MREN 318

Squirrel Feeder Project

Prepared By:

Matthew Gilbreath: 20353507
Abby Herbert: 20328450
Josh Westlake: 20349406

Table of Contents

1. Problem definition and functional requirements

This squirrel feeder aims to address the challenges of providing timely, precise, and consistent feeding for backyard squirrels while ensuring safety, convenience, and cost-effectiveness. Traditional feeding methods can be inconsistent and prone to issues like food theft by other animals, overfeeding, or contamination. By automating the process, the system not only saves time for users but also promotes healthy feeding habits for squirrels.

The design of the squirrel feeder is structured around achieving the following core objectives:

- **Flexibility for the user** to control feeding intervals, and scheduling for animals.
- An **accurate portion** control system
- Guaranteed **safety** of the animal
- **Secure food storage**
- An **affordable design** and manufacturing procedure

In addition to the core objectives, the design also incorporates three desired objectives to enhance user experience and improve performance:

- A **user-friendly interface** that simplifies setup, scheduling, and operation processes
- A squirrel identification feature to **prevent food theft** from other animals.
- A mechanism that is easy to **clean and maintain**

By focusing on these objectives, the project delivers a practical and efficient method for automated squirrel feeding—solving one of the backyard's most overlooked logistical challenges.

2. Conceptual Design Solution

2.1 Overview of conceptual design

The automatic pet feeder integrates a variety of mechanical, electrical, and software components to deliver a comprehensive feeding solution. The design utilizes a stepper motor to control an Archimedes screw mechanism for dispensing accurate food portions, while the servo motor operates a trap door for precise food release. A variety of sensor modules, in combination with machine learning, identifies authorized pets (squirrels), prevents unauthorized access to food and provides precise portion control, as well as accurate feeding time and scheduling. The complete prototype of the squirrel feeder can be seen in Figure 1 and the complete CAD can be seen in Figure 2.

Figure 1: Final Prototype of the squirrel feeder

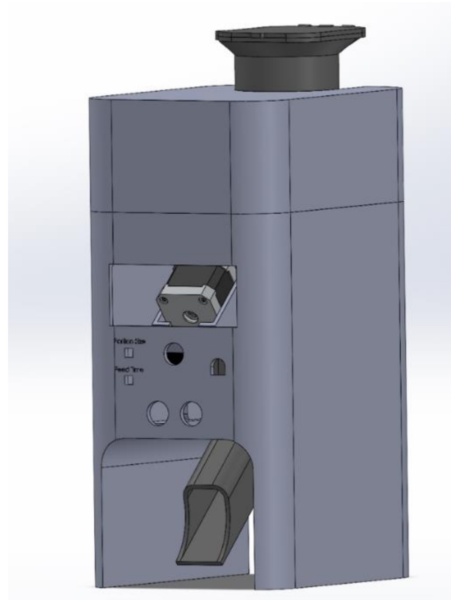

Figure 2 Complete CAD of the squirrel feeder

2.2 Component Selection

The automatic squirrel feeder uses a combination of carefully selected sensors to achieve accurate detection, portion control, and user monitoring. The sensors work together to ensure smooth operation and meet the functional requirements of the system. The system design, as illustrated in Figure 3, highlights the integration of the sensors, actuators, and power management systems.

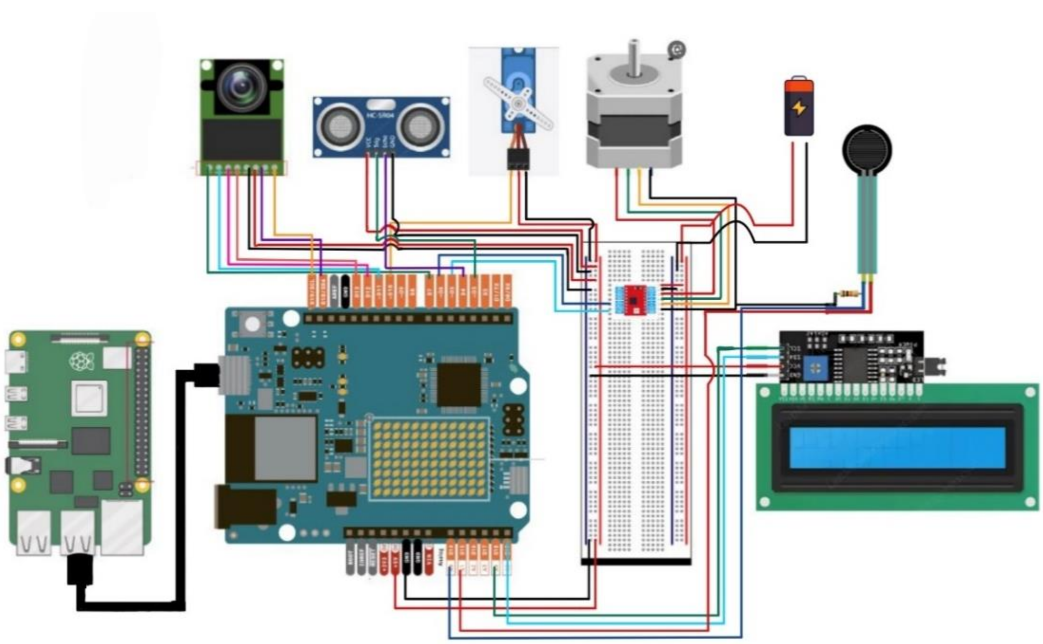

Figure 3: Wiring diagram for system

2.2.1 Sensor Selection

To achieve the systems functional requirements, the feeder relies on a combination of sensors that ensure precision, reliability, and seamless operation. The following sensors play a critical role in detecting the presence of squirrels, monitoring food portions, and maintaining overall system accuracy.

HC-SR04 Ultrasonic Sensor

The HC-SR04 was selected to be used as a proximity sensor. Operating at a frequency of 40 kHz, it emits sound waves from its transmitter that reflect off any nearby objects and returns to the receiver of the sensor. Then the internal logic of the sensor calculates the distance based on the time delay of the returning echo using the relationship defined in equation. According to the data sheet, this sensor provides accurate readings for a range of 2cm to 400cm ensuring a reliable detection for any approaching animals. This sensor is interfaced with the Arduino, using a combination of trigger and echo pins to detect motion in front of the feeder.

Arducam Mini Module Camera

The Arducam mini module camera was used as the primary sensor for squirrel identification. This sensor was used to capture images which were used to identify squirrels using machine learning. This camera interfaced with the Arduino Rev 4. Additionally, its compact size and compatibility with the design of the feeder made it an ideal choice for the application.

FSR 402 Pressure Sensor

The FSR 402 pressure sensor is a force-sensitive resistor that is used to measure the applied force or pressure, which allows for monitoring of the mass of the dispensed food. It operates by varying the resistance inversely with the applied force. When incorporated as a voltage divider an output voltage can be read which is proportional to the weight of nuts on the sensor. Its flat profile and flexible design allowed for easy integration on top of the trap door mechanism, allowing for closed loop feedback control system between the mass on the sensor and stepper motor. With a force sensitivity range of 0.2–20 N and a response time of less than 5 milliseconds, the FSR 402 delivers real-time feedback for accurate portion control. The following Force vs Resistance curve was utilized to map the mass of the food to the expected resistance of the FSR.

Potentiometer

A 20kΩ potentiometer was incorporated into the system to provide adjustable input for the UI, allowing precise control of the feeder's adjustable parameters.

In the context of the squirrel feeder, the potentiometer is connected to one of the Arduino microcontroller's analog inputs to allow the user to adjust parameters, such as portion sizes or feeding time. As the user turns the potentiometer, it generates a corresponding analog voltage signal, which the Arduino interprets. The connected LCD screen displays the current value of the parameter being adjusted in real time, providing immediate feedback and ensuring accuracy.

Push Buttons

Push buttons were incorporated into the squirrel feeder to allow users to confirm their selections for feeding parameters, such as portion size and scheduling. When pressed, the buttons send a digital signal to the Arduino, triggering the system to save the selected settings and move to the next step in the configuration process.

2.2.2 Actuator Selection

Actuators facilitate the squirrel feeder's mechanical functionality, transforming electrical signals from the microcontroller into precise movements that control food dispensing. Through using both the stepper and servo motors the nuts can be transported reliably throughout the entire system and dispensed to the squirrels.

QSH4218 Stepper Motor

The QSH4218 stepper motor provides precise control and sufficient torque to churn the Archimedes screw carrying nuts from the upper reservoir down to the feeding chute. It operates through discrete steps (200 steps per revolution), enabling a high positional accuracy. The motor is used in combination with an A4988 stepper motor driver, which simplifies interfacing with the Arduino by generating appropriate current control signals. The motors torque and reliability make it ideal for creating a steady flow of nuts from the storage tank to the later stages of the system.

HS-422 Servo Motor

The HS-422 servo motor is responsible for actuating the trap door that facilitates the accumulation of nuts and their controlled release down the feeding chute. This motor has an operational torque of up to 4.1 kg-cm, which significantly surpasses the required torque to open and close the trap door mechanism. Like any servo motor it is controlled using PWM signals which come from the Arduino and is rated for precise rotation between 0 and 180°, ensuring secure and controlled food dispensing. To correctly position the motor, the following relationship was derived between the pulse width signal and desired angle.

$$Angle = \frac{Pulse\ Width - Min\ Width}{Max\ Width - Min\ Width} * 180^{\circ} \tag{1}$$

Due to the servo motors' compact size, low power consumption (5V), and ability to maintain its positions without continuous input make it an excellent choice for the trap door mechanism in the squirrel feeder.

2.3 Mechanical Design

The mechanical system of the squirrel feeder can be seen in Figure 5. The process begins with the upper nut reservoir seen in Figure 7, designed to securely store the nut supply. This reservoir can be locked or twist-tied shut to prevent access by animals, ensuring secure food storage. Nuts are gravity-fed into the Archimedes screw mechanism as seen in Figure 4, which is powered by the QSH4218 stepper motor. The stepper motor precisely churns the screw to transport nuts from the reservoir down the vertical chute and onto the trap door mechanism visible in Figure 6. The Archimedes screw design was carefully adapted to address initial issues where the excessive torque of the stepper motor caused nuts to crush into paste and release their natural oils. This would cause the system to jam-up and the stepper motor to stall. By modifying the screw tolerances and introducing a flat section at the screw's terminal portion, the nuts are pushed directly into the chute when they reach the bottom, preventing jams and ensuring a consistent flow. Additionally, an algorithm was implemented in the stepper motor to perform a forward-backward rotation every 5 seconds, further reducing the risk of jams and improving overall reliability.

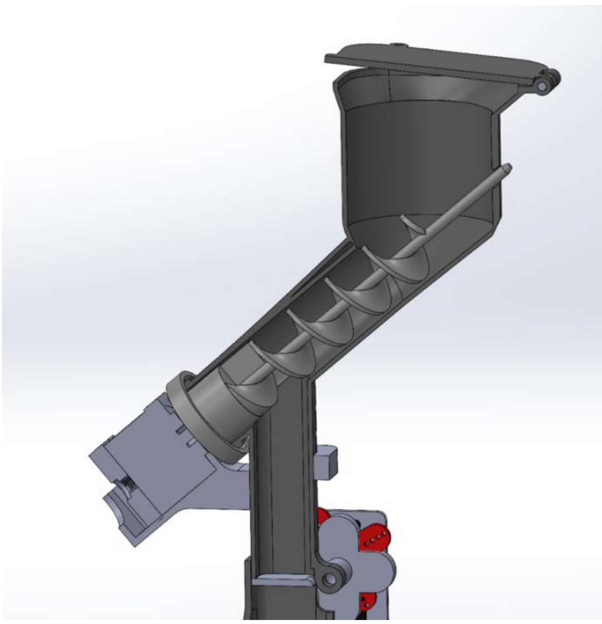

Figure 4: Internal Mechanism of Feeder

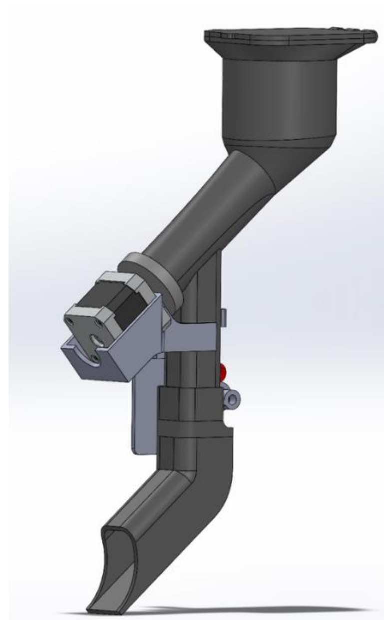

Figure 5: Mechanical System Design

As the nuts descend the chute, they land on the trap door mechanism, which incorporates a force sensor, and a small plate designed to focus the weight of the nuts onto the sensor. This configuration allows the system to measure the portion size in real-time, with feedback used to control the stepper motor until the target weight is reached. Once the desired portion is dispensed, the HS-422 servo motor secures the nuts on the trap door until the system confirms the presence of a squirrel. Upon detection, the servo releases the pre-portioned nuts by opening the trap door, dropping them down the feeding chute, and performing a quick back-and-forth twitch to ensure all nuts are fully cleared.

The squirrel feeder incorporates safety by enclosing all moving parts within a compact, robust box, as shown in Figure 2 previously. This design prevents squirrels from accessing internal mechanisms, reducing the risk of injury. The feeding chute directs nuts to a safe, accessible location, ensuring squirrels can retrieve food without exposure to internal actuation.

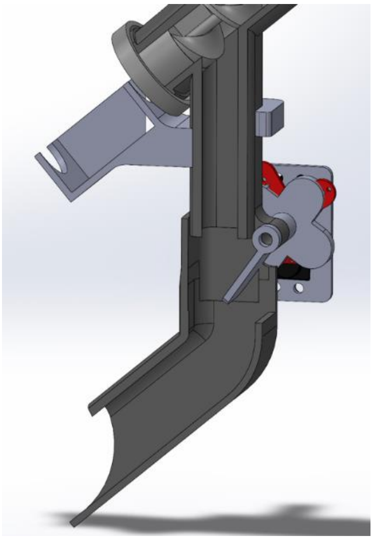

Figure 6: Internal Trap Door Mechanism

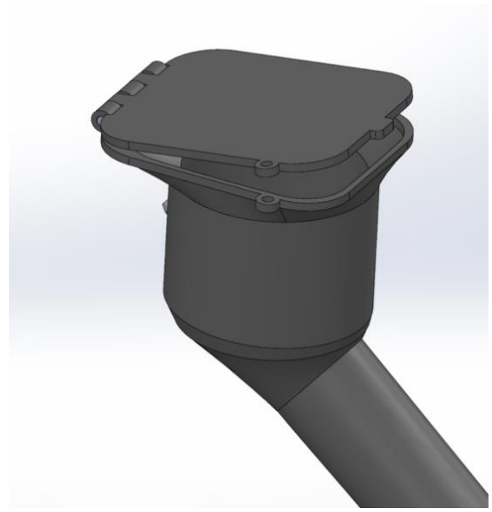

Figure 7: Upper lockable nuts reservoir

2.4 Software and System Architecture

The functional architecture of the squirrel feeder system is shown in Figure 8 below. It outlines the flow of the system including how the Arduino, Raspberry Pi, motors, and sensors work together.

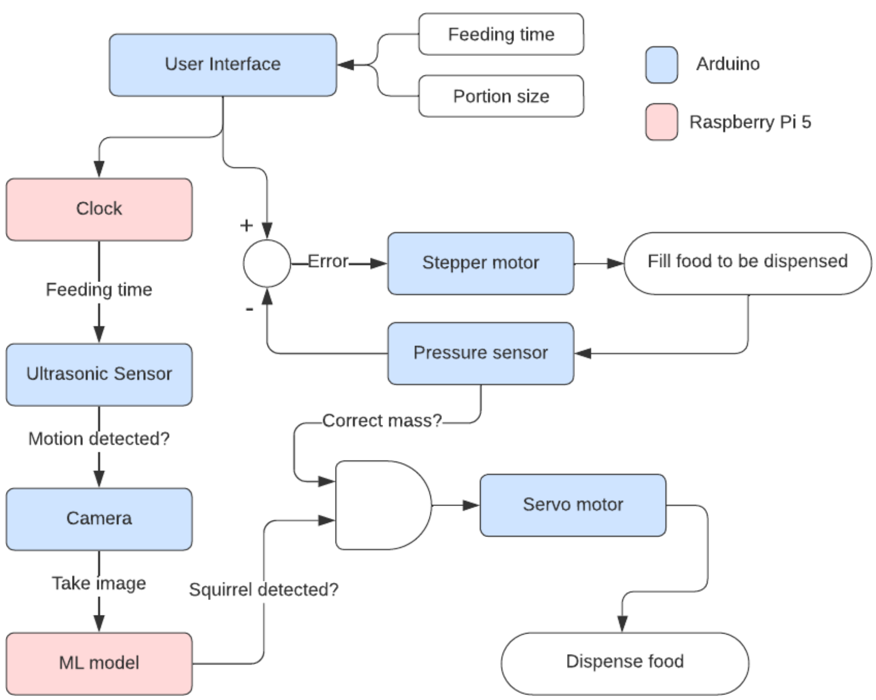

Figure 8: Software Architecture of squirrel feeder

A desired objective met with this design is the user-friendly interface. This was accomplished using an LCD screen, a potentiometer for precise control, and 2 buttons to confirm the user's selection. The setup portion of the software prompts the user to enter the feeding time (time of day available as precise as 3-minute intervals), as well the portion size from 0.1- 5.0 grams of nuts.

Once the user has selected portion size and feeding time, the stepper motor and pressure sensor feedback system is used to pre-load nuts into the chamber as discussed in section 2.3. Once complete, the Arduino sends the feeding time to the Raspberry Pi over serial. The Pi is connected to the internet and proceeds to compare the user's selected feeding time to the actual current time of day. Once the current time reaches the desired time, the Pi sends back a time flag to the Arduino, triggering it to move to the next phase, motion detection. In the motion detection phase, the ultrasonic sensor is used to detect movement in front of the feeder. If something comes within 40cm of the sensor, it triggers the camera to take an image. This image is sent over serial communication to the Raspberry Pi. The script on the Pi reconstructs and saves the JPEG image data locally. It detects the JPEG start and end markers to ensure the image is properly reconstructed.

This image is then used to meet another desired objective, pet identification to prevent food theft, using a machine learning model. To do this, a pre-trained model for identifying squirrels from Roboflow was implemented using their API. The model returns a classification result, including confidence scores for any detected objects. If the confidence score for "squirrel" is above a predetermined threshold, the system identifies the object as a squirrel. If a squirrel is identified from the image, a "SQUIRREL" flag is sent back to the Arduino, signaling it to actuate the servo, opening the trap door and dispensing the pre-loaded nuts down the feeding chute. If no squirrel is detected, a "NO_SQUIRREL" flag is sent back to the Arduino. In this case, readings will continue to be taken from the ultrasonic sensor, and if motion is detected again a photo is taken and the process repeats until a squirrel is identified.

3. Results

The automatic squirrel feeder project was successfully tested in a real-world backyard setting, achieving both the core and desired objectives. The system successfully and reliably detected and fed the squirrels while preventing access from other animals, demonstrating its effectiveness and robustness. Various testing stages were implemented to ensure that all the key functionalities, core objectives, and desired objectives were met. The success of the project was purely based on the following criterion.

3.1 Controlled feeding intervals and scheduling

The user-friendly interface, consisting of an LCD screen, rotary potentiometer, and 2 push buttons allows users to set precise feeding schedules down to the minute which is adjustable to ensure the user can meet the needs if the backyard squirrels. As a result, the implementation of controlled feeding intervals and scheduling was a success.

Figure 9: Feeding schedule implementation

3.2 Accurate portion control system

Similarly to the scheduling implementation, the portion control input from the user was implemented using a user-friendly interface.

Figure 10: Portion Control implementation

Additionally, to ensure maximum accuracy an FSR 402 pressure sensor and stepper motor combination was integrated with the system as highlighted in the mechanical design section. This combination provided a closed-loop feedback system and ensured that precise food portions were dispensed. The testing confirmed that the feeder consistently met the target weight for each portion with minimal error (± 0.1 g) highlighting an overall success in the portion control system.

3.3 Safety for the Animal

The feeder's all-encompassing design ensured that all moving parts were enclosed within a robust chassis, preventing squirrels from coming into contact with the internal mechanisms. Additionally, all electronics and wires have been carefully placed within the chassis to eliminate the risk of the squirrels gaining access to potentially dangerous electrical hazards.

3.4 Secure food storage

As highlighted in the mechanical design section the upper nut reservoir includes an easily lockable design, allowing for the security of the food - preventing the food supply from any tampering from animals. Testing confirmed that the reservoir remained secure despite the squirrels very quickly determining that the food supply was in the reservoir.

3.5 Affordable design and manufacturing procedure

The use of cost-effective components, such as 3D printed parts for the chassis and common electric modules, meant that the system remained within the budget constraints of the team. The entire cost breakdown is in **Table 1,** indicating a total cost of $267.

Table 1: Project Cost Breakdown

Component	**Description**	**Price (CAD)**
Arducam Mini Module Camera	2 MP camera for squirrel identification	$25.00
HC-SR04 Ultrasonic Sensor	Proximity detection sensor	$5.00
Raspberry Pi 5 – 4GB	Single board computer used for machine learning computation	$120
FSR 402 Pressure Sensor	Force-sensitive resistor for portion control	$10.00
QSH4218 Stepper Motor	Stepper motor for food dispensing	$18.00
HS-422 Servo Motor	Servo motor for trap door actuation	$12.00
Arduino Uno R4 WiFi	Microcontroller for system control	$50.00
A4988 Stepper Motor Driver	Driver for the stepper motor	$4.00
Rotary Potentiometer	Adjustable user input for UI	$2.50
Push Buttons	User interface control buttons	$2.00
3D-Printed Parts	Housing, hopper, and Archimedes screw	$10.00
Miscellaneous (Wiring, Screws)	Electrical and mechanical assembly components	$8.50
Total		**$267.00**

This prototyping cost is exaggerated, but on a larger scale with further optimizations, for example, the use of a less expensive SBC, and improved manufacturing strategies for the mechanical components the overall cost to manufacture could be brought down to $120, making it a competitive price in the very unsaturated market of squirrel feeders.

3.6 User-Friendly Interface

A user-friendly interface was incorporated into the design in the form of an LCD screen controlled manually by 2 simple buttons and a potentiometer. The LCD screen provides real-time feedback highlighting important information such as the current feeding time and portion size as well as an intuitive display indicating the status of the feeder during all points of the dispensing process. Figure 11 showcases the LCD screen at various points throughout the process highlighting the successful implementation of a user-friendly interface.

Figure 11: User-friendly interface implementation

3.7 Pet identification to prevent theft

The squirrel identification system ensures that only squirrels can access the dispensed food, preventing theft by other animals. As discussed in section 2.4, this feature combines the Arducam Mini Module Camera, a Raspberry Pi and a pre-trained machine learning model from Roboflow. When the motion is detected from the ultrasonic sensor the Arducam successfully captured an image, sent the image to the Pi where it was processed to determine if there is a squirrel or no squirrel. This process can be seen below in Figure 12, where an image was taken of a squirrel and the Pi outputs a flag to the Arduino which is shown in the terminal below.

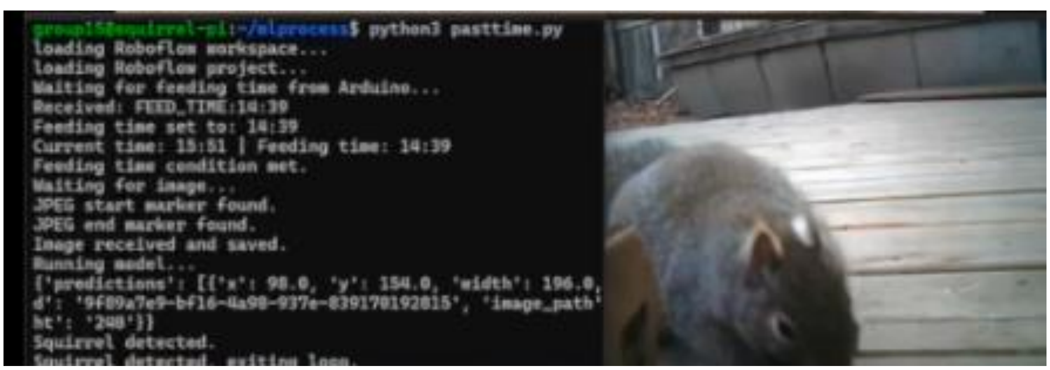

Figure 12: Output of Pi and image taken on a test where squirrel was detected

Throughout testing the system was able to distinguish squirrels from other animals with minimal false positives, demonstrating its effectiveness even in outdoor conditions.

3.8 Easy to clean and maintain

The design meets the desired objective of being easy to clean and maintain as the stepper motor can be activated to rotate the screw mechanism to clear out any remaining food. Simultaneously, the servo can open the gate allowing all leftover food to move through the system. The system can also be dissembled if a full deep cleaning is required.