MREN 318 Course Project Report
Automated Pet Feeder

Queen's University, Kingston, Canada
Department of Electrical and Computer Engineering

Group Members:

Name	Student Number
Nathan Duncan	[redacted]
Tony Yang	
Daniel Poon	

Date Report Submitted:
12/01/2023

Introduction

The aim of this course project was to design, construct, and program a pet feeder. A detailed exploration of the rationale behind the selection of sensors and actuators is covered, and how our solution aligns with the primary objectives as well as addressing some of the desired objectives. An explanation of the scope of the project along with a list of the project's requirements are provided in Appendix A. The final product successfully achieved the given objectives and constraints and deployed for preliminary consumer testing, November 2023. Figure 1 shows a customer enjoying our pet feeder.

Figure 1: A pet cat named Tobi eating food out of our pet feeder.

Sensor and Actuation Selection

Force Resistive Sensor

The FSR 402 Force Sensing Resistor Pressure Sensor was chosen for leftover food measurement to ensure the pet was eating expected amounts of food. The FSR 402 was chosen over the Flexiforce A201 sensor because through our experimental results, it was determined that the Flexiforce A201 had a standard deviation of around 20.614 g compared to the FSR 402 which had a linear relationship with an error of less than 3% of its full-scale output determined both from the datasheet and our own experimental data as seen in Figure 2. The FSR 402 also has a response time of less than 3 µs which is 40% faster than that of the Flexiforce A201. The FSR 402 also requires only a simple voltage divider circuit to be usable which increases the simplicity of the circuit. [1] [2]

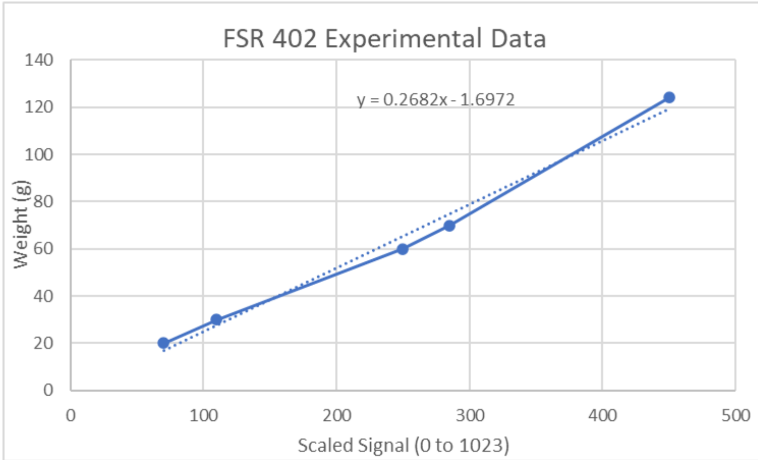

Figure 2: A plot showing weight over scaled signal of the FSR 402.

The FSR 402 was chosen over the load cell due to simpler ease of implementation as the load cell requires a cantilever beam setup which would require many structural changes and reinforcements using more material.

Ultrasonic Sensor

We decided to use the HC-SRF04 Ultrasonic Distance Sensor to sense the amount of food leftover in the food storage container, displaying the fullness as a percentage, indicating when a refill was required. The selection of the ultrasonic sensor was preferred over the infrared sensor due to its linear relationship, as depicted in Equation 1. In contrast, the infrared sensor, as shown in Figure 3, exhibited a nonlinear relationship between duration and distance output. This linear characteristic allows for precise position readings and straightforward implementation. The ultrasonic sensor also displayed higher resolution than the infrared sensor providing more accurate position measurements.

$$d = \frac{t * 343}{2} \quad (1)$$

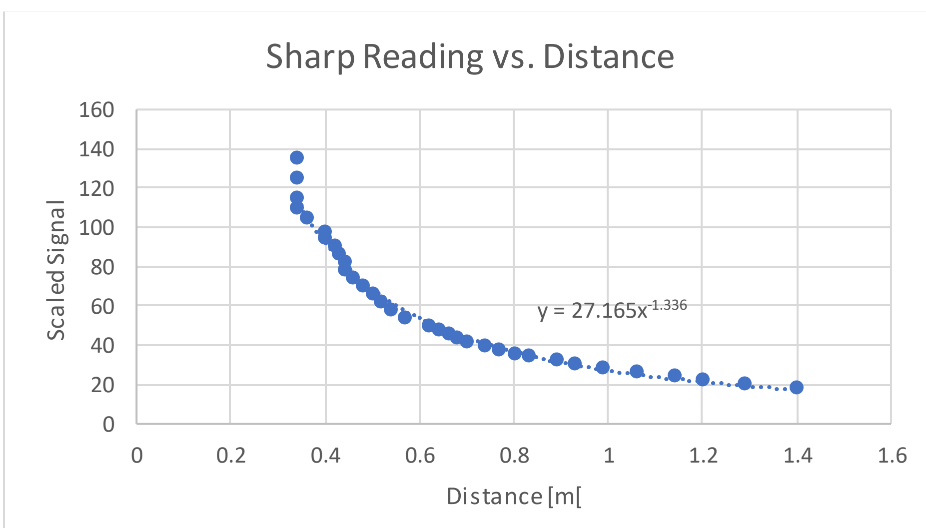

Figure 3: A plot showing scaled signal over distance reflecting the experimentally determined relationship between the two parameters.

Stepper motor

Our group decided to use the QSH4218 Stepper Motor to control portioning of the food dispensing system. Compared to the servo, the stepper motor provides higher torque and allows for full rotations resulting in simplicity in the design of the dispensing mechanism. The stepper motor's torque was 0.400 Nm whilst the servo had a maximum torque of around 0.324 Nm. The ability to fully rotate combined with the stepper's flat face design made it much easier to implement into the pet feeder system than the servo motor. Both motors featured low power consumption, so this was not factored in actuator selection. [3] [4]

Core and Desired Objectives

This analysis delves into the components of both the physical and software systems of our pet feeder, illustrating how it aligns with and satisfies all core objectives and five additional desired outcomes.

Physical System

Indexer

The indexer component of our pet feeder consists of six sections, guaranteeing accurate portion control **{ 2 }**. Figure 4 showcases the SolidWorks model of the indexer. Using a stepper motor with 200 steps per revolution, the indexer underwent testing to dispense cat food, with each section (a 60-degree turn) accurately dispensing around 28 grams.

Figure 4: SolidWorks model of the indexer that dispenses food.

Food Storage

The food storage compartment of our cat feeder comprises eight acrylic panels, accompanied by a securely sealed lid fastened with two stainless steel latches and brackets connecting the acrylic panels, ensuring a reliably secure food storage solution **{ 4 }**. Refer to Figure 5 for a picture of the food storage system. The use of acrylic allows for clear visibility of the remaining food quantity within the container.

Figure 5: Food storage container of the cat feeder to ensure secure storage.

Feeder Structure

The feeder structure primarily utilizes 3D printed PLA for construction. Designed with rounded corners and cylindrical poles to mimic a cat tree, the system prioritizes safety in its use **{ 3 }**. The pet feeder features a specially crafted bowl for pets, complemented by foam stands that provide a comfortable resting place for the pet's neck during meals. Refer to Figure 6 for a photo of the pet feeder's body. To ensure the safety of the pet, secure electronics covers have been implemented to encapsulate the electronics. It's important to note that, during the demo which was when Figure 6 was taken, the cover for the Raspberry Pi was temporarily removed to showcase the backend of our website hosted on the Raspberry Pi to the judges.

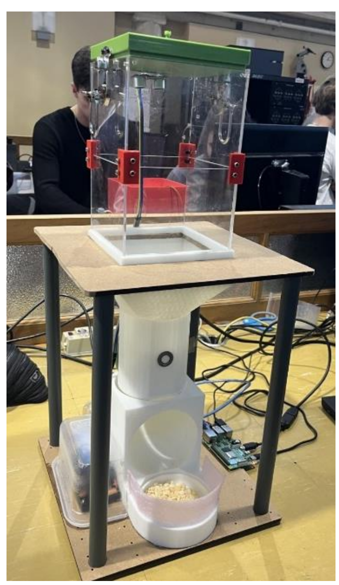

Figure 6: Picture of the pet feeder taken during the day of the demo.

Cost

The pet feeder is priced affordably at $162.21, with a breakdown of parts and associated costs provided in Table 1. This cost is justified by the feeder's ability to automate feeding, relieving the pet owner from the responsibility of manual feeding **{ 5 }**. Additionally, it ensures that the pet maintains a balanced diet by preventing both overeating and undereating.

Table 1: List of parts that make up the pet feeder and their costs respectively.

Part Name	Cost ($)
Arduino	37
Raspberry Pi 4	77
10 AA Batteries	9
Stepper Motor	10
Ultrasonic Sensor	2.80
FSR 402 Sensor	1.41
Physical Structure	25
Total	*162.21*

Power Consumption

Table 2 presents the power consumption details for our pet feeder when it is active. The primary power-drawing components include the Raspberry Pi, the Arduino, and the stepper motor which add up to 15.78 W with is energy efficient **{ 9 }**. Given that one double A battery supplies 4 W-h and there are 10 batteries in our pet feeder, the total energy capacity of the pet feeder is 40 W-h. With an active operation power consumption of 15.78 W and a passive operation power consumption of 5.28 W (excluding motor activity), the pet feeder can operate for approximately 7.5 h. It's important to note that this is a prototype, and the final version of the pet feeder will incorporate an AC to DC converter to draw power from the outlets.

Table 2: Name of electronics and the amount of power they draw respectively.

Electronics Name	Power (W)
Arduino	0.28
Raspberry Pi	5
Stepper Motor	10.5
Total	*15.78*

Software System

Microcontrollers

The main computational unit of the pet feeder is the Raspberry Pi. This device hosts the interactive website, controls the interaction of data from the website, and the Arduino’s input and output messages. The Arduino Uno is used to interface with sensors rather than the Pi as its specialized analog and PWM pins allow for more effective commands.

Bidirectional messaging between the Arduino and Raspberry Pi was achieved using serial communication. The communication protocol established involved three types of messages; motor commands originating from the RPi, and FSR and Ultrasonic readings from the Arduino.

The Pet Feeder Site

The Group 4 Pet feeder web application is designed using the Python Django web framework. This structure allows access to an SQLite database to store project variables and remote access to the server, for devices on the same network.

The site covers many of the project objectives including **{ 1 }**, **{ 7 }**, **{ 10 }**, **{ 11 }**, **{ 14 }**. The main feature of the web page is a dynamic information table, displaying a list of pets, their given serving size, and up to two serving times per day. The void rows below are intended to display feeding characteristics like mass of food consumed and the duration of time the pet spent at the feeder, though this feature is currently not implemented. For remote monitoring and control of the feeder, a user can observe the current feeder status as a percentage of fullness and can override the scheduled feeding time and feed the pet in real time using the "Feed (pet) now!" button.

The user interface, shown in Figure 7, is presented in a tabular fashion with each pet given a unique row. Actionable buttons are described with simple and clear language so that users can use the website intuitively. New pets may be added to the feeder's database simply using the form at the bottom of the page and the parameters of current pets may be edited or deleted using the buttons to right. As precaution, more specific instructions for using the app as well as an in-depth description of the pet feeder is provided on the "About" page.

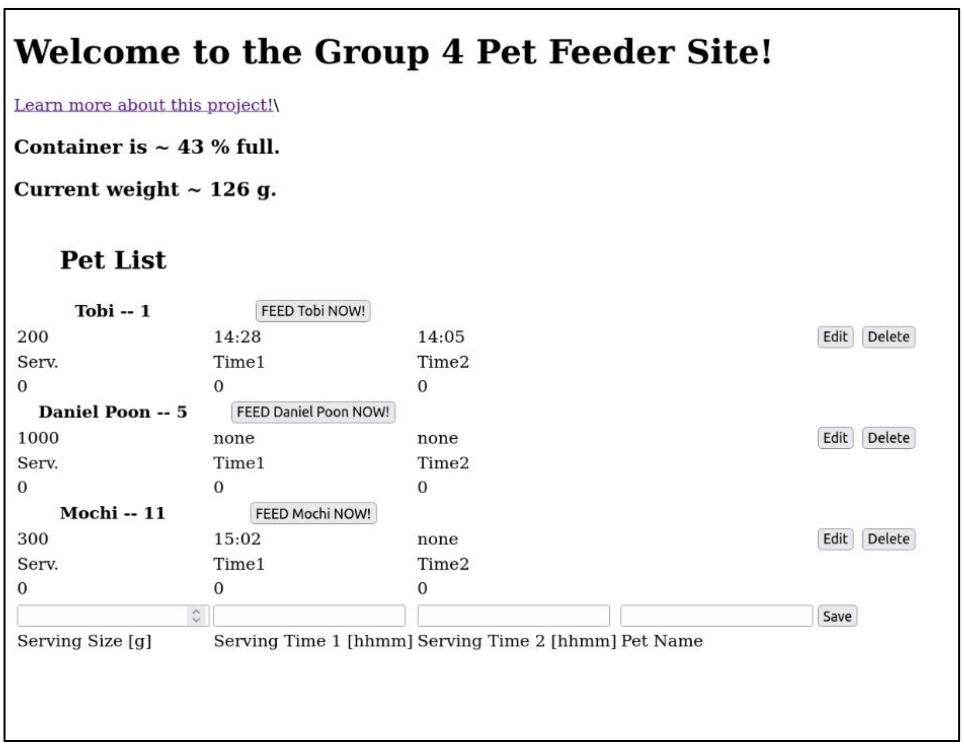

Figure 7: Screenshot of the web server interface displaying a dynamic information table and other features.

Scheduling

An important objective of the pet feeder is to allow for feeding intervals and scheduling **{ 1 }**. This is achieved through a secondary Python program, scheduler.py, which periodically reads from the site's database and checks if the current time matches any of pet objects' serving times. In the event there is a match, the schedular program will send a command to the Arduino using the serving size of the associated pet.

Bowl Feedback

On the site's backend there is a function, adjustServing(), which is used to conform with objectives of accurate portion control and monitoring of pet activity levels to adjust portion sizes accordingly to maintain a healthy weight. This function is called immediately before a serving command is sent to the Arduino motors and is passed the serving size to be poured. The function first requests the weight of the bowl which read across the force sensitive resistor beneath the bowl. A proportional controller then takes the difference between the measured weight and the desired serving size and returns the error as shown in Figure 8. This feedback control ensures that each serving is accurate to the desired size and does not exceed this size, preventing over feeding.

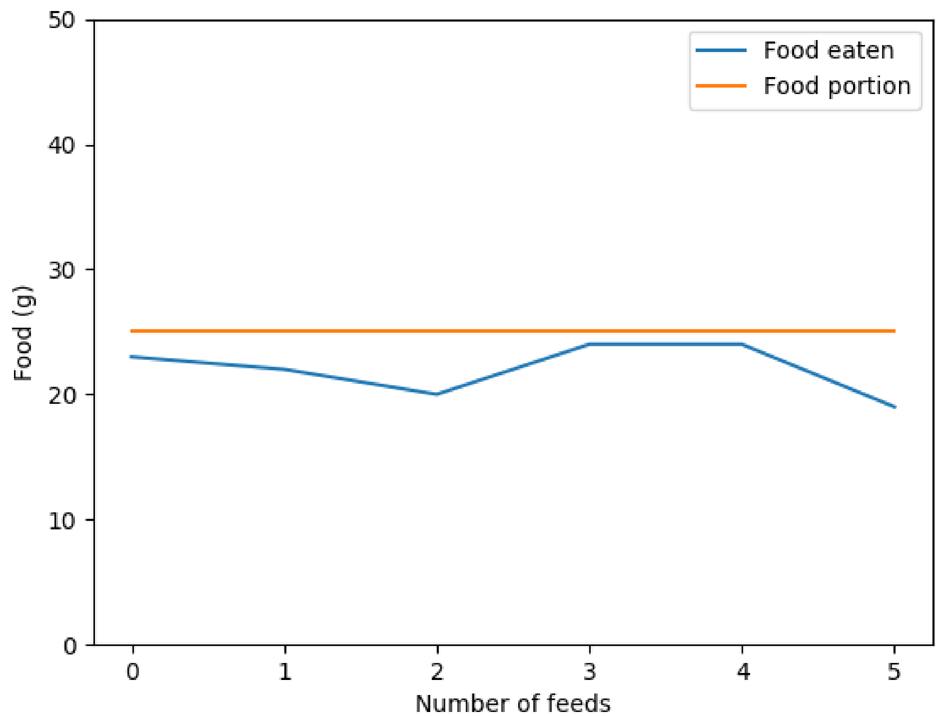

Figure 8: A plot showing food portion and food eaten of the pet.

Appendix A: Objectives

A pet feeder must meet provided objectives and constraints provided by the course makers to be considered viable products. These requirements are sub divided into three categories;

- **Core objectives** – "fundamental, non-negotiable goals that must be achieved for the project or product to be considered successful."
- **Desired Objectives** – "goals and features that, while not critical for the project's core functionality, enhance the product's appeal, usability, and user experience."
- **Constraints** – "Constraints are limitations, restrictions, or factors that impose boundaries or restrictions on a project, process, or system"

The designed Group 4 pet feeder successfully achieved all five core objectives, and six desired objectives. The project also conforms to all three constraints, using two provided sensors, the provided stepper motor, and designed the system so that all electronic components could be easily disassembled.

To easily refer to each objective in the report each objective has been enumerated below.

Core Objectives

{ 1 } Your pet feeder should allow flexibility for the user to control portion size, feeding intervals, and scheduling.
{ 2 } Your pet feeder should ensure accurate portion control.
{ 3 } Your pet feeder should be safe for a pet to use and should not endanger your pet in any way.
{ 4 } Your pet feeder should ensure secure food storage.
{ 5 } Your pet feeder should be affordable.

Desired objectives

{ 6 } Your pet feeder enables a notification and alert system for pet owners.
{ 7 } Your pet feeder enables remote monitoring and control.
{ 8 } Your pet feeder enables voice and/or video interaction.
{ 9 } Your pet feeder is energy-efficient, with low power consumption during operation and standby mode.
{ 10 } Your pet feeder has a user-friendly interface.
{ 11 } Your pet feeder integrates with pet activity monitoring to monitor pet activity levels and adjust feeding schedules or portion sizes accordingly to maintain a healthy weight.
{ 12 } Your pet feeder enables pet identification and access control to prevent food theft or overeating by another pet.
{ 13 } Your pet feeder is easy to clean and maintain.
{ 14 } Your pet feeder can accommodate multiple pets with individual feeding schedules or portions.
{ 15 } Your pet feeder could be compatible with popular smart home systems like Amazon Alexa, Google Assistant, or Apple HomeKit for seamless home automation.

References

[1] I. Electronics, "FSR 402 Data," 26 10 2010. [Online]. Available: https://www.trossenrobotics.com/productdocs/2010-10-26-DataSheet-FSR402-Layout2.pdf.

[2] FlexiForce, "FlexifForce Standard Model A201," FlexiForce, 2021. [Online]. Available: https://www.tekscan.com/sites/default/files/FLX-Datasheet-A201-RevI.pdf.

[3] T. M. Control, "Analog," 2023. [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/QSH4218_datasheet_rev1.10.pdf.

[4] Sparkfun, "Announced specification of HS-422 standard deluxe servo," 2023. [Online]. Available: https://cdn.sparkfun.com/datasheets/Robotics/hs422-31422S.pdf.