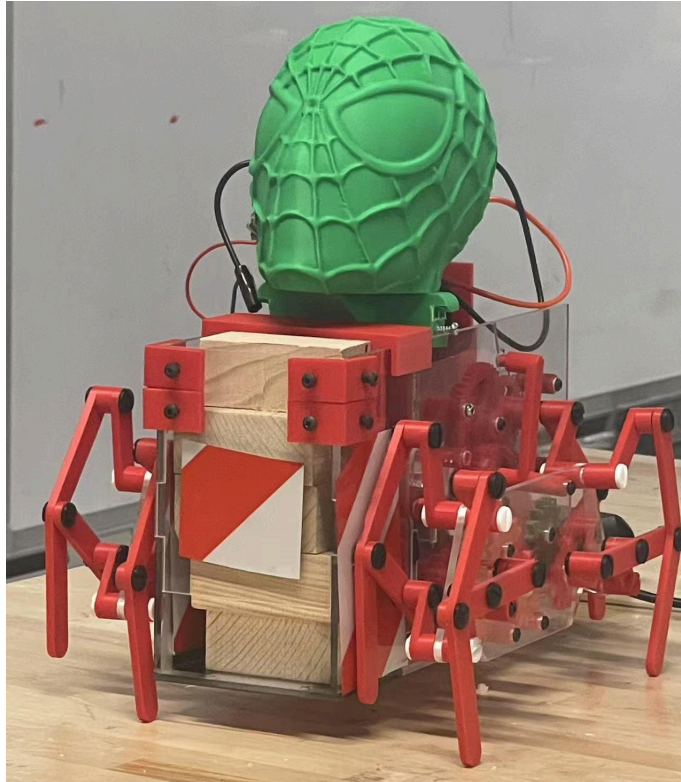


# ME370 REPORT

## SPIDERMAN



Shihong Yuan (syuan19), Liangbing Zhao (lz36), Daniel Koltchev (dvk2), Sebastian Misong (missong2)

GROUP 48

Section CB5, Friday 1:30–2:50 pm

TA: Tianyi Han

December 17, 2025

## 1. Abstract

The objective of this project was to create a legged robot that would incorporate a dispensing mechanism from the previous project. The user group we created this robot for was students who needed various sized packages delivered to their doorstep. The dispenser used is a crank slider that features a quick-push mechanism while the walking motion is accomplished using 4 pairs of klann linkages. The theme for this project focused on safety, which was achieved by wrapping the robot in high-vis reflective tape. This would allow the robot to be easily distinguishable during operation, lowering the risk of tripping hazards that can compromise robot payload and functions. The robot was able to dispense packages at an interval of 2.14 meters at an average speed of roughly 4.49 m/min while maintaining a relatively straight trajectory. If the project were to be further developed, improvements could be made to the ability of the robot to follow a straighter trajectory.

## 2. Project Goals and Design Specifications

The goals for this project revolved around creating a legged dispensing robot for students seeking reliable doorstep package delivery. The robot accommodates and dispenses different box dimensions used by courier companies to meet the demands of this user group. Additionally, the robot features high-visibility reflective tape. This specification addresses safety concerns associated with human collisions in the robot's main operation environment, hallways. Human collisions with the robot can create a safety hazard for people moving through the hallway, but also potentially compromise the functionality of the robot and its payload. To note, the reflective tape also makes the robot better suited for operation during night when there may be no lighting in the operational environment. This can be beneficial if the end user prefers operation during less-busy hours without any additional risks.

Other specifications that the robot was designed around involve operational stability. This is associated with both the dispensing mechanism and the walking motion. To address stability concerns in the dispensing mechanism, all gears used in the dispensing reduction are constantly meshed. A previous iteration of this robot included a partial gear, but this design consideration introduced sudden force impulses that harmed the operation of the dispensing mechanism. Additionally, the package pusher was hollowed and the crank is spoked in order to reduce the inertial mass that can strain the drivetrain and alter its operation. As for ensuring proper walking stability, a maximum allowable roll, pitch, and yaw of 20 degrees was permitted. This specification was mostly met using 4 pairs of klann linkages which ensure 4 points of contact with the ground at any given time.

Another aspect of operational stability that the robot was designed to meet was a "straight" trajectory without deviation from the starting position. With the weight of the payload, the robot was able to walk relatively straight for roughly 6 meters. After the dispensing of that third package, the trajectory of the robot began to deviate noticeably. This is most likely due to the center of gravity of the robot changing, affecting the dynamics significantly. If one were to address this in a future iteration, more attention should be placed to assessing how the center of gravity can be less influenced by the mass of the payload. This could mean optimizing for more mass and the experimental walk speed of the robot.

### 3. Detailed Design Discussion

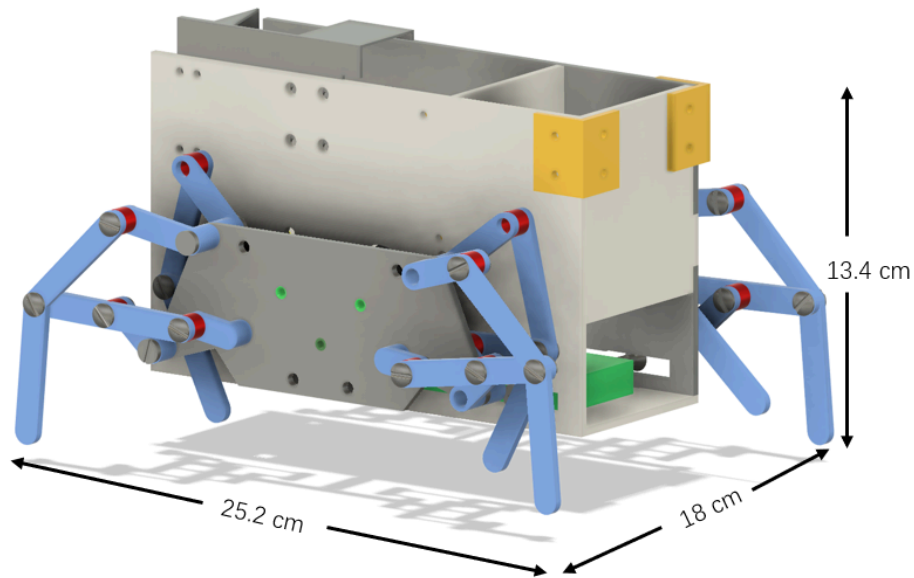


Figure 1: Isometric View of Full Assembly

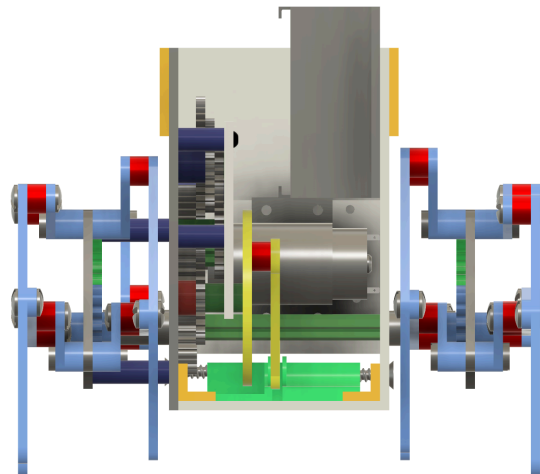


Figure 2: Front View of Walker

Our robot includes three main sub-systems; the drivetrain and dispenser, the legs, and the housing which integrates all of them. All of these sub-systems are easily accessible and serviceable separately which allowed for easy fixes and adjustments while working on the robot. The main structure consists of laser-cut acrylic sheets which all components (such as gears, shafts, spacers, the legs, and slider) are mounted to. All components, not including fasteners, are custom designed and 3d printed. This includes all the gears, the shafts for mounting the gears,

shafts to transmit power, and the legs. Printing all of these components allowed for precise lengths and profiles to be easily made, saved us the time and uncertainty in measurement that comes from cutting shafts, and saved us the cost of purchasing off the self components. The final length, width, and height from the ground of our walker is 25.2cm, 18cm, and 13.4 cm respectively.

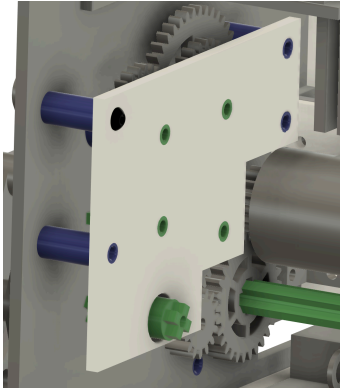


Figure 3: Close-Up View of Mechanism Used to Connect Parts to Acrylic

Figure 3 above offers a detailed view of how components were secured to the acrylic. On every plastic spacer (blue component), gear directly connected to the acrylic, and shaft (green component) there is a circular extrusion with a 5 mm outer diameter, a 3mm inner diameter and a length of  $\frac{1}{8}$  in. This corresponds to a hole in the acrylic which has a diameter of 5mm and a thickness of  $\frac{1}{8}$  in. The extrusion on the plastic fits into the hole in the acrylic and (shown in the top left) a M3 screw is screwed directly into the plastic to secure the connection. This design proved to work extremely well and made working on our robot extremely simple. This design has minimal components which offered many benefits during the assembly process; screwing directly into the plastic saved time with installing heat set inserts, the extrusion being the same length as the thickness of the acrylic saved us from the cost and complexity of using shaft collars to secure the driveshafts, and the circular profile allowed for smooth rotation without the need for expensive bearings or bushings.

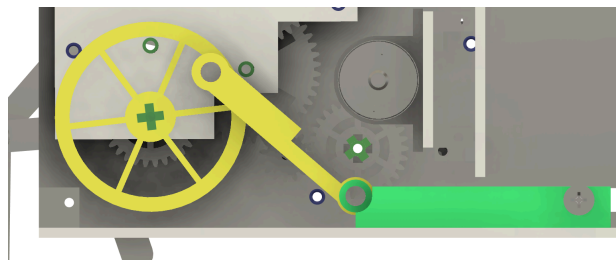


Figure 4: Side-View of Crank-Slider Mechanism

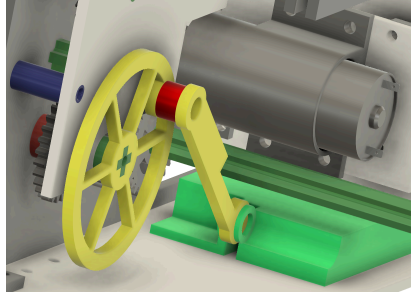


Figure 5: Isometric View of Crank-Slider

The dispensing mechanism is shown above in figure 4 and figure 5. The crank-slider is a 4-bar linkage with 1 DOF. The links consist of ground, the yellow crank, the yellow link, and the green slider. The crank is connected to the gear reduction via a cross profile shaft and is then secured to the shaft using an M3 screw, screwed directly into the plastic shaft. The link is connected to the crank and the slider using plastic barrel fasteners at each connection. The slider is constrained to a slot in the acrylic housing using screws that are drilled into the slider and slide along in the slot with minimal friction. The crank is offset from the acrylic board securing the shaft and the link is offset from the crank using a spacer. These offsets are necessary for clearance between the links and the heads of the fasteners securing the links in place during operation of the mechanism. Originally we tried to use a horizontal crank in order to save space internally but this required a bevel gear to transmit the power which led to many issues, so we changed to a vertical crank.

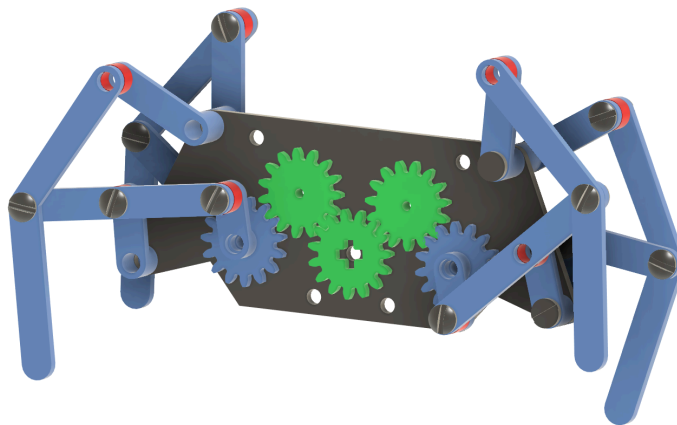


Figure 6: Entire Leg Sub-Assembly

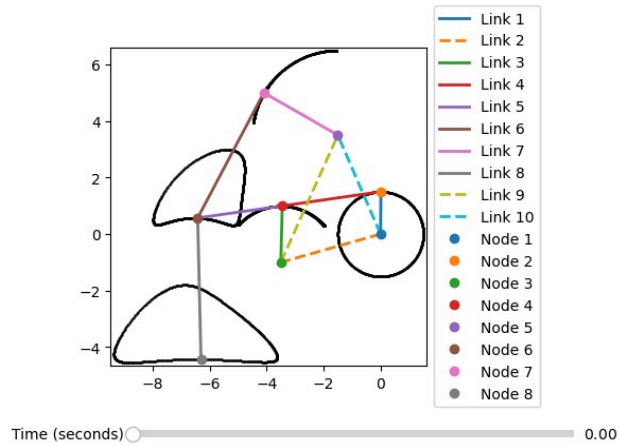


Figure 7: Leg PVA

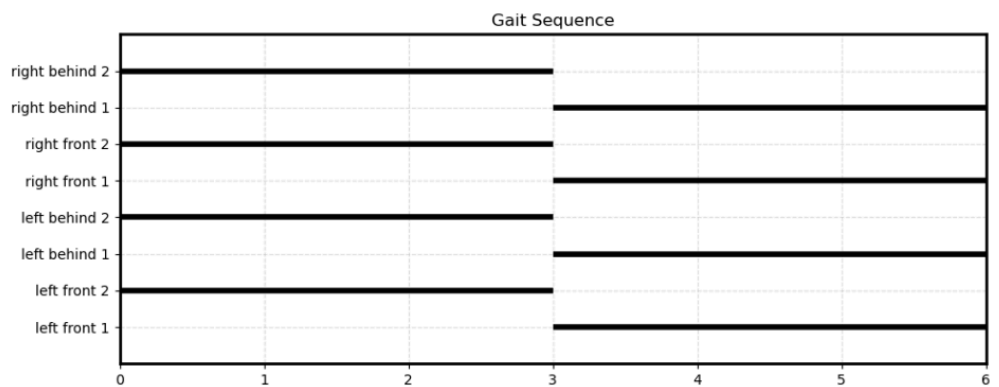


Figure 8: Gait Pattern of Leg

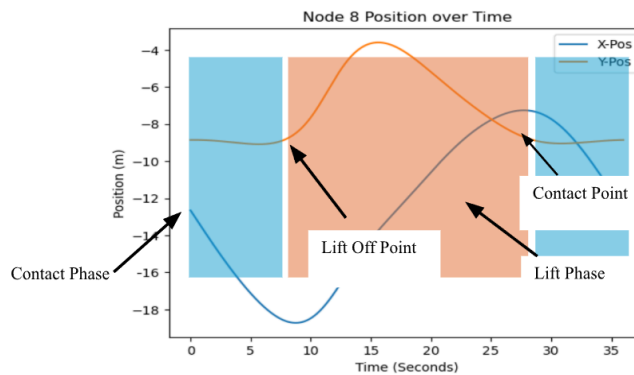


Figure 9: Graph of Leg Position as a Function of Time

The sub-assembly of the leg mechanism is shown in figure 6 above. There are two leg assemblies on opposite sides of the full assembly. A klann linkage is used for each leg which gives the gait pattern shown in figure 6, 7 and 8. This gait is beneficial because the contact phase is about equal to the lift-off phase and the path on the ground is essentially horizontal. This

combined with the fact that each corner has two legs 180 degrees out of phase with each other, means that at each corner there will always be a leg in contact with the ground, keeping the robot stable and fitting our design specifications.

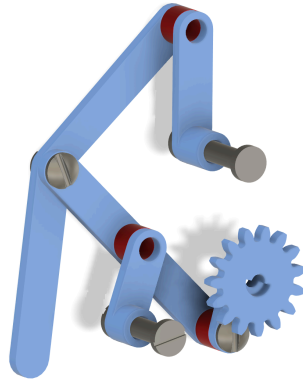


Figure 10: Crank-Side Leg Assembly

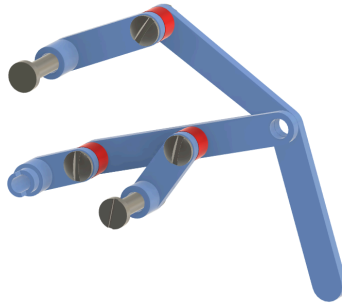


Figure 11: Opposite-Crank Leg Assembly

Figure 10 and 11 show the crank-side leg opposite-crank side leg assemblies, respectively. In the leg, all of the links including the crank link with the spur gear connected are 3d printed. The crank link has a keyed hole in its rear surface which the opposite-side crank for the paired leg is inserted into. Heatsets are inserted into each side's crank and a screw is put through both heatsets, securing the cranks together. This method of assembly ensures that the legs are exactly 180 degrees out of phase due to the keyed feature and the screw keeps the assembly secure. The leg links are all connected using barrel fasteners and printed spacers as necessary to ensure clearance with the fastener heads. Some joints were widths that were between the sizes of barrel fasteners offered in the innovation studio; in these cases a larger barrel fastener was cut down to the necessary size. Each leg pair is connected to the motor power through a spur gear mounted on the acrylic board. This spur gear connects to a gear mounted on a shaft which runs the entire width of the robot and delivers power from the motor to the leg assemblies. During assembly, the gears were aligned so that each leg pair on the board was 180 degrees out of phase with the other. This ensures that in the final assembly, each opposite leg pair is in phase with each other. This originally was not considered but when the robot was not walking straight, we did this to help correct its path. We also tightened the barrel fasteners which improved the walking path.

The total length of each step is about 5.4 cm and the gear ratio from the motor to the leg is 2:1. The 2:1 ratio was chosen in order to decrease the torque load on the motor. To calculate an estimated velocity, an estimated motor velocity of 170 RPM at 9.6V at no load (found during the motor lab) is used. The legs will move at 85 RPM due to the gear reduction between the legs and the motor. Each rotation results in two steps due to the leg pairs at each corner. Since each rotation results in 5.4 cm (0.054 m) of travel, the estimated velocity of the walker is 4.59 m/min. In practice, we observe our walker moving at about 4.49 m/m. This discrepancy is due to the motor speed being lower than the estimated speed used in the calculation because of the load of the drivetrain on the motor. In practice the legs don't move the body the entire length of a stride due to slipping between the legs and the ground.

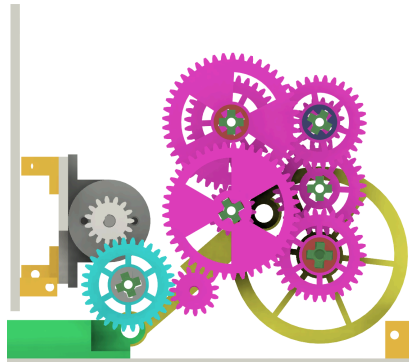


Figure 12: Side View of Complete Drivetrain

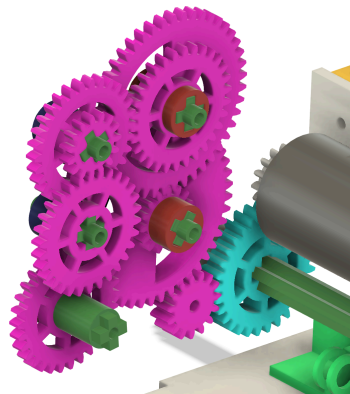


Figure 13: Isometric View of Dispenser Compound Geartrain Reduction

In order to connect both the legs and the dispenser to the singular motor we designed the geartrain shown above in figures 12 and 13. The white gear is the motor gear, the blue gear is the gear connected to the legs, and the pink gears are the reduction for the dispenser. All of the pink gears except the one directly adjacent to the blue gear are mounted onto cross-profile shafts mounted onto the acrylic boards. The gear directly adjacent to the blue gear is mounted directly onto the acrylic using the same mechanism as the shafts, which was discussed earlier. The gears in the compound geartrain were mounted using spacers with the same cross-profile as the gears. The ratio between the motor and the legs is 2:1 and the final ratio between the motor and the dispenser is 77.2:1. The geartrain design with the cross-profile shafts and the spacers and gears

with matching profiles proved to be amazing. Its modularity allowed for easy adjustability of the gear ratio of the dispenser to adjust dispensing distance and it offered reliable operation without the need for additional fasteners to keep the gears in place. Originally we had a ratio of 1:72 between the motor and the dispenser which resulted in the packages being dispensed about every 1.5 meters. Through using gear sizes of diameters of 14, 31, 32 and 28 mm we could easily adjust the ratio until we achieved a very accurate dispensing timing of every 2 meters. Through empirical testing, we adjusted the gear train to a specific configuration of 3:1, 3:1, 28:30, 14:31, and 14:31. This precise adjustment corrected the discrepancy, extending the dispensing timing to the desired 2 meter target.

#### **4. Creative theme**

The theme of the robot was a mix of Spider-Man and holiday festiveness. Due to the characteristic operation of the Klann linkages used mimicking that of a spider, most noticeably the fact that 8 legs were responsible for the gait, Spider-Man was agreed upon as an amusing aesthetic choice. Additionally, the reflective tape utilized also fit into the creative theme of the dispensing robot. Besides meeting our qualitative safety specification, the red and white color scheme complements the green Spider-Man head to resemble a festive scheme. This theme is reflective of the holidays and suits the operation of the robot where the packages could be gifts. Overall, the robot's color scheme reflects the gift-giving spirit of the winter holidays, while the addition of Spider-Man makes the robot more approachable and exciting while being consistent with the operational characteristics of the robot. Younger audiences will definitely find the theme of this dispensing robot very amusing.

#### **5. Mechanism Performance**

##### **1. Performance Summary**

The robot successfully met all design specifications, with final dimensions of 25.2 cm x 18 cm x 13.4 cm and a compliant assembly free of prohibited materials. Regarding dispensing, the mechanism was highly consistent but exhibited a slight systematic error. The average drop interval was 214.2 cm (based on drops of 200, 226, 210, 215, and 220 cm), resulting in a 14.2 cm overshoot relative to the 2-meter target. This placed the performance in the 60% accuracy tier.

In terms of locomotion, the robot tracked straight within the 50 cm lane, which is quite straight and required no interventions. It completed the 10.71 m course in 2 minutes and 23 seconds, yielding an average speed of 4.49 m/min.

For problems, for the average drop distance, we have a 14.2 cm average error. According to the rubric, this places the performance in the range for 60% accuracy points, showing that while the robot was consistent, there was a systematic slight overshoot in distance.

## 2. Discussion of Deviations & Problems

A slight discrepancy exists between our theoretical drop interval of 208.4 cm (calculated as  $5.4 \times 77.2/2$ ) and the actual average of 214.2 cm. This 2.8% difference was likely caused by minor interactions with the floor surface. Occasional slippage or momentum during the swing phase may have caused the robot to slide forward slightly further than the kinematic model predicts, accumulating a small extra distance per cycle.

The actual speed (4.49 m/min) was slightly lower than the predicted velocity of 4.59 m/min. The primary problem encountered during the run was intermittent collision between the moving legs and the central chassis box. Although the robot stayed within the lane, these collisions caused the robot to skew slightly, leading to a path that was not perfectly straight. This "crabbing" motion meant that some of the motor's energy was directed laterally rather than forward, effectively shortening the net travel distance per cycle and slightly reducing the overall speed.

To generate more accurate predictions and improve performance, future iterations would focus on increasing the clearance between the leg sub-assemblies and the main housing. Eliminating these collisions would ensure a perfectly straight path, matching the theoretical linear velocity more closely

1. Appendix A (Drawings):

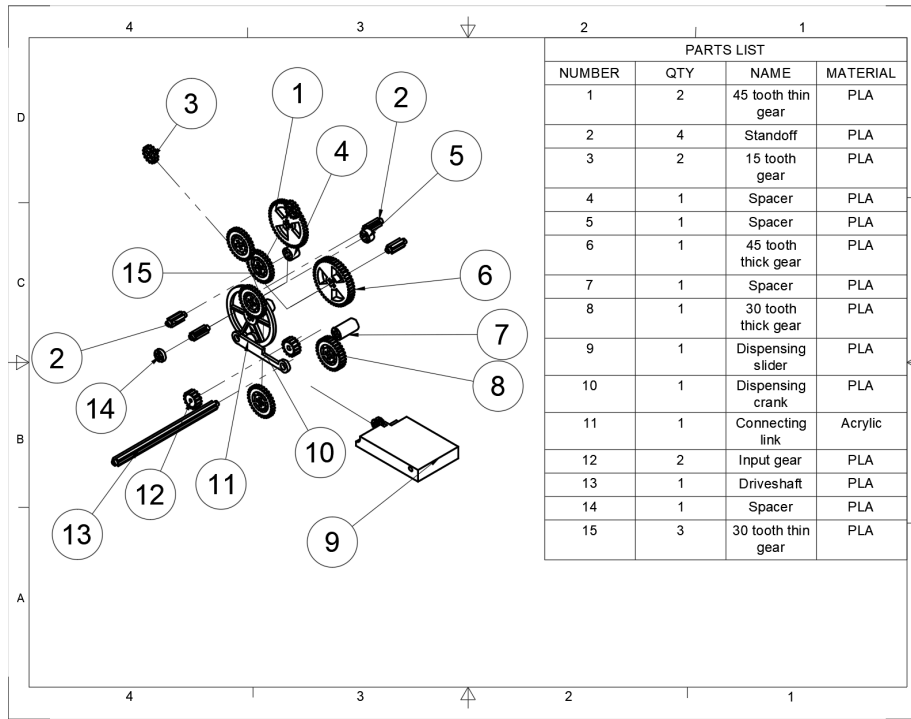


Figure 14: Dispensing Mechanism and Geartrain Drawing

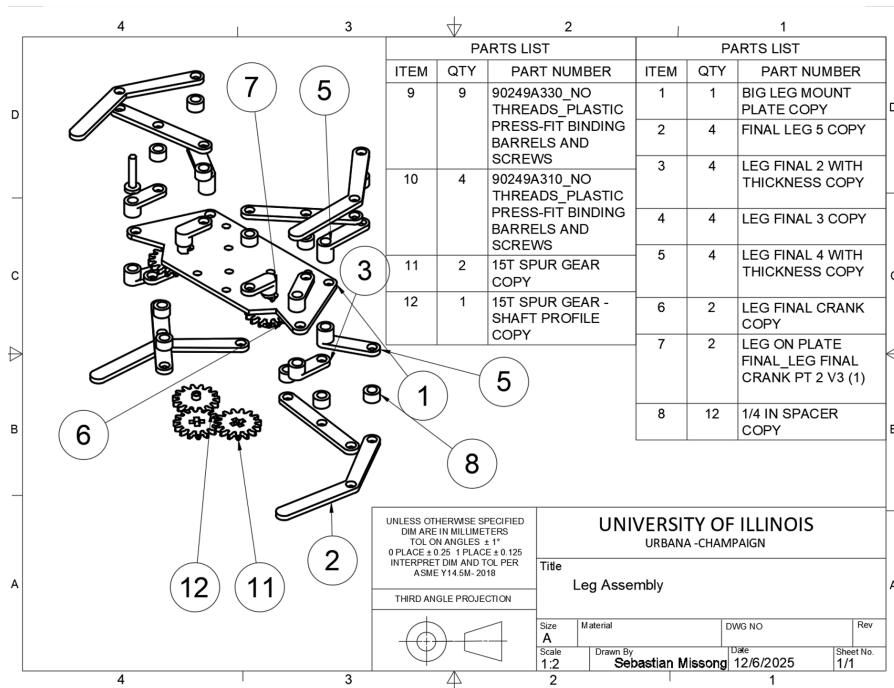
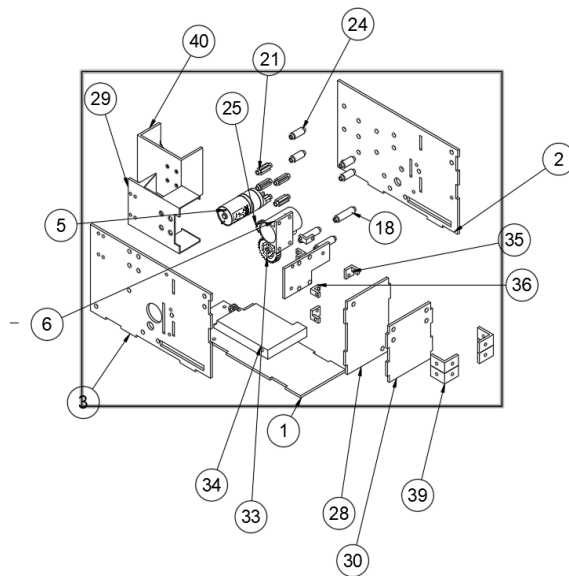


Figure 15: Leg Assembly Drawing



Parts List			
Number	Qty	Part name	Material
1	1	Bottom board	Acrylic
2	1	Left board	Acrylic
3	1	Right board	Acrylic
5	1	Motor	-
6	1	Motor mount	PLA
17	1	Spacer 22.8mm	PLA
18	3	Con for leg and board shaft	PLA
21	4	Con gear shaft	PLA
23	1	Con gear shaft 2	PLA
24	4	Con board and sandwich	PLA
25	2	Gear 15 fixed	PLA
28	1	Board front 2	PLA
29	1	Battery box	PLA
30	1	Board front 1	Acrylic
32	1	Board motor plate	Acrylic
33	1	Gear 30	PLA
35	2	Motor bracket mount	PLA
36	3	Small motor bracket	PLA
39	4	External bracket	PLA

Figure 16: Housing Assembly Drawing

## 2. Appendix B (Expense Report):

Lab section number, day, time: (click on cell to right & select section from drop-down list - click on down arrow in lower right corner)		Team Number and Names: (in cell to right, enter team number and names of team members)				
CB5 (13:30-14:50 F)		Team 48. Daniel Koltchev, Sebastian Misong , Shihong Yuan, Liangbing Zhao				
Description	Qty/\$	Unit Price	Qty purchased	Source (click in space below and use drop-down list)	Purpose	Total Cost
cost for printing	1g/\$0.03	\$ 0.03	344	Innovation Studio	Creating the leg structure	\$ 10.32
cost for printing	1g/\$0.03	\$ 0.03	158	Personal Purchase	Manufacturing gears and transmission stru	\$ 4.74
HDRHS M3 x 6	6/\$	\$ 0.17	75	Innovation Studio	Fixed gears, main body, leg structure	\$ 12.50
HDRHS M3 x 10	6/\$	\$ 0.17	35	Innovation Studio	Fixed gears, main body, leg structure	\$ 5.95
HDRHS M3 x 16	6/\$	\$ 0.17	1	Innovation Studio	Fixed gears, main body, leg structure	\$ 0.17
HDRHS M3 x 20	6/\$	\$ 0.17	6	Innovation Studio	Fixed gears, main body, leg structure	\$ 1.02
HDRHS M4 x 10	6/\$	\$ 0.17	3	Innovation Studio	Fixed gears, main body, leg structure	\$ 0.51
Heat-Set Insert M3x0.5	5/\$	\$ 0.20	19	Innovation Studio	Link body	\$ 3.80
Heat-Set Insert M4x0.7	5/\$	\$ 0.20	2	Innovation Studio	Link body	\$ 0.40
1/8" Acrylic, 12x24"	1/\$10	\$ 10.00	3	Innovation Studio	Constructing the main structure	\$ 30.00
1/8" Acrylic, 12x12"	1/\$5	\$ 5.00	1	Innovation Studio	Constructing the main structure	\$ 5.00
Metal Barrel Fastener, 1/2-5/8" L	10 Sets/\$5	\$ 0.50	1	Innovation Studio	Fixed leg structure	\$ 0.50
Socket Head Cap Screw, 10-32, 1.5"	2/\$	\$ 0.50	2	Innovation Studio	Fixed gears, main body, leg structure	\$ 1.00
Hex Nut, 10-32, 3/8" W	24/\$	\$ 0.04	3	Innovation Studio	Fixed gears, main body, leg structure	\$ 0.12
Locknut M3	20/\$	\$ 0.05	43	Innovation Studio	Paired with the M3	\$ 2.15
Locknut, 10-32, 3/8" W	18/\$	\$ 0.06	4	Innovation Studio	Paired with the Hex Nut	\$ 0.24
Plastic Barrel Fastener, 1" L	5 Sets/\$1	\$ 0.20	8	Innovation Studio	Fixed leg structure	\$ 1.60
Plastic Barrel Fastener, 1/2" L	3 Sets/\$1	\$ 0.33	29	Innovation Studio	Fixed leg structure	\$ 9.57
Plastic Barrel Fastener, 1/4" L	3 Sets/\$1	\$ 0.33	20	Innovation Studio	Fixed leg structure	\$ 6.60
Washer #10, ID: 0.203"	24/\$	\$ 0.04	1	Innovation Studio	Fixed gears, main body, leg structure	\$ 0.04
Manufacturing cost for printing	\$0.025/cm³	0.025	100	Innovation Studio	Manufacturing the legs and the conveyor s	\$ 2.50
Manufacturing cost for laser cutting	\$0.001/cm	0.001	130	Innovation Studio	Cutting the main structure	\$ 0.13
Total Expenses						\$ 98.86
Total Cost of items from the Innovation Studio cannot exceed \$50						
The expense report should document all incurred costs: spending at Jackson Innovation Studio stockroom, manufacturing costs for printing or laser cutting, estimated cost of "found" items, and personal spending (*Personal spending is not reimbursed. Cost of 3D printed parts on personal printer should be included using the same cost formula for printing in the Jackson Innovation Studio.)						

Figure 17: Expense Report

The items we purchased mainly include 3D printing PLA filament, acrylic sheets for laser cutting, M3 screws and nuts for securing the entire device, heat-inserts for fixing the main body, and plastic screws for securing the legs.

Our projects 1 and 2 cost a total of \$98.86, which meets the requirement of the total project budget being less than \$100.

### 3. Appendix C (Team Contributions):

**Sebastian Missong** worked on the CAD modeling for the legs and made the conceptual design manufacturable and be able to fit into the design. He also worked on the design of the housing and how it would be assembled, including brackets, puzzle-pieced acrylic panels, and the motor mounting plate. Also helped with the manufacturing process.

**Daniel Koltchev** worked on the quick-push dispenser mechanism design alongside Shihong. He was also responsible for the compliance with the high-vis safety spec of the robot. Additionally, he worked alongside Sebastian and Liangbing to complete the assembly of the dispensing robot. This involved testing fitment of 3D printed parts and completing modifications when necessary for the betterment of the design. He was also responsible for the bulk of the 3D printing manufacturing.

**Shihong Yuan** was primarily responsible for the integrated CAD modeling of the dispenser, leg mechanism, and the gear transmission system. To meet the specific 2-meter performance requirement, he conducted an iterative optimization of the gear ratios. This involved close collaboration with Liangbing, performing multiple cycles of assembly and disassembly to experimentally verify different gear configurations. Additionally, he handled the troubleshooting and maintenance of the dispensing module and fabricated the wooden package.

**Liangbing Zhao** Assisted in the manufacturing process, performing laser cutting and 3D printing in the laboratory, assembling the robot, debugging the robot with teammates, replacing components to meet the 2m length requirement, and participating in package creation. Assistance with writing PowerPoint presentations and reports.

*I, Shihong Yuan, hereby agree that I followed all academic integrity policies while producing this report. In addition to my original contributions, I have read through this entire report and certify that all materials, including the designs, are correct and not plagiarized.*

Signature: shihong yuan

Date: 12/08/2025


*I, Daniel Koltchev, hereby agree that I followed all academic integrity policies while producing this report. In addition to my original*

*contributions, I have read through this entire report and certify that all materials, including the designs, are correct and not plagiarized.*

Signature: \_\_\_\_\_  \_\_\_\_\_

Date: \_\_\_\_\_ 12/09/2025 \_\_\_\_\_

*I, Sebastian Missong, hereby agree that I followed all academic integrity policies while producing this report. In addition to my original contributions, I have read through this entire report and certify that all materials, including the designs, are correct and not plagiarized.*

Signature: \_\_\_\_\_  \_\_\_\_\_

Date: \_\_\_\_\_ 12/12/2025 \_\_\_\_\_

*I, Liangbing Zhao, hereby agree that I followed all academic integrity policies while producing this report. In addition to my original contributions, I have read through this entire report and certify that all materials, including the designs, are correct and not plagiarized.*

Signature: \_\_\_\_\_  \_\_\_\_\_

Date: \_\_\_\_\_ 12/12/2025 \_\_\_\_\_

#### **4. Appendix D:**

We grant permission for the course staff to use de-identified parts of this report as examples for future classes.