Cat Feeder Mechanism

Group 8

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Part I & II: Clarify and Ideate

Overview:

The purpose of this project was to design a mechanical cat feeder that can reliably dispense dry cat food, in controllable portions, that can be released when a human steps on a pedal. Problems arise for cat owners who may have limited hand strength, arthritis, injuries, or disabilities that make twisting, lifting, and pushing traditional feeders difficult. This human pedal-based system is a hand-free solution that requires minimal upper body strength, allowing users to dispense food with their feet. Other concerns include hygiene, as frequent contact with the food bowl, lids, levers can easily transfer dirt, bacteria, or residue. A pedal operated mechanism reduces the need for direct hand contact, reducing cross-contamination. These factors make feeding easier for individuals with reduced hand mobility while offering a hygienic way to dispense cat food. Key challenges included ensuring a proper fit and movement between all parts, determining the correct distance the platform opens to release a precise portion of food without spilling, and ensuring the mechanism returned to its closed position after each use. Additional challenges also included preventing any jamming, minimizing friction between parts, and designing the system to be durable with repeated use. Safety considerations, such as avoiding pinch points for the user's foot, were also important factors in the design process.

In developing the cat feeder, 3d printing with PLA was established as the main fabrication method for the parts due to its durability and ease of printing. Early mockups of the 3D printed linkages, and chassis were assisted by rubber bands acting as connectors while parts were printed in 50% scale to test the initial motion and assemblage of the mechanism. CAD models also assisted in dimensioning and modeling the mechanism in the following weeks. Programs like *SolidWorks,* including assembly motion simulations, were used to verify part movement—identifying potential collisions. This form of digital modeling minimized material waste and production errors, optimizing prototype assembly. After meeting the professor, testing began immediately as prototypes of the links and pedals were created to explore pedal sensitivity and platform movement. This included analyzing and refining the linkage geometry and thickness, finding prototype tolerances, and identifying any failure points. Continuous CAD modeling occurred between each week, with the final assembly week reserved for adjustments, motion tests, and ensuring smooth and reliable operation of the mechanism. Overall, the design process, prototyping, and assembly spanned an entire month, during which multiple iterations of the feeder were created and tested. The manufacturing plan began with scaled down prototypes to understand the motion path of the pedal and platform. Once feasibility was confirmed, CAD was used to finalize the dimensions and create accurate linkage designs. Furthermore, after refining clearances around the platform, chute, spring tensions, etc. the mechanism was tested multiple times to ensure reliable operations.

Chosen Concept and Skeleton Diagram:

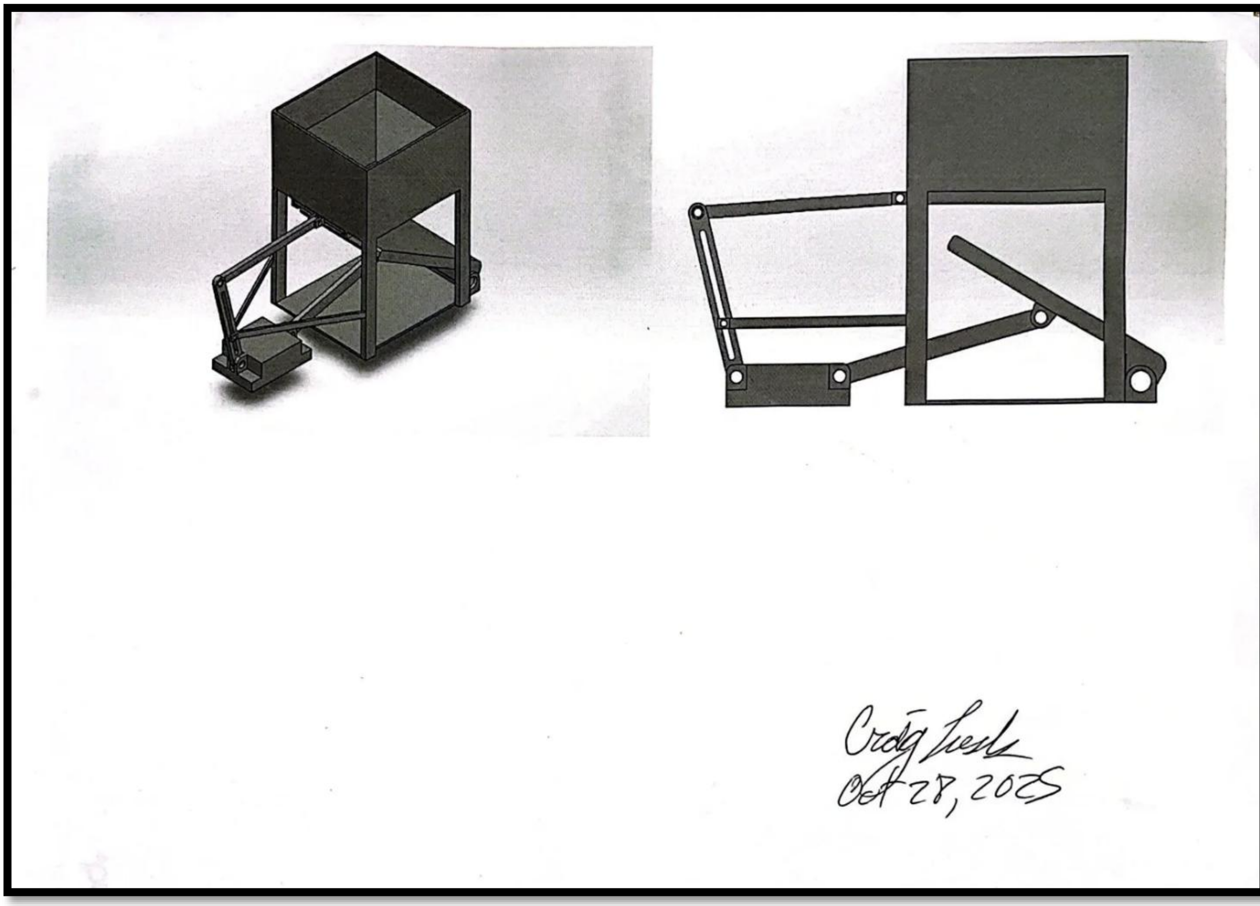

Figure 1: Signed Skeleton Diagram

The chosen concept is a human pedal operated linkage system that opens a platform at the bottom of a hopper when stepped on. Pressing the pedal pulls a connecting link system that slides the platform, opening the hopper chute which dispenses the cat food onto a slide. Springs are placed vertically under the pedal to return the mechanism to a closed position with minimal effort. This single degree-of-freedom mechanism provides a smooth and reliable operation with, transferring the pedal motion efficiently through the linkage system. The accompanying skeleton diagram illustrates the main components, their connections, and the path of motion.

Part III: Develop

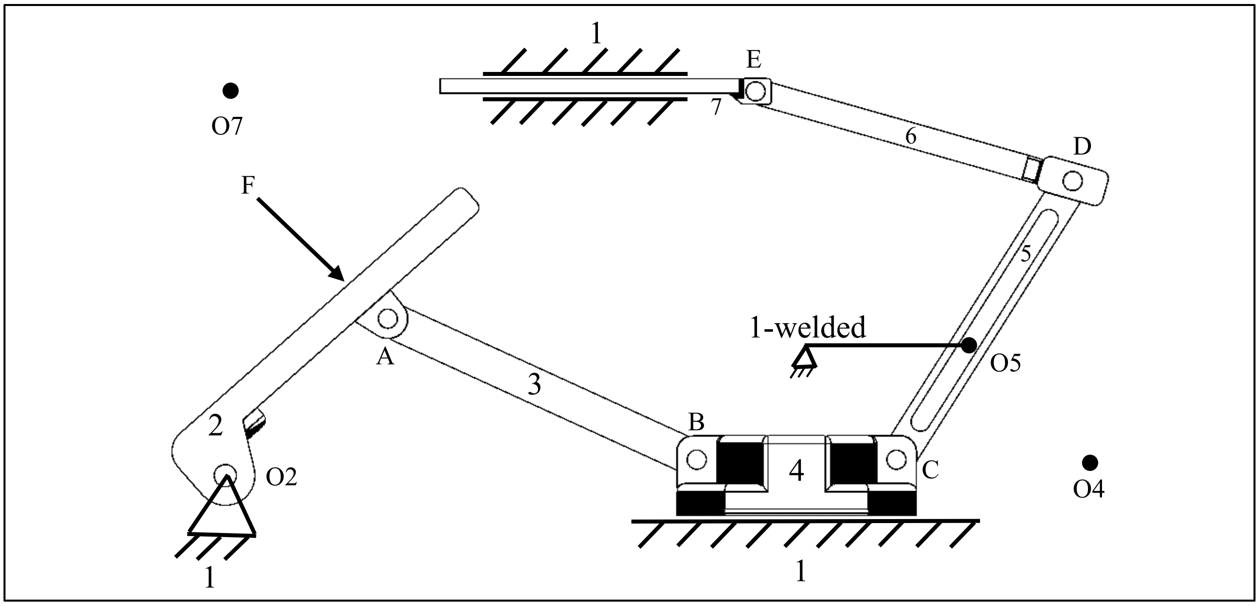

Figure 2: Labeled skeleton diagram of cat feeder mechanism

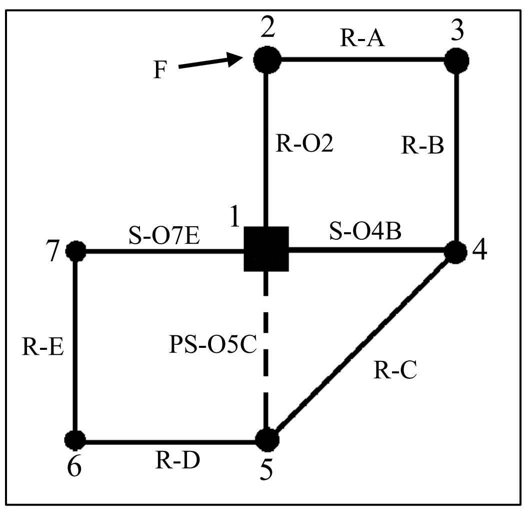

Figure 3: Mechanism graph of foot powered cat feeder mechanism

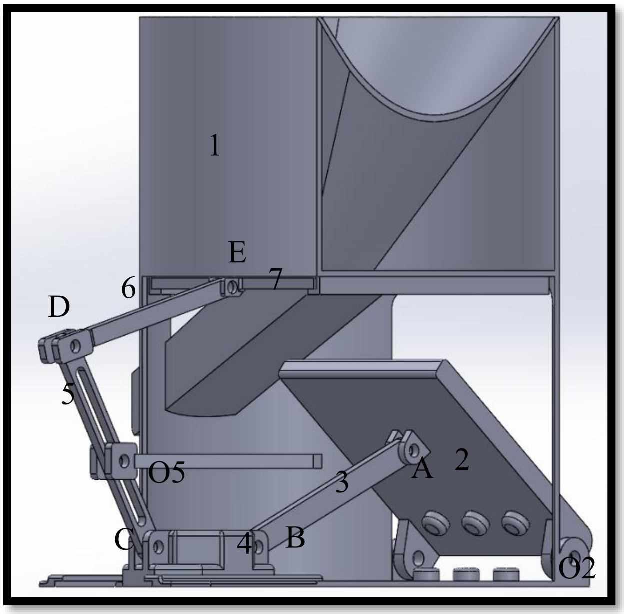

Figure 4:Labeled CAD model of the mechanism for the cat feeder

Table 1: Description of items with respect to what they correspond to on the graph

Name	Description
1	Housing for the cat feeder acting as the ground link for the mechanism
2	Input link of the cat feeder, also referred to as a pedal because the mechanism is foot powered
3	Coupler link between link 2 and 4
4	Slider link between link 3 and 4 to convert planar motion in purely translational motion
5	Coupler link between 4 and 6 that converts the translational motion back into planar motion but connected to ground with a pin and slot that switches the direction of motion
6	Coupler link between link 5 and 7
7	Slider link connected to link 6, which could also be considered the output link. This link has no force outputs but acts as the trapdoor for food to fall through and complete functioning mechanism
O2	Pin between link 1 and 2 acting a revolute joint pair
O4	Reference point for which slider link 4 travels parallel to with respect to pin B
O5	Pin and slot higher order pair between link 1 and 5 acting as a pivot point for link 5 while being able to slide across it
O7	Reference point for which slider link 7 travels parallel to with respect to pin E
A	Pin between link 2 and 3 acting a revolute joint pair
B	Pin between link 3 and 4 acting a revolute joint pair
C	Pin between link 4 and 5 acting a revolute joint pair
D	Pin between link 5 and 6 acting a revolute joint pair
E	Pin between link 6 and 7 acting a revolute joint pair

Listed above are the table and graphs of the mechanism that was created to perform the tasks that the cat feeder needs to do with respect to the challenges that are faced. The mechanism as shown in figure 2 is a seven-link mechanism with only one higher pair and 8 lower pairs. This mechanism has 1 degree of freedom.

First Degree of Freedom:

As shown in equation 1, the 8 lower pairs and 1 higher pair give a mobility or degree of freedom of 1. This would make sense because everything in the mechanism moves in a predictable manner with respect to the one input from the input link. This input is the rotation of link 2 about pivot O2. When link 2 rotates, it influences the movement of link 3 through their revolute pair joint which causes a series of movements throughout the mechanism that ultimately cause the slider at link 7 to translate back and forth along the guide path with respect to point O7 as shown in the mechanism graph in figure 3 which causes the opening and closing of the sliding trapdoor for cat food to be released.

Degrees of Freedom Equation (Mobility Equation):

$$M = 3(L - 1) - 2J_1 - J_2 \tag{1}$$

L = Number of Links

J1 = Lower Pairs

J2 = Higher Pairs

$$M = 3(7 - 1) - 2(8) - 1 = \mathbf{1\ DOF}$$

Detailed Design:

A more descriptive outline as to how the mechanism operates to perform the required task by turning inputs into outputs will now be explained. For this description of motion, it will be done without considering the kinetics of the mechanism. This eliminates any variability in how someone may press down on the pedal and at what rate, changing the force applied which would affect the output of the mechanism. Also, without considering any specific numbers to describe the motion of the mechanism, a clear picture should be able to be drawn in one's mind. Starting with the motion of the pedal, it rotates with respect to a pin that's connected to ground, meaning that it could only rotate about the axis of the pin. One this pedal, or link, is pushed forward, its connection to link three also causes it to move forward. Since link three has planar motion and is connected to a ground link like link three, it's free to move translationally and rotate at the same time. This movement allows an influence of moment from link three to link 4 which is slider. This slider is directly connected to the ground link and constrained to it as well. With no movement up and down, this slide can only travel left and right which is where its connection with the next link is important. Because link five is pinned and slotted with the ground, it allows the translational movement of the slider to move one part of link five forward, and another part of link five backwards. This pin and slot act a pivot point for the mechanism's movement at link 4 with respect to link 6 while at the same time allowing for any changes in length on each side of the pivot point. The next link which links five is connected to is link six which acts similarly to link three in a way that its planar motion will carry out motion through the mechanism for link seven to move which is constrained to be in a slider motion. This slider specifically is the trapdoor for the food to drop through. As shown in figure 5 and 6, the slider will slide forward towards the front of the mechanism, opening a path for the cat food to travel through the inside of the ground link, or housing, and the slider as well, to go into the bowl off to the side of the mechanism. From the motion of the pedal to an opening created by sliding the trapdoor, the seven links of the mechanism work together to create a foot powered cat feeder, removing any need for a cat owner to continuously pour food in a bowl for their animal.

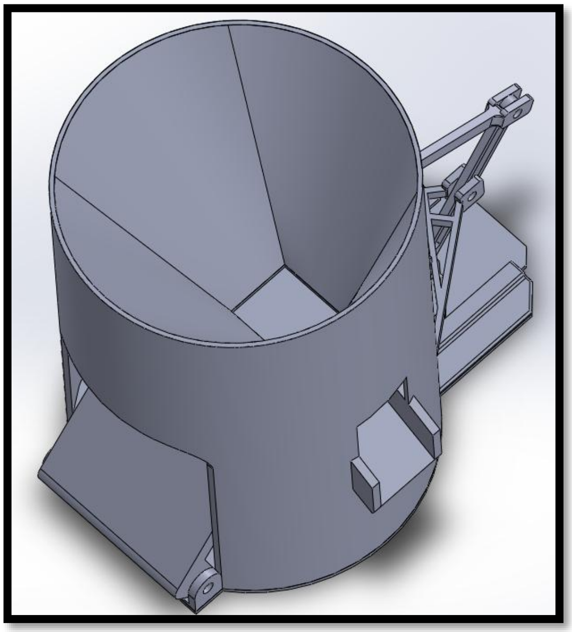

Figure 5: Cat feeder mechanism at closed position

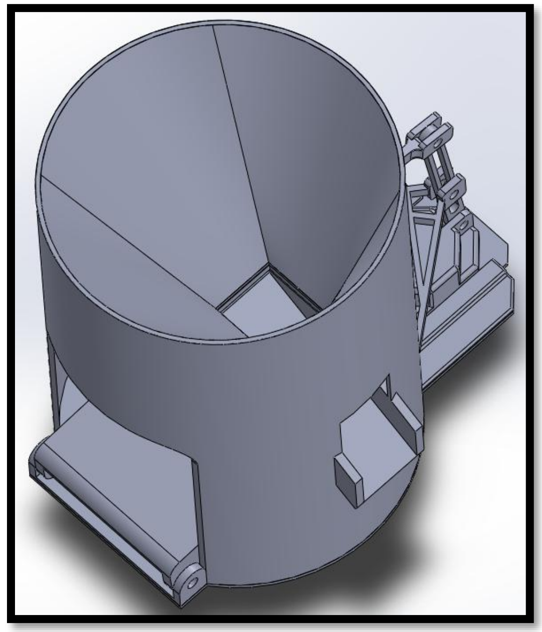

Figure 6: Cat feeder mechanism at open position

Now after taking a look into how the mechanism moves, it's also important to consider how the lengths of each link affect the final distance that the trapdoor slider had to travel. If the slider did not travel enough distance, the trapdoor wouldn't open enough for the food to fall through. An analysis of how small changes in the lengths for each link would affect the final sliding distance for the slider was done to see if any changes could be made either help increase or decrease the distance traveled. Initially when creating the mechanism, an issue was run into where the sliding link would not travel far enough to the spot, we wanted it to travel to. Using this analysis, and the data found in table 2, it was determined that changed the lengths of links 2,3, 4 and 6 where optimal places to make changes as small changes in geometry would add roughly 10 percent to the distance traveled by the slider. No changes to link 5 were made throughout the prototype process of making the cat feeder because of the information gathered in the graph where any changes in length would result in little to effect on the final result. Although small changes were made to the links for the sliding distance, it should be noted that there were two other possible choices to help eliminate the negative impact of a short sliding link, this would be the housing and trapdoor slider itself. For this mechanism specifically, the lengths were not chosen to match up with the hole and trapdoor slider hole position. Instead, it was the opposite where the hole would be placed the position where the sliding link, after the mechanism has been fully extended, was at top dead center.

Table 2: Parameter change analysis and how they affect final sliding distance

Link Number	**Original Length**	**Parameter change (%Change from nominal)**	**Effect on output distance range (%Change from nominal)**
Link 2	2.82776413	ΔR = 0.1 (3.5%)	1.79432528 (9.4%)
		ΔR = -0.1 (3.5%)	1.47811922 (9.9%)
Link 3	4.25	ΔR = 0.1 (2.4%)	1.7944854 (9.3%)
		ΔR = -0.1 (2.4%)	1.47793039 (9.9%)
Link 4	2.5	ΔR = 0.1 (4%)	1.79432528 (9.3%)
		ΔR = -0.1 (4%)	1.47811923 (9.9%)
Link 5	4.125	ΔR = 0.1 (2.4%)	1.66567487 (1.5%)
		ΔR = -0.1 (2.4%)	1.61359266 (1.6%)
Link 6	4.125	ΔR = 0.1 (2.4%)	1.74163789 (6.14%)
		ΔR = -0.1 (2.4%)	1.54002884 (6.14%)

Significance:

One external feature of the mechanism which was not considered in any of the diagrams or computer models is the springs involved in putting the mechanism back into the starting position. This feature of the product was important in the aspect of the kinetics involved for how the mechanism moves. Since the spring force is the only force resisting the force of the users' foot, without taking into account any gravitational forces, it is important that the springs have enough force with respect to their spring constant so that they would be able to spring back in a timely manner. It was no question whether the springs would be able to spring back the pedal because the force of gravity on the springs was so negligible compared to the output force the springs had on the pedal at a travel distance of zero. Simply considering the time was necessary to best accomplish the desired amount of cat food dispensed from the product after the pedal is pressed down. If the springs are unusually slow because of a low spring constant, it would most likely cause the system to be open for longer, meaning that more cat food would be dispensed. To ensure the best efficiency of the system, these springs, with easy access in variability, should be changed and applied to some sort of equation where the spring force directly affects how much food is dispensed after someone releases their foot off the pedal. An optimal system would have the closest amount to the required food weight over that period of time.

Part IV: Implement

After choosing to design a cat feeder as a group we decided to go forward with Christain's initial design. Moving forward we decided on the dimensions of our links through CAD trial and prototyping. We had a system of designing in CAD then testing that the CAD model worked, then moving forward with printing each prototype to make sure the printed version worked as well. We learned a lot through this system such as the fact that printing a model at a different scale can cause errors in efficiency, and that tolerance issues occur when using multiple printers to print the parts. We would go back into the SolidWorks Assembly and adjust dimensions such as thickness to improve tolerance issues. In total we printed and edited three prototypes.

Mechanism's Motion:

To document the motion of our prototype, we took photos of the mechanism in its initial, intermediate and final positions. Through doing this we can compare the mechanism's motion with what we hypothesized it would look like through our CAD model. In the initial position the foot pedal, link 2, is fully pushed against the stopper that has been designed into the food slide. This initial starting position can be seen in Figure 7 below.

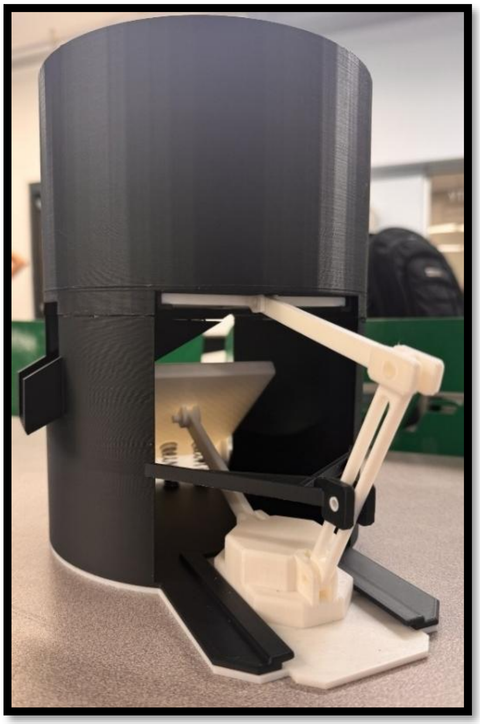

Figure 7: Initial Position of Final Printed Prototype

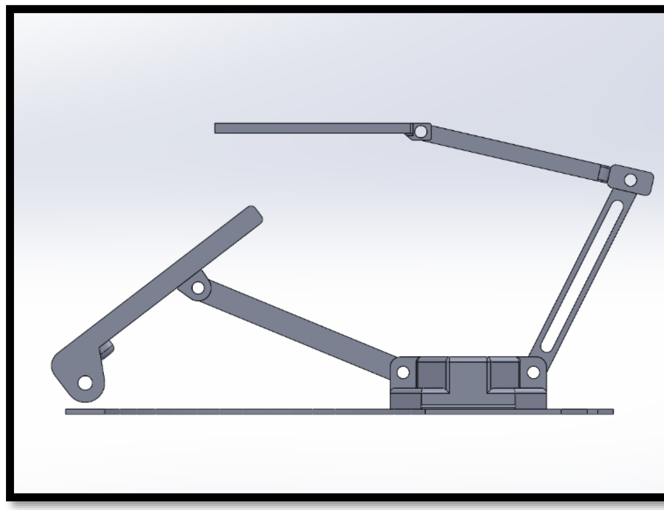

Figure 8: Initial Position in Final CAD Model

The pedal is aided by springs attached to the underside and connected to the ground plate. This was done as we needed the springs to return the pedal back to the initial position once it has been pressed, so that it matches the initial position of the CAD model seen above in Figure 8. For viewing purposes, we have hidden the “ground” link, the canister, so that the links can be seen in the CAD model.

While pushing the pedal down we begin to see movement in the mechanism. Link 3 can be seen pushing the slider link 4 which is connected to ground. Using the ground link, we have designed railings for the slider to keep it constrained to the ground. As the slider moves towards the back of the mechanism, link 5, our pin in slot is rotated to a more upright position. As link 5 pivots, it changes the direction of our mechanical movements. It does this by pushing link 6 which is connected to the slider at link 7 acting as a trap door for the food to come out of the canister. The beginning of this looped motion can be seen below in Figure 9 showing the intermediate state of movement.

Figure 9: Intermediate Position of Final Printed Prototype

In the final position the pedal reaches as far as the springs will allow, this differs slightly from the CAD design that has no resistance to hitting the floor plate and can be seen below in Figure 10. The final CAD design can be seen in Figure 11, with no restraint on how far the pedal may reach. With the pedal as far as is allowed, the sider reaches maximum distance with link 5 restrained to a totally upright vertical position and the slider at link 7 is fully open. With the addition of the springs, releasing the pedal provides a smooth return to the initial position with no added effort.

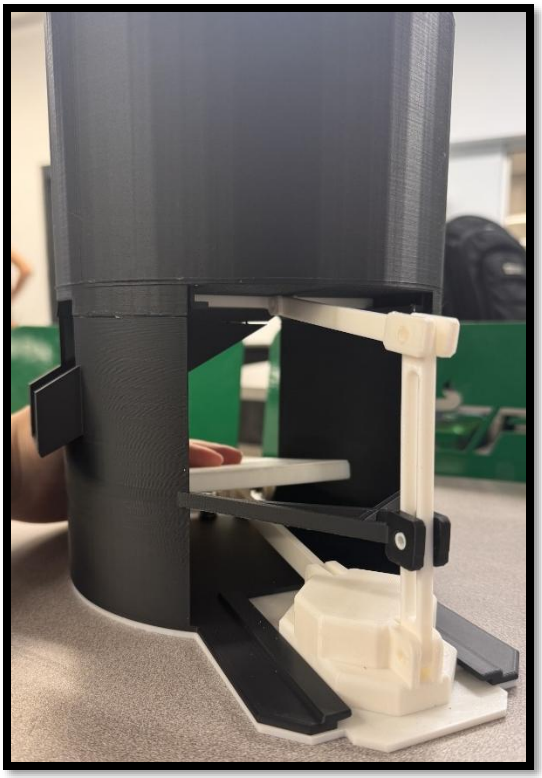

Figure 10: Final Position of Final Printed Prototype

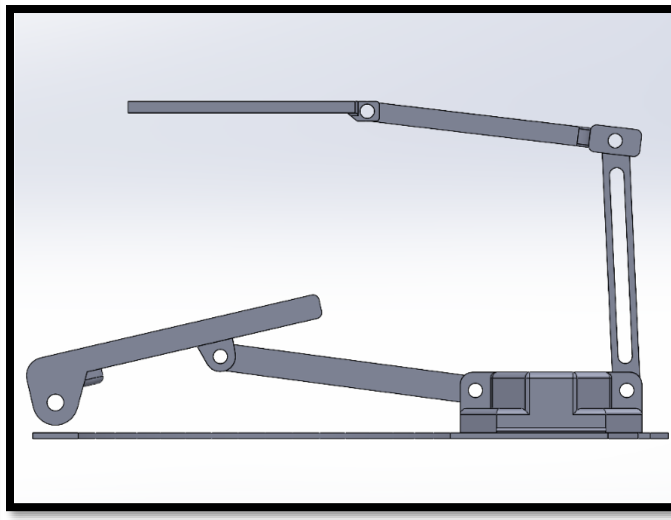

Figure 11: Final Position in CAD Final Design

Overall, this prototype followed the general motion path we predicted with our CAD design with the only true difference coming from our use of springs to make the mechanism loop when used. In addition, the original CAD design had slider 4 constrained to the ground in CAD, when prototyping we realized this would not be the same in real-life and decided to design a rail system to keep the slider constrained to ground as seen above in Figure 10.

Functionality:

Our final prototype behaved as we would have expected of a planar rigid body mechanism, with each link rotating about its pins in a manner consistent with the CAD model. The overall path and movement of our links closely matched the idealized simulation of our design. However, working with 3D-printed filament introduced several secondary effects that influenced the smoothness of this motion. Printing tolerances and material issues were some of the secondary effects we dealt with. Printing tolerances caused some joints to fit too tightly or too loosely, which created minor friction and occasional resistance during movement. To deal with this we printed our links at multiple tolerances, 97%, 98%, and 99% percent of the full-scale width. We made sure we only adjusted the widths of the links and not the length. These issues also required small adjustments to hole diameters and pin clearances to achieve smoother rotation. In addition, we used 3D printed pins to ensure that the strength of our links wasn't affected by heavier materials such as metal pins. We did this because we were worried about future deterioration of the plastic from the metal bolts. Despite these manufacturing limitations, the secondary effects did not significantly alter the mechanism's behavior. Overall, the prototype was a successful demonstration of the mechanism's concept, with the only discrepancies arising from typical 3D-printing tolerance and surface-finish limitations.

Based on our original CAD assembly, our mechanism protype functioned the way the group had designed it to. After printing and assembling the mechanism, we observed that the overall geometry and motion path aligned with our expectations, and the prototype was able to achieve the full range of motion we needed for its function. Although initial prints contained minor dimensional and tolerance errors, correcting these issues allowed the mechanism to operate smoothly and without resistance. With these adjustments made, the final prototype demonstrated that the underlying concept is sound, and a fully fabricated version with precise manufacturing would reliably perform the intended function.

Conclusion and Future Improvements:

If we were to complete this project again, several changes would help improve the quality and accuracy of the prototype. Most importantly, we would “measure twice, print once” by double-checking all dimensions and tolerances in the CAD model before producing the first physical print. This would reduce the number of reprints required and prevent the early issues we encountered with joints that were either too tight or too loose. We would also incorporate more deliberate tolerance allowances into the design from the beginning, ensuring smoother assembly and more consistent motion. In addition, we have ideas for future improvements to the design including a lid so the cat cannot get into the feeder. Another idea would be to incorporate a box or canister of some kind that is much taller and holds entire bags worth of food so that the feeder would only need to be filled when the bag has run out of food. Overall, a more careful upfront review of dimensions, clearances, and print settings would result in a prototype that operates smoothly on the first attempt and more closely represents an ideal realization of the mechanism.