Robotics Studio [MECHE 4611]
*Spring 2022*

# Assignment 1: Concept Sketches

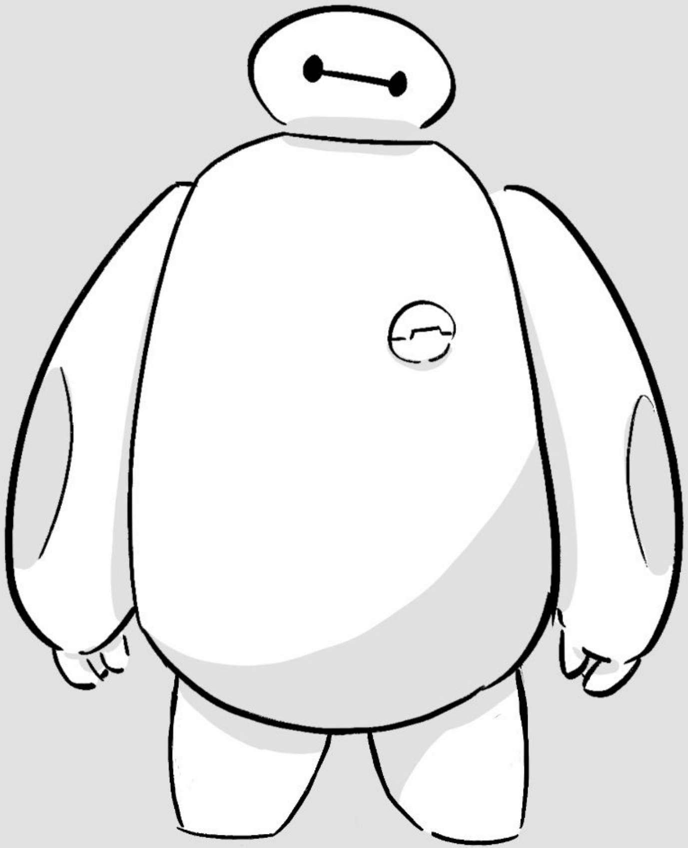
Nico Aldana [na2851]
Kennedi Wade [kaw2216]

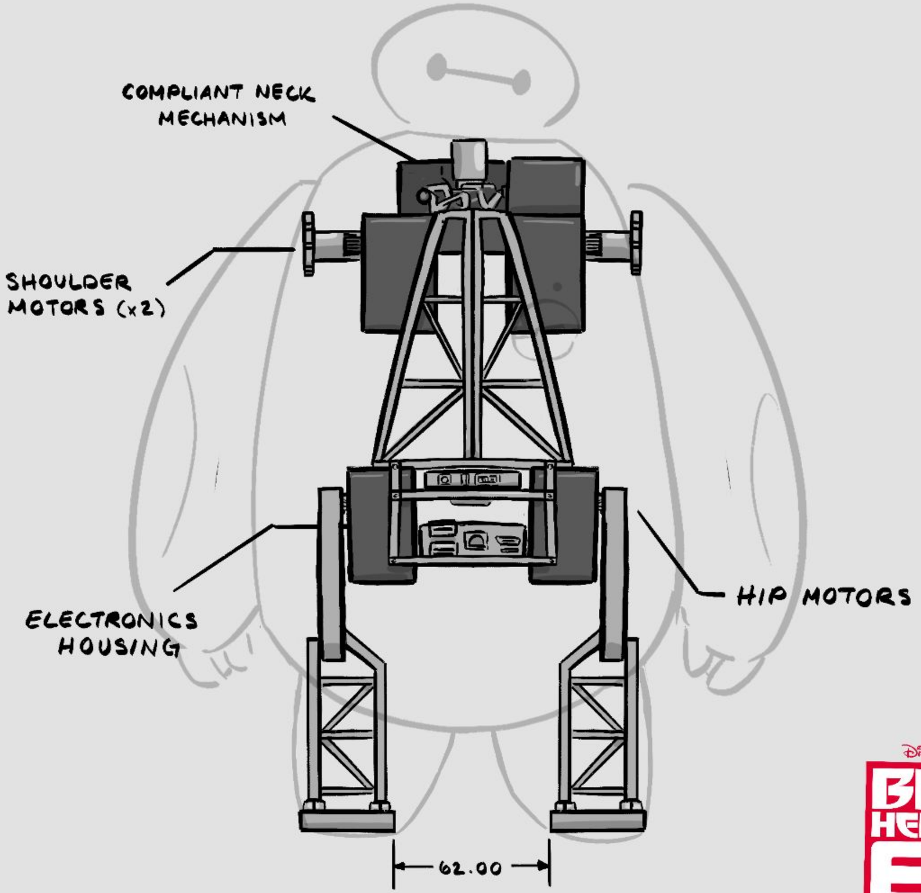
**Date Submitted: 01/29/22**

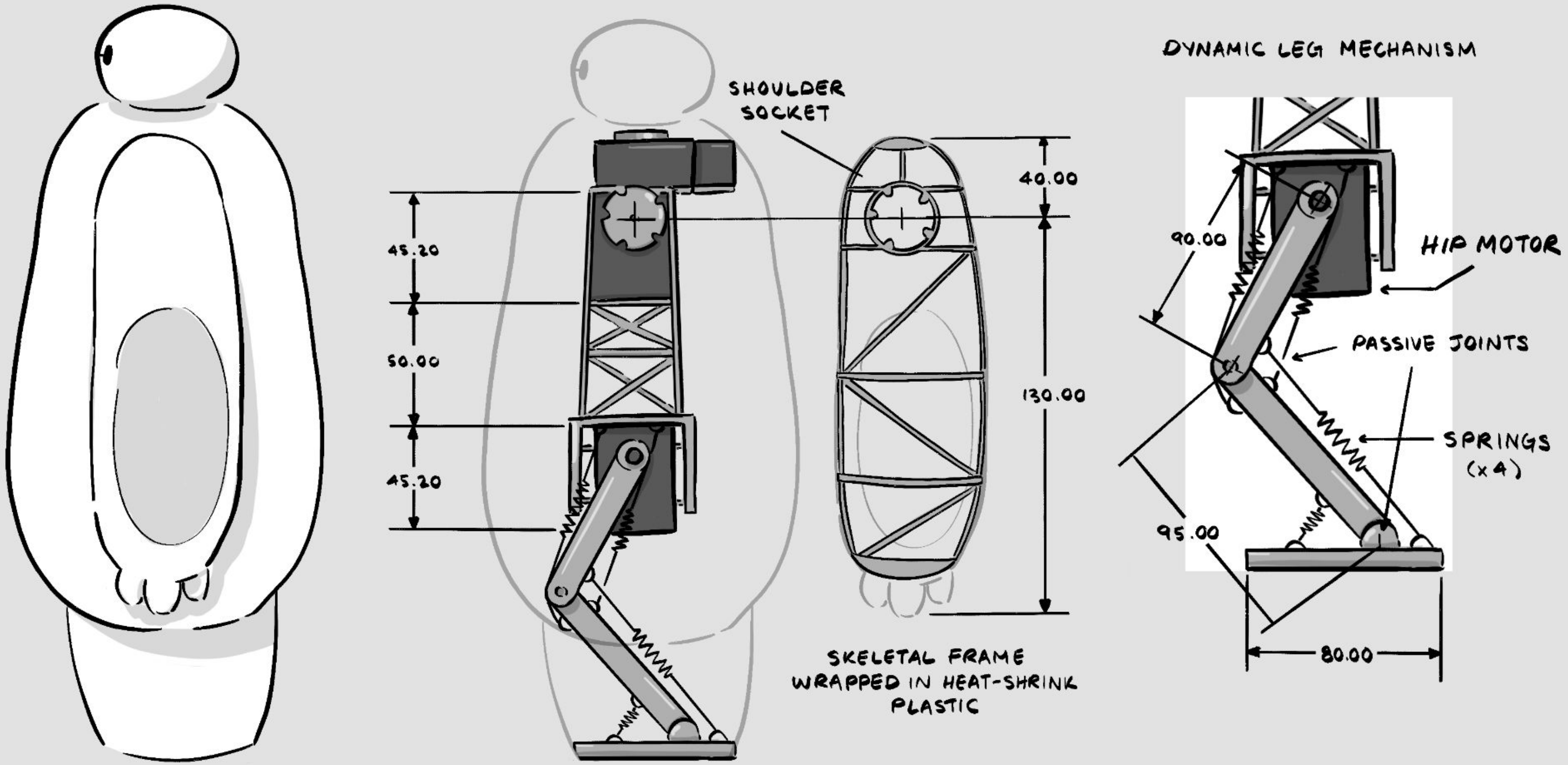
**Grace Hours: 96 (to start)**

# Concept 3: Baymax

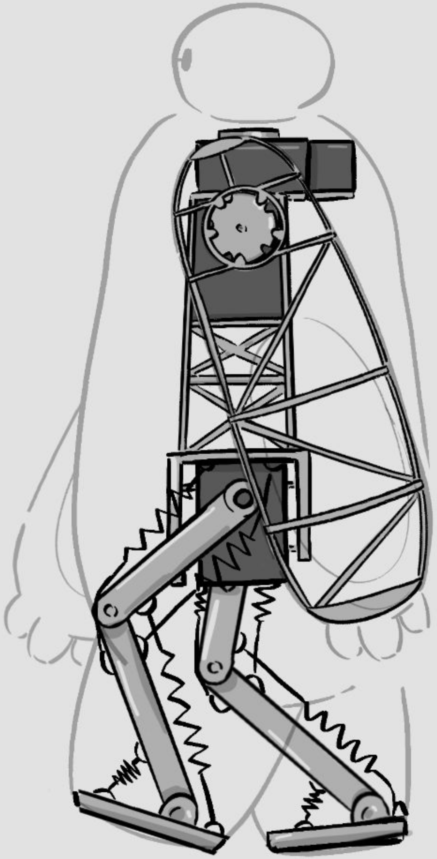
# BAYMAX - INSPIRED ROBOT

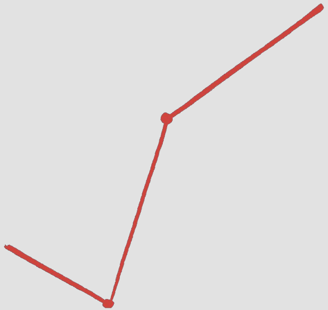







ALL MEASUREMENTS IN MM



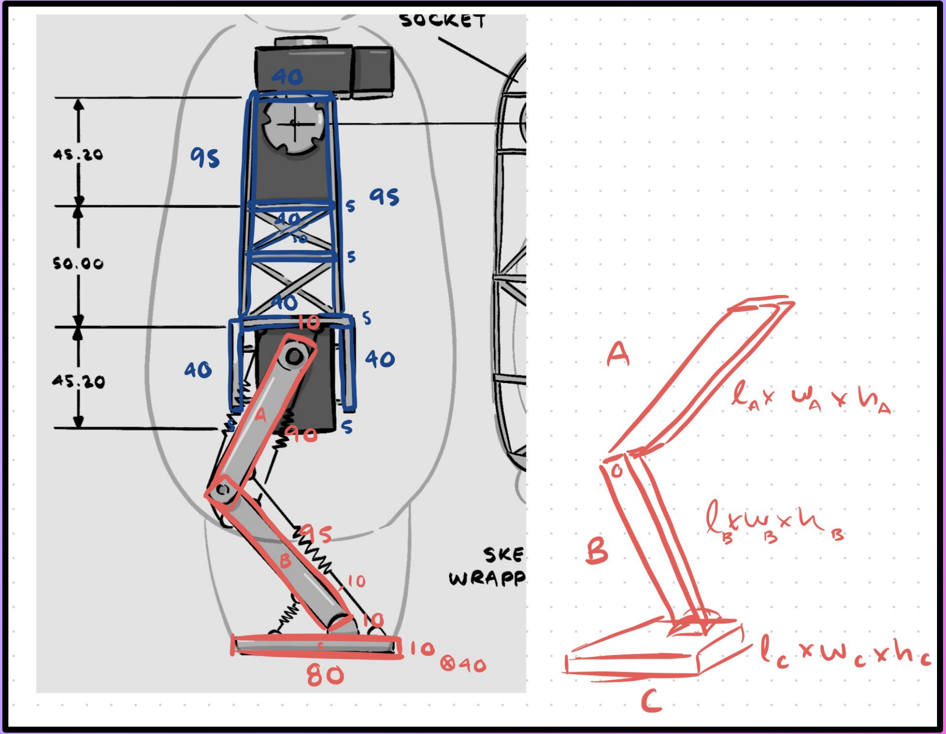


Animated GIF Link

# Weight Calculations

We estimated the mass of the robot by simplifying the frame and legs down to sums of basic rectangular volumes, then multiplied by the density of aluminum. We added the total mass of the electronic components (0.8 kg) at the end.

We estimated the weight of the frame, legs, and motors to be roughly **2.25 lbs** (1.02 kg). Adding in the weight of the arms and head, we estimate this will add another **1.1 lbs** (0.5 kg).



From previous weight calculations:

$$M_{LEG} = (2.17 \times 10^{-5}\ m^3)(2700\ \tfrac{kg}{m^3}) = 0.05859\ kg$$

$$d_{LEG} = 19\ cm\ \text{(extended)}$$

$$\tau_{LEG} = M_{LEG} d_{LEG} = 1.113\ kg \cdot cm = 10.92\ N \cdot cm$$

$$M_{TORSO} = \underbrace{(0.10935\ kg)}_{\text{FRAME}} + 4\underbrace{(0.052\ kg)}_{\text{SERVO}} + 2\underbrace{(0.1\ kg)}_{\text{ARM}}$$

$$= 0.51735\ kg$$

$$d_{TORSO} = 17\ cm$$

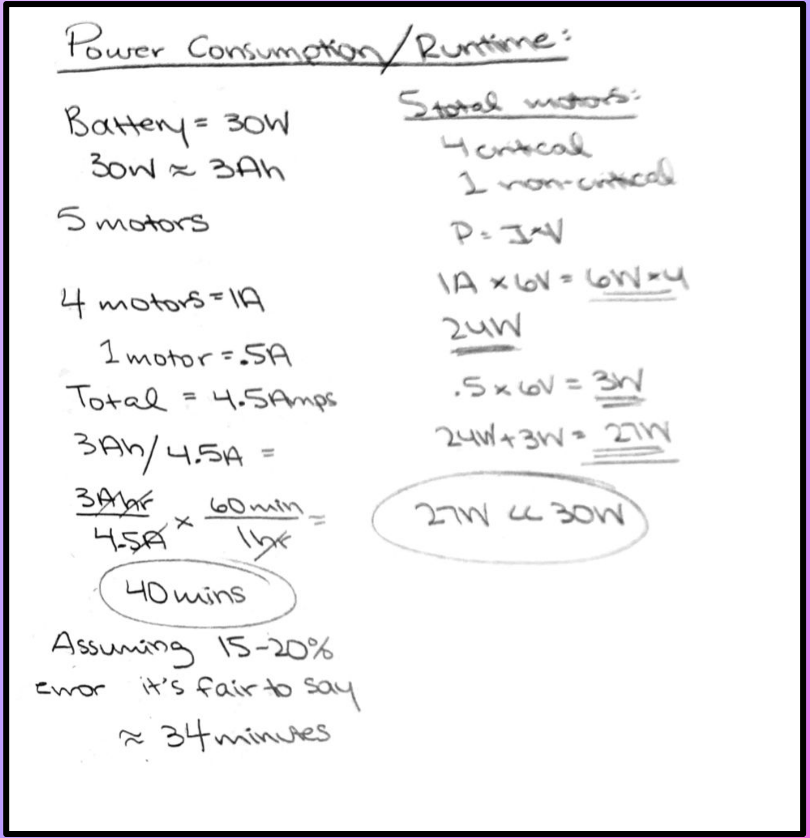
$$\tau_{TORSO} = 8.795\ kg \cdot cm = 86.28\ N \cdot m$$

$$10.92\ N \cdot cm \ll 86.28\ N \cdot m \ll 166.7\ N \cdot cm$$

We're well under torque limits :)

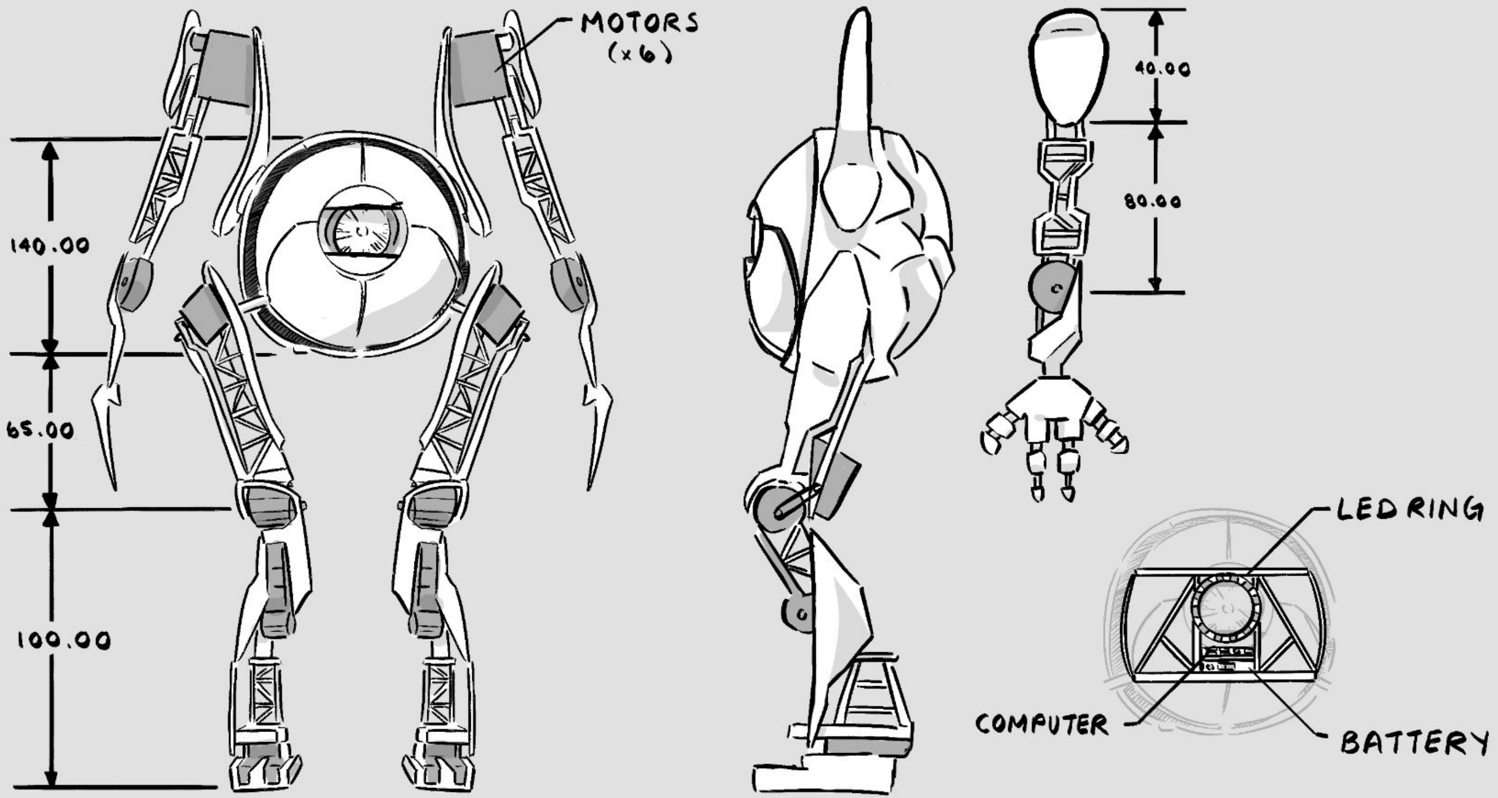
# Power Consumption/Runtime Calculations

In computing the necessary power and runtime for our Baymax bot, we found that our robot will run for approximately **34 minutes** on one charge, and will require around **27W** of the 30W the battery can supply.

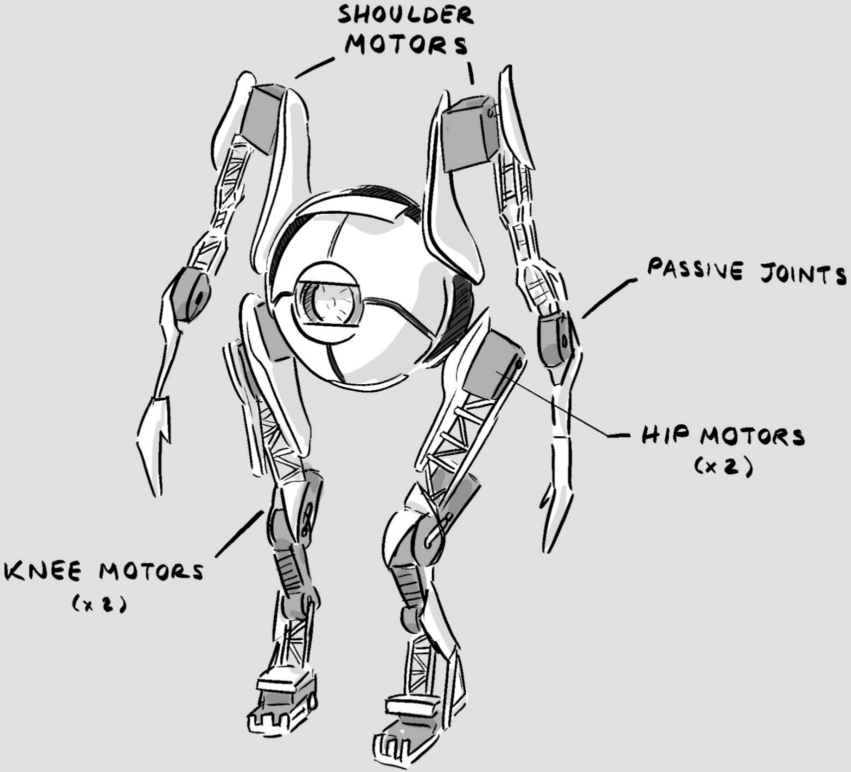


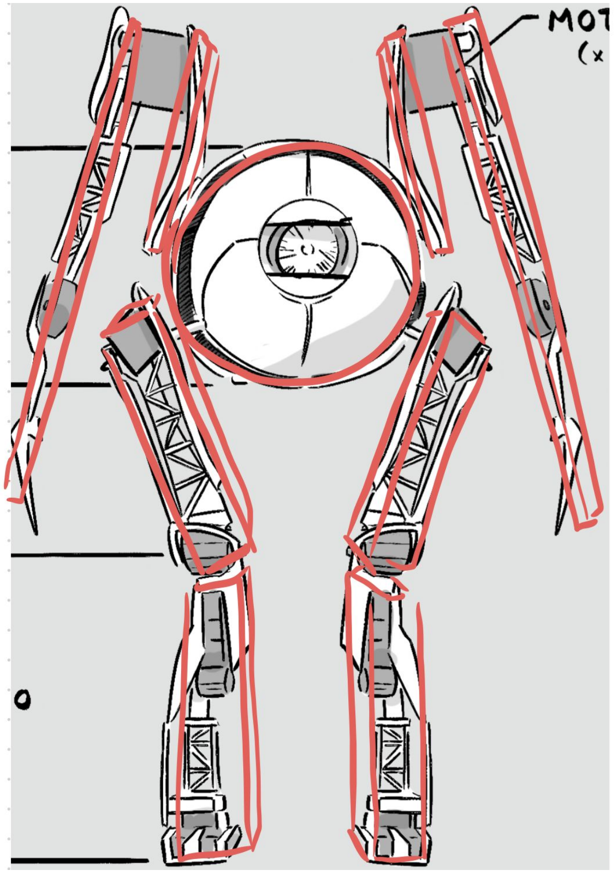
# Concept 2: Atlas

# ATLAS-INSPIRED ROBOT




PORTAL 2


SHOULDER MOTORS
PASSIVE JOINTS
HIP MOTORS (x2)
KNEE MOTORS (x2)



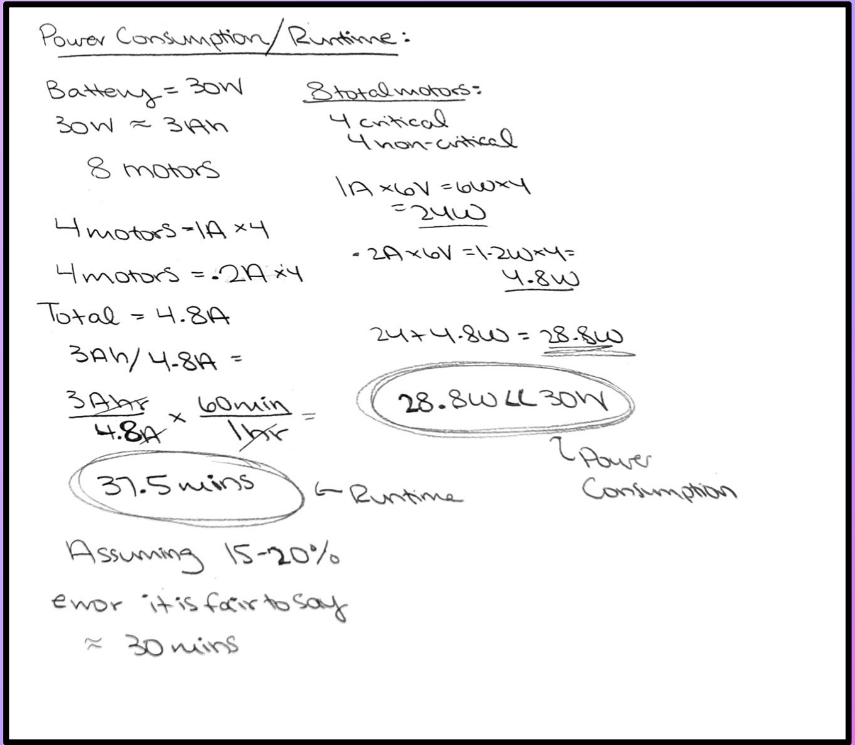

Simplifying down the basic shapes of the robot…

We assumed the limbs to be made of aluminum and the spherical body to be made of ABS plastic.

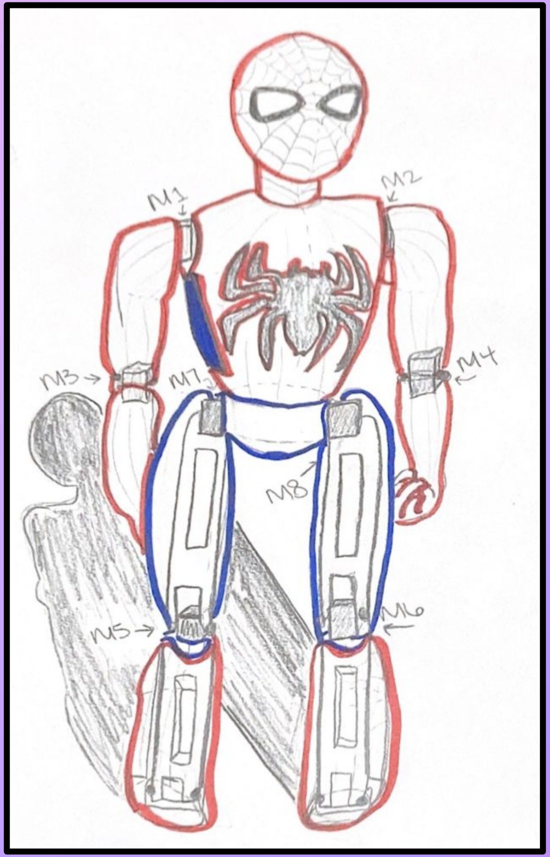
Adding the weight of four motors and the electronic components, we get a total weight of approximately **2.17 kg**, or 4.78 lbs.

# Power Consumption and Runtime

We found that Atlas consumes **28.8W** of the 30W the battery supplies and will run for approximately **37.5 minutes.**

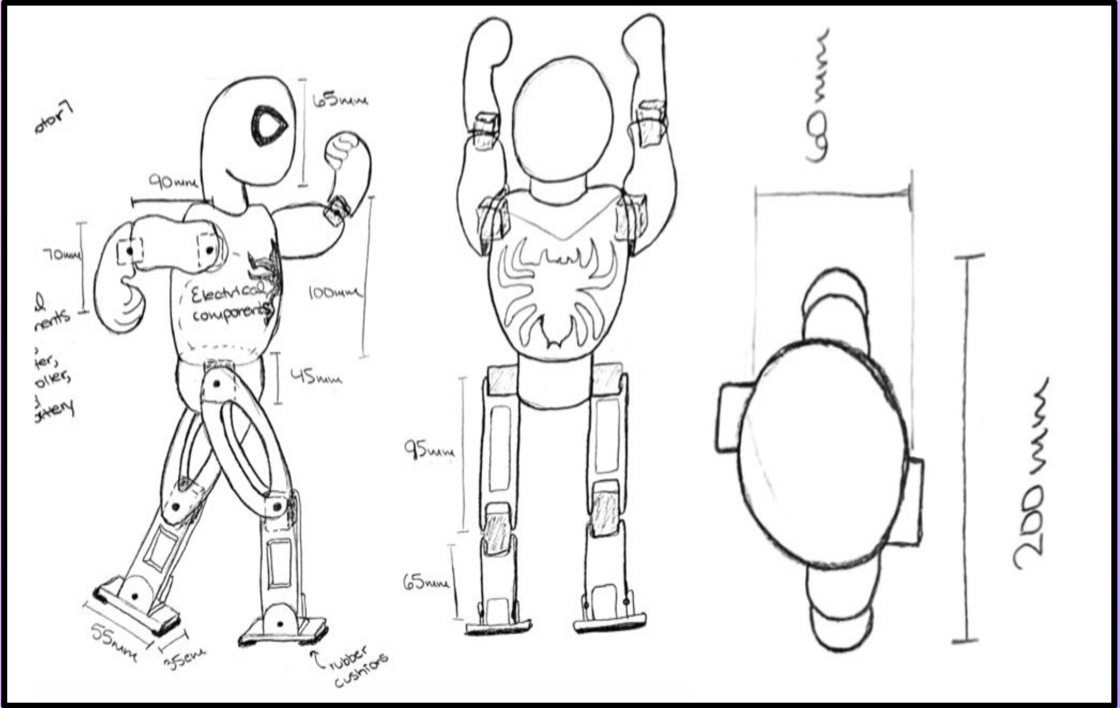


# Concept 3: Spiderman

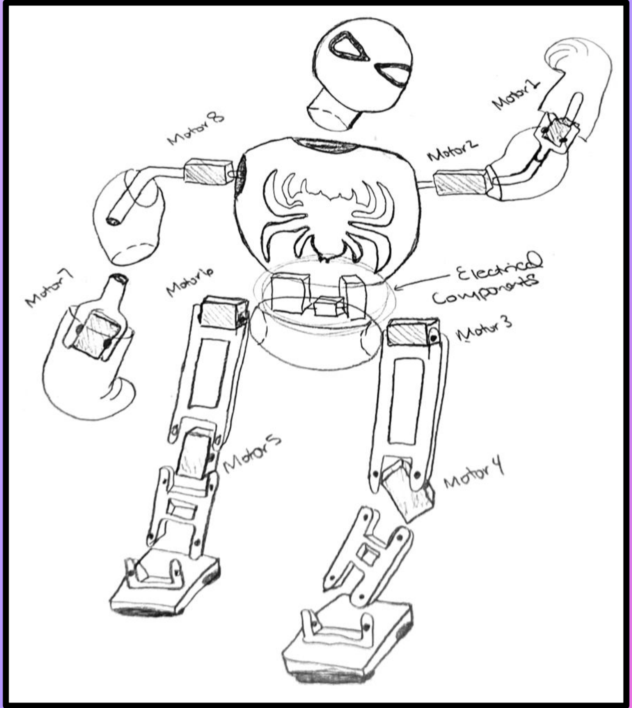



Red = Parts 3D printed in red
Blue = Parts 3D printed in blue

# Different Poses and Views

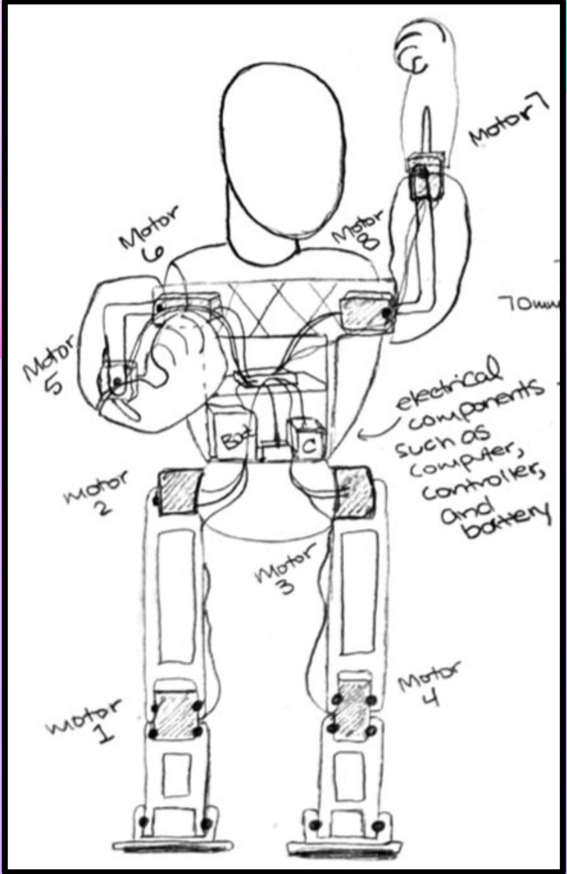


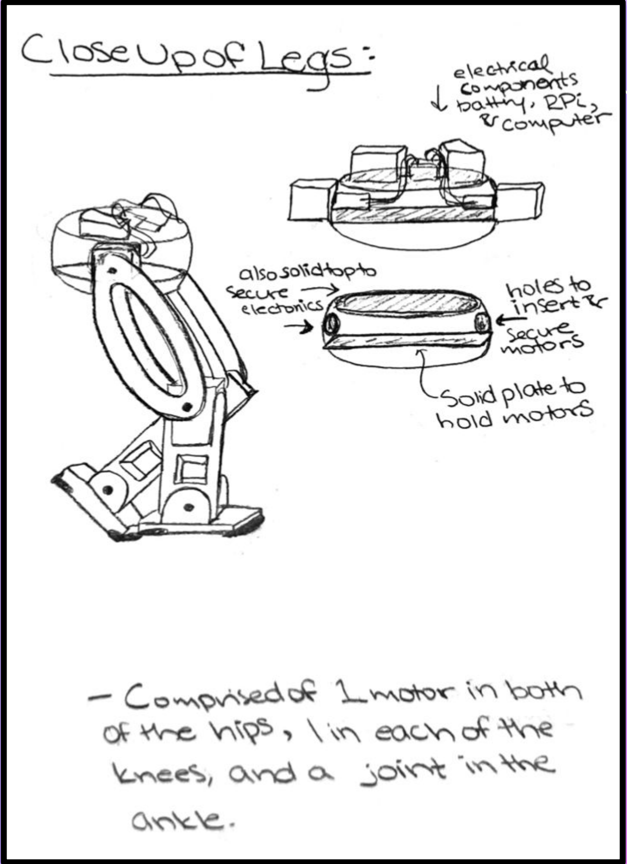

Side View Rear View Top View



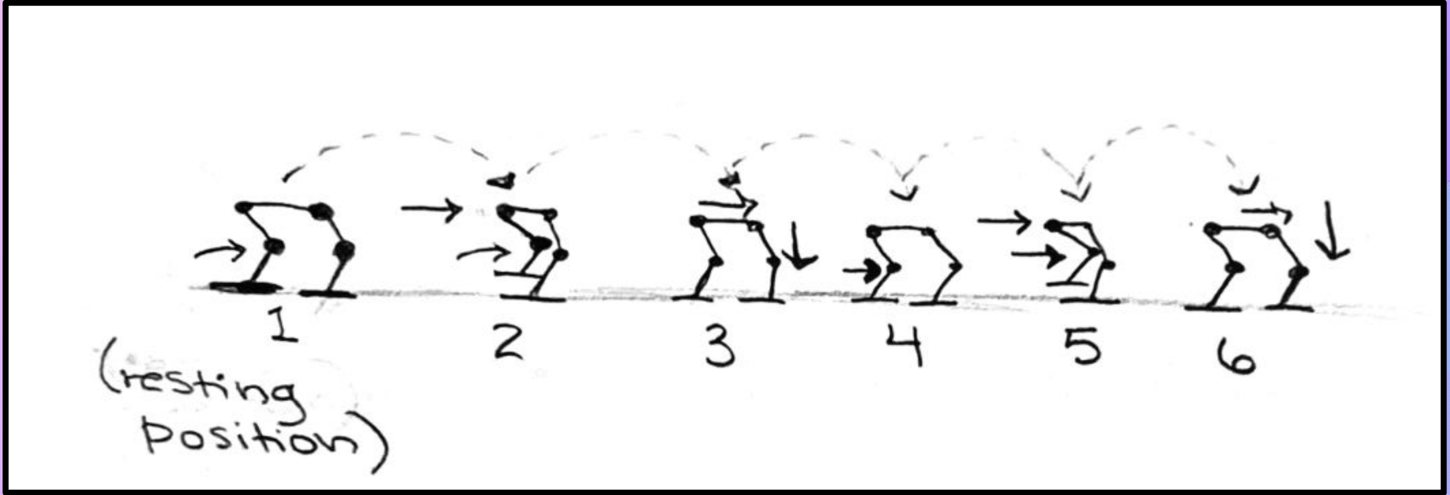

Exploded View

# A Closer Look Inside: “Zoom In”



# Gait Analysis



# Weight Estimation

**Weight:**

Legs:


$V=(95\times5\times5)+(65\times10\times10)+(55\times35\times10)$

$V = 28125\ mm^3$

$V \approx 2.8125e^{-5}\ m^3$

$\frac{m}{V}=\rho$

$\rho=2710\ kg/m^3$

$m=(2710)(2.8125e^{-5})$

$m = .0762\ kg$

*2 legs* $M=2(.0762)$

$M= .1524\ kg$

**Filament:**

$V=\frac{4}{3}\pi r^3$ $r=32.5mm$

$V=\frac{4}{3}\pi(32.5)^3 = 143793.314\ mm^3$

$\approx .00014379\ m^3$

$\frac{m}{V}=\rho \rightarrow m=(1235)(.00014379)$

$m= .17758\ kg$

$V=\pi r^2 h$ $r=42.5mm$ $h=100mm$

$V=\pi(42.5)^2(100)$

$V= 567450.173\ mm^3$

$\rightarrow .00056745\ m^3$

$m=(1235)(.00056745)$

$m= .70080075\ kg$

$V=\pi r^2 h$ $r=45mm$ $h=160mm$

$V=\pi(45)^2(160) = 1017876.02\ mm^3$

$V = .001078\ m^3$

$m=(.001078)(1235)$

$m = 1.3313$

*2 arms*

$m=2(1.3313)$

$m = 2.663\ kg$

**Frame:**

$V=(200\times60\times10)+(90\times2\times2)(2)+2(160\times5\times5)$

$V=128720\ mm^3$

$V\approx .00012872\ m^3$

$\frac{m}{V}=\rho$

$m=(2710)(.00012872)$

$m= .34883\ kg$

**Total Estimated Weight:** *Including the 8 52g motors:

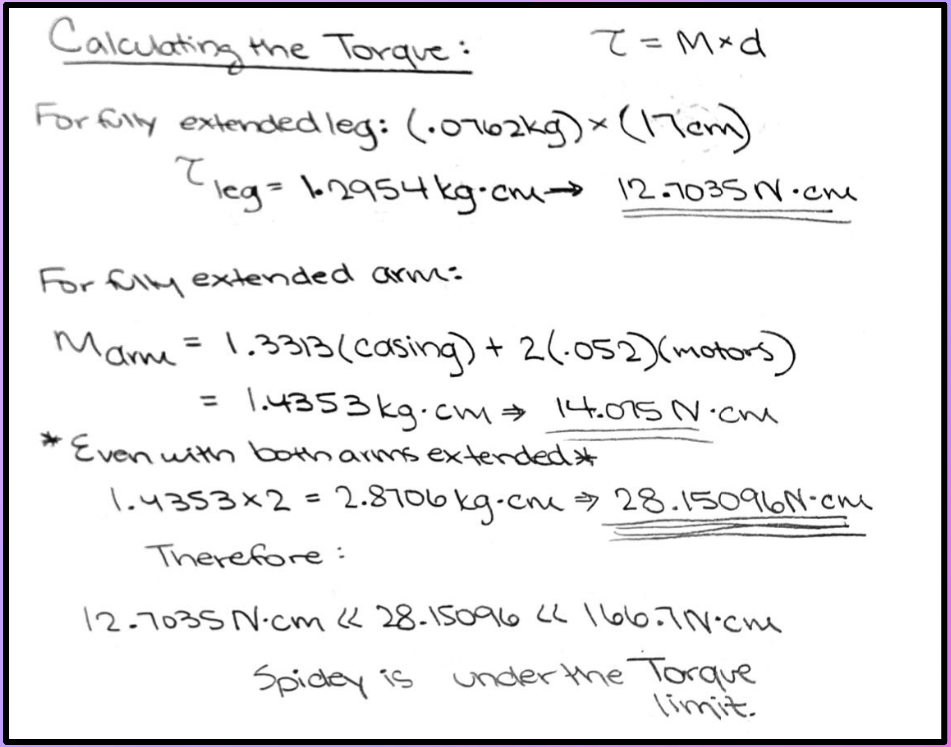
.34883 + .1524 + .70080075+.17758+2.663 + 8(.052) =

**3.75778kg**

**Materials:** Aluminum for the Frame and Legs, and TPU (Thermoplastic Polyurethane) for the exterior hollow pieces

# Torque Calculations

After estimating the total weight of Spiderman and its different components, we calculated the maximum amount of torque needed at the fully extended arms and legs of the robot. Using the distances of the fully extended appendages and the mass calculations from the previous slide, we found that in both of these cases Spidey is under the torque limit.



Calculating the Torque: $\tau = M \times d$

For fully extended leg: $(.0762kg) \times (17cm)$

$\tau_{leg} = 1.2954 \, kg \cdot cm \rightarrow 12.7035 \, N \cdot cm$

For fully extended arm:

$M_{arm} = 1.3313(\text{casing}) + 2(.052)(\text{motors})$

$= 1.4353 \, kg \cdot cm \Rightarrow 14.075 \, N \cdot cm$

* Even with both arms extended *

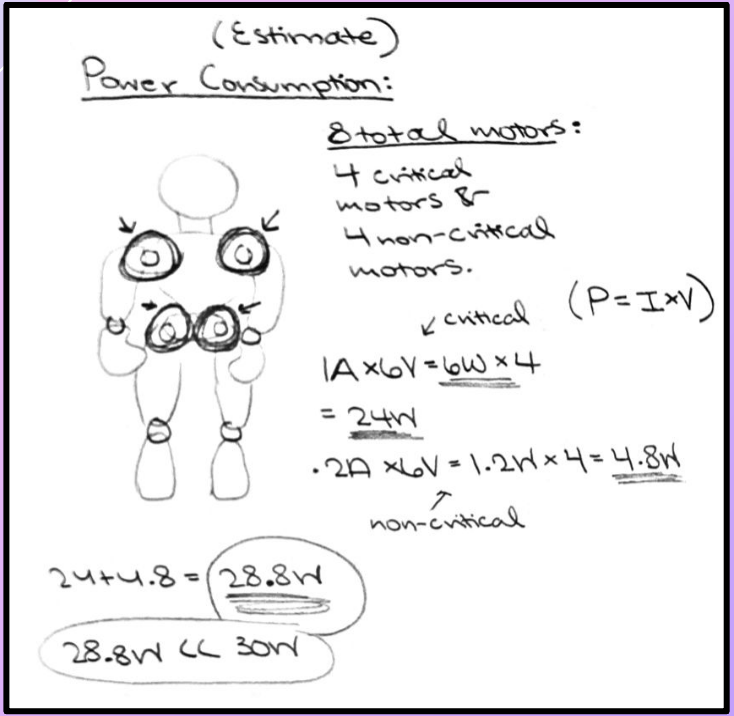
$1.4353 \times 2 = 2.8706 \, kg \cdot cm \Rightarrow 28.15096 \, N \cdot cm$

Therefore:

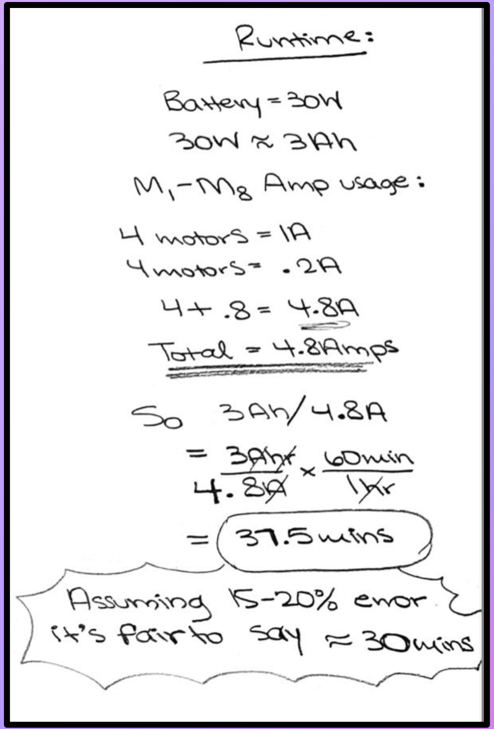
$12.7035 \, N \cdot cm \ll 28.15096 \ll 166.7 \, N \cdot cm$

Spidey is under the Torque limit.

# Power Consumption/Run Time Estimation




**Max Power Consumption: 28.8W,** which is less than the 30W supplied by the battery




**Estimated Runtime:** Around **30 minutes** including 20 percent error

# Screenshots of Constructive and Positive Comments to Classmates

## Saturday Jan. 29th

because it really looks amazing. I was going to mention the balance but from the other comments I see that you're already figuring that part out :) Good luck!

1 Reply •••

K Kennedi Wade 20m

I completely agree you are so talented!!! The shading, the detail, just amazing. This robot reminds me of a ballerina, so graceful and poised!

Reply Edit Delete •••

**1**

Comment •••

Sort by Newest

Add comment

**2**

K Kennedi Wade 35m

Sidd this is amazing!! I also second that @Thomas Danza that would be way cool if you printed everything in green like the real Mike Wasowski! The cross-section of your piece looks great as well and leaves plenty of room for the electrical components and storage. Super excited to see this guy come to life!!

Reply Edit Delete •••

K Kennedi Wade

26 minutes ago

**3**

Wow what fantastic sketches Fernando!! I especially appreciate the level of detail shared across all 3 of your designs. Personally I think Robot #2 resembles a tourist walking around and taking pictures the most, and I think it would be super cool to run into one of those bots taking pictures on the street IRL!!

Comment Edit Delete •••

# RECOUNT OF POINTS AND GRADING FOR ASSIGNMENT 1:

- 5 points Title slide complete
- 5 points overall aesthetic/layout/formatting of slides
- 5 points submitting a sketch of our robot 24hr before the deadline (Saturday evening) AND commenting positively on at least 3 other's postings **(shown above) (slide 23)**

**For <u>each</u> Concept Sketch:**

- 5 pts for 3D sketches with key dimensions and labels (concepts 1, 2, and 3) (slide 3,4,5,6,9,10,11,13,15,16)
- 5 points shading and shadows (all drawings) (3,4,5,10,11,15)
- 5 points weight estimate and gait stability analysis (5,6,7,15,16,17)
- 5 points for power estimates and run time (8,13,21,20)
- 5 points including electrical components (battery, controller, and computer) (3,4,9,10,13,14)
- 5 points showing in multiple poses (3,4,5,9,10,11)
- 5 points showing "Zoom in" of some feature (14,13,9,10,3,4)

**Our Total Point Summation:**

**120 points**

Met and Fulfilled EVERY point in the rubric

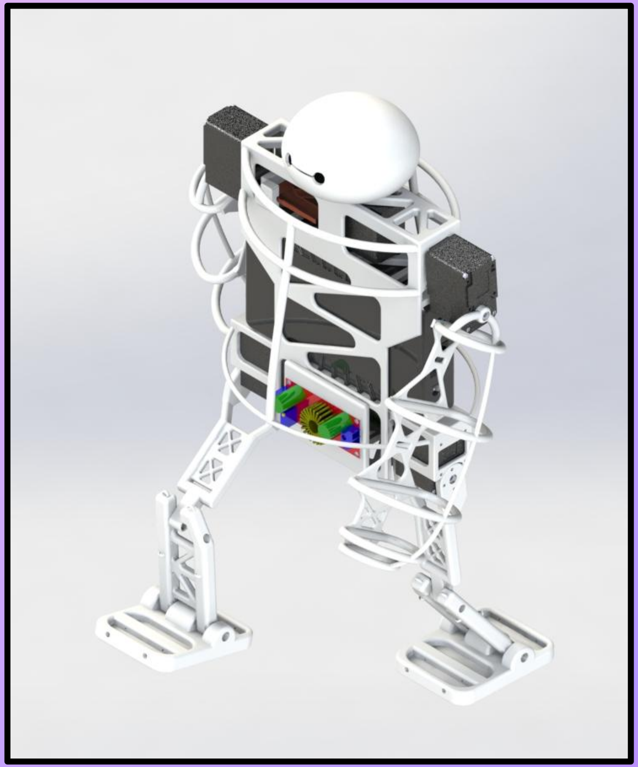
Robotics Studio [MECHE 4611]
*Spring 2022*

# Assignment 2: Preliminary CAD Model
# Big Hero 6's Baymax

Nico Aldana [na2851]
Kennedi Wade [kaw2216]

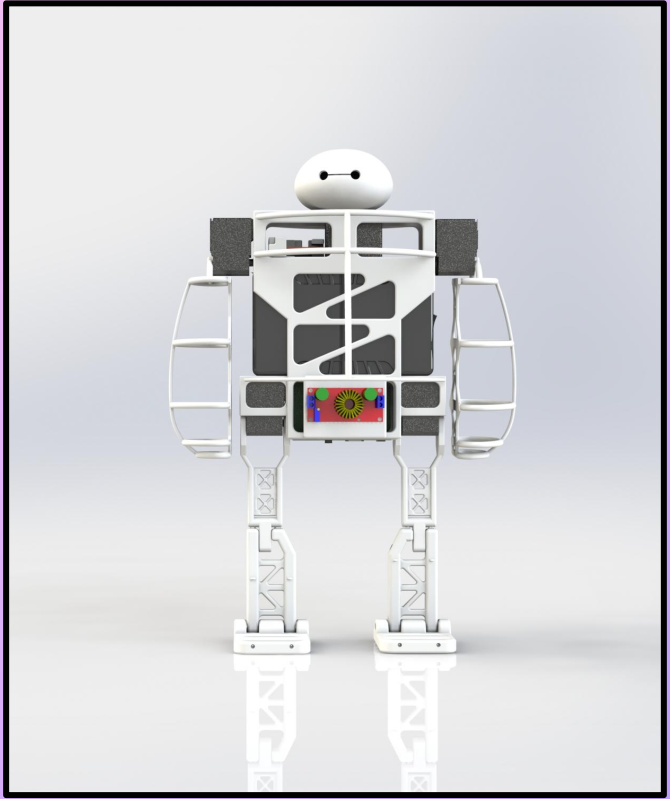
**Date Submitted: 02/05/22**

# General Robot Rendering

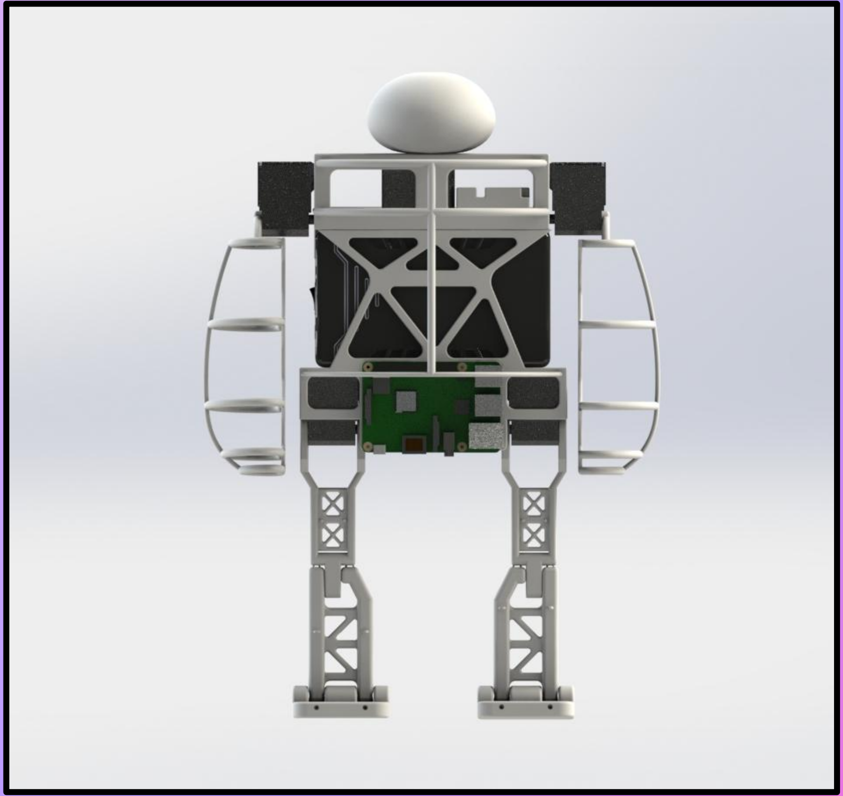


# Baymax: 3D Rendering in Perspective

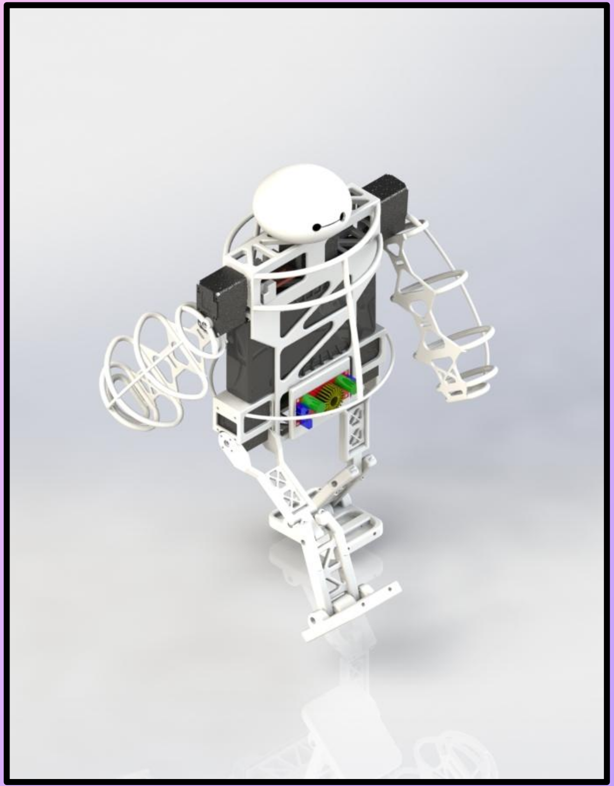
**Front View**

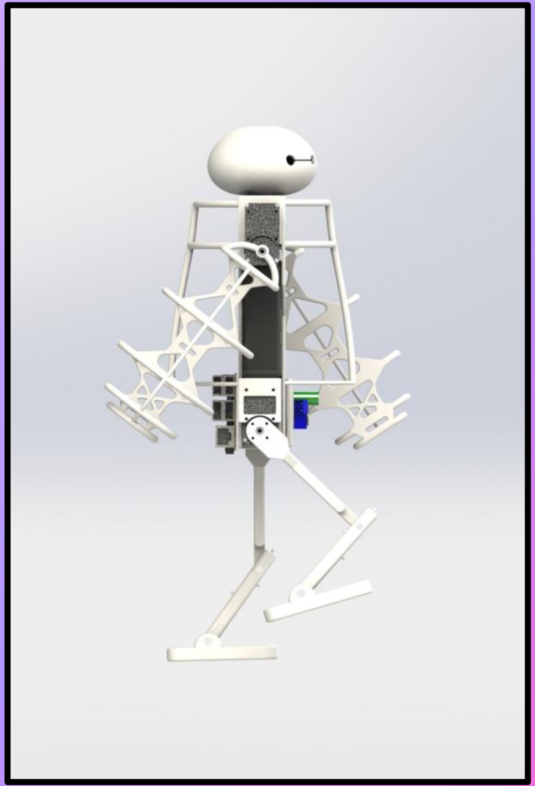


**Rear View**

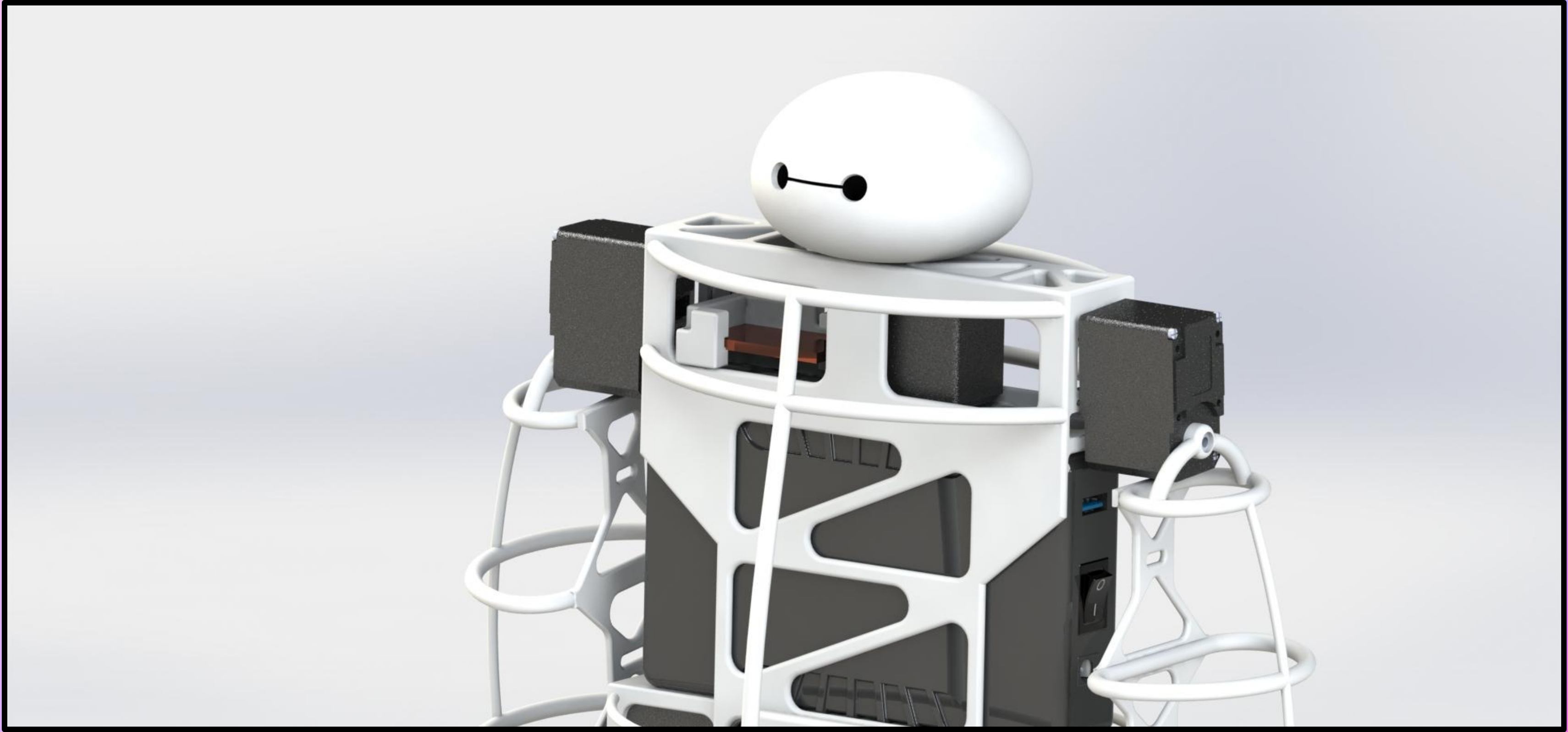


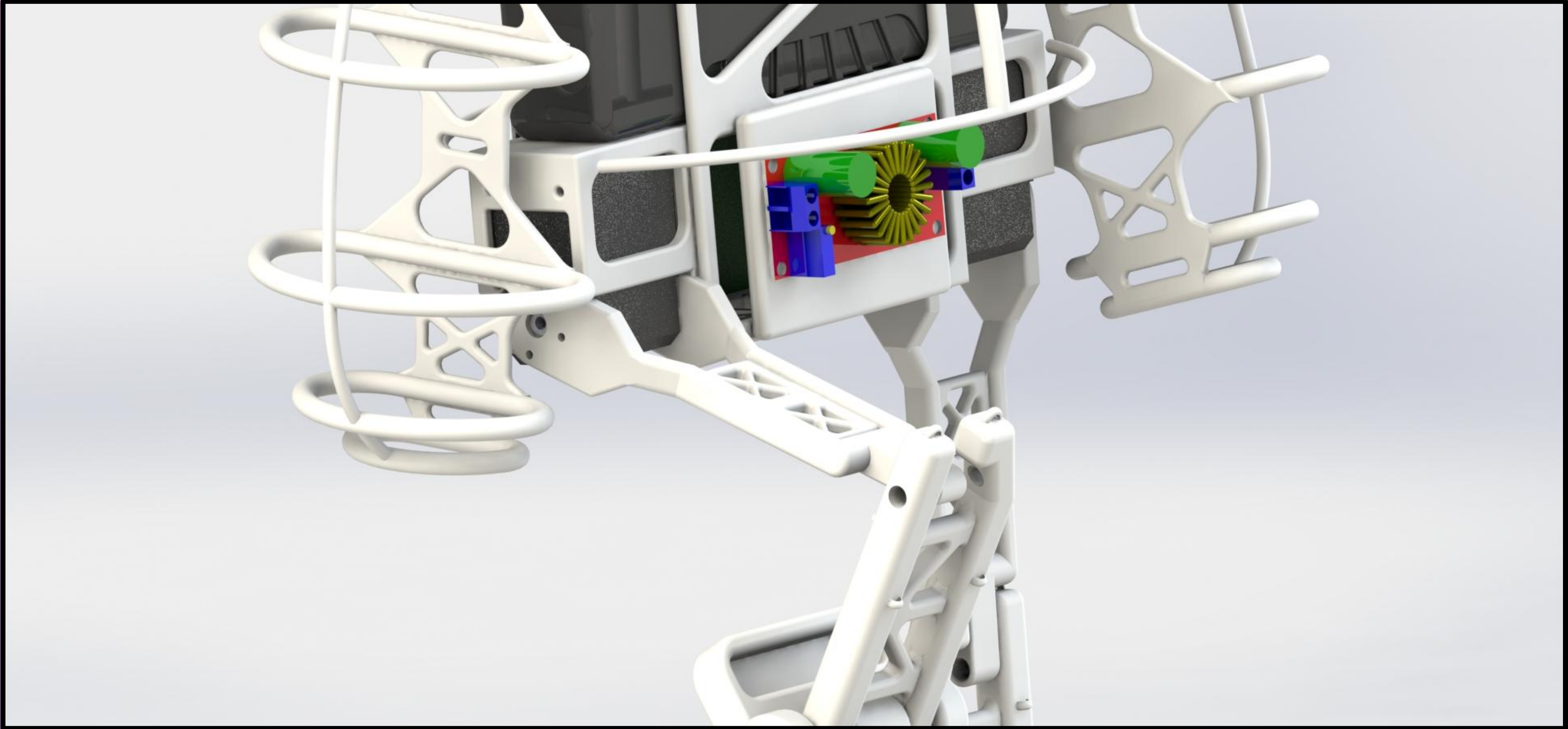
# Multiple Poses



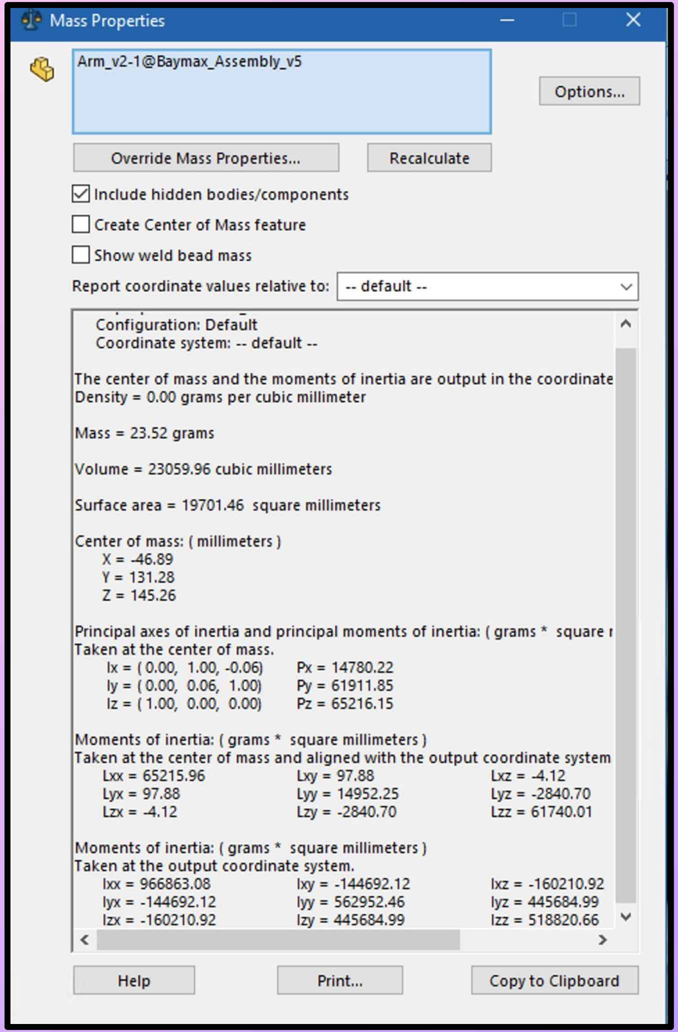


# Close Ups

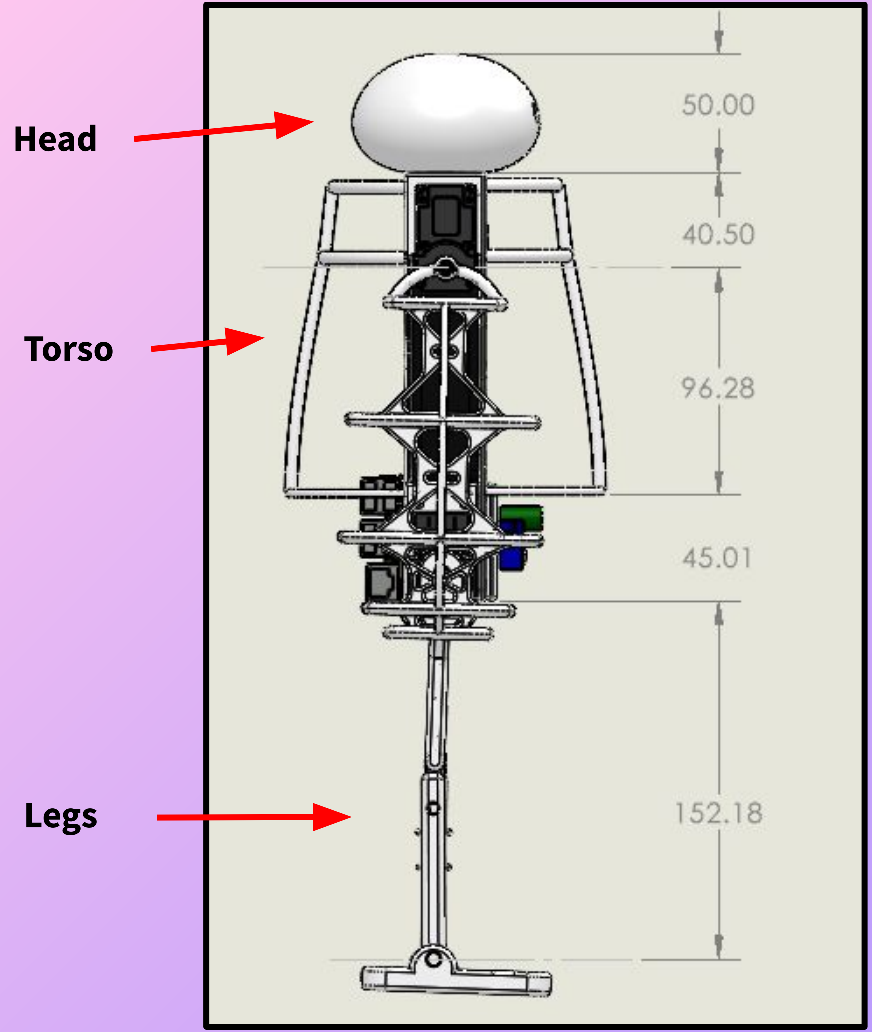




# Speed and Mass Properties Window

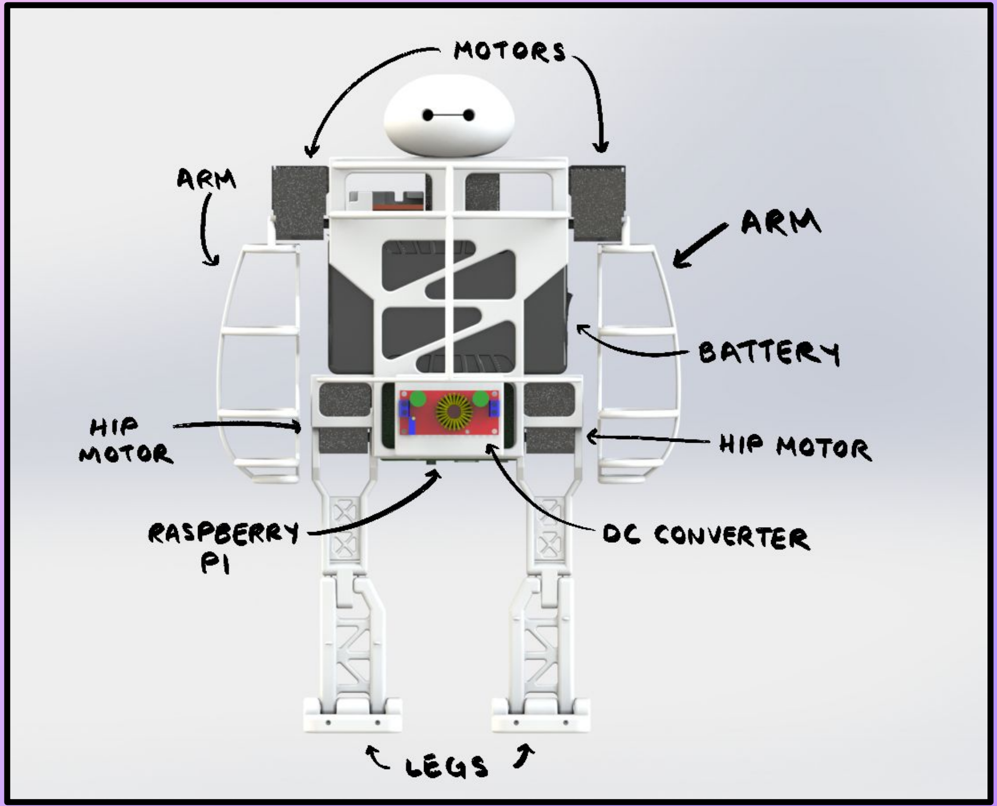


# Side View with Main Dimensions

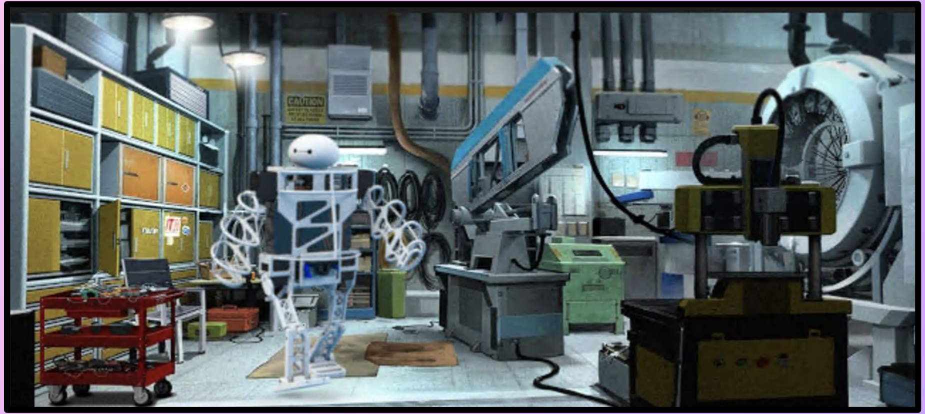


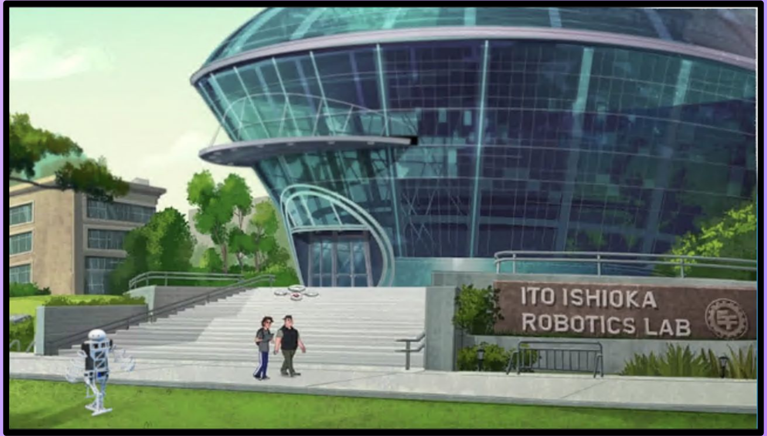

This side view depicts the main dimensions of our robot (in millimeters), including the robot's head, torso, and leg structures.

# Key Components



# Photorealistic Rendering

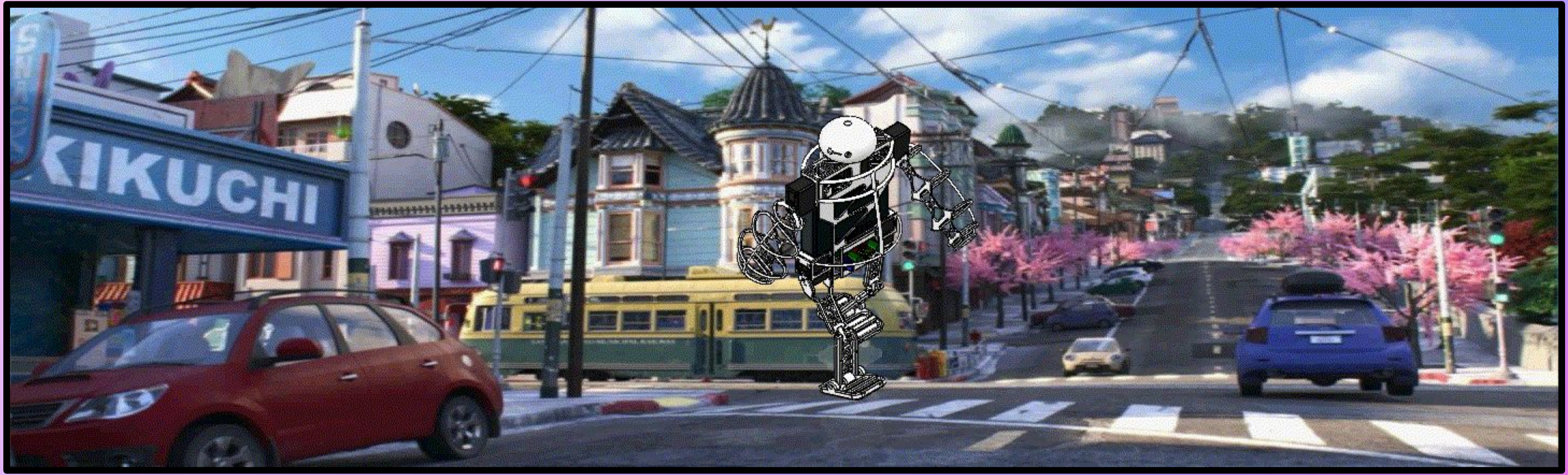




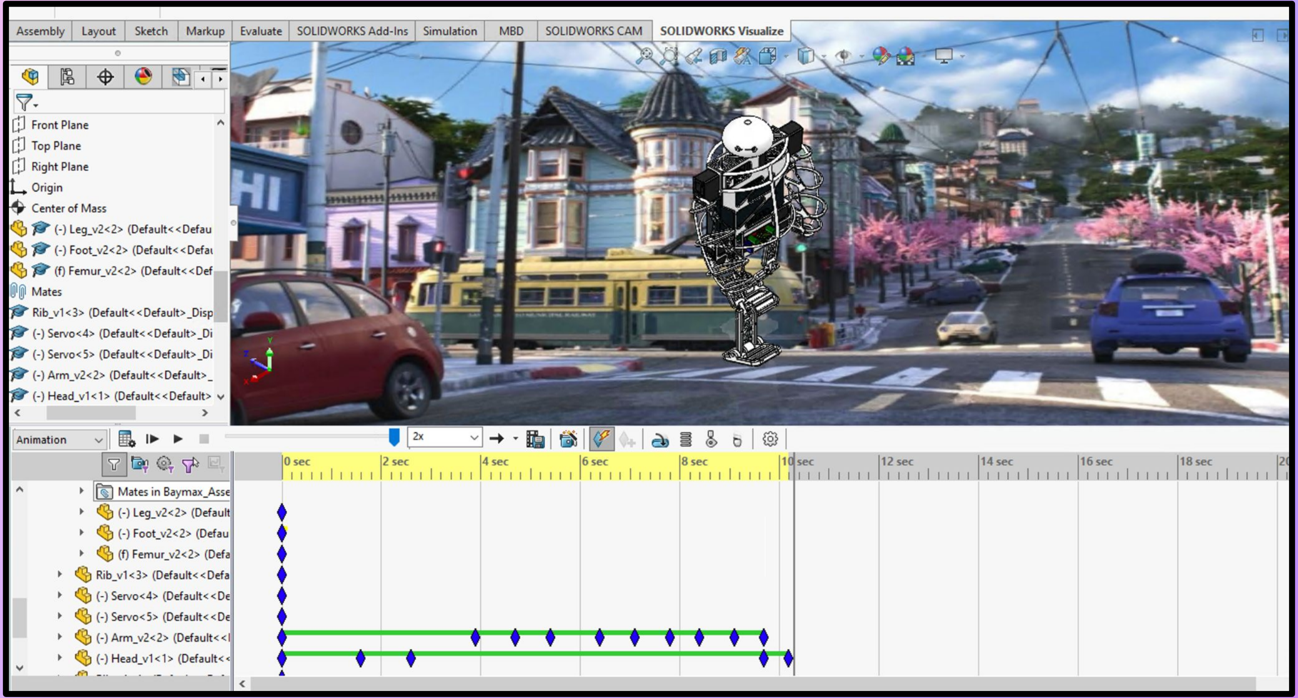
# Context Rendering


ALMA MATE

# Animation: Always Wave and Look Both Ways Before Crossing the Street :)

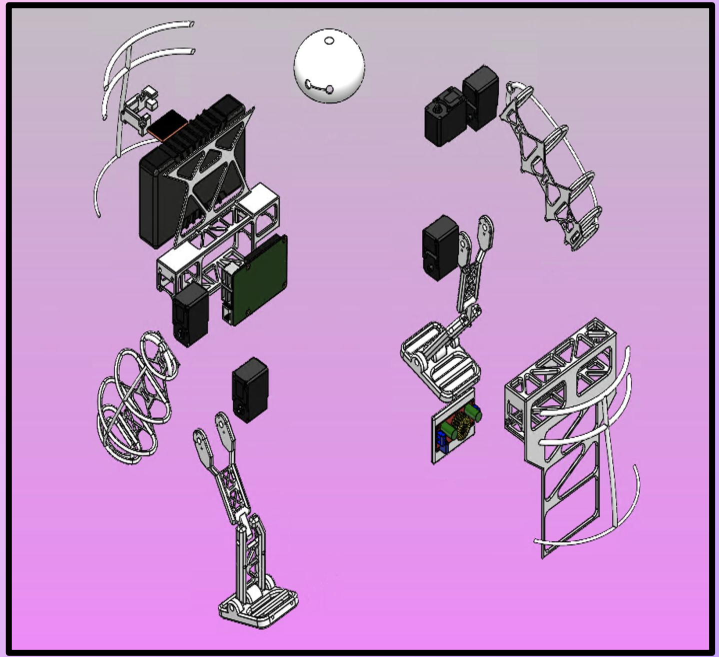


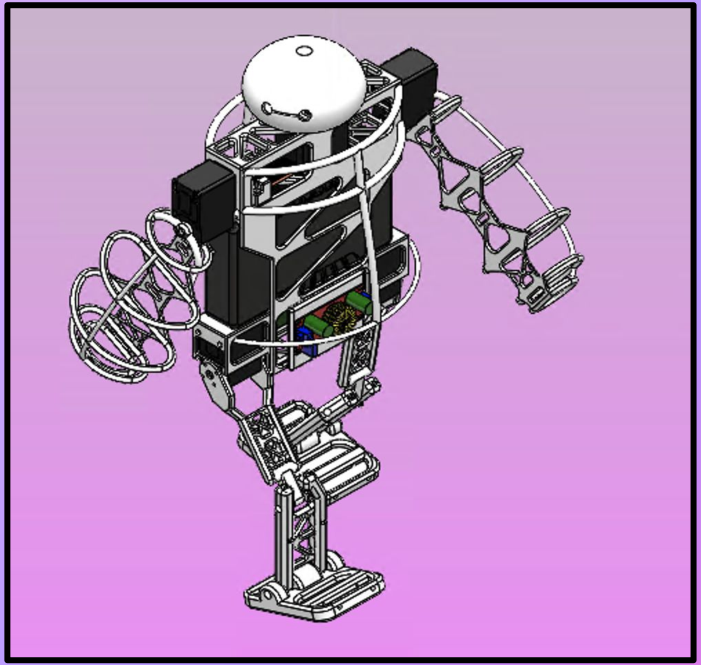
# Animation Video Frame and Link




[Animation Video Link!]

# Exploded View

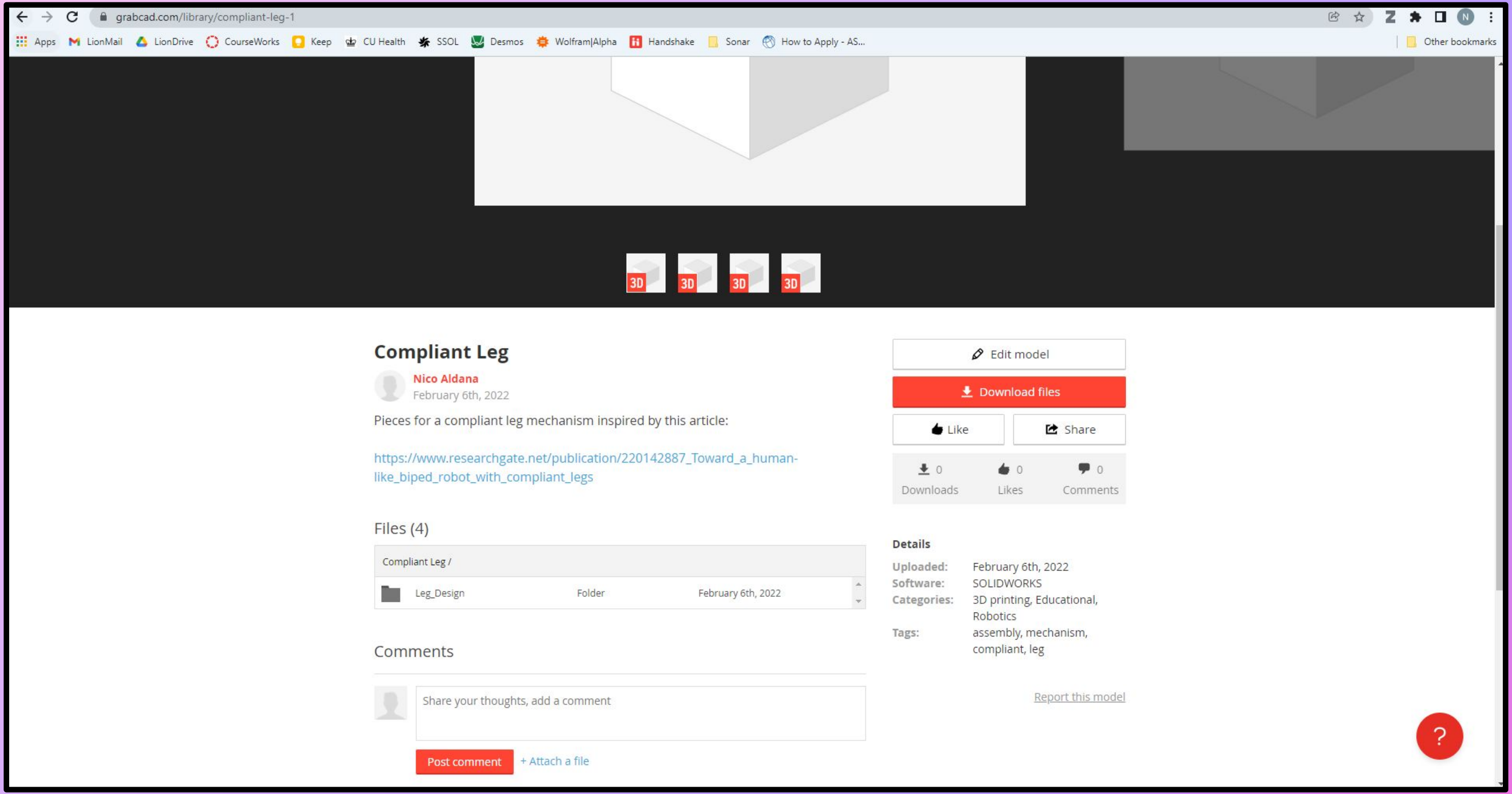




This slide displays each of the exploded individual components, (arms, legs, ribs, motors, battery, RPi, head, etc) of Baymax and how they fit together.

# GrabCAD Share (Screenshot)

https://grabcad.com/library/compliant-leg-1



# Screenshots of Constructive and Positive Comments to Classmates

**Saturday Feb. 5th**

K Kennedi Wade
now

Oh my goodness Fernando this is OUTSTANDING!!! F.R.I.E.N.D looks like he came straight out of a store! Absolutely fantastic you did an amazing job on this robot :)

Comment Edit Delete •••

**1**

K Kennedi Wade
now

Awww Sidd this is wonderful! I love how you did the context and photo rendering, BurgerBot looks SO real how amazing! I especially love how you decided to store the electronics. Do you think there is enough ventilation to keep the robot from getting too warm?

Comment Edit Delete •••

**2**

K Kennedi Wade
now

WHOA!! Sanjana this is super realistic! You have more than achieved your goal and I love how you attach the motors to the different parts of the leg as well, super detailed and well-thoughtout!

Comment Edit Delete •••

**3**

# RECOUNT OF POINTS AND GRADING FOR ASSIGNMENT 2:

- 5 points Title slide complete
- 5 points overall aesthetic/layout/formatting of slides
- 8 points commenting positively on at least 3 other's postings **(shown above) (slide 40)**

**For <u>each</u> Concept Sketch:**

- 8 pts 3D Renderings in perspective (All slides)
- 8 points Key components included (33)
- 8 points organic shape (no/few straight edges) (All slides)
- 8 points photorealistic rendering (34)
- 8 points context rendering (35-36)
- 8 points  animation (37-38)
- 8 points exploded view (39)
- multiple poses shown (25-30)
- detail close-up shown (28-30)
- Speed and mass properties window (31)
- side views with main dimensions (32)
- sharing a relevant CAD component on GrabCAD or Thingiverse (show screenshot) (40)

**Our Total Point Summation:**

**120 points**

Met and Fulfilled EVERY point in the rubric

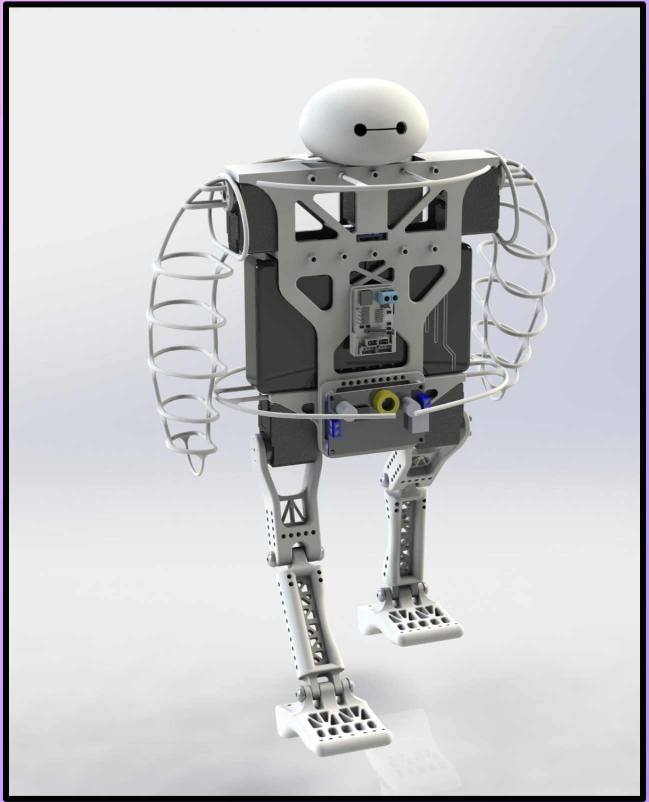
Robotics Studio [MECHE 4611]
*Spring 2022*

# Assignment 3: Detailed CAD Model
# Big Hero 6's Baymax

Nico Aldana [na2851]
Kennedi Wade [kaw2216]

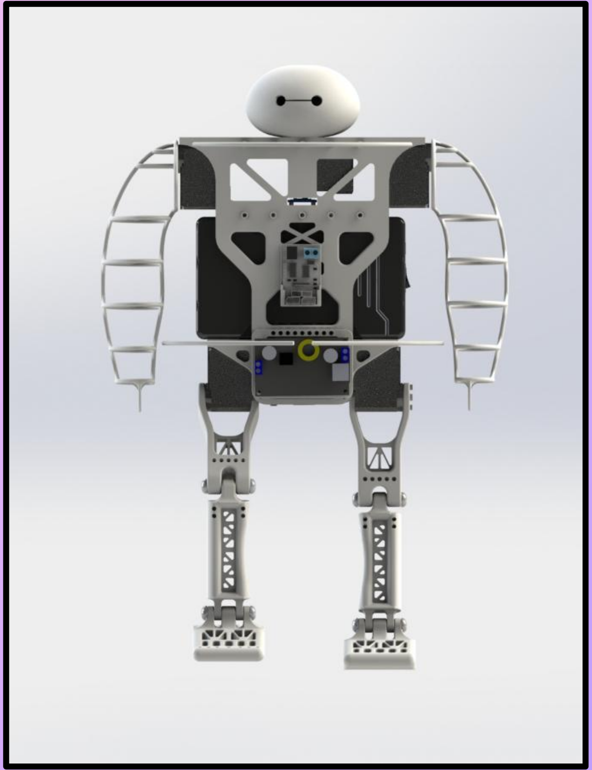
**Date Submitted: 02/25/22**

# General Robot Rendering

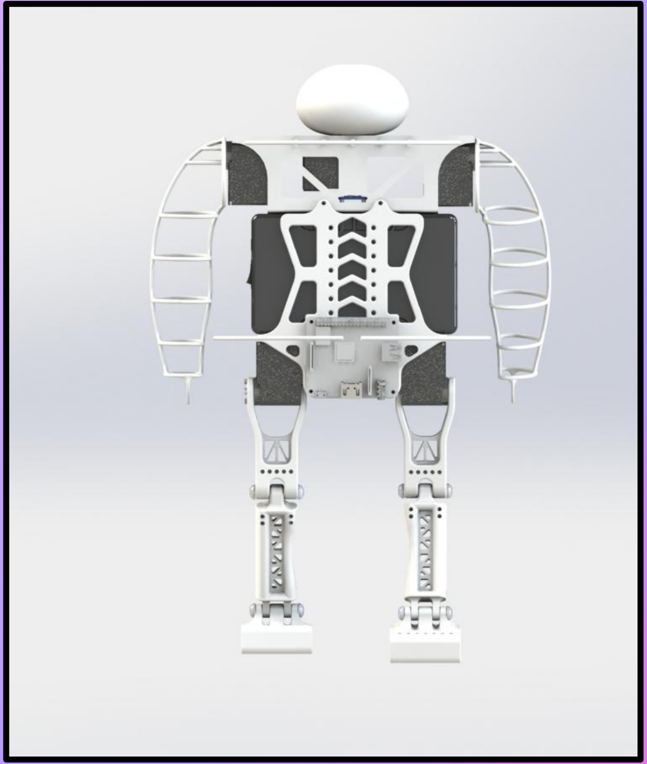


# Baymax: 3D Rendering in Perspective

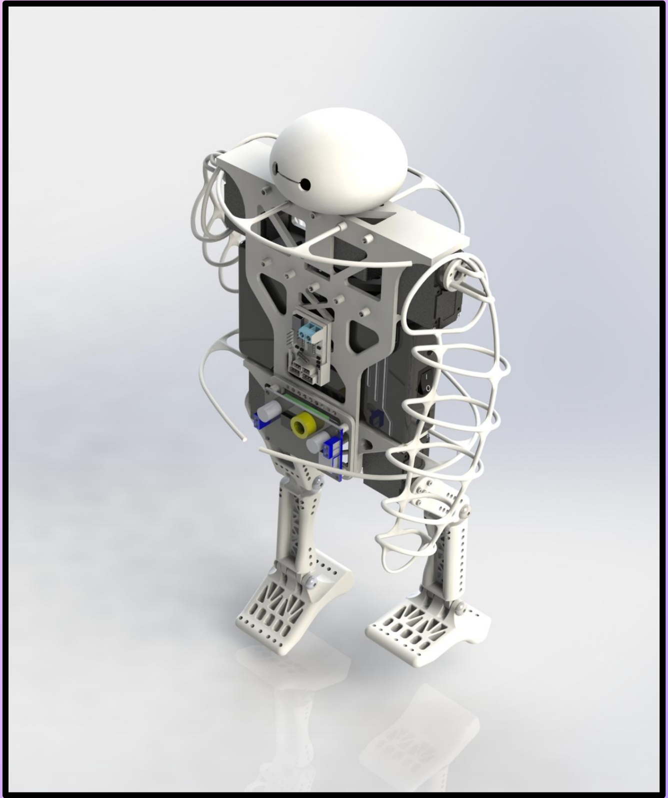
**Front View**

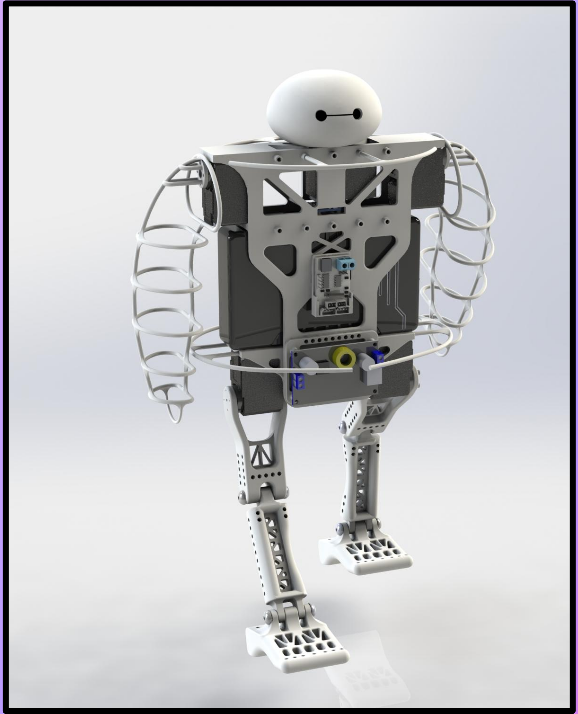


**Rear View**

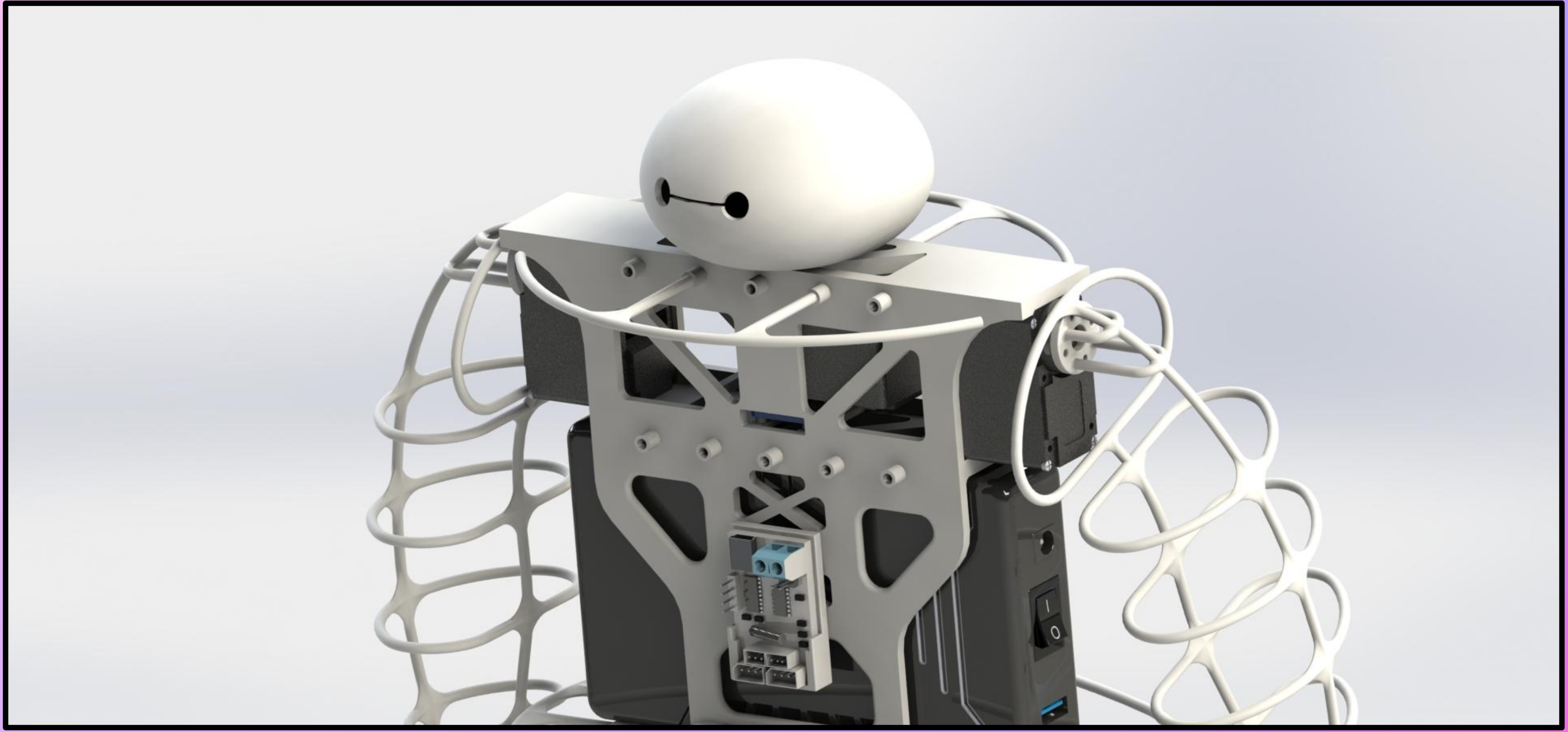


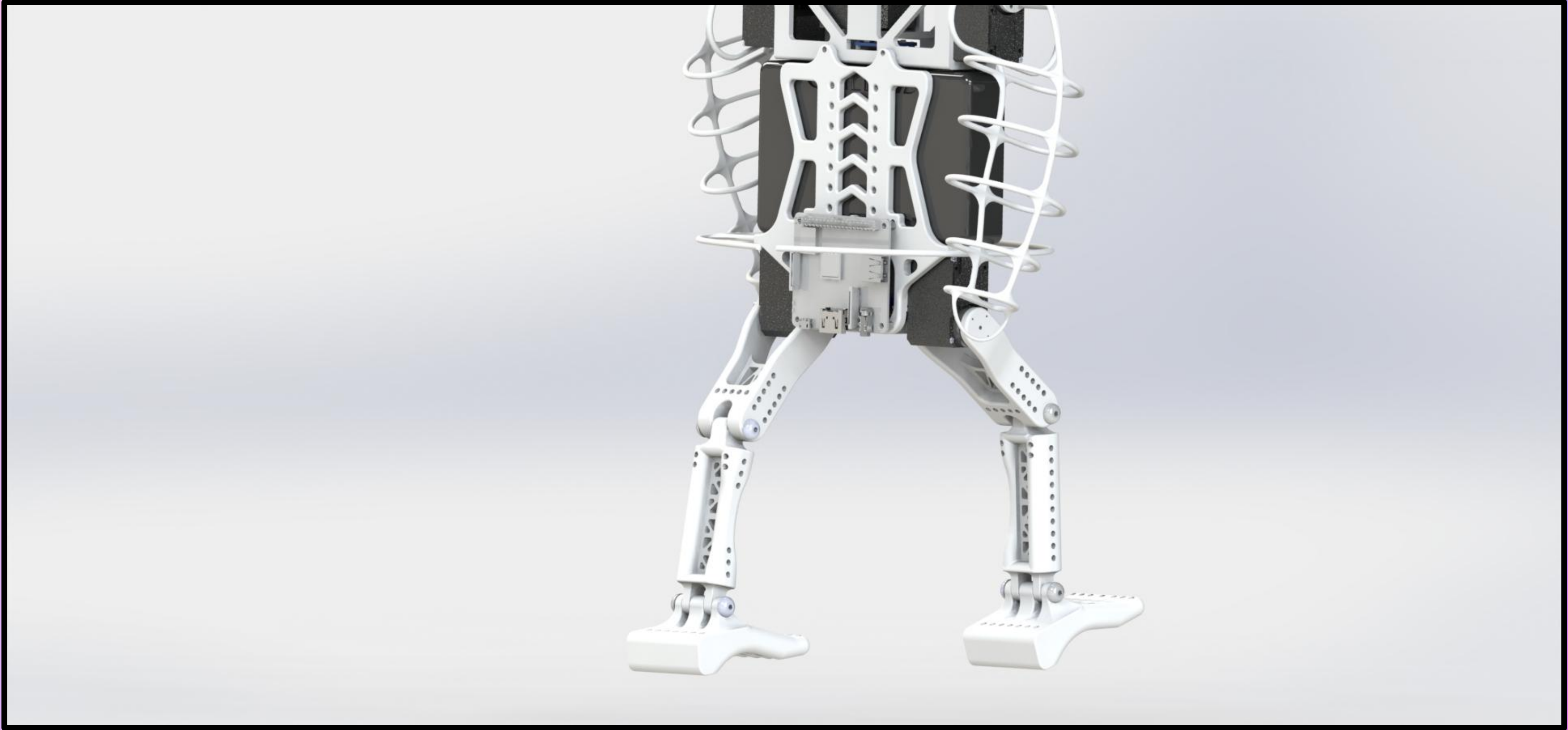
# Multiple Poses

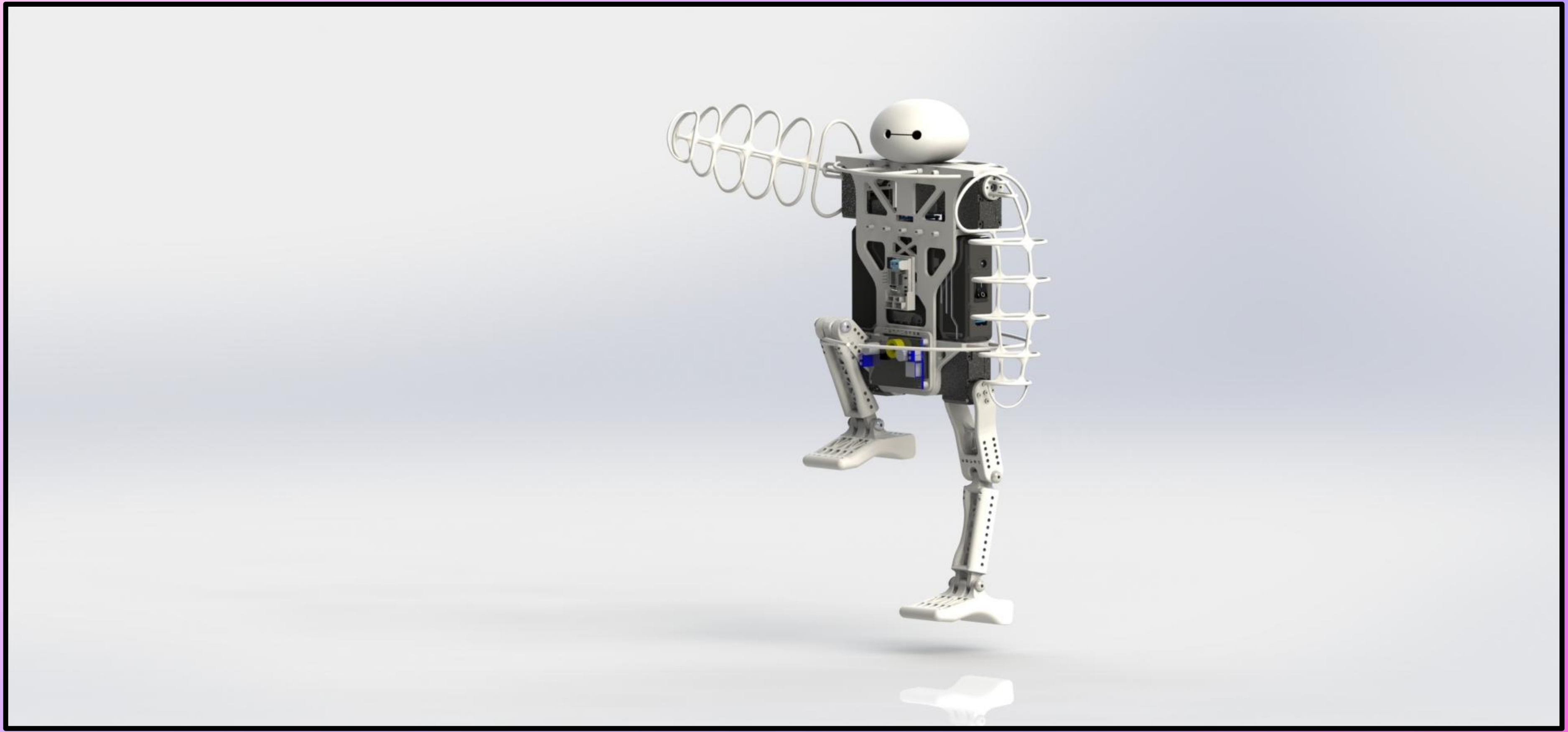


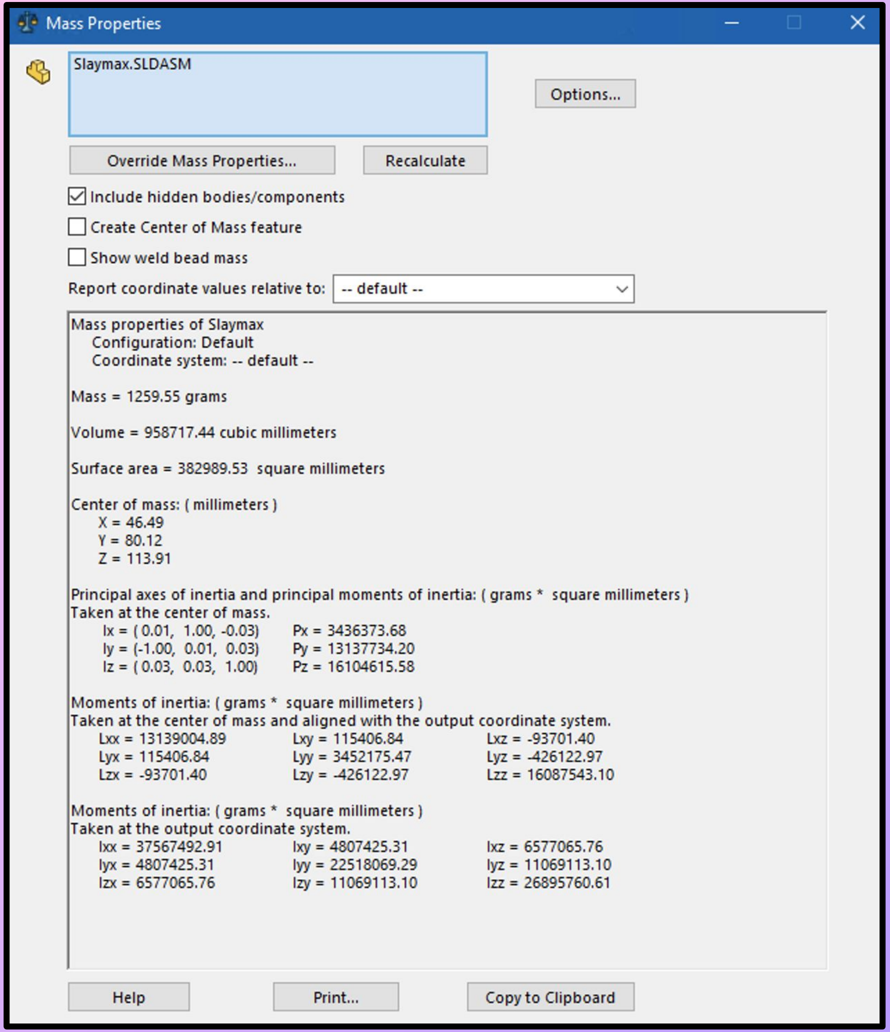


# Close Ups



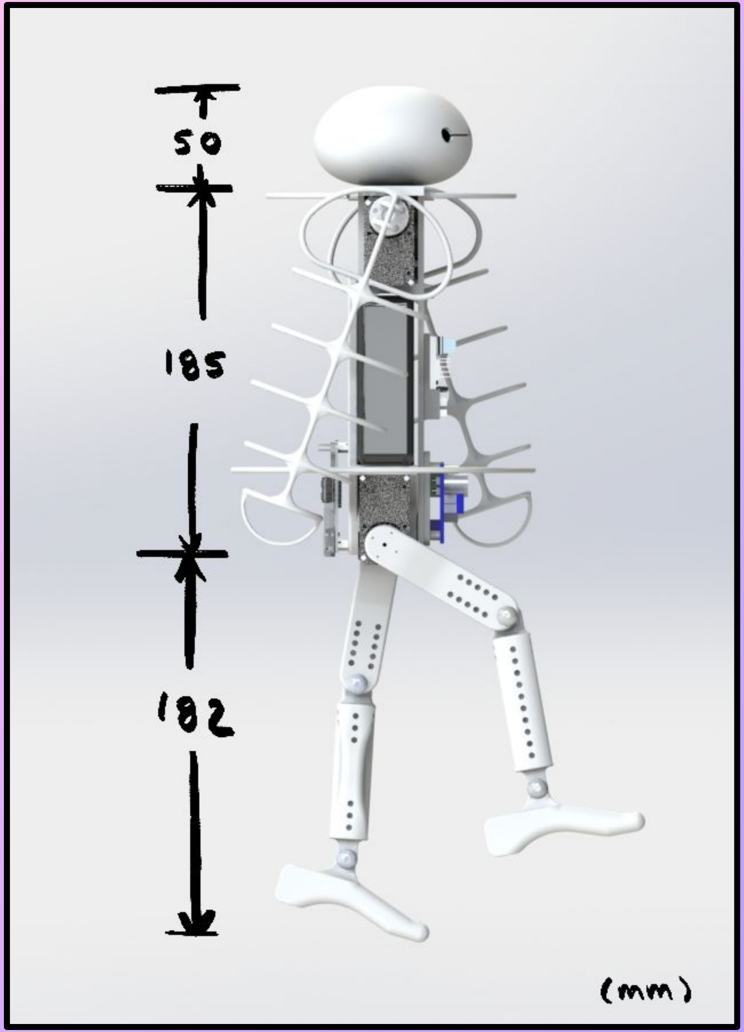







# Speed and Weight Properties

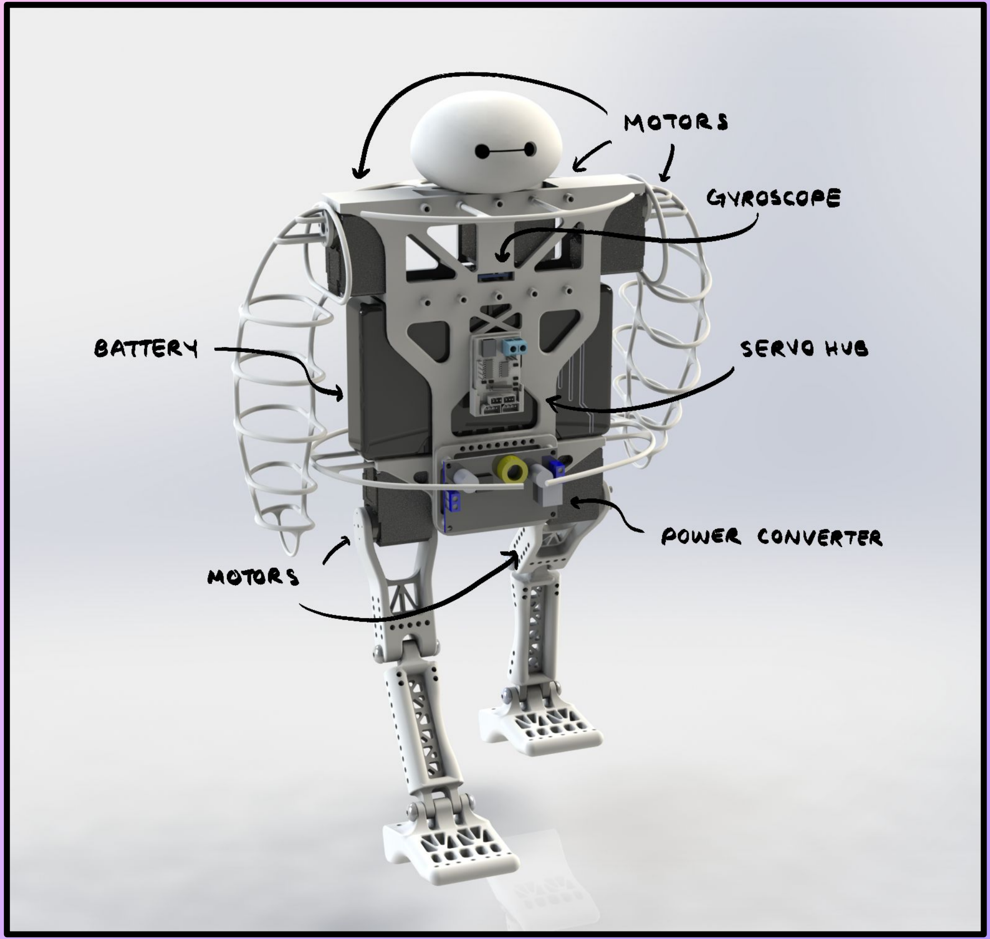
Under the assumption that it takes **2 seconds to move the leg assembly,** and then a second for the opposite leg to transition, the robot will be able to **take one step in about 2.5 ~ 3 seconds**. We hope to improve the speed of his gait, but for now it is safe to assume that Baymax will take **one step in approximately 2.5 seconds.**




# Side View with Main Dimensions

This side view depicts the main dimensions of our robot (in millimeters), including the robot's head, torso, and leg structures.

# Key Components

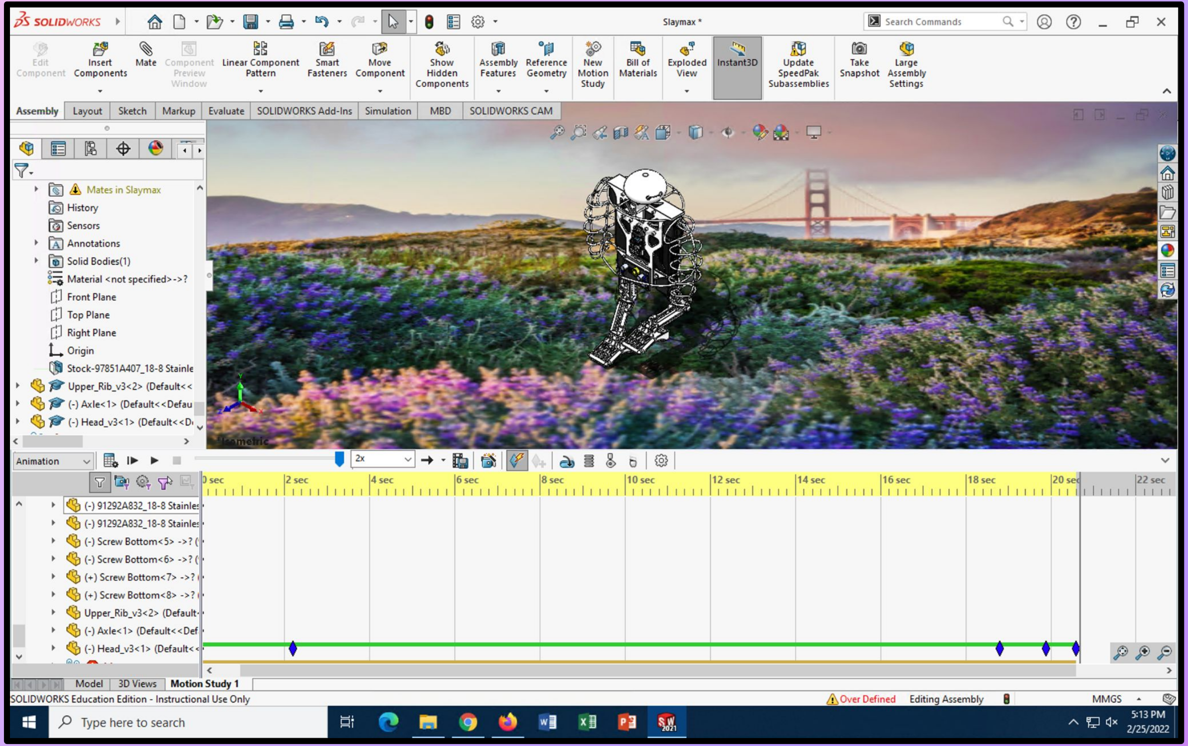


# Photorealistic Rendering

# Context Rendering

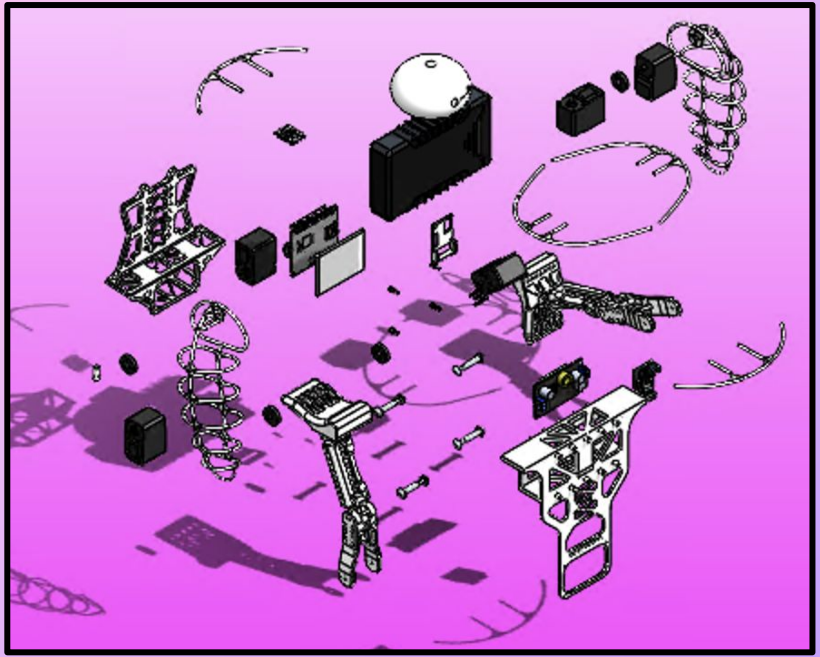
# Animation: Stop and Smell the Roses :)

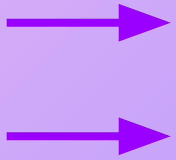
# Animation Video Frame and Link

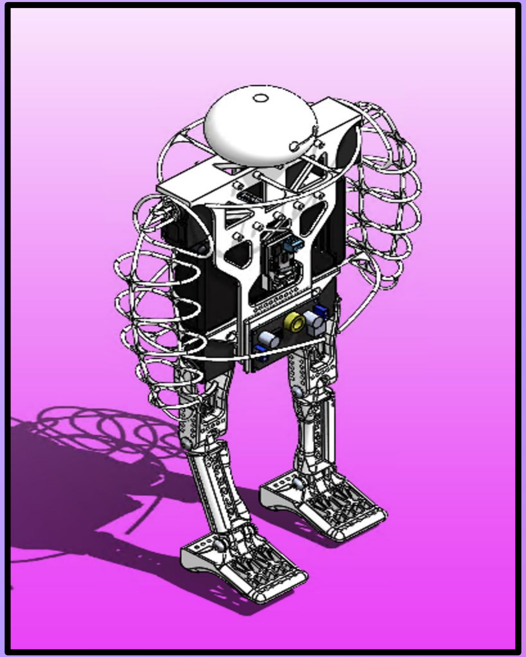



Animation Video Link!

# Exploded View

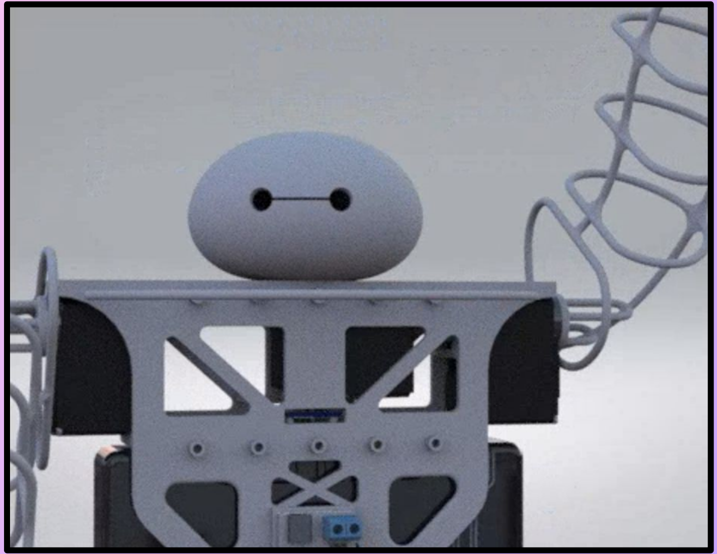


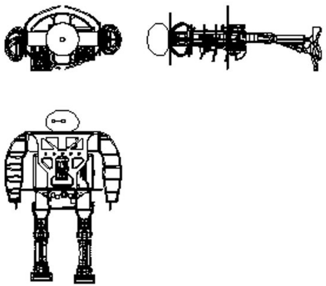




This slide displays each of the exploded individual components, (arms, legs, ribs, motors, battery, RPi, power supply, power converter, head, etc) of Baymax and how they fit together.

# Bill of Materials (BOM)





| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | Pelvis_v3 | | 1 |
| 2 | Leg_Assembly_v3 | | 1 |
| 3 | Servo | Rhino converted to STEP | 5 |
| 4 | bracketadapter1 | | 4 |
| 5 | RaspberryPi 3 A+.stp | | 1 |
| 6 | Battery | | 1 |
| 7 | Torso_v3 | | 1 |
| 8 | hex spacer standoff_M2_5 SW4 L5.stp | NONE | 4 |
| 9 | Arm_v4 | | 1 |
| 10 | Power Converter Mount | | 1 |
| 11 | dc_buck_converter_6_32v_to_1.5_32v | | 1 |
| 12 | Leg_Assembly_v3_Mirrored | | 1 |
| 13 | BusLinker_Holder_v1 | | 1 |
| 14 | BusLinker_V2.2 | | 1 |
| 15 | Arm_v4_Mirrored | | 1 |
| 16 | Gyroscope | | 1 |
| 17 | Rib_v3 | | 2 |
| 18 | Upper_Rib_v3 | | 2 |
| 19 | ScrewTop | | 4 |
| 20 | 91292A832 | 18-8 Stainless Steel Socket Head Screw | 5 |
| 21 | Screw Bottom | | 4 |
| 22 | Axle | | 1 |
| 23 | Head_v3 | | 1 |

# Screenshots of Constructive and Positive Comments to Classmates

## Friday Feb. 25th

Kennedi Wade
4 minutes ago

Sanjana this is INSANE!! I mean like unbelievable, the pelvis is just unreal and I can't wait to see this in real life, fantastic job :)

Comment Edit Delete •••

1

Kennedi Wade
now

Wow! Awesome job with your detailed CAD!! The neck, legs, and feathers look incredibly realistic and I second what Kat mentioned about the weight and balance. I also love the placement of the electronics, overall a fantastic use of space and design!

2

Kennedi Wade
now

Pika Pika he looks so goooood!! Well done, I especially love his realistic tail and how you developed his exterior cover, just amazing! Are his ears able to move too??! :))

3

# RECOUNT OF POINTS AND GRADING FOR ASSIGNMENT 3:

- 5 points Title slide complete
- 5 points overall aesthetic/layout/formatting of slides
- 8 points commenting positively on at least 3 other's postings **(shown above) (slide 59)**

- 8 Points 3D Renderings in perspective (44-49)
- 8 Points all key components included and labeled (52)
- 8 Points organic shape (no straight edges) (all slides)
- 8 Points photorealistic rendering (53-54)
- 8 Points animation (55-56)
- 8 Points exploded view (57)
- 8 Points key specs listed including speed, weight (50)
- 8 Points multiple poses shown (45-49)
- 8 Points detail close-up shown (47-49)
- 8 Points side views with main dimensions (51)
- 8 Points Bill of materials (58)

**Our Total Point Summation:**

**110 points**

Met and Fulfilled EVERY point in the rubric

Robotics Studio [MECHE 4611]
*Spring 2022*

# Assignment 4: Working Leg
# Big Hero 6's Baymax

Nico Aldana [na2851]
Kennedi Wade [kaw2216]

**Date Submitted: 03/06/22**

# Leg Components

**Femur and Tibia components**

Final versions attached to motors, failed prints show above. Only issues were that the dimensions for the motor attachments were slightly off (6.5 mm vs 7 mm radius 😭), and one of the prongs snapped off from the stress while putting in a screw. The final versions have threaded inserts!

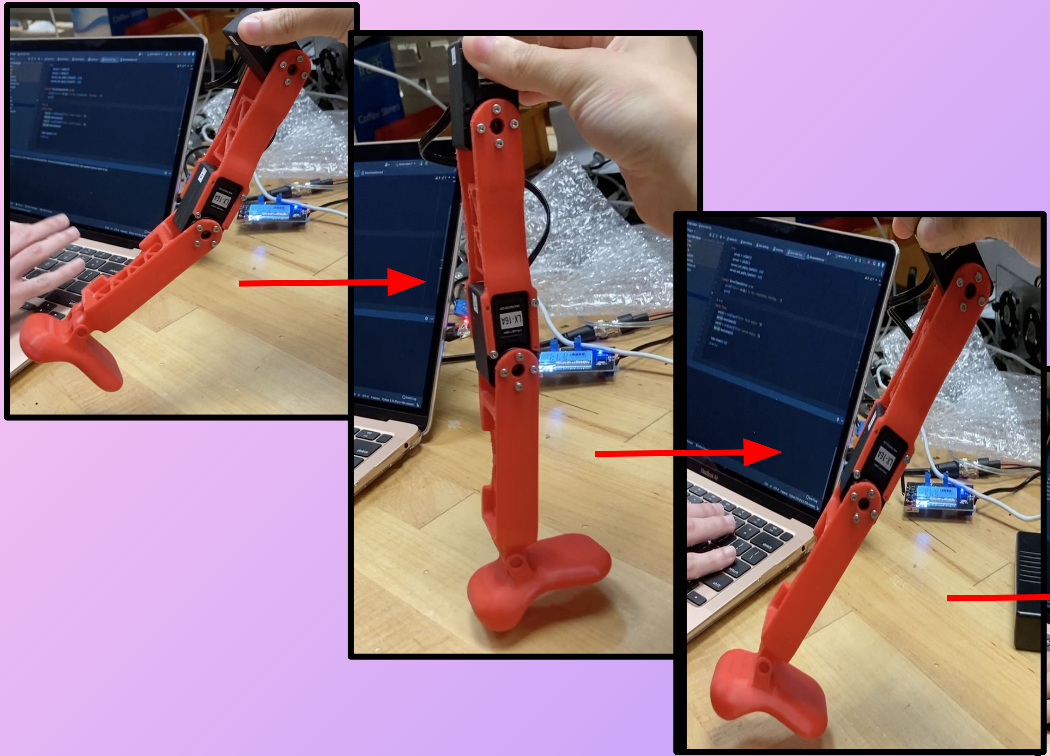
**Foot**

This piece gave us no trouble, thankfully :)

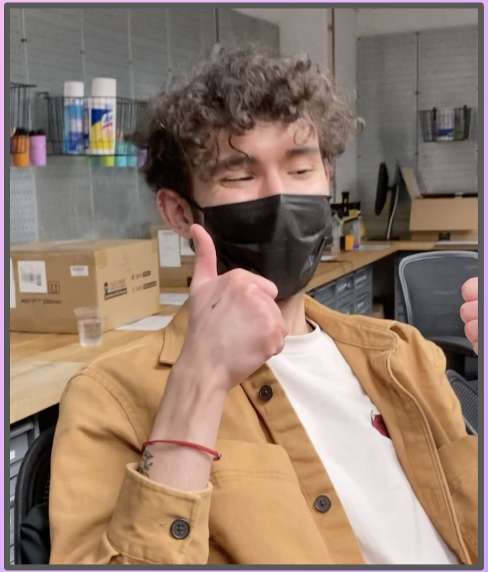
**Leg Assembly**

It stands up on its own :) In the final version, the cables will be routed through the pelvis piece.

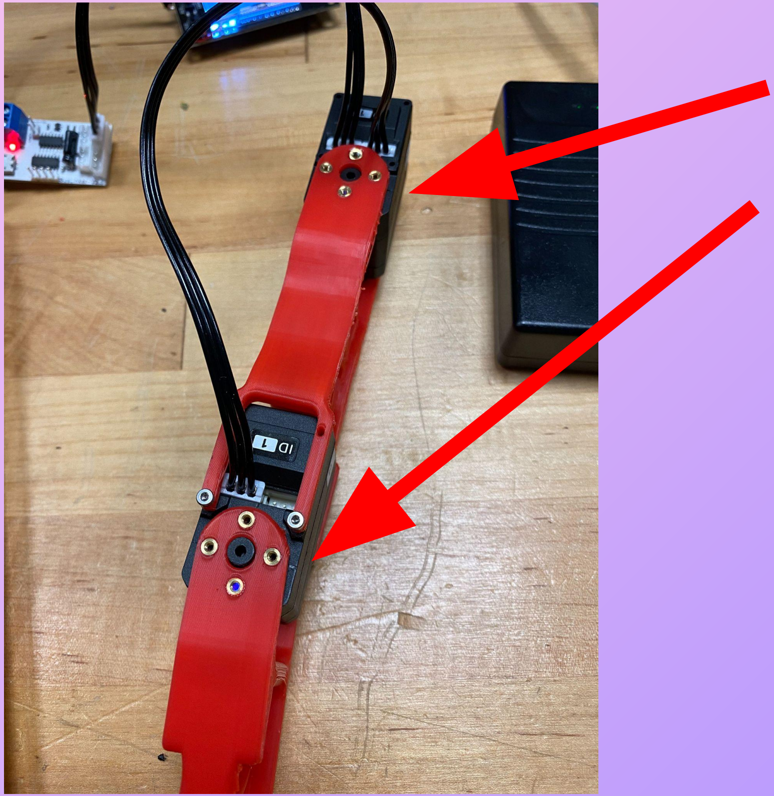
# Sequence of Photos Showing Leg In Motion




# Video of Leg Moving



ROBOTS FIRST STEPS!!!

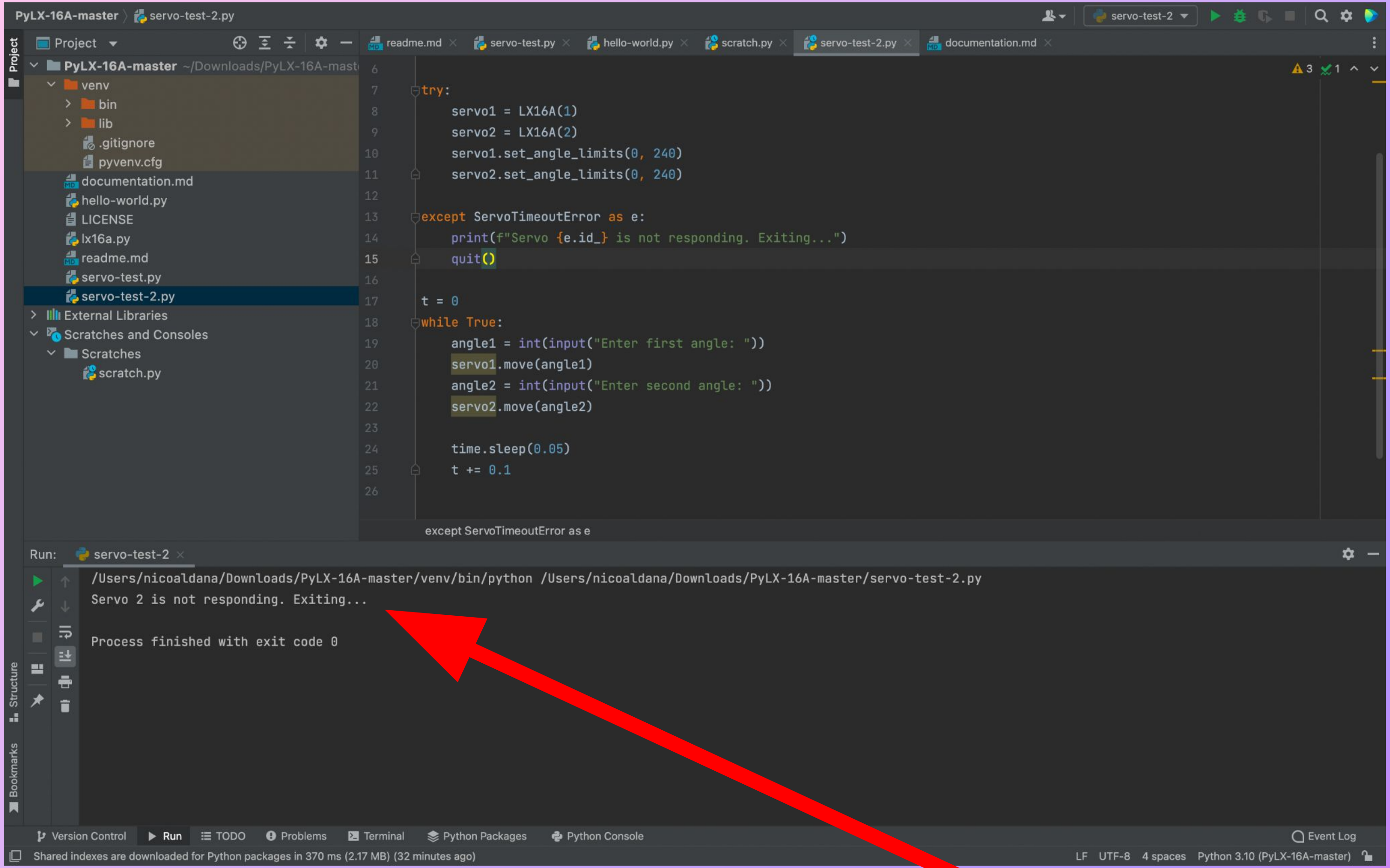



**Threaded Inserts**

We added threaded inserts for screws on both sides to retain symmetry, but the motor's passive side is secured through a hole so it's not necessary to screw anything in.

**Range of Motion**

The top motor (hip) can handle the full 0-240 degrees, but the range of motion on the knee motor is slightly more restricted, knocking off about 30 degrees off each bound.




## Exception Handling

We start the program by making sure both servos are connected. If one/both aren't, it will quit and print the message shown.

# RECOUNT OF POINTS AND GRADING FOR ASSIGNMENT 4:

-

1. 5 Points Title slide complete
2. 5 Points overall aesthetics, layout and formatting of the slides
3. 10 Points Sequence of photos showing leg in motion
4. 10 Points posting video of moving leg on the discussion board at least 24h in advance of deadline, and commenting constructively and positively on at least three other's postings (show screenshots)
5. 10 Points extreme leg positions tested and measured
6. 10 Points form/fit issues identified, listed and addressed (show how)
7. 10 Points all components properly bolted and connected (with inserts)
8. 10 Points 3D-print quality, support structure removed
9. 10 Points Different leg motion patterns explored
10. 10 Points Leg Modularity demonstrated
11. 10 Points Two or more legs tested in tandem
12. 10 Points Cables routed properly and securely
13. 10 Points Exception handling in code catches motor disconnect

**Our Total Point Summation:**

**120 points**

Met and Fulfilled EVERY point in the rubric

Robotics Studio [MECHE 4611]
*Spring 2022*

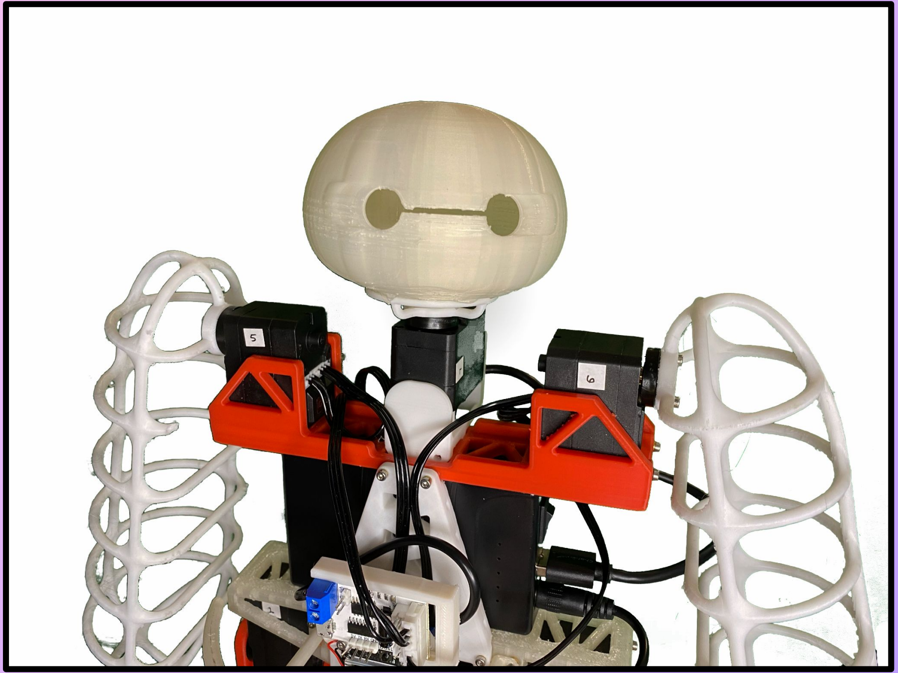
# Assignment 5: Assembled Robot Big Hero 6's Baymax

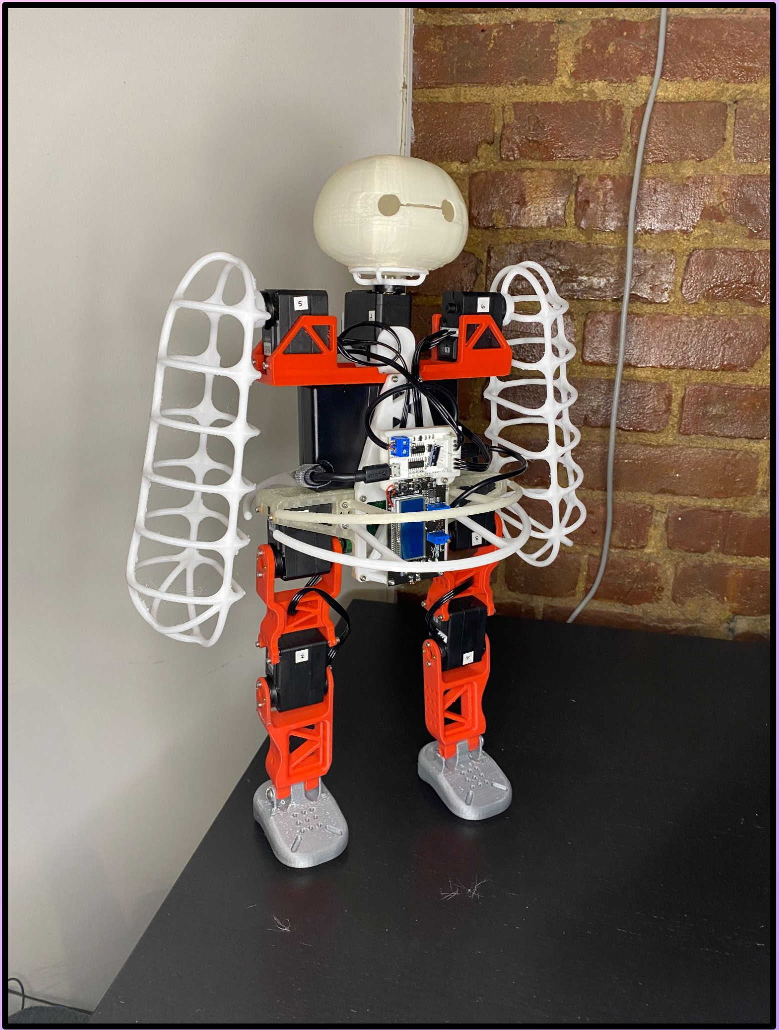
Nico Aldana [na2851]
Kennedi Wade [kaw2216]

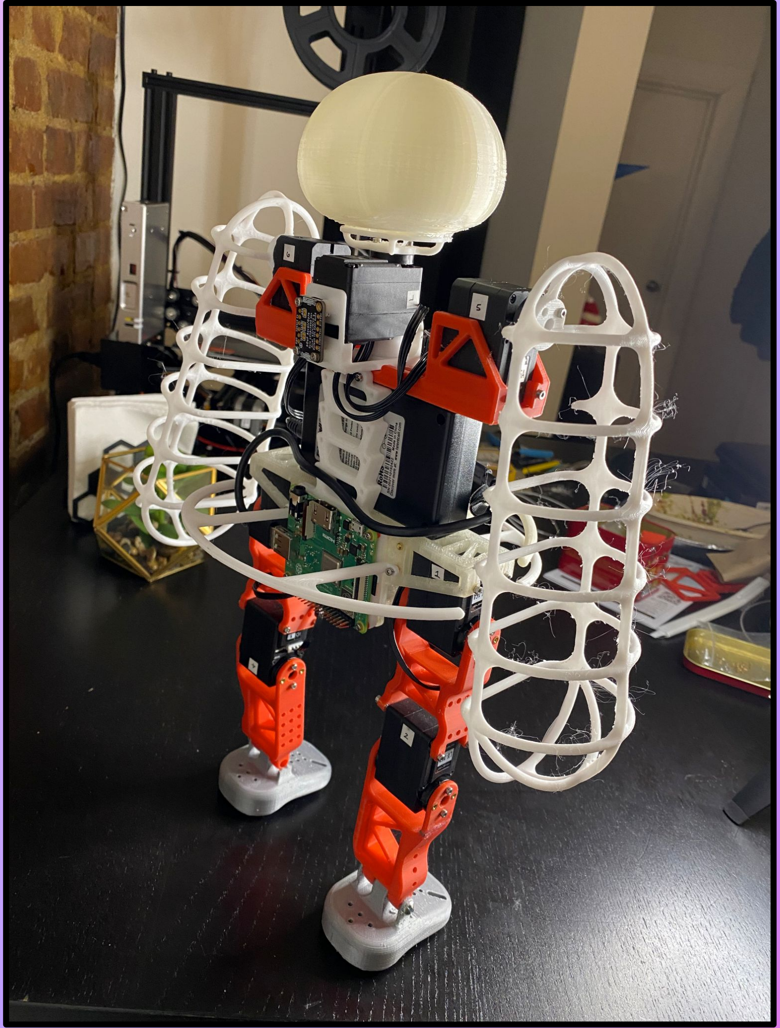
**Date Submitted: 03/27/22**

# Glamour Shots

(Better lighting and a full body shot coming in the future, we promise)

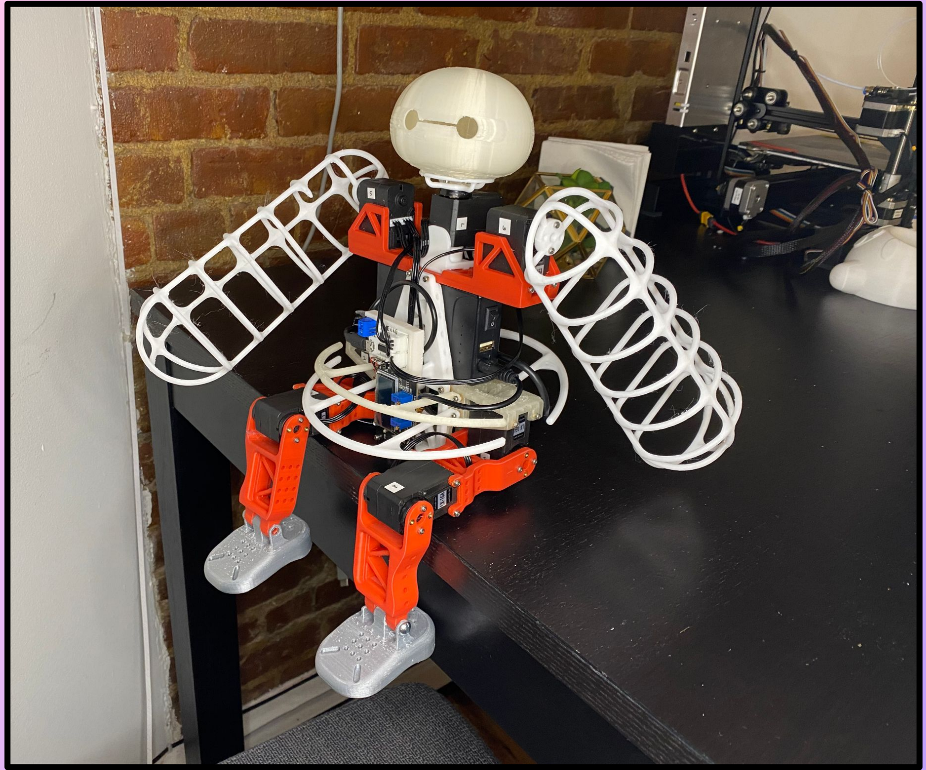






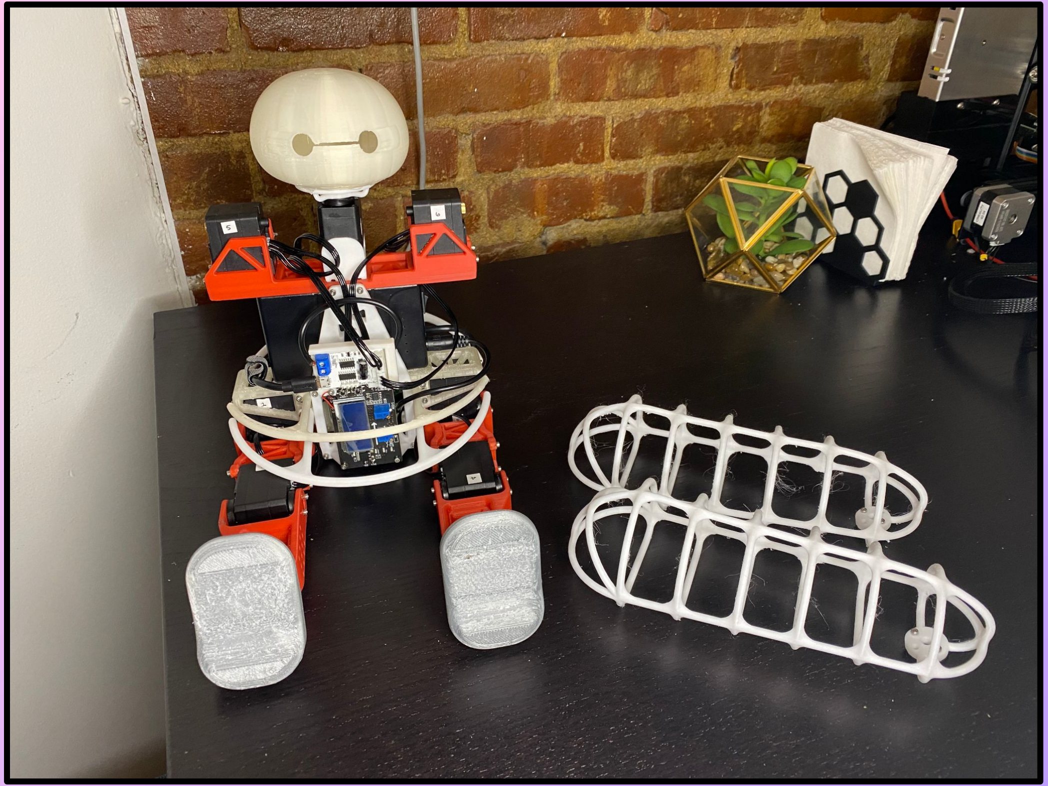
Standing straight up is stable.

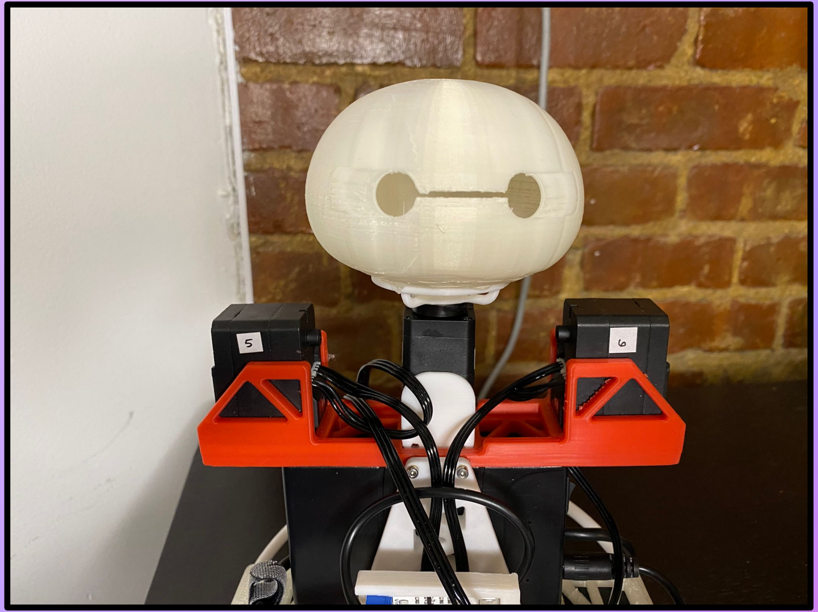
In order to improve stability, we will add springs between the tibia and feet (mimicking the Achilles tendon and metatarsal bones).



Baymax's skeleton can sit down with no issues so long as the arms aren't vertical.

Note: We decided not to attach *all* the ribs just yet, since we'd like to have easier access to the components as we make Baymax's walk cycle. The final robot will have more ribs attached than the ones shown above.



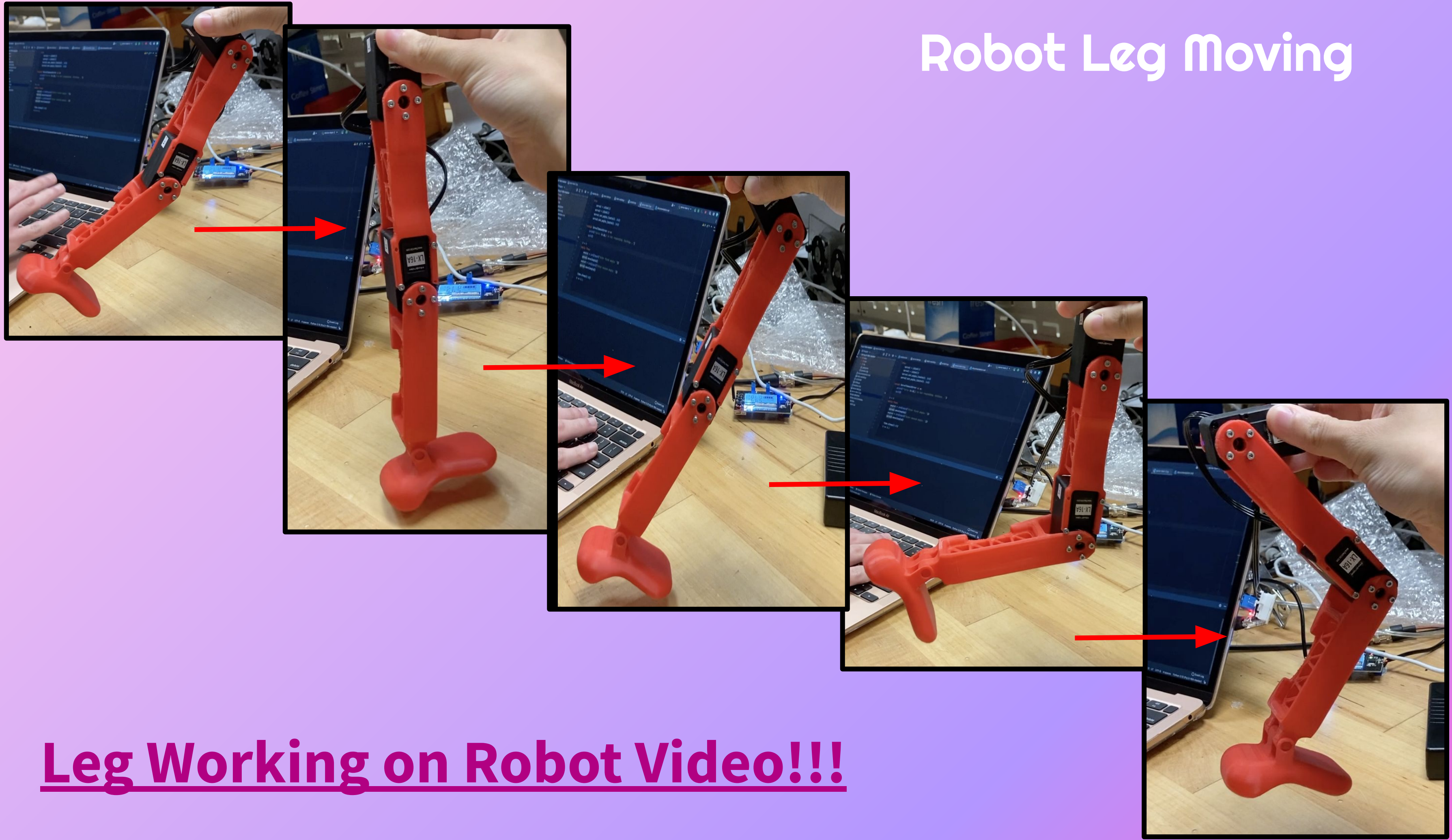


Everything except the arms are screwed into place. It is easy to remove the ribs, motors, and limbs. The battery is held by the tension between the pelvis, shoulders, ribcage, and spine pieces, and can be removed by loosening the shoulder screws. The bottoms of the feet have been sanded.

**Leg Moving**

Here is one of the iterations of our leg standing up on its own and being able to move!

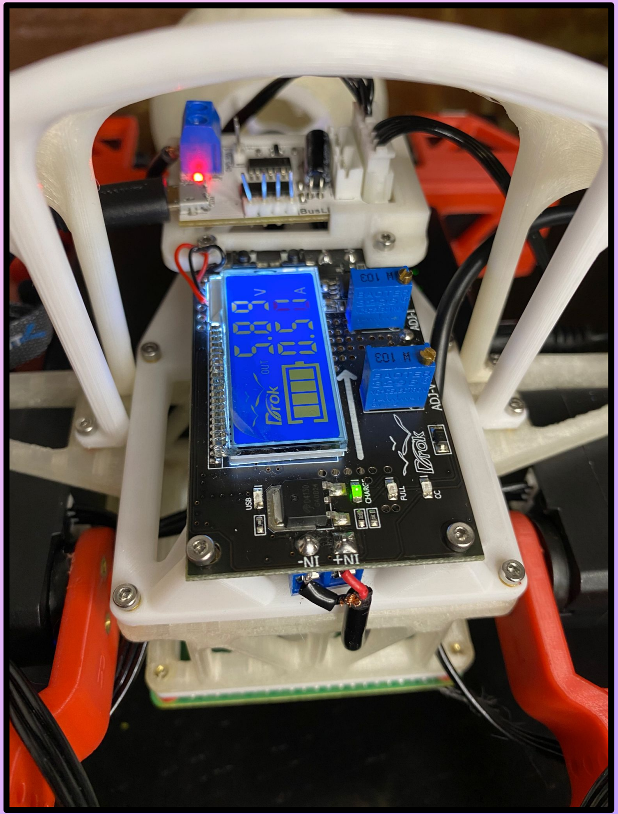
# Robot Leg Moving

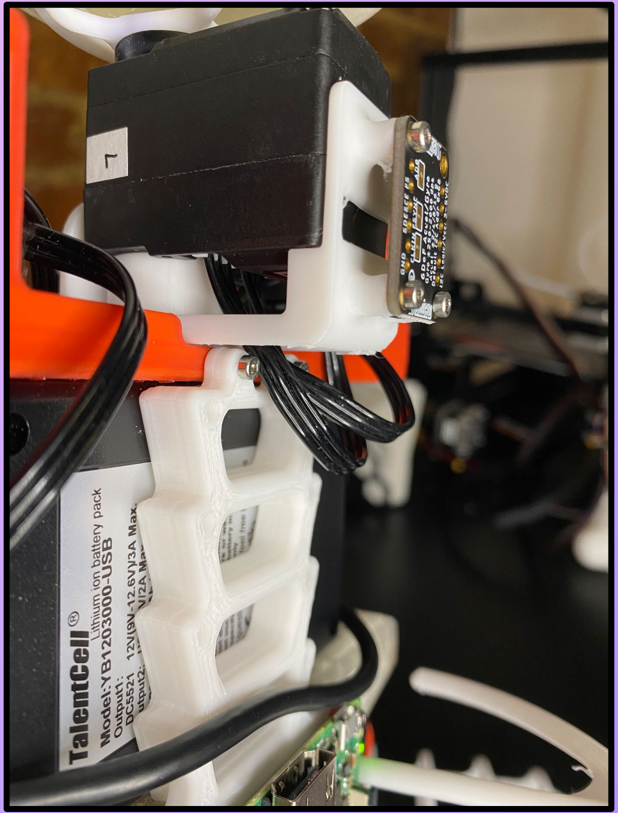


**Leg Working on Robot Video!!!**

# Components

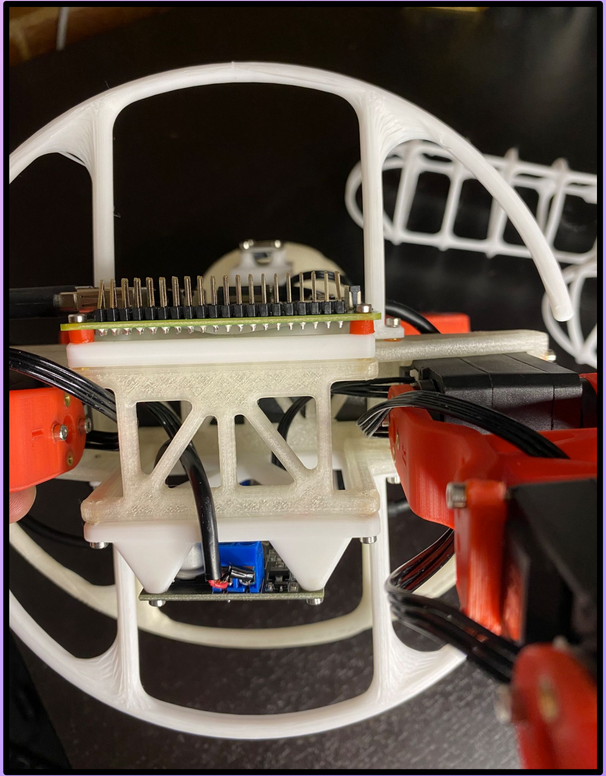
Closer look at how each component is mounted. Cable management is handled by the trusses in the printed pieces :)

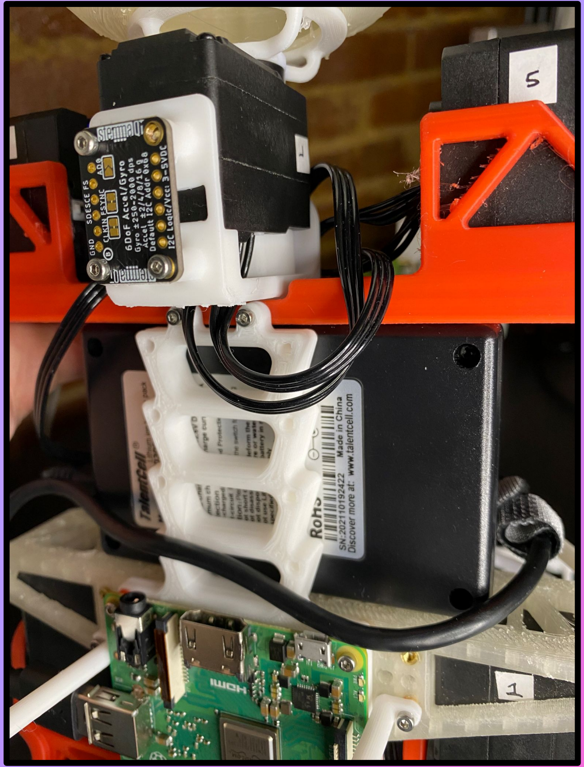





# Print Quality

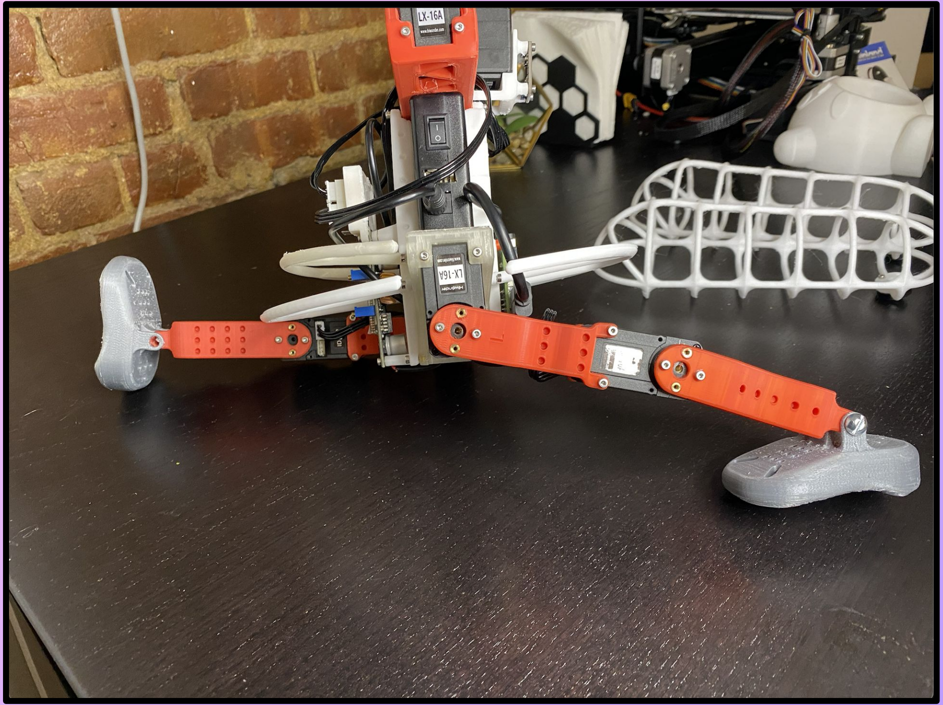
Overall pretty smooth, the final bot will have all its parts printed at around 0.1mm layer height and in the same color filament. Ideally, there will be no need for sanding.

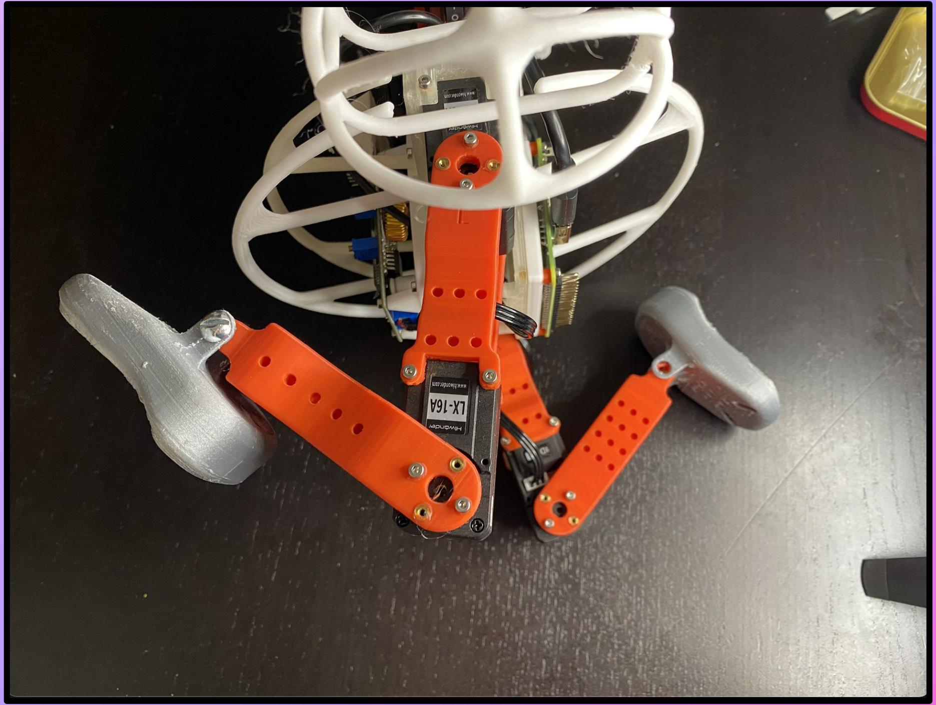





# Mobility Limits (Leg)

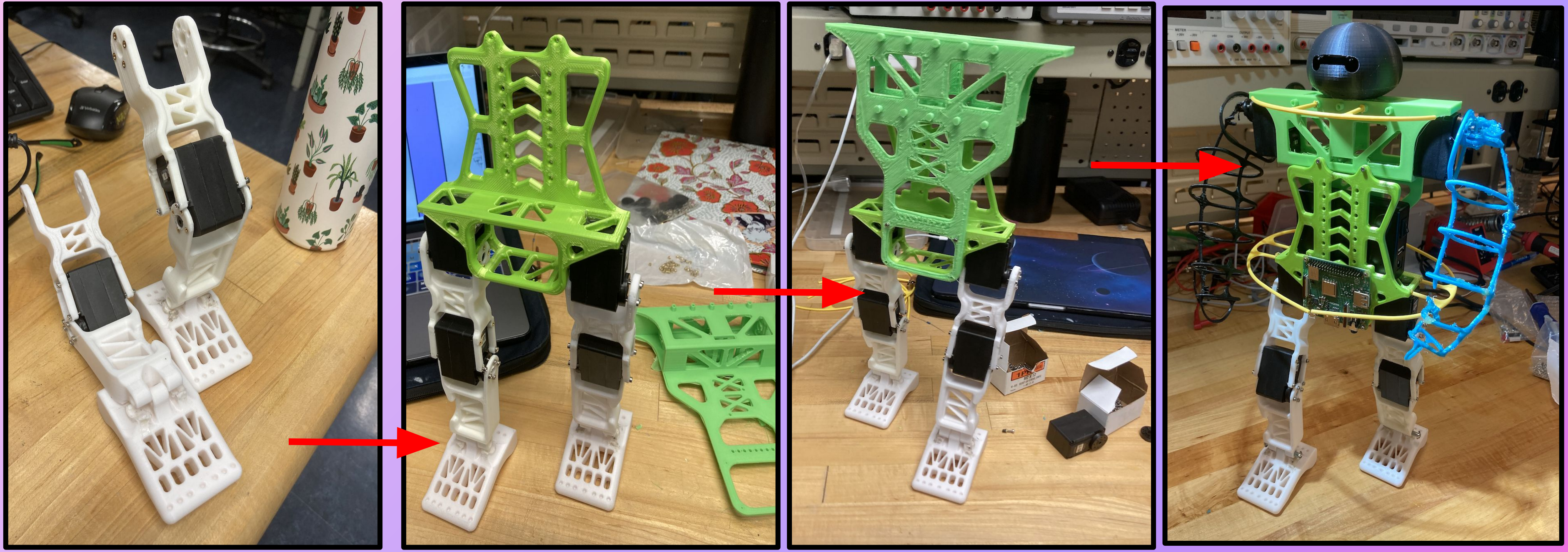
Each motor can pretty much access its full range of motion, except for the Left Hip motor, due to the USB cable running out of the Pi, but this will likely not be an issue.



# Robot Build Procession Execution

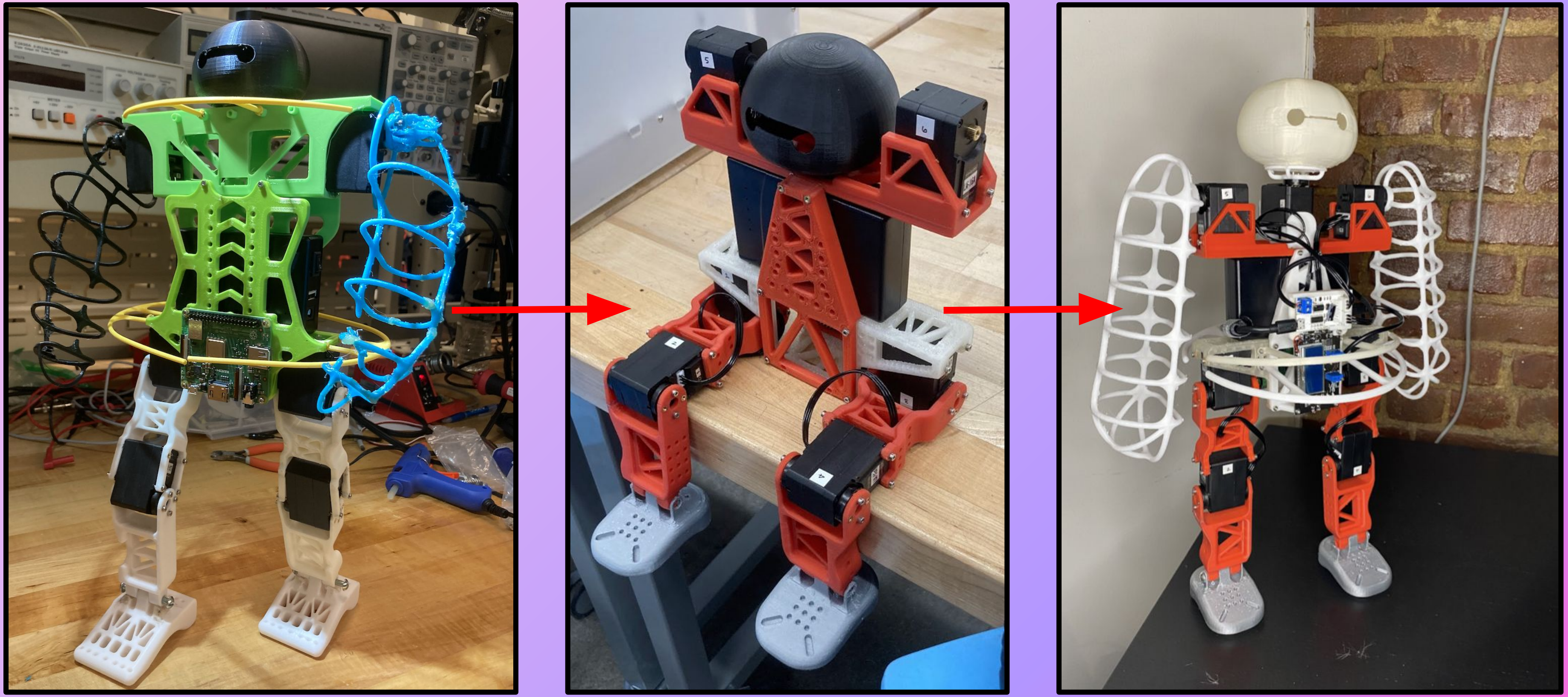
This slide depicts the iterative process of our design and the stages of the build we took to complete our robot.



# Robot Build Procession Execution


First design Iteration of our robot!!!

# Robot Build Procession Execution



# Robot Modularity Demonstrated

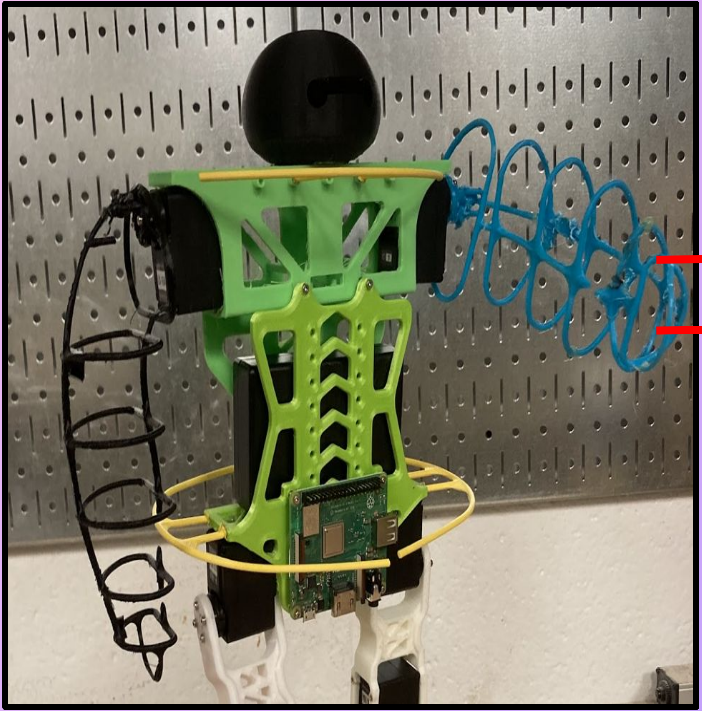
To illustrate the modularity of our robot, we've included photos and videos of the development and iteration of our robot design/3D printed parts

**OR**

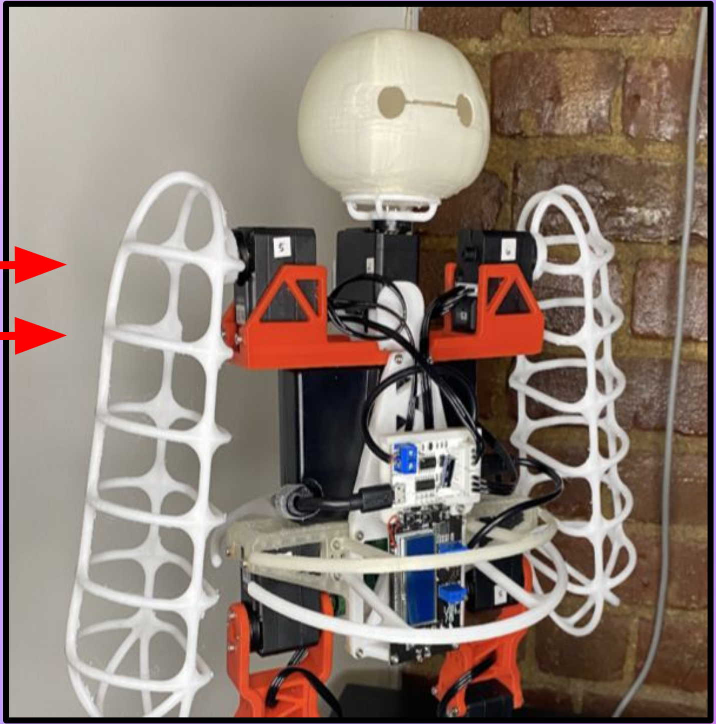
The modularity of our leg design is shown in this photo via the way we are able to swap out the different models of the feet, femur, and tibia.

# Robot Modularity Demonstrated

To illustrate the modularity of our robot, we've included photos and videos of the development and iteration of our robot design/3D printed parts



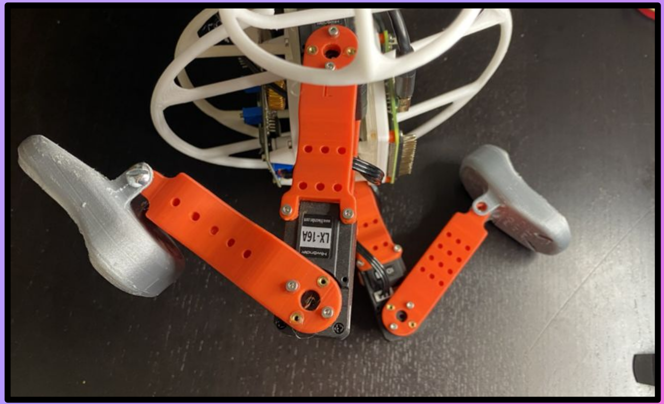
OR



The modularity of our arm and body design is displayed through the clear improvements from the more original part models on the left, to the revised/updated parts on the right which of course can be swapped out on an individual basis.

# Multiple Configurations Tested

Baymax's appendages were moved in multiple configurations to find his maximum and minimum limits of freedom and how far he is able to move.



# Screenshots of Constructive and Positive Comments to Classmates

## Sunday March 27th

Kennedi Wade
now

Wow!!! What a great looking robot Thomas amazing job on the prints and the assembly and the context rendering with your robot and the water bottle beside it :)

Comment Edit Delete •••

1

Kennedi Wade now

WHOA!!! This robot is stunning! The prints, the detail, the crispness of the parts, absolutley amazing job and so nice to see how the parts fit inside the core as well!

Reply Edit Delete •••

2

K

Kennedi Wade now

Awesome! The levitating head is again blowing my mind and your assembly looks great. I'm so excited to see this guy walk!

Reply Edit Delete •••

3

# RECOUNT OF POINTS AND GRADING FOR ASSIGNMENT 5:

1. 5 Points Title slide complete **(All slides)**
2. 5 Points overall aesthetics, layout and formatting of the slides **(All Slides)**
3. 10 Points glamour photo of printed robot (70,71,72,73 AND MINE AT THE END)
4. 10 Points posting some rendering of your robot on the discussion board at least 24h in advance of deadline, and commenting constructively and positively on at least three other's postings (show screenshots) **(85)**
5. 10 Points robot legs moving (frames shown + link to video) **(75, 76)**
6. 10 Points extreme leg interference tested and measured
7. 10 Points stability verified in various configurations **(77)**
8. 10 Points form/fit issues identified and addressed **(78, 70)**
9. 10 Points all components properly bolted and connected (71,72,73, 76)
10. 10 Points 3D-print quality, support structure cleanly removed (All slides)
11. 10 Points parts sanded and painted
12. 10 Points Robot modularity demonstrated **(81, 82)**
13. 10 Points Multiple configurations tested **(84)**
14. 10 Points Cables routed properly and securely **(71, 72)**
15. 10 Points motors controlled directly from Raspberry Pi
16. 10 Points motors powered using battery
17. 10 Points overall aesthetics of the presentation **(All slides)**
18. 10 Points Robot boot test routine implemented
19. 10 Points Robot homing routine implemented

**Our Total Point Summation:**
**110 points**
Met and Fulfilled just about every point in the rubric

# THANK YOU!

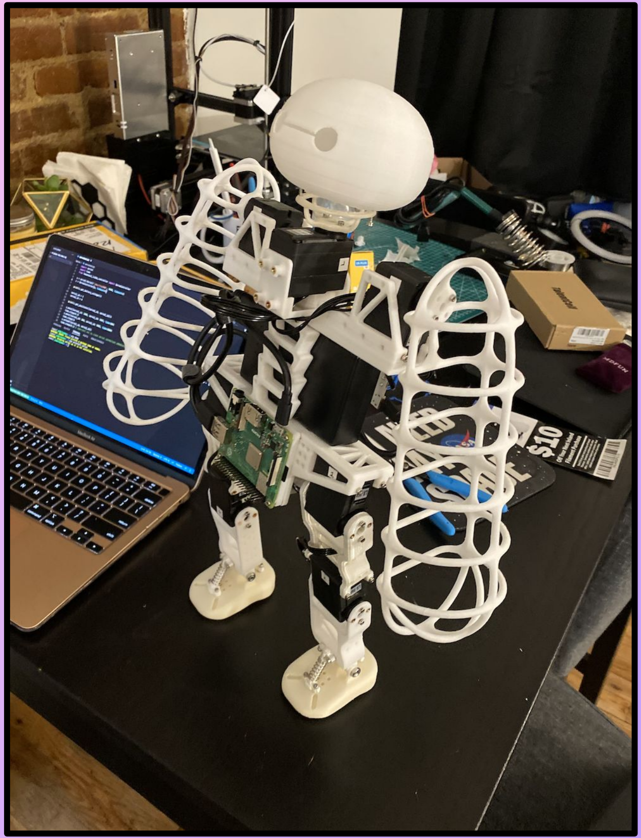
Robotics Studio [MECHE 4611]
*Spring 2022*

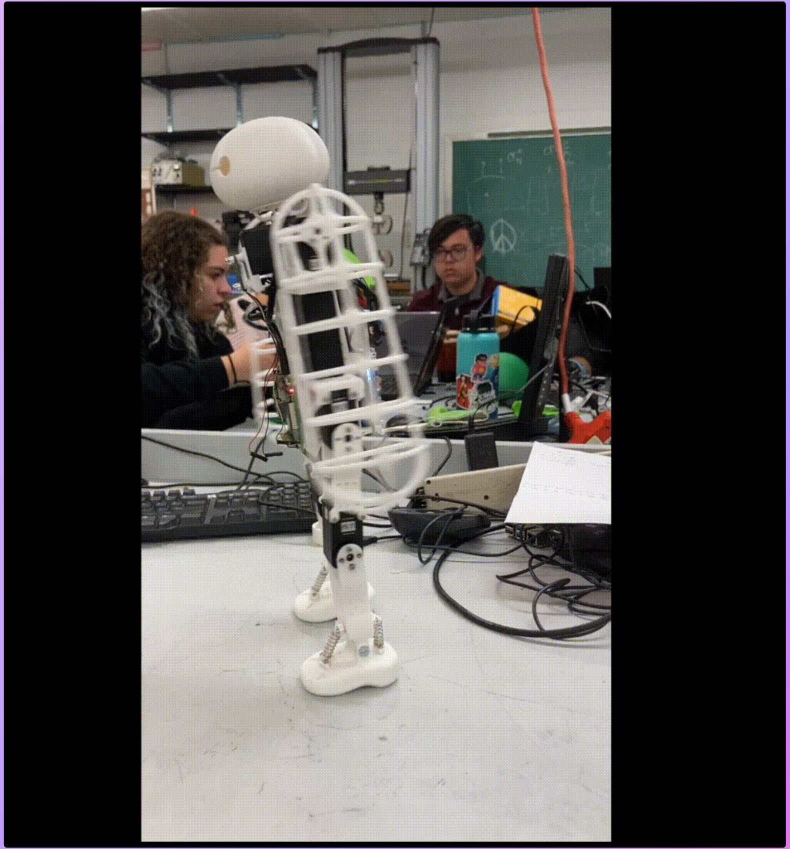
# Assignment 6: Walking Robot Big Hero 6's Baymax

Nico Aldana [na2851]
Kennedi Wade [kaw2216]

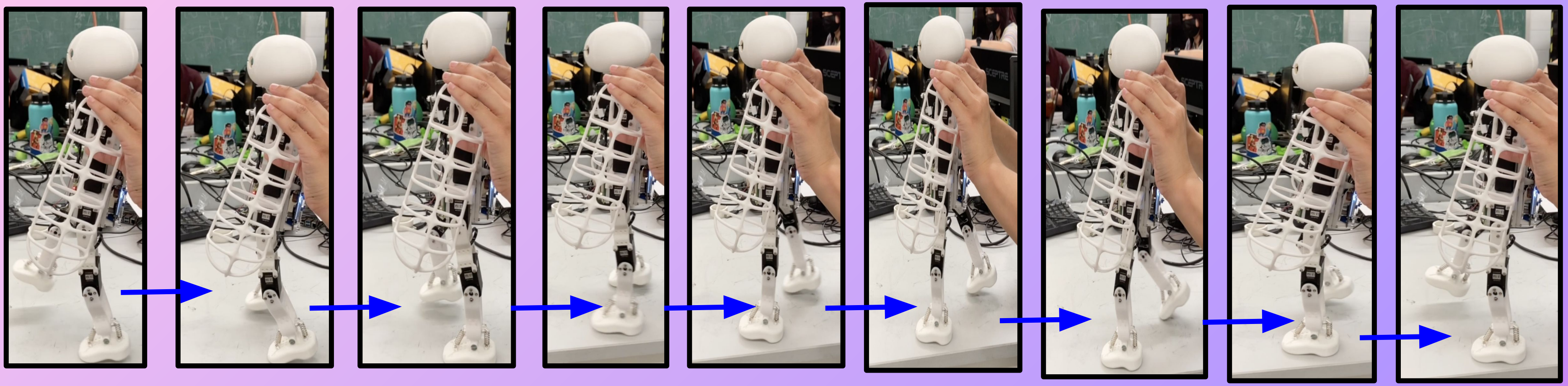
**Date Submitted: 04/17/22**

# Glamour Photos Of Working Robot





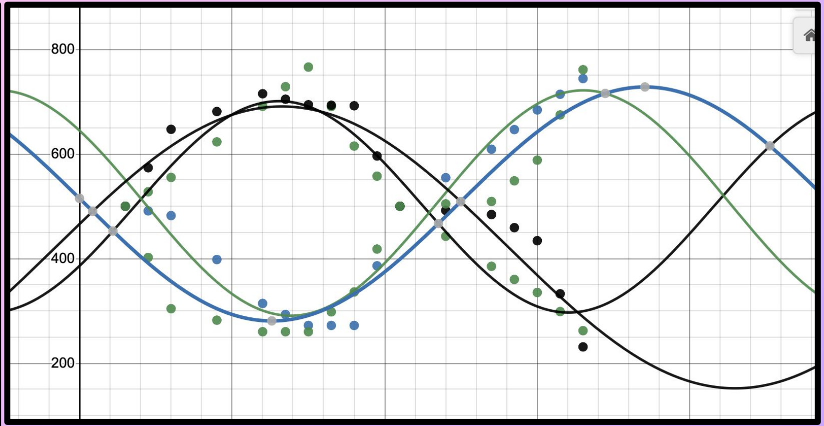
# Moving Baymax!



This slide depicts the walking cycle/gait of Baymax which then loops back to the first initial position shown above :)

## Robot Moving Link!! :)

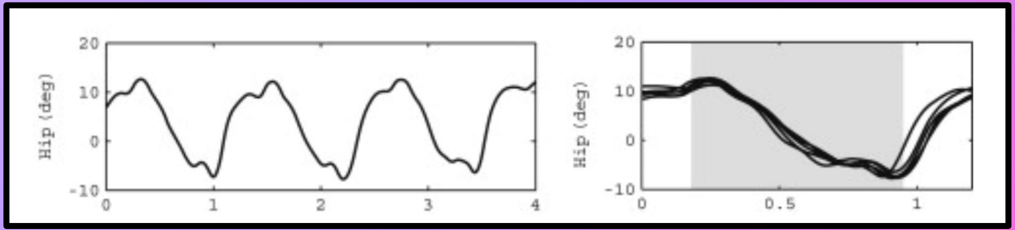
| $x_1$ | $y_1$ |
|---|---|
| 1.5 | 500 |
| 2.25 | 402 |
| 3 | 304 |
| 4.5 | 282 |
| 6 | 260 |
| 6.75 | 260 |
| 7.5 | 260 |
| 8.25 | 298 |
| 9 | 336 |
| 9.75 | 418 |
| 10.5 | 500 |
| 12 | 504.5 |
| 13.5 | 509 |
| 14.25 | 548.5 |
| 15 | 588 |
| 15.75 | 674.5 |
| 16.5 | 761 |



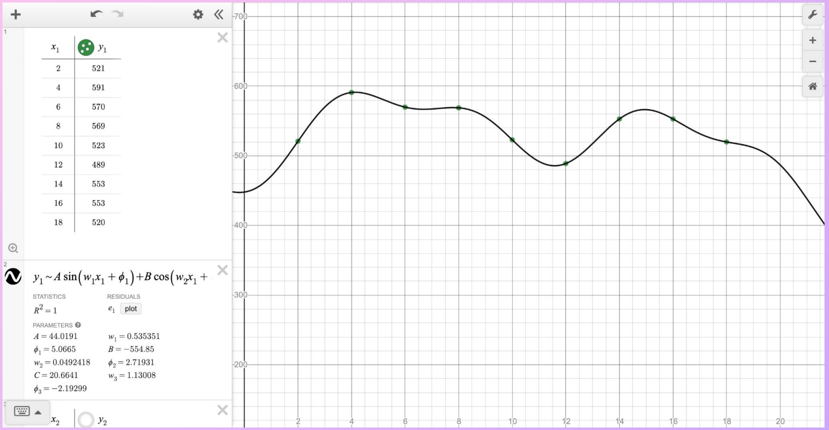

# Plotted Motor Angles as Functions of Time

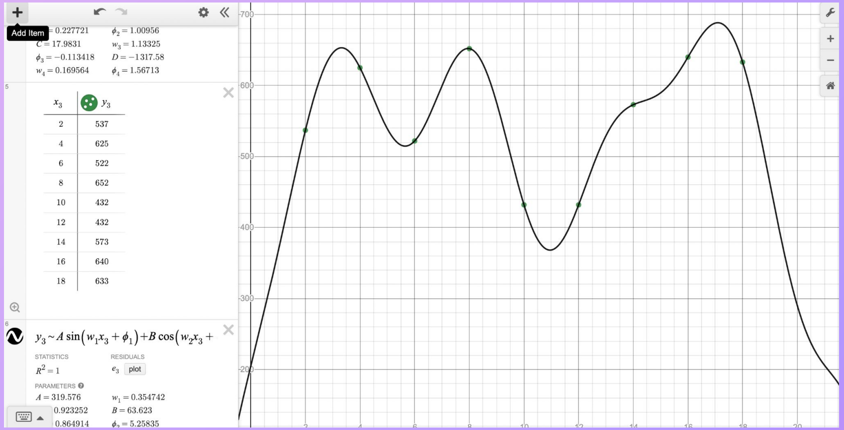
To begin calculating the walking cycle for Baymax, we extracted the angle positions of the motors in different static positions. We then took the different angle positions for the hip and knee on each leg and plotted the mock walk cycle with time on the x axis and the angle positions on the y axis, and plan to use a Fourier series partnered with simulation to perfect this cycle. In our case, our minimum angle range is 0, with 1000 being the maximum position, and 500 being the equilibrium position. An example of one of these plots is show to the left.

To the right is an example of a robotic hip walk cycle in literature using a method similar to ours that plan to emulate.



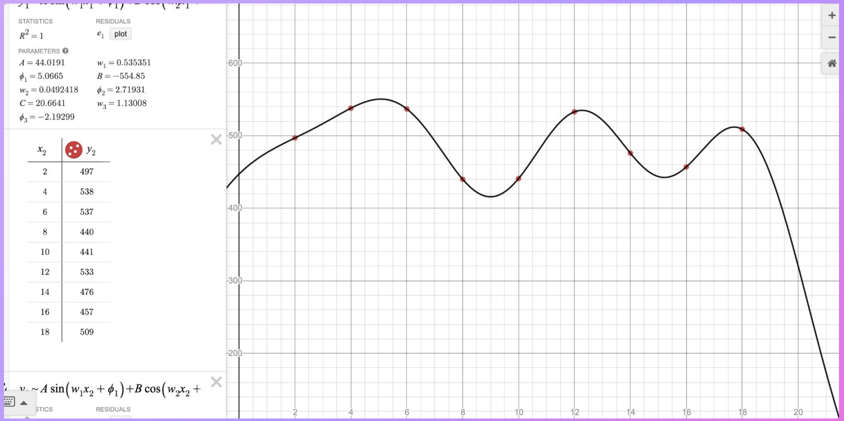

**“Toward a Human-Like Biped Robot with Compliant Legs”**



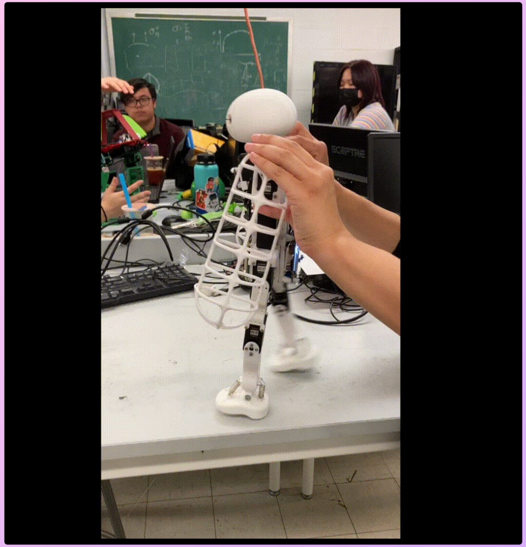




More examples of us using regression analysis to determine the best smooth position function for each joint.

We plan to use tilt feedback from the IMU to adjust each parameter.



# Robot Speed Measured

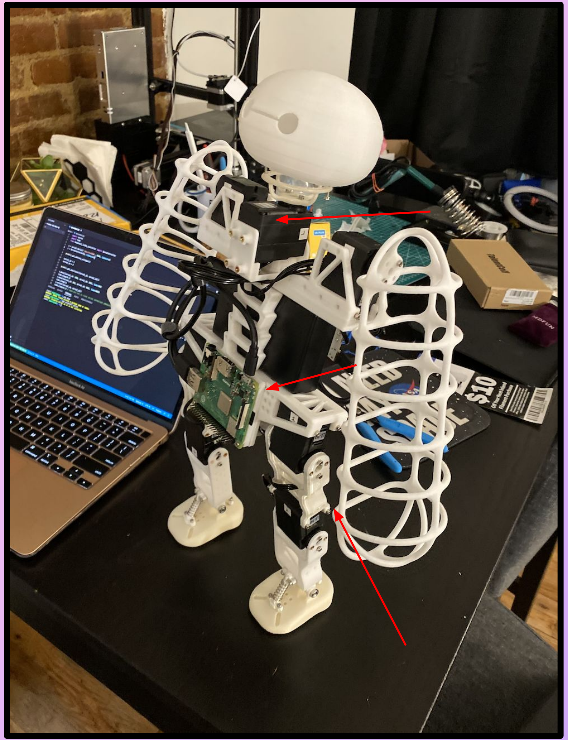



| Time Cycle | Hip1 | Knee2 | Hip3 | Knee4 |
|---|---|---|---|---|
| 0 | | | | |
| 1.5 | 500 | 500 | 500 | 500 |
| 2.25 | 527.5 | 491 | 573.5 | 402 |
| 3 | 555 | 482 | 647 | 304 |
| 4.5 | 623 | 398 | 681 | 282 |
| 6 | 691 | 314 | 715 | 260 |
| 6.75 | 728.5 | 293 | 704.5 | 260 |
| 7.5 | 766 | 272 | 694 | 260 |
| 8.25 | 690.5 | 272 | 693 | 298 |
| 9 | 615 | 272 | 692 | 336 |
| 9.75 | 557.5 | 386 | 596 | 418 |
| 10.5 | 500 | 500 | 500 | 500 |
| 12 | 442.5 | 554.5 | 492 | 504.5 |
| 13.5 | 385 | 609 | 484 | 509 |
| 14.25 | 360 | 646.5 | 459 | 548.5 |
| 15 | 335 | 684 | 434 | 588 |
| 15.75 | 298.5 | 714 | 332.5 | 674.5 |
| 16.5 | 262 | 744 | 231 | 761 |

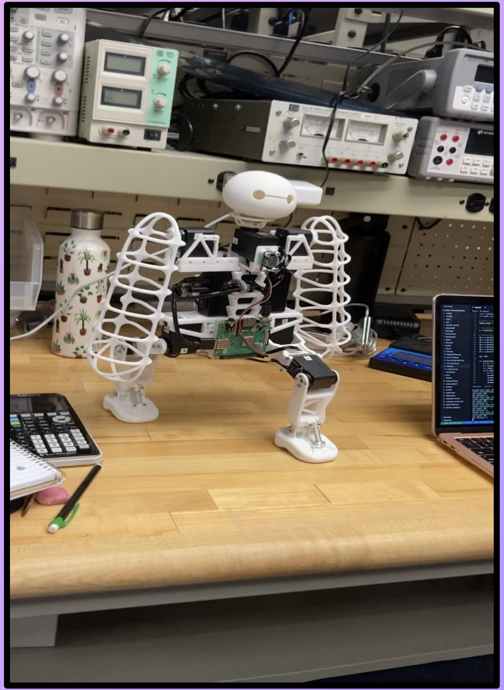
To the right displays a snapshot of our method for constructing the walk cycle. We calculated the approximate speed for each motion/angle during the walk cycle gait, and estimated that around **3 full cycles (where the robot starts and ends at the equilibrium position of 500 degrees), would take approximately around 16.5 seconds.**

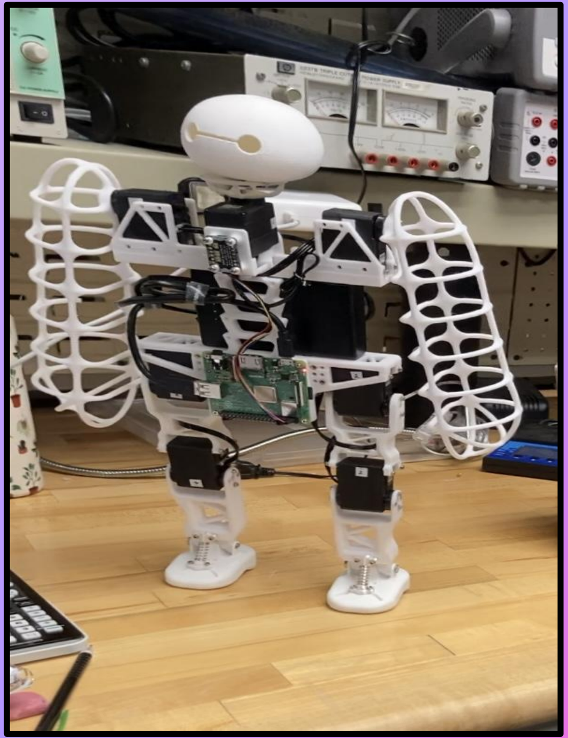
Or, in terms of distances, **5.5 cm a cycle.**

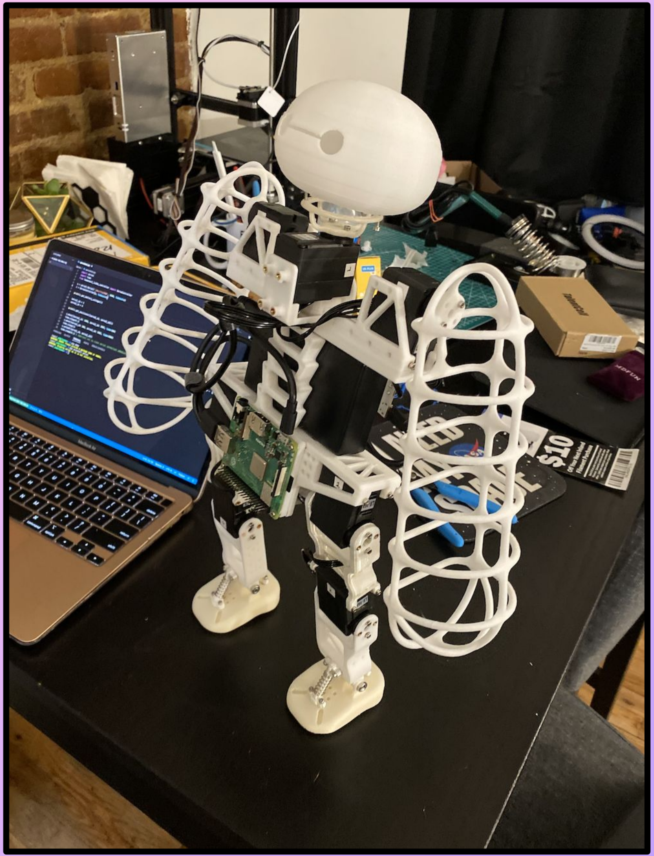
# Components All Properly Bolted And Connected



All components properly bolted and connected to ensure movement success and also no damage to electrical components.



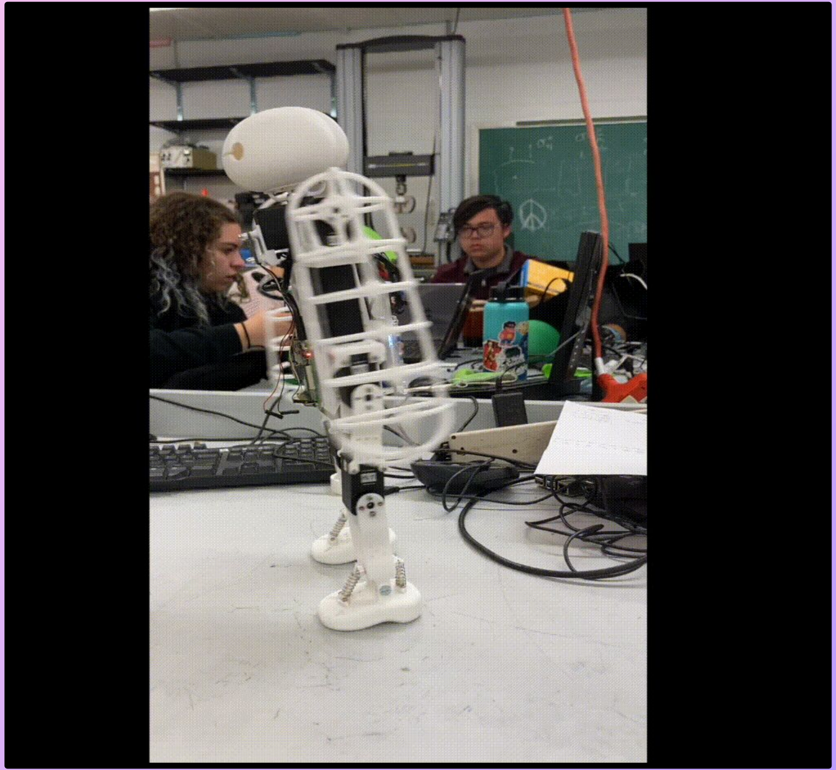





# 3D Print Quality/Removed Support Structure/Cables Routed Properly and Secure

All of Baymax’s parts were 3D printed with a very high print resolution and quality filament. **All of the support structures were removed** on each part to ensure safety and elegance. Additionally, cable management and security was enforced throughout the whole of the robot as well.

# Robot Controlled From the Raspberry Pi/Battery Powered

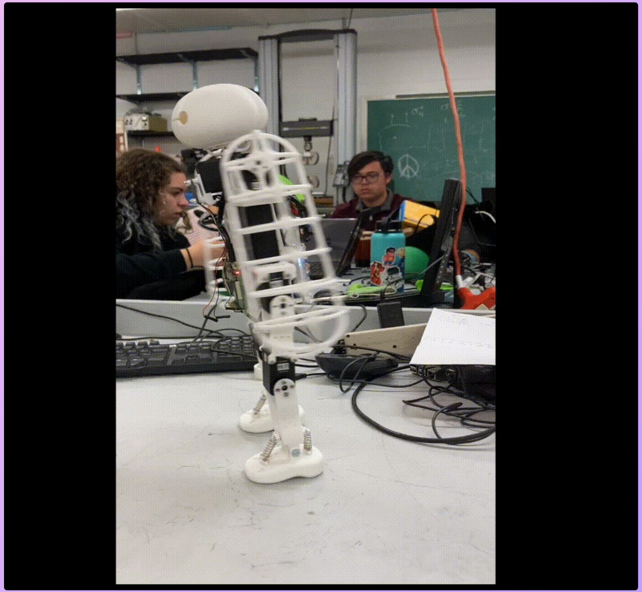


**ALL** of the motors and instruments on Baymax were **controlled directly from the Raspberry Pi** using SSH and **powered by the battery provided in our kits.**

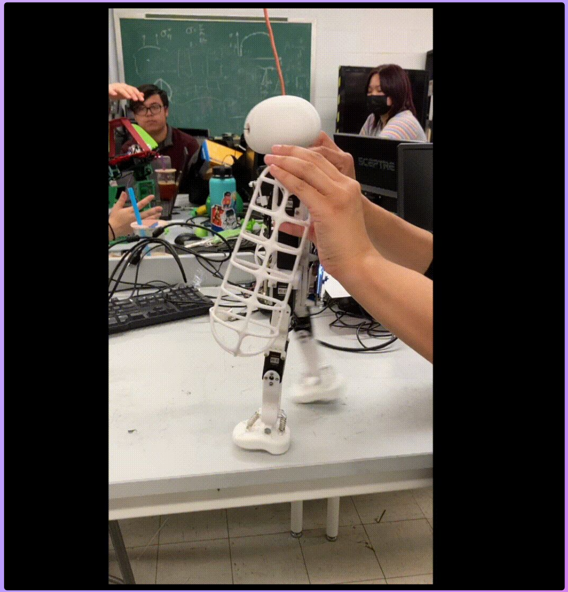
# Multiple Walking Patterns (And Dances) Tested

As of now we have tested and almost mastered 2 walking patterns for Baymax: the first is a dance/scoot that resembles the running man, and the second is one to actually mimic human style walking, with the picking up and placing of his feet. **The stability of the robot was also verified in these locomotion configurations/are in the process of being improved.** More walking patterns and dances to come soon!!!

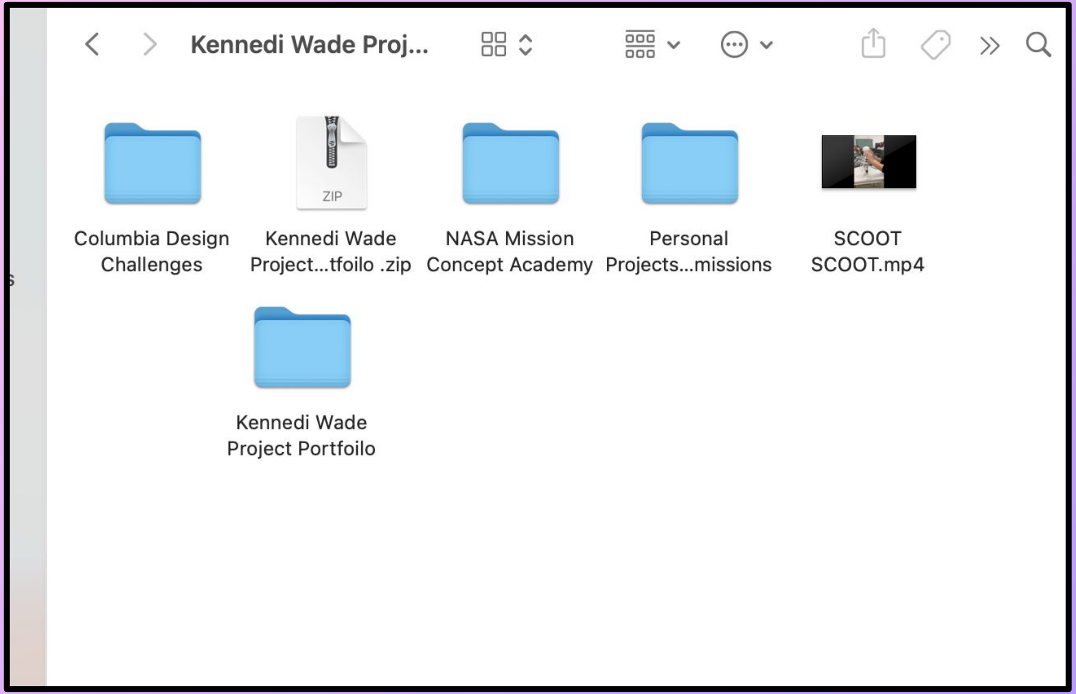
**The Running Man/Twist**



**Human Walking**



# Video of Robot Posted to Online Portfolio




Here is a snapshot of the robot's first steps video in my *developing* online portfolio, and the link to the video again as well!

Link to Robot's First Scoots Video:

SCOOT SCOOT.mp4

# Video of Walking Robot on Discussion Board + Link + Positive Comments

## Baymax's First Steps/Scoots :) #236

Kennedi Wade
less than a minute ago in General

STAR WATCHING 3 VIEWS

Gooood evening everybody! We hope you are having a wonderful evening. Here are some clips of Baymax's first scoots around campus (the MechE lab). Hope you enjoy!!

-Nico and Kennedi

https://drive.google.com/file/d/1VrCcxPaQWu49JcQ_AgWdFCZeU_sMZvgz/view?usp=sharing

Comment Edit Delete •••

Link to Baymax's First Steps/Scoots:
https://drive.google.com/file/d/1VrCcxPaQWu49JcQ_AgWdFCZeU_sMZvgz/view?usp=sharing
Link to Discussion Board:
https://edstem.org/us/courses/19587/discussion/1409270

## Positive Comments to Peers:

**1**

Kennedi Wade
now

As usual FANTASTIC job Fernando :) FRIEND looks fantastic and I absolutley adore his rainbow light.

Comment Edit Delete •••

**2**

Sort by Newest

Add comment

Kennedi Wade now

Awesome job Nick!! His speed is really coming along and I'm super impressed with the control in the feet as he lands on the groud, awesome job!

Reply Edit Delete •••

**3**

Kennedi Wade
now

Wowww great job Thomas!! I also really like all of the colors in your robot as well, the design is very well done!

Comment Edit Delete •••

# RECOUNT OF POINTS AND GRADING FOR ASSIGNMENT 6:

1. 5 Points Title slide complete **(Slide 88)**
2. 5 Points overall aesthetics, layout and formatting of the slides **(All slides)**
3. 10 points glamour photo of working robot **(89)**
4. 10 points robot moving (frames shown + link to video) **(90)**
5. 10 points Plotted motor angles as function of time. **(91)**
6. 10 points Robot speed measured (cm per cycle, cm per sec, robot sizes per cycle) **(93)**
7. 10 points Robot stability verified in various locomotion configurations **(97)**
8. 10 points all components properly bolted and connected **(94)**
9. 10 points 3D-print quality, support structure removed **(All slides)**
10. 10 points Robot sanded and painted **(95)**
11. 10 points Multiple walking patterns tested **(97)**
12. 10 points Cables routed properly and securely **(95)**
13. 10 points motors controlled directly from Raspberry Pi **(96)**
14. 10 points motors powered using battery **(96)**
15. 10 points post some video of the walking robot on Discussion Boarda (show screenshot, provide link) **(99)**
16. 10 points post video of your robot on your online portfolio (include screenshot and link)**(98)**
17. 10 points Robot ongoing health test routine implemented
18. 10 points Robot shutdown routine implemented

**Our Total Point Summation:**

**120 points**

Met and Fulfilled just about every point in the rubric

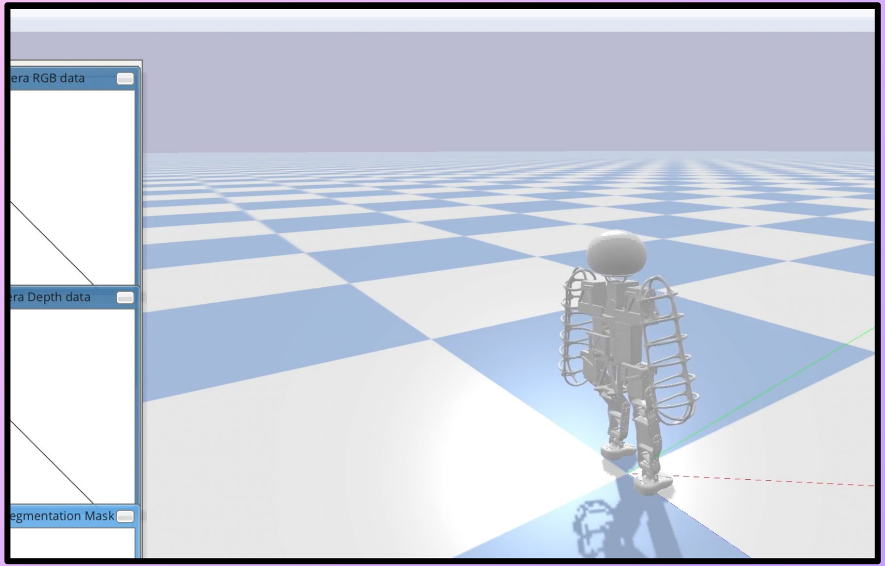
Robotics Studio [MECHE 4611]
*Spring 2022*

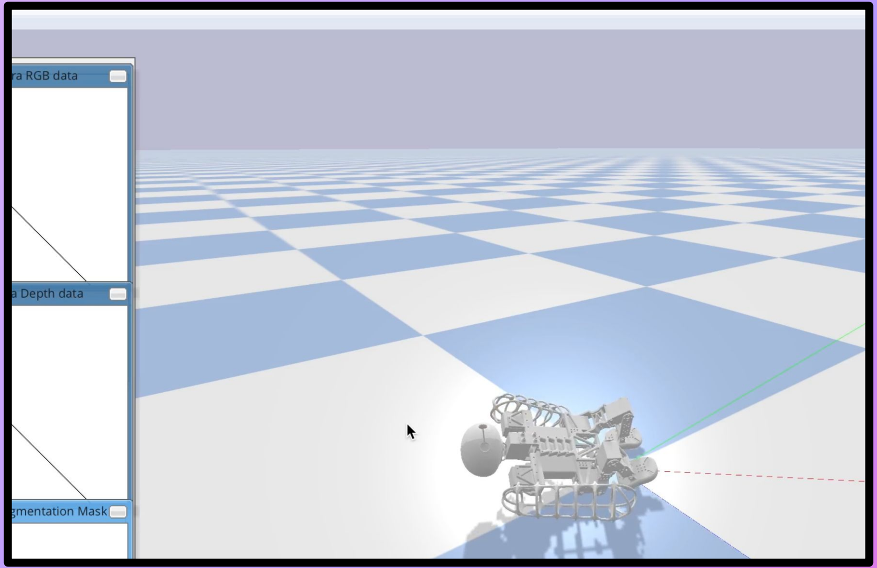
# Assignment 7: Simulation Big Hero 6's Baymax

Nico Aldana [na2851]
Kennedi Wade [kaw2216]

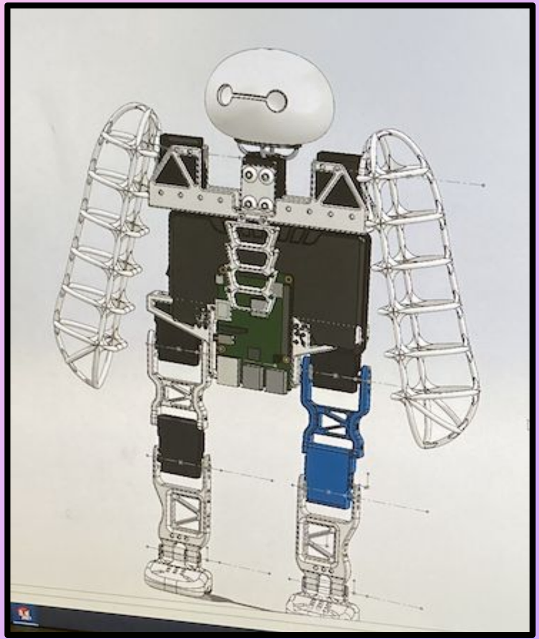
**Date Submitted: 04/24/22**

# Simulated Robot

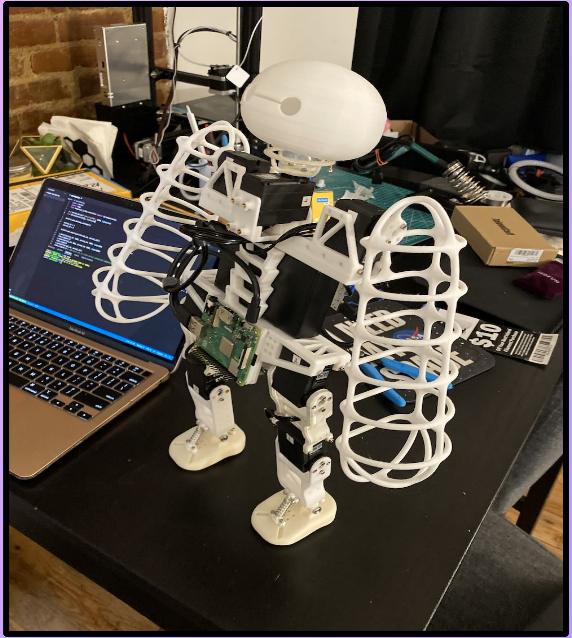


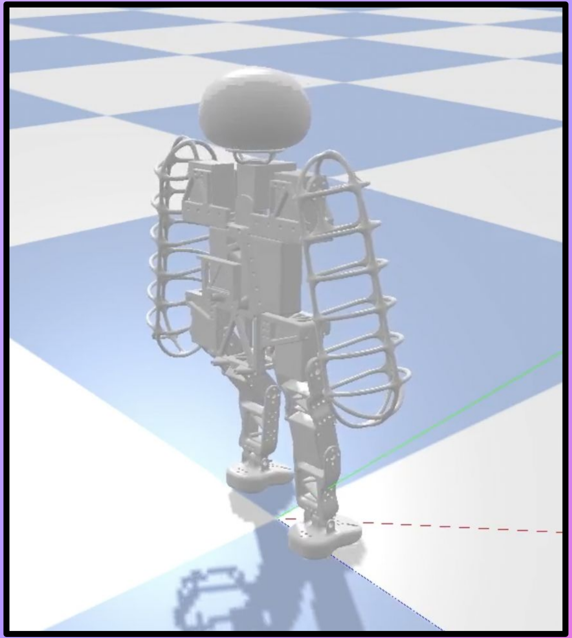
# Simulated Robot/CAD/Real Robot



CAD Rendering

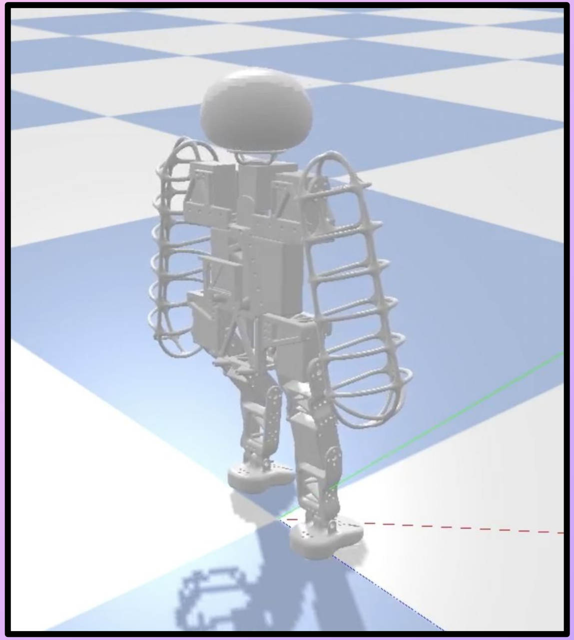


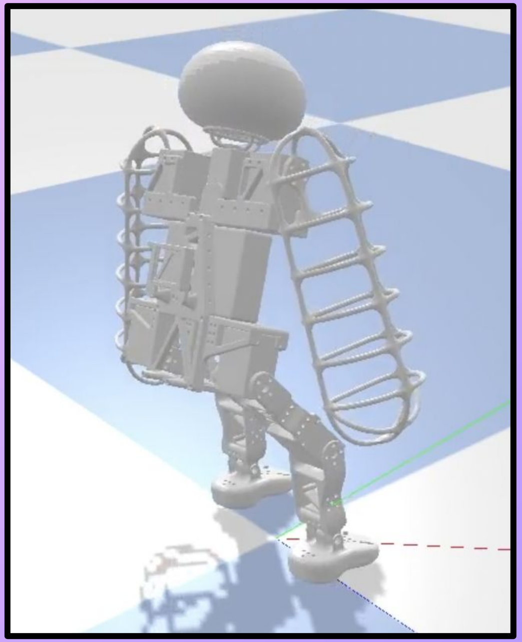
Real Robot

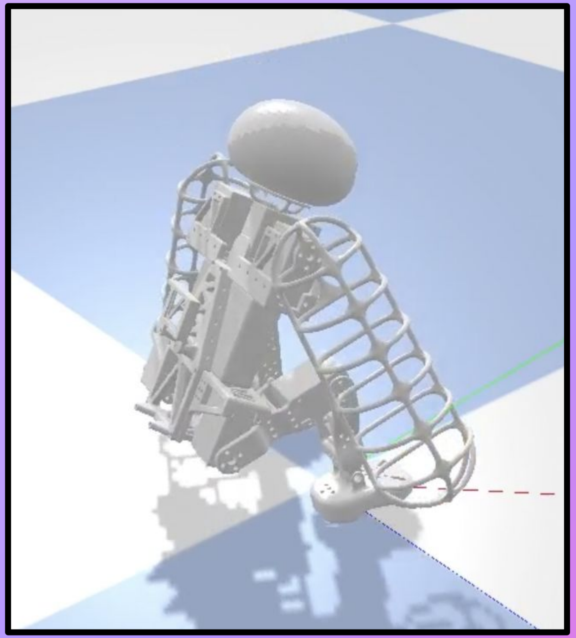


Simulation

# Robot Moving







https://drive.google.com/file/d/1AOiOlAU8V8YLWLiUwYPvmqroTO2z0gBa/view?usp=sharing

# Discussion Post

## Baymax PyBullet Simulation #260

Nicolas Aldana
a minute ago in General

STAR | WATCHING | 4 VIEWS

1

hey y'all, Kennedi and I got our simulation up and running over the weekend! we used a Solidworks URDF exporter and it saved us a LOT of time. next steps are to figure out the ML algorithm to optimize our parameters 😩

here's a video of virtual baymax :)

-- Nico

SimulationClip.mp4

Comment Edit Delete •••

https://edstem.org/us/courses/19587/discussion/1438560

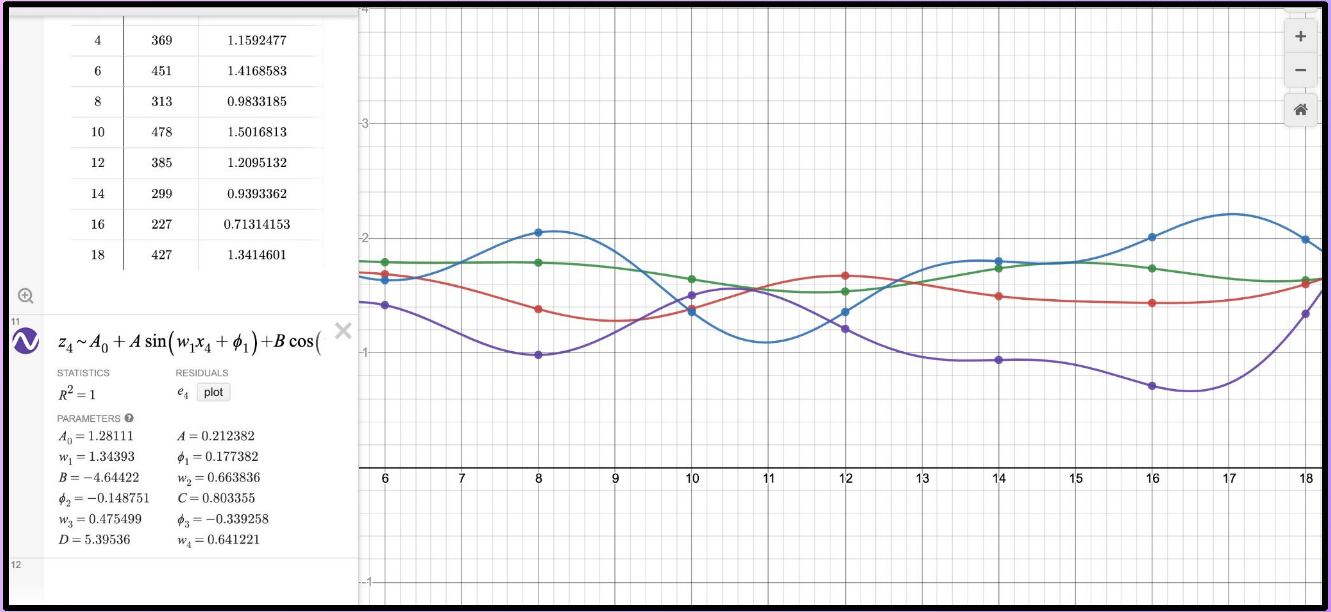
# Position of Centroid & Speed

```
# Get initial position and orientation
robotPos_i, robotOrn_i = p.getBasePositionAndOrientation(robotID)

for i in range (4320):
    p.stepSimulation()
    p.setJointMotorControl2(robotID, right_hip, controlMode=mode, ta
    p.setJointMotorControl2(robotID,left_hip, controlMode=mode, targ
    p.setJointMotorControl2(robotID,right_knee, controlMode=mode, ta
    p.setJointMotorControl2(robotID,left_knee, controlMode=mode, tar
    time.sleep(1./240.)

# Get final position and orientation
robotPos, robotOrn = p.getBasePositionAndOrientation(robotID)
print(robotPos, robotOrn)
speed = (robotPos - robotPos_i)/18
print("Speed: " + str(speed))
```

Simulation runs for 18 seconds

# Angle Functions

```
le, targetPosition=(1.70338-0.147192*sin(0.536376*i*1.19 -0.16*cos(0.798*i-0.719)+0.16*sin(0.973*i-0.74))), force=0)
, targetPosition=2*pi-(1.784-0.3*sin(0.142*i+0.01)-0.04*cos(1.44*i+0.062)-0.03*sin(1.48*i-0.4)-0.169*cos(0.873*i+30.03)),
le, targetPosition=(1.72-0.22*sin(0.835*i-1.944)+0.233*cos(0.469*i-8.189)+0.23*sin(1.41*i+2.11)), force=0)
e, targetPosition=2*pi-(1.281+0.212*sin(1.34*i+0.177)-4.64*cos(0.663*i-0.148)+0.8*sin(0.475*i-0.339)+5.385*cos(0.641*i)),
```




We are using several superimposed sine and cosine functions in our gait.

We used regression and inverse kinematics to determine our initial parameters.

# Mass & Inertial Properties

```
ax_Assembly_v5 > urdf > Baymax_Assembly_v5.urdf > robot > joint > limit
<?xml version="1.0" encoding="utf-8"?>
<!-- This URDF was automatically created by SolidWorks to URDF Exporter! Originally
     Commit Version: 1.6.0-4-g7f85cfe  Build Version: 1.6.7995.38578
     For more information, please see http://wiki.ros.org/sw_urdf_exporter -->
<robot
  name="Baymax_Assembly_v5">
  <link
    name="body">
    <inertial>
      <origin
        xyz="-0.000340546339943015 0.0554073352907688 0.000995096614026969"
        rpy="0 0 0" />
      <mass
        value="0.557387700854644" />
      <inertia
        ixx="0.000249349313736852"
        ixy="2.03485518443982E-08"
        ixz="-1.59447832339548E-07"
        iyy="0.00046755882613099"
        iyz="1.26638174140914E-06"
        izz="0.000565421692129242" />
    </inertial>
```

```
<link
  name="right_femur">
  <inertial>
    <origin
      xyz="0.00105436591512603 -0.0606769567160788 0.0022003414096914 7"
      rpy="0 0 0" />
    <mass
      value="0.056878153336309" />
    <inertia
      ixx="1.42673800949385E-05"
      ixy="-3.77171451926842E-08"
      ixz="1.18041286972665E-09"
      iyy="1.17398146054724E-05"
      iyz="2.89002297380683E-07"
      izz="2.09357529204908E-05" />
  </inertial>
```

```
<link
  name="right_tibia">
  <inertial>
    <origin
      xyz="-0.000715900473451603 -0.0767312487079654 -0.0075746549737653"
      rpy="0 0 0" />
    <mass
      value="0.0863872063907743" />
    <inertia
      ixx="3.53005160974805E-05"
      ixy="-1.14366326359723E-07"
      ixz="-6.92064022621181E-09"
      iyy="3.73865783414239E-05"
      iyz="-8.70941856589314E-07"
      izz="2.89174905703592E-05" />
  </inertial>
```

# Contact & Collision

```
<collision>
  <origin
    xyz="0 0 0"
    rpy="0 0 0" />
  <geometry>
    <mesh
      filename="package://Baymax_Assembly_v5/meshes/body.STL" />
  </geometry>
</collision>
```

There is no need for joint limits to be set since self-collision is on and our arms have 360° motion in servo gear mode.

```
robotID = p.loadURDF("Baymax_Assembly_v5/urdf/Baymax_Assembly_v5.urdf", robotStartPos, robotStartOrientation, p.URDF_USE_SELF_COLLISION)
```

Using self collision based on STL meshes

# RECOUNT OF POINTS AND GRADING FOR ASSIGNMENT 7:

1. **10 points Title page correct and complete (101)**
2. **10 points Slides nicely formatted (e.g. consistent fonts/sizes, aligned images/text) (All slides)**
3. **10 points posting some video of the simulated robot on Discussion Board (show screenshot, provide link (105)**
4. **10 points screenshots of simulated robot (102, 104)**
5. **10 points robot moving (frames + link to video)  (104)**
6. **10 points Position of robot centroid determined and speed calculated (105)**
7. **10 points plotted motor angles/speed/torque as function of time. (106)**
8. **10 points mass/inertia properties included in URDF (107)**
9. **10 points contact/collision included in URDF (108)**
10. 10 points joint limits included in URDF
11. **10 points sinusoidal gait used (106)**
12. 10 points forward kinematics calculated
13. **10 points inverse kinematics used in motion planning (106)**
14. 10 points other locomotion patterns tried
15. 10 points other goals tried (e.g. jumping)
16. 10 points other environments tried (e.g. obstacles, wind)
17. 10 points post video of your simulated robot on your online portfolio (include screenshot and link)

**Our Total Point Summation:**
**110 points**

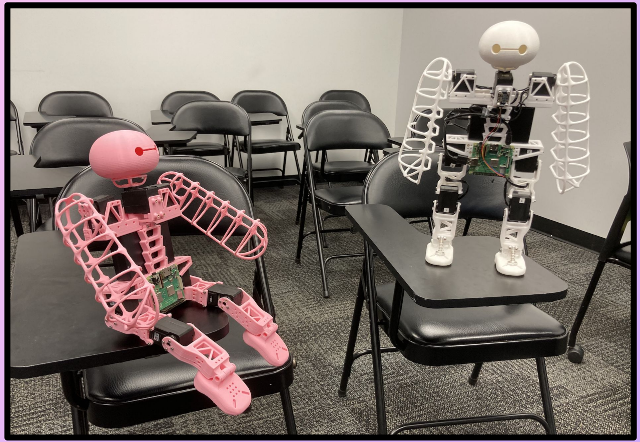
Robotics Studio [MECHE 4611]
*Spring 2022*

# Final Performance Evaluation!
# Big Hero 6's Baymax

Nico Aldana [na2851]
Kennedi Wade [kaw2216]

**Date Submitted: 05/10/22**

# Glamour Shots of Robots

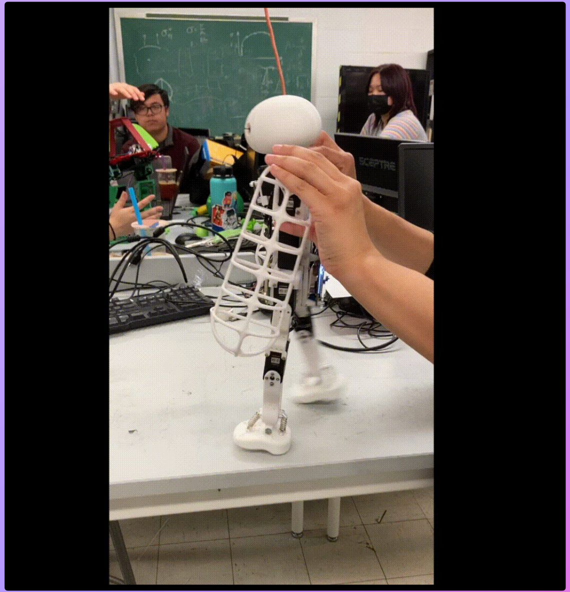


This semester, we built two robots inspired from the movie Big Hero 6 who can walk and dance.

# The Early Stages of Baby-Stepping to Finally Finding His Stride

**Before(Baby Steps/Kicks):**
Baby Steps!!

**Link to Official Steps Video: (After)**
Walking the Walking



# Quantified Speed in cm/sec Next to a Tape Measure

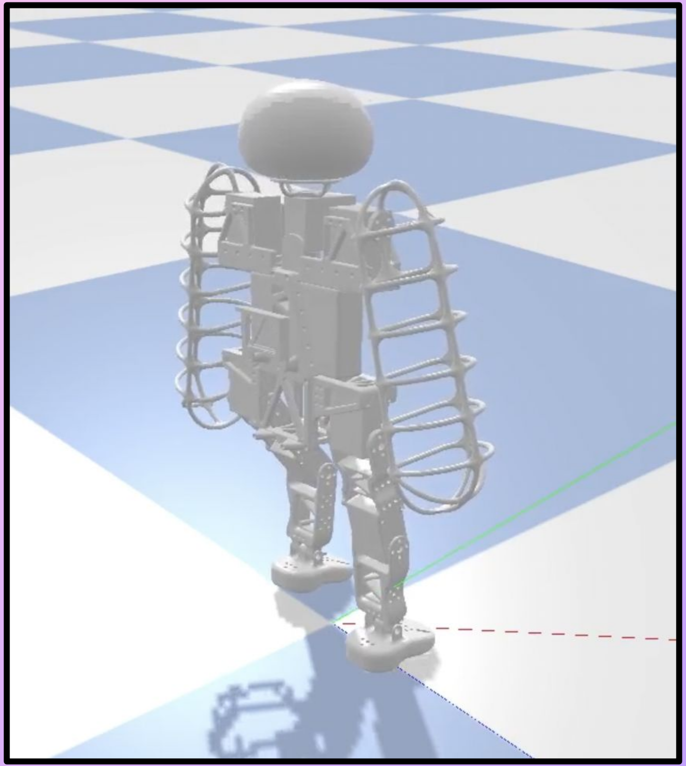

**Link to Official Steps Video:**
Official Steps

**Link to Official Steps Video with Tape Measure:**
How Far Did He Go??

Overall we quantify that our bot is moving 4 inches in 16 seconds, OR 10 centimeters in 16 seconds in this video, or allllmost 1 cm/sec :)

Link to Journey Video :) We hope you enjoy!! It's Been a Great Semester :)

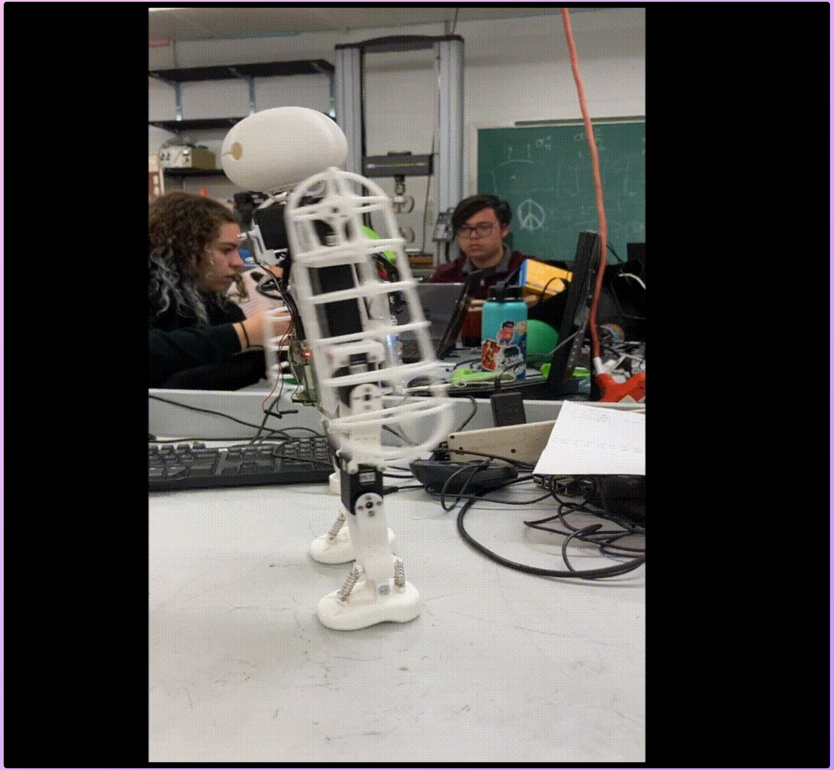
# Conquering the Simulation



We used a simulation to narrow down Baymax's walk cycle and apply it to real life to try and simulate a human walk cycle.

**Simulation Video Link:**
Simulation Time

# Dancing :)



For **bonus points,** we also taught our robots how to dance and “Do The Twist” :)) We plan to incorporate/develop more dance moves in the future.

**Dancing Video Link (At the End of the Video)**

Happy Dance :)

# Thank You For a Great Semester!!