FEED

MREN 318 Course Project

Automatic Pet Feeder

Queen’s University, Kingston, Canada

Department of Electrical and Computer Engineering

Group Members:

Name	Student Number
Luke Parna-Gile	20281609
Callum Berry	20273953
Callan Robinson	20295701

Introduction

The team's automatic pet feeder solution implements a system of sensors and actuators to meet and exceed the needs of supporting customers. This report covers defined sections of the project development including Sensor Selection, Actuator Selection, Core Objectives and Desired Objectives. These sections highlight the extensive testing and iteration conducted to achieve the final product. Additionally, the team's code for both the hardware and website can be found on GitHub.

There is significant overlap between methods and sensors used and the analysis and reasoning behind their selection. For concise coverage of all engineering design decisions, more analysis and reasoning for sensor and actuator selection is covered under the objective sections 3.0 and 4.0.

1.0 Sensor Selection

Sensors implemented in the autonomous pet feeder were tested and compared with similar options. Feedback of the weight in the pet bowl was deemed ideal for achieving many objectives covered in succeeding sections. To achieve this closed loop control, three sensors were considered. The FSR 402 Pressure Sensor, A201 Flexiforce Pressure Sensor and the SENS-5 5Kg Load Cell Sensor.

Table 1: Max and min resistances and output voltages for both sensors.

402		A201	
Max ohm = infinite	Min ohm = 325 ohms	Max ohm = infinite	Min ohm =2.5k
Min vout = 25mV	Max vout = 5.08	Min vout = 23.5 mV	Max vout = 3.85 V

$$A_{FSR402} = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{18.28\times10^{-3}}{2}\right)^2 = 2.624\times10^{-4}\ m^2$$

$$A_{A201} = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{9.53\times10^{-3}}{2}\right)^2 = 7.133\times10^{-5}\ m^2$$

$$A_{Coupler} = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{9\times10^{-3}}{2}\right)^2 = 6.362\times10^{-5}\ m^2$$

Table 2: Pressure calculations for both the 10 g and 20 g weights

Weight	Pressure (402)
10g	$P = \frac{m}{A_{Coupler}} = \frac{10\ g}{6.362\times10^{-5}\ m^2} = 157.18\ kg/m^2$
20g	$P = \frac{m}{A_{Coupler}} = \frac{20\ g}{6.362\times10^{-5}\ m^2} = 314.37\ kg/m^2$

Table 3: Pressure calculations for both the 10 g and 20 g weights, same coupling as 402.

Weight	Pressure (A201)
10g	$P = \frac{m}{A_{Coupler}} = \frac{10\ g}{6.362\times10^{-5}\ m^2} = 157.18\ kg/m^2$
20g	$P = \frac{m}{A_{Coupler}} = \frac{20\ g}{6.362\times10^{-5}\ m^2} = 314.37\ kg/m^2$

Table 4: Recorded data of output voltage at specific applied weights for increasing and decreasing applied weights.

Increasing Weights	
Applied weight (g)	Vout (V)
Coupling piece	0
10	0
20	0.35
40	2.15
50	2.51
100	3.45
200	3.90
300	4.03
400	4.11
500	4.21

Figure 1: The three sensors considered for measuring weight in the bowl. From left to right: FSR 402 Pressure Sensor, 201 Flexiforce Sensor Pressure Sensor, SENS-5 5Kg Load Cell Sensor.

After this testing of the 402 and the A201, the A201 was selected as its output values did not drift. Also, the A201 has a calibration mode when first turned on which results in more accurate readings compared to 402. The SENS-5 5kg load cell sensor was not chosen due to time constraints has it is more complex, and time consuming to setup and calibrate in comparison with the 402 and A201.

The hardware user interface was determined to require a method of switching between modifiable values and a method of varying those values. To implement this, two options were considered that were viable with available materials: a button paired with a 3386 series potentiometer or a KY-040 rotary encoder.

The KY-040 rotary encoder has an output of 2-bit gray code as well as a built-in button with a separate output bit [1]. For a compact design, less physical space used is beneficial, under the condition that the objectives are met. With use of the KY-040, the circuitry and physical space needed for a separate potentiometer and button is not required. Additionally, the board determined necessary to meet other objectives does not support analog input. Implementation of the rotary encoder less complex and more time efficient because ADC circuitry and logic is not required.

To determine the amount of food in the feeder's container, two distance sensors were considered. The HC-SRF04 is an ultrasonic distance sensor with a distance range of 2 cm to 400 cm [2]. The GP2Y0A02YK0F IR distance sensor has a peak output voltage at approximately 15 cm, and its usable detection range is greater than this. [3] This information is apparent in Figure 3.

Figure 2: The distance sensors considered. From left to right: HC-SRF04, GP2Y0A02YK0F

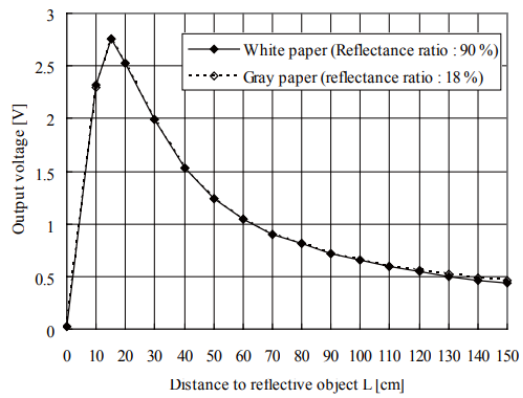

Figure 3: IR sensor GP2Y0A02YK0F measuring characteristics. [3]

The automatic pet feeder container is relatively small for practical implementation in common households. This includes the container depth. Therefore, it is important to have accuracy at smaller distance values. Thus, the HC-SRF04 ultrasonic sensor was determined to fit the application of measuring container data well.

2.0 Actuator Selection

A motor was required for dispensing food from the feeder's container to the bowl. The stepper motor was ultimately chosen over the servo because of a few key reasons: continuous rotation, movement controls, and its high torque at low speeds. The benefit of continuous rotation is that every 360 degrees of rotation dispenses 4 portions of food. If the servo was used instead, for every 360 degrees of rotation only 2 portions would be dispensed. Half of the rotations would be for dispensing a portion and the other half for returning to original position to collect more food. The benefit of this is that it reduces the wear on the mechanical components of the system, as it moves half the amount. The stepper has a 1.8° step angle, which is smaller than servo. This increased resolution of the stepper allows for more precise rotation, and when operated slowly, greatly reduces the likelihood of jamming of the pet feeder [4] [5]. An additional benefit of the stepper is that unlike the servo, it does not move to a target angle, it moves clockwise or counterclockwise in the chosen direction. This is essential to our testing and prototyping process, as the location of the hopper outlet, slide entrance, and motor spin direction influenced the feeder's likelihood to jam. A cooling fan was added to the A4988 stepper motor driver to prevent overheating of the chip when supplying 1.5 amps to the stepper motor.

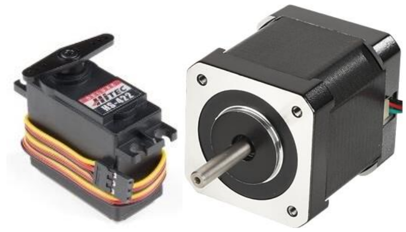

Figure 4: The motors considered for food dispensing. From left to right: HS-422 Servo Motor, SY42STH38-1684A Stepper Motor.

3.0 Core Objectives

Flexible Controls

The FEED pet feeder gives the user full control of the amount of food dispensed and when throughout the day. The user can control the number of portions (approximately 5 grams each) and the times of day to dispense this amount. The user has the option of specifying these options either via the LCD screen and encoder interface above the bowl, or via the web application. The data related to portion number and scheduling updates on the hardware when it is change on the website and vice versa. See section 4.0 for more details on the flexible controls.

The decision to synchronize hardware and online controls was made for ease of use. Additionally, the scheduling uses network time protocol for obtaining the time of day through the internet. In a real application, the feeder would include an onboard clock, so it would function as specified even if the internet connection was lost.

A minimum 5-hour gap between feeding times was chosen to ensure the pet has 2 separate meals and doesn't overeat in a short period of time [6] [7].

Accurate Portion Control

The original design used the servo motor with the V1 indexer as shown in Figure 5. This design dispensed smaller portions and wasted time and energy rotating back and forth. The V2 indexer uses the stepper motor, and supported a continuous motion in one direction, addressing the flaws of the previous design.

The increased resolution of portion indexer allows for increased flexibility and accuracy when dispensing food. The final design of the indexer has section sizes that hold approximately 5-6 grams, as seen in Figure 6. This **high resolution** allows for a more precise food dispensing and gives the ability for more specific error correction.

Use of a **reliable actuator** that can apply a sufficient amount of torque to avoid jamming is important when outputting a specified value. The decision to use the stepper motor is important to the reliability of the feeder as a whole.

A **portion feedback loop** was implemented and allows for increased accuracy and error correction. Code was implemented to continue indexing the stepper motor by one portion if the pressure value recorded from the bowl has not increased. When it does this twice and there is still no increase, a warning that something has gone wrong is printed.

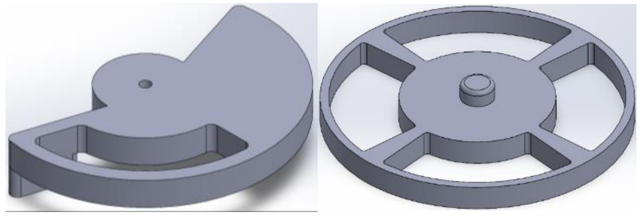

Figure 5: SolidWorks models of the V1 indexer (left) and V2 indexer (right).

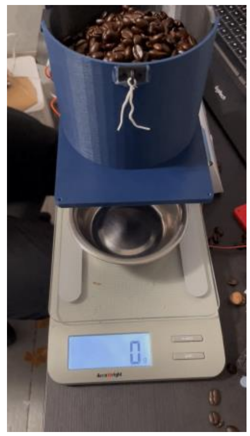

Figure 6: Demonstration of the mass of one portion dispensed by the FEED pet feeder (5 grams)

Safety

The final model was developed with **pet safety in mind**. The feeder has **no exposed moving parts** and **no sharp or other potentially harmful surfaces,** ensuring that your pet is safe when eating. Moving parts were considered for many different models of the feeder but having the mechanism enclosed inside achieved the goal of safety.

Notifications regarding potential pet endangerment were considered and implemented on the website. Particularly, a notification of when the container lid was left open ensures that the user is aware when the cat might have access to the food and is at risk of overeating.

Remote monitoring also provides information to the user about the pet feeder via the web application. For instance, the state of the container being full, half full or almost empty. The user is always aware of when they should be filling the container so that the feeder can operate, and the pet can eat as expected. Also, the webcam provides livestreamed video monitoring from the feeder as an additional safety feature.

Secure Storage

The feeder has a large base in comparison to its height to improve the **stability** of the enclosure. The lid securely holds the food in with a **latch system** and **hinge**, ensuring the pet is unable to access the food inside the hopper even if the feeder is knocked over, as shown in Figure 7.

Figure 7: Picture of latch system (left) and hinge system (right).

Affordable

The team focused on implementing a **single board** system to reduce cost. A Raspberry Pi is used without a separate microcontroller such as an Arduino. Prices from online retailers show a Raspberry Pi or similar technology meets the price of microcontroller-only systems [8]. Using a single board reduces the cost and complexity of system integration between two boards produced by two different companies.

The aim was to have our product fit within the range of market value prices. The range of cost for automatic pet feeders on the market is between $70 and $250 [9] [10]. Considering the bill of materials shown in Table 3, our product **matches the market value** of automatic pet feeders. The materials have a cost of approximately $140 (does not include manufacturing and advertising cost).

Table 3: Bill of materials

Additionally, a margin of relative cost between FEED's pet feeder and mass-produced pet feeders available today is reasonable. A cost margin between a prototype and manufacture product is reasonable to account for when creating an initial design [21]. Therefore, fitting in the range of the market value with a prototype that obtains all or more features than common pet feeders found online proves affordability.

4.0 Desired Objectives

4.1 Remote Monitoring and Control

Remote monitoring and control were achieved by implementing a **full stack web** application. This set up was chosen because it is commonly used in systems for remote connection. It allows for server-client implementation where important data and hardware functions are running fully on board the pet feeder and the client-side application is passed to the user's device and does not overwhelm the pet feeder board. Moreover, remote monitoring and control is covered in 4.2 User-Friendly Interface.

The code base is large with many features. One important feature when monitoring and control can be remote is that the device saves valuable data. The overall system can be seen in a simplified block diagrams in Figure 8. Data files can be seen on the server side where the important information is saved like how full the container is or if the lid is open. When the device is powered off and on again, this data is still saved to the device and will not be lost. This contributes to high practicality and quality of all other aspects of the project including pet safety.

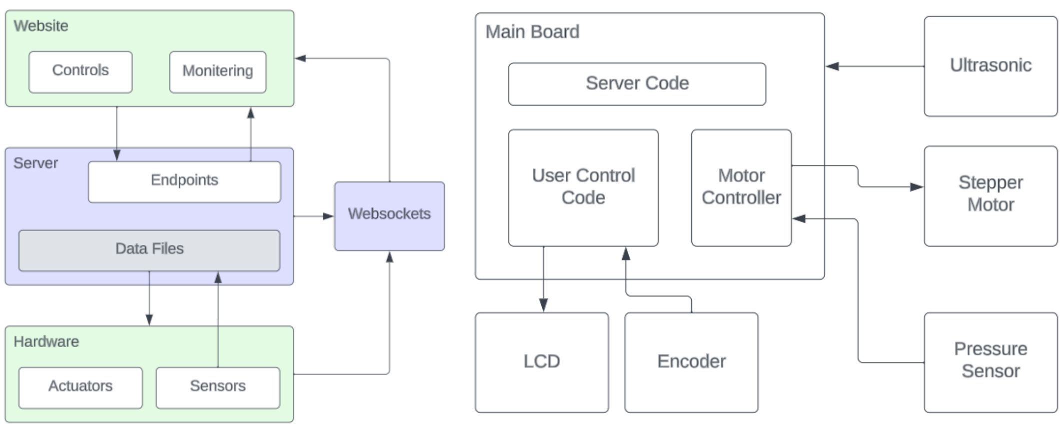

Figure 8: Simplified overall system diagram (left) Simplified hardware system (right)

The ultrasonic sensor records the distance seen from the top of the food container. It then determines whether the container is full (less than 20% of the container height is returned), half full (20% to 80% of container height is returned), or almost empty (80% of container height is returned). It will pass this data to the front end for the user to see. There is also a feature where when more than 100% of the container height is being returned it displays to the user that the container was left open. This functionality was decided on because it plays into pet safety ensuring that the user knows important information that contributes to keeping the pet safe. More on live monitoring is covered in sections 4.2 User-Friendly Interface and 4.5 Video Interaction.

4.2 User-friendly Interface

The web application has a variety of easy to understand and organized pages and features. This structure was determined based off the hardware design decisions made, splitting it into pages such as controls and remote monitoring. All data from the pet feeder is converted and displayed as easy to understand information such as a diagram of the container fullness and sliders for the currently set portions and feeding times. This data as well as the live camera feed is divided into the controls and remote monitoring pages.

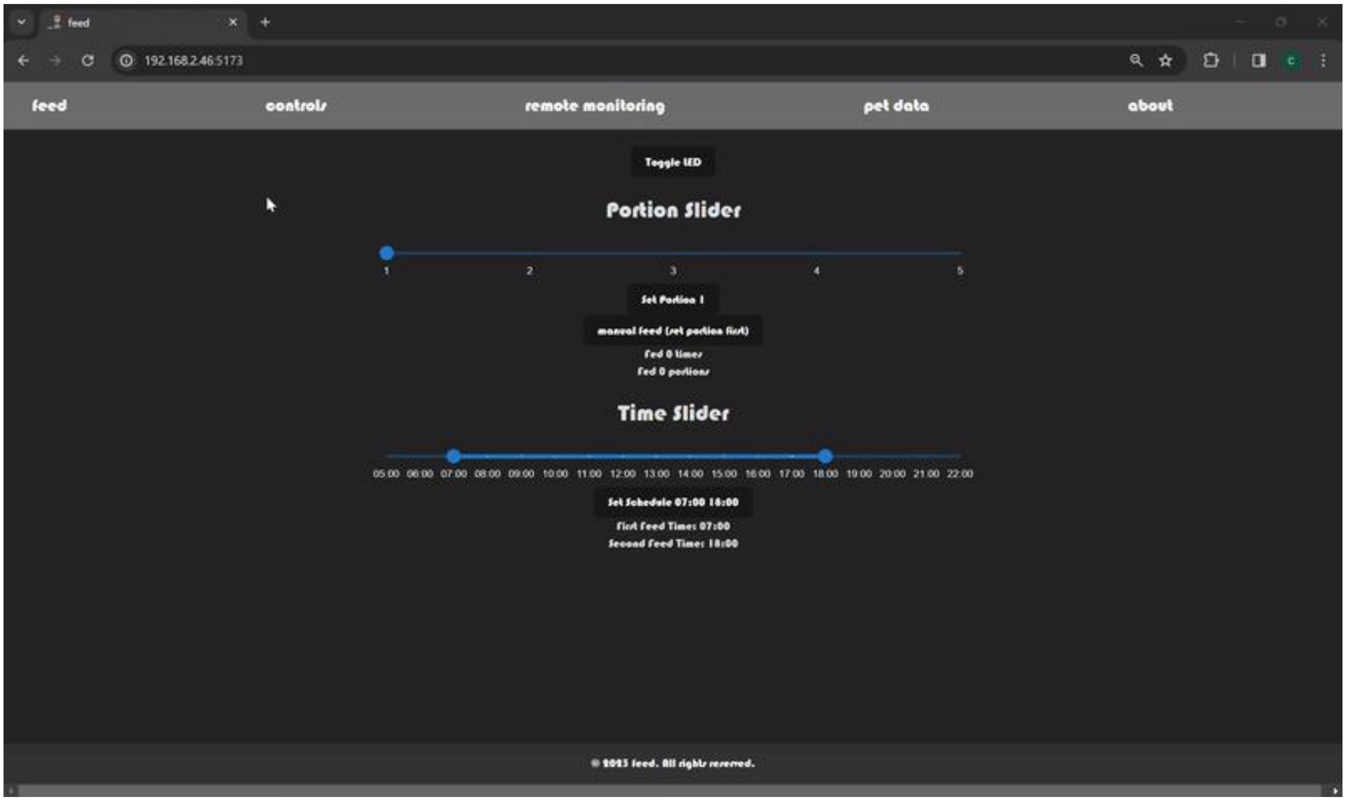

Figure 9: GIF showcasing the main features of the website.

Additionally, a simple hardware interface is included on the front of the feeder, it allows the user to control portion and feeding times with the KY-040 encoder.

Figure 10: Video of hardware UI using LCD1602 Lcd Display and KY-040.

4.3 Easy Cleaning and Maintenance

The device has **toolless cleaning** with modular components. Once the lid is open the user can easily slide out the hopper giving them access to the stepper motor indexer which can also slide off. Once the indexer is removed the user can remove any debris that has collected over the use of the device. While maintenance is not toolless, the device can be disassembled and repaired with the use of a standard M3 screwdriver. Four screws hold the electronic box cover, four hold the motor in place, and two hold the bowl piece in place. Also, a metal bowl was chosen to ensure longevity of the bowl and its simplicity to clean.

4.4 Notification System

The notification system ensures that the user has the most up to date information about their pet feeder. The most basic notification confirms to the user that after selecting a value on the website that it has correctly been sent to the server. The device also informs the user when the manual feeding has been completed. Also, if the user leaves the lid of the device open a notification will pop up, informing the user to close the lid. A GIF of the notification system and more details can be found in section 4.2.

4.5 Video Interaction

The original plan was to use Pi Cam as it has a lower cost and is smaller than the Logitech webcam, seen in Figure 11. However, the Pi Camera only supports a 32-bit Ubuntu Kernel, not the 64-bit Ubuntu Kernel that is now standard. The Logitech webcam is a suitable replacement as the feeder can still display live monitoring to the user, albeit at an increased cost.

Figure 11: Picture of Pi Cam (left) and Logitech USB Webcam (right).

Product Summary

The final product incorporates a well-structured system of sensors and actuators implemented in a way that achieves a complete autonomous pet feeder. Analysis of sensors and actuators ensured quality engineering design decisions that contributed to meeting all core objectives and the majority of the desired objectives. Sensors selected include the A201 Flexiforce pressure sensor, the KY-040 rotary encoder, and the HC-SRF04 ultrasonic sensor. The selected actuator for the dispensing mechanism is the SY42STH38-1684A Stepper Motor. Overall, the analysis and testing of sensors and actuators allowed FEED's product to achieve flexible controls, actuate portions, safety for the pet, secure storage, affordability, remote monitoring and control, user friendly interface, easy cleaning and maintenance, notification system, and video interaction.

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