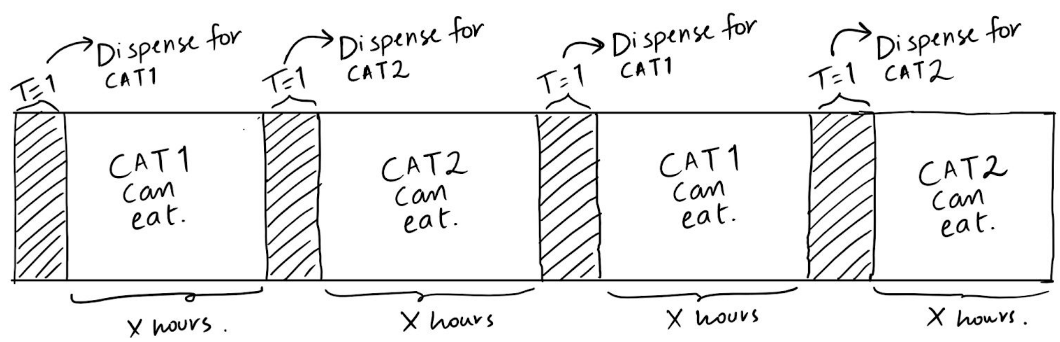

Figure 5: Times A Cat Can Eat and Dispense Times

There are certain times throughout the day when the input signal T = 1. These times are when the device checks if there is enough food in the bowl for a given cat that is supposed eat in the following block of time (See Figure 5). The blocks of time when each can eat are inputted by the user via the I/O interface.

The device is by default in a wait state. When the right cat approaches, the flap opens and the cat can eat the dispensed food. If the wrong cat approaches, the flap door is closed. If the wrong cat approaches close enough to the dispenser while the right cat is eating, then the flap door will close until the wrong cat goes away.

2.3 Block Design

Functional Overview

2.3.1 Sensory Unit

The sensory unit will function as the feedback and input unit to the control unit. It will read input from the cats' RFID tags/microchips and load cells to send weight feedback and RFID detection signals to the control unit.

2.3.1.1 RFID/Microchip Detection [8]

Most pet owner in the US have a microchip implanted in their pet cats. This microchip runs at a frequency of 125kHz [3]. In case the cat is not "chipped" an RFID (125kHz) tag can be attached to the collar of the cat.

The RFID tag/microchip will be read by the RFID reader when it is within a range of 5-7 cm. The RFID reader will be placed on an arm protruding from of the dispenser as depicted in Figure 3. This optimal position of the RFID reader will help improve the accuracy of detecting the right cat when it is in the vicinity of the food dispenser.

To minimize the cost of the project, we will be designing our own antenna. We will experiment with the material of the wire, shape, orientation and number of turns on the coil to optimize the reading distance [7].

Requirement	**Verification**	**Points**
1. Works at a resonant frequency of 125kHz	1.a. Use a 125kHz RFID tag. 1.b. Connect The RFID receiver to the microcontroller. 1.c. Bring the tag close to the RFID detector and observe	5

2. Range of 5-20cm with a detection accuracy > 90%	if 125kHz is detected or not. 2.a. Connect the RFID receiver to the microcontroller. 2.b. Place a distance ruler along the direction of motion of the RFID tag. 2.c. Slowly move the tag along the ruler until it is detected and mark the distance. 2.d. Repeat 2.c. 10 times and along 3 other lines of motion.	15

2.3.1.2 Low Food Weight Detection [13]

A weight sensor (dispenser load cell) at the bottom of the dispenser will determine the amount of cat food left in the food tank. This weight sensor will measure the total weight of the device, and the weight of the device without the food will be subtracted from it to measure the amount of food in the food tank. It will notify the owner when the food left is below a certain weight (100g).

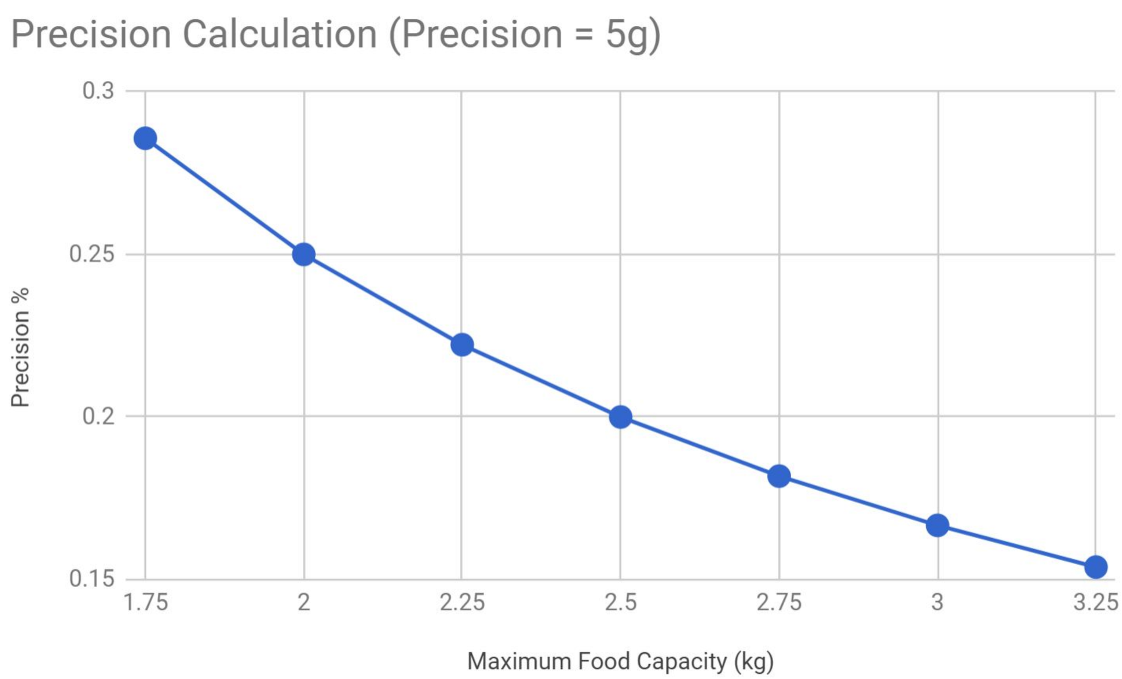

Figure 6: 10kg Load Cell Precision scaled down to different weights of food

Requirement	**Verification**	**Points**
1. Measurement range of 0-10 kg	1.a. Connect the load cell to a microcontroller. 1.b. Measure the weight when no load is placed on the	2.5

2. Precision of at least 0.5% of full scale 3. Error tolerance of at most ± 0.5%	load cell. 1.c. Measure the weight displayed when a known weight of 10kg is placed on the load cell. Check if the correct weight is displayed. 2.a. Connect the load cell to a microcontroller. 2.b. Place known weights of 500g, 525g, 550g, 600g. Compare measurement with actual weight. 3.a Connect the load cell to a microcontroller. 3.b. Place 500g on the load cell and note the weight measured. 3.c. Repeat the experiment 10 times and find the average error.	 5 2.5

2.3.1.3 Food Consumption Weight Detection [14]

A second weight sensor (bowl load cell) will determine the amount of food dispensed into the bowl. The weight determined by the load cell will be processed and sent in as feedback to the microcontroller to determine whether more food should be added to the bowl.

Potentially, the output of the sensor will be used to determine the amount of food the different cats eat over a period of time. This information can be displayed on the screen to help the owner keep better track of the cats' health.

Requirement	**Verification**	**Points**
1. Measurement range of 0-1.00 kg 2. Precision of at least 1% of full scale 3. Error tolerance of at most ± 0.1%	1.a. Connect the load cell to a microcontroller. 1.b. Measure the weight when no load is placed on the load cell. 1.c. Measure the weight displayed when a known weight of 1.00 kg is placed on the load cell. Check if the correct weight is displayed. 2.a. Connect the load cell to a microcontroller. 2.b. Place known weights of 10g, 15g, 20g, 25g. Compare measurement with actual weight. 3.a Connect the load cell to a microcontroller. 3.b. Place 500g on the load cell and note the weight measured. 3.c. Repeat the experiment 10 times and find the average error.	2.5 5 2.5

Load Cell Amplifier [10]:

The load cells work as transducers converting mechanical energy to alter a resistance. The magnitude of the change in resistance is offer very low (<1Ω). In order to increase the change in resistance and to easily detect it, a load cell amplifier is used. The load cell amplifier works on the principles of a wheatstone bridge.

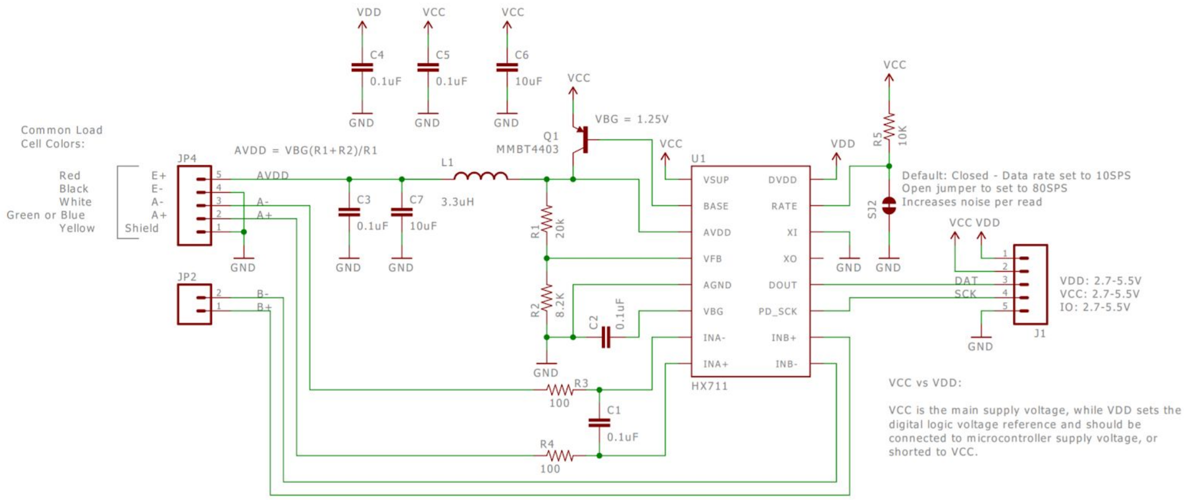

Figure 7: Load Cell Amplifier Schematic [10]

2.3.2 Control Unit

The control unit will function as the brain of our device. It will process signals from from the different sensors and I/O devices listed below and control the motors in the mechanical unit.

2.3.2.1 Microcontroller (ATmega328p) [15]

The ATmega will be programmed using an Arduino and fixed onto the PCB. The ATmega will process the signals from the microchip detector and weight sensors and output signals to the motors.

First the user will input the time he/she wants the cats to be fed, this is compared to the time to determine when the flaps are opened. An algorithm will account for delays in signals from the bowl load cell and signal the motor to accurately dispense the right amount of food.

The dispenser load cell output will be refreshed each time food is dispensed. When the amount of cat food in the dispenser is below the threshold value (100g) the controller will send a signal to the LED to light up indicating low food. The controller will simultaneously process the microchip detector signals to allow/disallow the cat approaching the feeder to eat.

Requirement	Verification	Points
Should be able to process at least 2 analog and 10 digital signals	a. Count the number of available digital and analog pins. Add excess pins if requirement isn't met. b. Connect the microcontroller to 3.3V and run LED light test code to identify any bad pins.	10

2.3.3.2 Motor Driver [5]

The motor driver provides regulated power to the motors and prevents them from drawing too much current. Apart from this the driver also doubles as a controller for the motors. Depending on the signal sent from the microcontroller, the driver will send a second signal to the motor. In the case of the entrance flap motor it will also change the opening and closing by determining the direction of the motion. Shown in Figure 8 [5] and 9 [12] are a typical application and schematic, respectively of the motor driver with two motors.

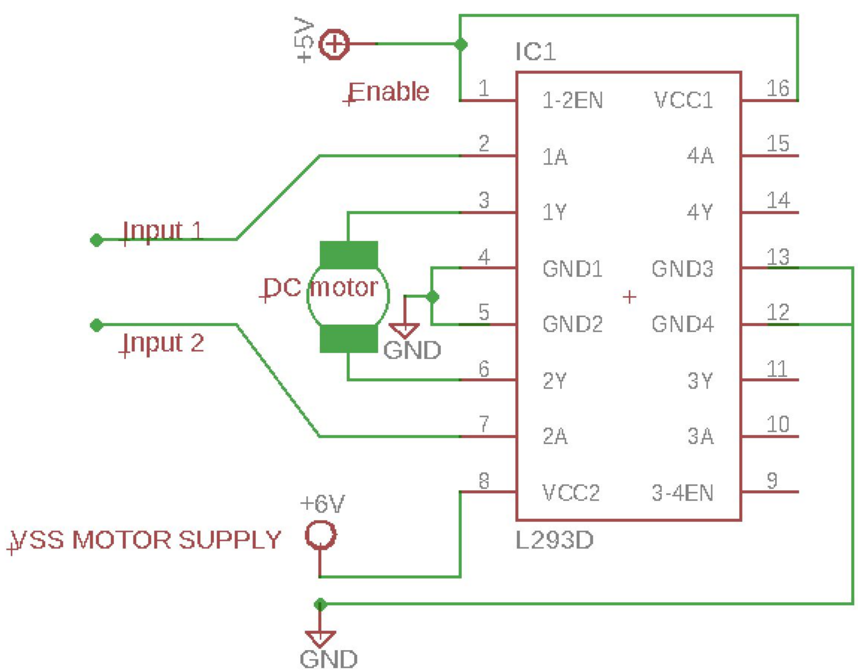

Figure 9: Motor Driver Schematic [12]

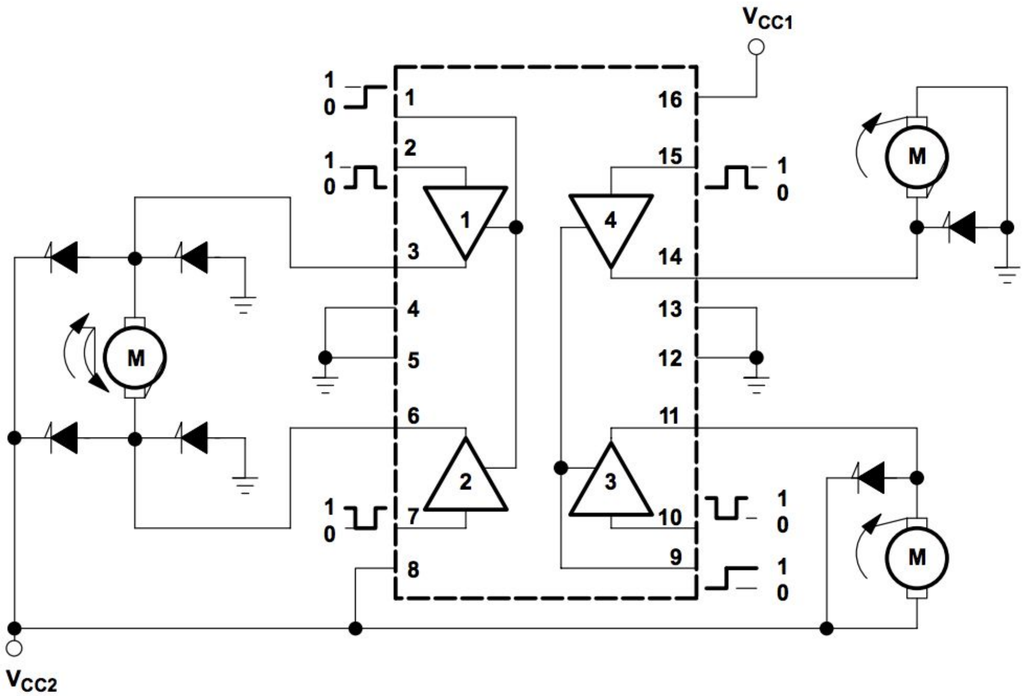

Figure 8: Motor Driver Application [5]

Requirement	**Verification**	**Points**
1. Motor Supply Voltage 6V DC	1.a. Setup the motor driver circuit 1.b. Input 6V in the VM (voltage motor) pins 1.c. Ensure that 6V is outputted from chA/chB output pins	5
2. Supports motor current 200mA	2.a. Connect the motors to the motor driver circuit setup 2.b. Using a 30Ω load and a ammeter, measure the output current.	5

2.3.3 Mechanical Unit

The mechanical unit consists two motors which play crucial roles in the design, one controls the food dispensed while the other prevents the wrong cat from getting food.

2.3.3.1 Dispenser Knob Motor [16]

This motor is attached to the knob of the dispenser. The motor rotates the knob, which in turn rotates a spin wheel with divisions that dispenses certain quantities of food.

The knob motor is a DC motor that must be able to rotate 360°. The voltage to the motor, and the signals controlling the motion are supplied by a motor driver running on a PWM signal.

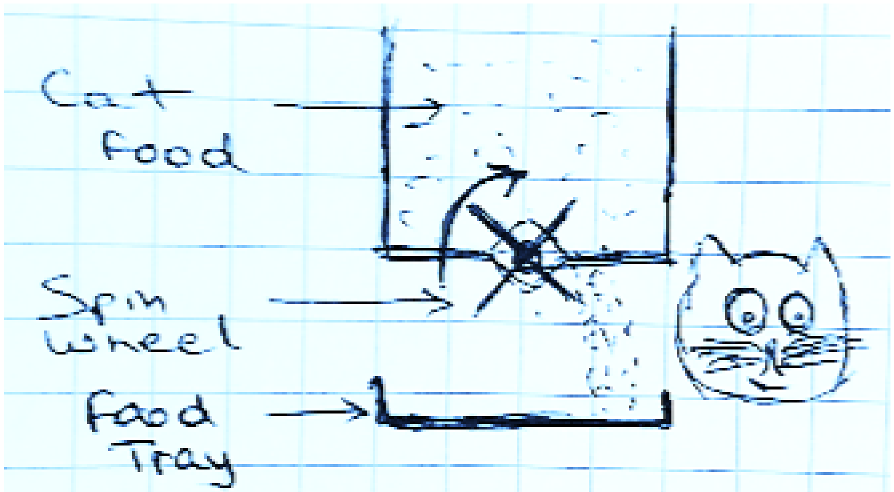

Figure 10: Food dispensing into tray

Requirement	Verification	Points
1. Adjustable 0-20RPM 2. Current < 1.2A	1.a. Connect the motor to a DC power supply. 1.b. Change the duty cycle of the PWM to change the speed of motor. 1.c. Plot PWM vs speed graph 1.d. Determine the duty cycle required to maintain required speed. 2.a. Power the motor with a power supply and use an ammeter to measure the current. 2.b. Power the motor using the motor driver and use an ammeter to measure the current.	5 5

2.3.3.2 Entrance Flap Motor [16]

This motor rotates the flap located on the outside of the food bowl chamber. The microcontroller uses the signals sent from the RFID readers to determine the motion of the flap. It is meant to open and close to allow/disallow a cat from eating the dispensed food. The motor must be able to hold up against a cat exerting force on the flap.

Torque Calculation:

When the RFID reader reads the wrong cat. The motor powers up and holds the flap in place. The motor must be able to withstand any torque the cat exerts on the flap. On average a typical cat is able to exert a maximum force of 2-2.5N [6]. The motor must be able to withstand this force.

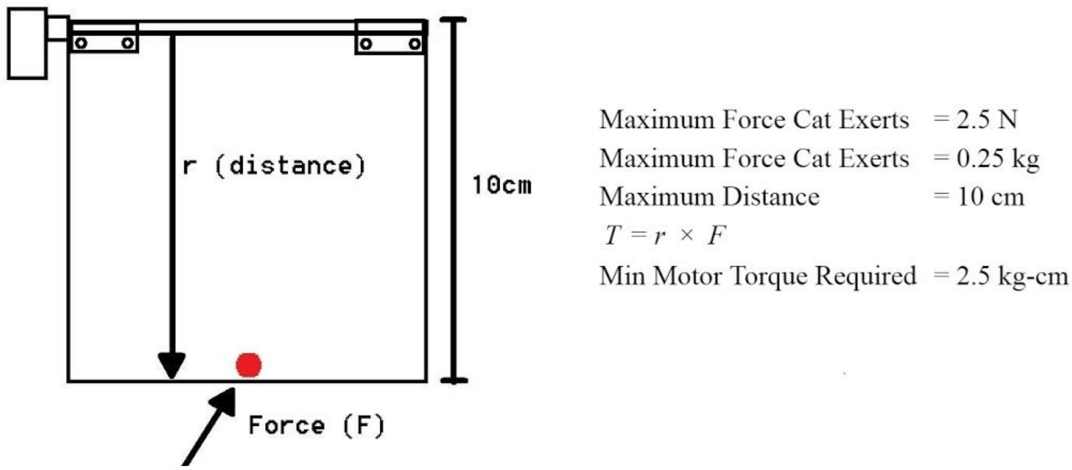

Figure 11: Maximum Torque Calculation

Requirement	**Verification**	**Points**
1. Adjustable 5-10 RPM 2. PWM frequency < 100kHz 3. Torque > 2.5 kg-cm	1.a. Connect the motor to a DC power supply. 1.b. Change the duty cycle of the PWM to change the speed of motor. 1.c. Plot PWM vs speed graph 1.d. Determine the duty cycle required to maintain required speed. 2.a. Power the motor with a power supply and use an ammeter to measure the current. 2.b. Power the motor using the motor driver and use an ammeter to measure the current. 3. Attach a 1 kg weight using a string 2.5cm from the the center of the motor and check whether the motor can lift it off the ground.	5 5 5

2.3.4 I/O Unit

The I/O unit acts as the interface between the cat owner and control unit. This unit will take in the dispense times and weights from the owner and also notify the owner when the cat food level is low.

2.3.4.1 OLED Display [17]

The user will use this screen to input how much food and when each cat eats. This display will indicate the amount of food left in the food tank. The display will also consist of an LED, which will light up/blink rapidly in order to notify the owner when the food level is low (below 100g).

2.3.4.2 Keypad

The keypad will have buttons to move up, down, left, right, and select. These buttons can be used to navigate through the user interface that will be displayed on the OLED Screen. This keypad will be covered so that it is not accessible to the cat.

Requirement	Verification	Points
NO (normally-open) buttons	a. Connect a DC voltage to the button and a resistor in series. b. Measure the voltage across the resistor when the circuit is open and when it is closed	5

2.3.5 Memory Unit

An SD card with at least 512 Mb and at least 5 Mbps read and write speed will be used as our memory device. It will store any information required for processing and memory required to refresh and display different screens on the OLED display.

2.3.6 Power Unit

This unit will power the I/O interface, the sensors, motors and the microcontroller inside the device.

2.3.6.1 Wall Outlet Power Adapter

The adapter will convert voltage from a common electrical outlet (120V 60 Hz AC) to a desired 9V DC.

Requirement	Verification	Points
1. Output Voltage: 9V ± 0.5V 2. Output Current: 650mA ± 50mA	1. Place a digital multimeter in parallel with the output of the adaptor and check if the required specification is met. 2. Place a digital multimeter in series with the output of the power adaptor and measure the current.	2.5 2.5

2.3.6.2 Voltage Regulators [18]

The voltage regulator ensures that the power is regulated at a near constant value. The 9V coming from the adapter needs to be stepped down to 3.3V, 5V and 6V required for the other units of the device. Consequently, voltages 3.3V, 5V, 6V and 9V will be available to use.

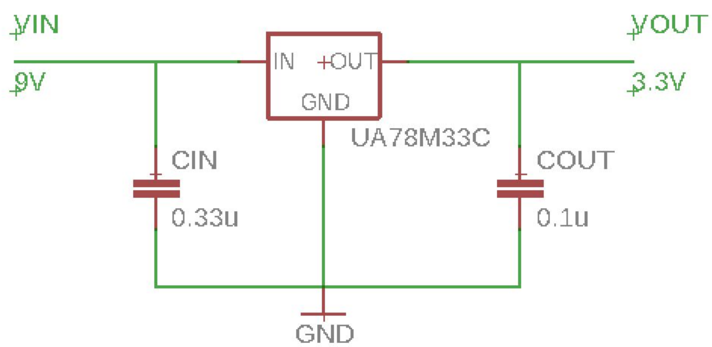

Figure 12: 9V to 3.3V Voltage Regulator Schematic

Requirement	**Verification**	**Points**
1. Output Voltage: 3.3 ± 0.2V 2. Output Voltage: 5 ± 0.2V 3. Output Voltage: 6 ± 0.3V	Place a digital multimeter in parallel with the output of the regulator and check if the required specification is met.	5

2.4 Tolerance Analysis

The RFID reader is the component that may break our project. The range of the RFID reader is crucial to the functioning of the project. The reader must be mounted close enough on the dispenser so that the back of the cats neck (where a 125kHz microchip would be implanted) is within its reading range. In the case where the cat is not chipped, the collar will contain and external 125kHz RFID tag. If the reader is placed too far the reader may not be able to detect the presence of a cat, consequently the cat cannot access its food. The purpose of this analysis is to understand the constraints of the RFID reader and estimate if the reader can meet one of our main high level requirement:
The food dispenser must be able to distinguish between two or more different cats using RFID/Microchip from a distance of at least up to 5 cm with an accuracy of at least 90%.

For our project we are using the Grove - 125kHz RFID reader which claims to have a maximum detection distance of 7cm [8]. Another option was to use the ID-12LA from Sparkfun that boasts a higher range but costs 3 times more, consequently it blows up the cost of the project.

In order to satisfy the range requirements of both the reader and our project, while also ensuring there is at least some head clearance between the cats head and RFID coil (refer to *Figure 13*) we plan to place the reader about 6 cm from the RFID tag/chip on the cat. The average cat is about 24 cm tall, to account for the fact that when walking a cat's neck and back are slightly lower than it's head we estimated the cat's neck and back to be 20 cm from the ground.

Height of dispenser + counter weight:	35.8 cm
Estimated height to cat's back:	20 cm
Planned distance from reader to tag:	6 cm
Ideal height of RFID reader coil:	26 cm

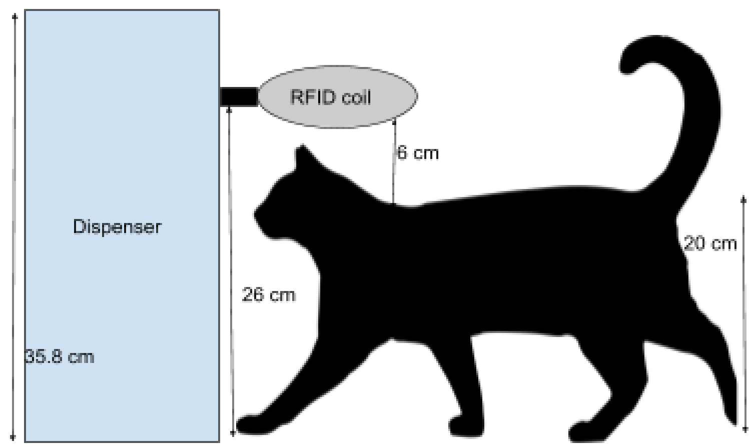

Figure 13: RFID height from cat

The allowed read range tolerance of our design based on the mounting location is as follows:

$$\text{Percentage maximum range error tolerance} = \frac{\textit{Maximum Range} - \textit{Selected Range}}{\textit{Maximum Range}} \times 100$$

$$\Rightarrow \frac{7-6}{7} \times 100 = 14.28\ \%$$

Our design might need changes if the reader's range (need to empirically measure this in the lab as tolerance specifications are unknown) is not within the specified tolerance.
Another aspect that will reduce the accuracy of our reading is the variable cat itself. The height of the cat and the cat's orientations are variables that can undermine the robustness of our mechanical design.

Some alternate ways to improve our design are by buying the more expensive RFID reader or changing the mechanical design of our system.

The analysis and conclusions above resulted in us deciding to use the cheaper RFID reader but designing/modifying the antenna coil of the RFID reader to improve it's range [7]. We plan to do this by experimenting with different coil shapes, apertures, and perhaps concentrating magnetic flux in required directions using a ferrite rod [9].

The radius of the coil to maximize the read range is given as:

$$a = \sqrt{2}r \qquad \textit{(Eq. 1)}$$

Where,
a = radius of the antenna coil and
r = read range desired [11]

The magnetic field at a point from the center of a circular loop is given as:

$$B = \frac{\mu_o I N a^2}{2(a^2+r^2)^{3/2}} \qquad \textit{(Eq. 2)}$$

Where,
I = current
a = radius of loop
r = distance from the center of loop
µ0 = permeability of free space and given as 4 π x 10-7 (Henry/meter) [11]

3 Cost & Schedule

3.1 Cost Analysis

Labor
Advika Battini: $40/hour*2.5*60 hours = $6,000
Ali Yaqoob: $40/hour*2.5*60 hours = $6,000
Vibhu Vanjari: $40/hour*2.5*60 hours = $6,000
Total: $18,000

Parts List

Part	Include	Unit Cost	Cost
Adaptor 9V	1	5.95	5.95
Barrel Jack to 2-pin JST	1	2.95	2.95
Regulator to 3.3V	1	1.95	1.95
Regulator to 5V	1	0.95	0.95
Regulator to 6V	1	1	1

OLED Screen 128x32	1	17.5	17.5
Buttons (12 pack)	1	4.95	4.95
0.78 kg Load Cell	1	6	6
10 kg Load Cell	1	6.95	6.95
Load Cell Amplifiers	2	9.95	19.9
RFID Reader	2	12.9	25.8
RFID Tags	1	2.5	2.5
Arduino Uno (Atmega328P)	1	22	22
Cereal Dispenser	1	11.83	11.83
Motor	2	14.99	29.98
Motor Driver	1	4.95	4.95
			165.16

Total Cost of the Project (Labor + Parts) = $18,165.16

3.2 Schedule

Week	Advika Battini	Ali Yaqoob	Vibhu Vanjari
February 5	- Finish Project Proposal	- Finish Project Proposal	- Finish Project Proposal
February 12	- Prepare for Mock Design Review - Finish Eagle Assignment	-Prepare for Mock Design Review - Finish Eagle Assignment	- Prepare for Mock Design Review -Finish Eagle Assignment
February 19	- Select parts for RFID detector, microcontroller, regulators, power adaptor - Complete Design Document - Order plastic food tank - Finalize state diagram	- Select parts for microcontroller, motor, OLED display - Complete Design Document - Finalize state diagram	- Select parts for microcontroller, motor, load cells, motor driver, SD card - Complete Design Document - Finalize state diagram
February 26	- Prepare for Design Review and order parts. - RFID, load cell schematics	- Prepare for Design Review and order parts. - Motor driver and motor schematic	- Prepare for Design Review and order parts. - Motor driver, motor, and load cell schematic
March 5	- Complete soldering	- Complete soldering	- Complete soldering

	assignment - Design, test, and debug power circuit - ATmega testing and verification	assignment - ATmega testing and verification - Set up the buttons and test with the ATmega	assignment - Determine the duty cycles needed for each motor and test Torque - Load cell verification
March 12	- Finalize PCB - Test range of RFID receiver for different antennas	- Finalize machine shop - Work on OLED screen communication if available/arrived	- Finalize PCB - Connect motors to the driver and ensure continuous motion and test the circuit
March 19 (Break)	- Individual Progress Reports - Look into wireless communication and addition of an app.	- Individual Progress Reports - Work on user interface on the screen	- Individual Progress Reports - Integrate memory with microcontroller
March 26	- Program sensors to output signals to the microcontroller - Integrate with memory unit	- Work on user interface on the screen - Work on having the buttons work with the user interface	- Program microcontroller to send outputs to the motor driver to power the motors - Program and integrate with memory unit
April 2	- Finalize power and RFID modules	- Set up user interface to work with the weight readings from the load cell and the clock set up	- Integrate load cells into design
April 9	- Solder & Test PCB	- Mount electronics on physical design	- Solder & Test PCB
April 16	- Integrate project modules	- Integrate project modules	- Integrate project modules
April 23	- Prepare for presentation - Start Final Paper	- Prepare for presentation - Start Final Paper	- Prepare for presentation - Start Final Paper
April 30	- Finish Final Paper - Submit Lab Notebook	- Finish Final Paper - Submit Lab Notebook	- Finish Final Paper - Submit Lab Notebook - Lab Check out

4 Ethics & Safety

In order to align ourselves with the IEEE Code of Ethics # 9 "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment" [4], we must consider all parts of this project which might be injurious to the pet and/or people who come in contact with the device.

Exposed wires and power components may be hazardous if the animal or a person comes in contact with them. There may also be small parts of the device that might come off and make the animal choke upon swallowing. The animal also has the potential of knocking over the device. We commit ourselves to following IEEE Code of Ethics #1, "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment"[4] and will provide appropriate support and shielding in the design so that the components which have the potential of heating up or shocking are far from reach and the device is stable enough to not be knocked over by the cat. We will 3D print portions of the device that will allow us the flexibility in controlling aspects of our physical design which might be endangering.

If the device malfunctions, this could potentially lead to the pet not being able to eat and could potentially lead to it being starved. The owner must check the device every 24 hours to ensure it is working. This is not meant to be a device that should be used in the absence of an owner over a long period of time.

Another consideration to pay heed to is the transformer inside the ac/dc adaptor that plugs into the 120V electric outlet. High voltages lead to problems related to safety. The adaptor that we plan to use is compliant with the electric safety code and must have passed all the safety tests. This complies with IEEE Code of Ethics #1 [4], mentioned above.

With all these considerations, we will also include a list of warnings and precautions that an owner must take in order to ensure the safety and product optimizations. These will include instructions on how to position the device and where to place it so that the device may not be disconnected from the power outlet and is not near any sources of water, as well as other precautions.

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