TEXAS A&M UNIVERSITY
Engineering

Active Prosthetic Ankle (ANKL)

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TEXAS A&M UNIVERSITY
ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Problem Definition

Create an active 3 Degree of Freedom (DOF) ankle prosthesis based on a modified Stewart Platform to improve patient mobility compared to traditional ankle prosthetics.

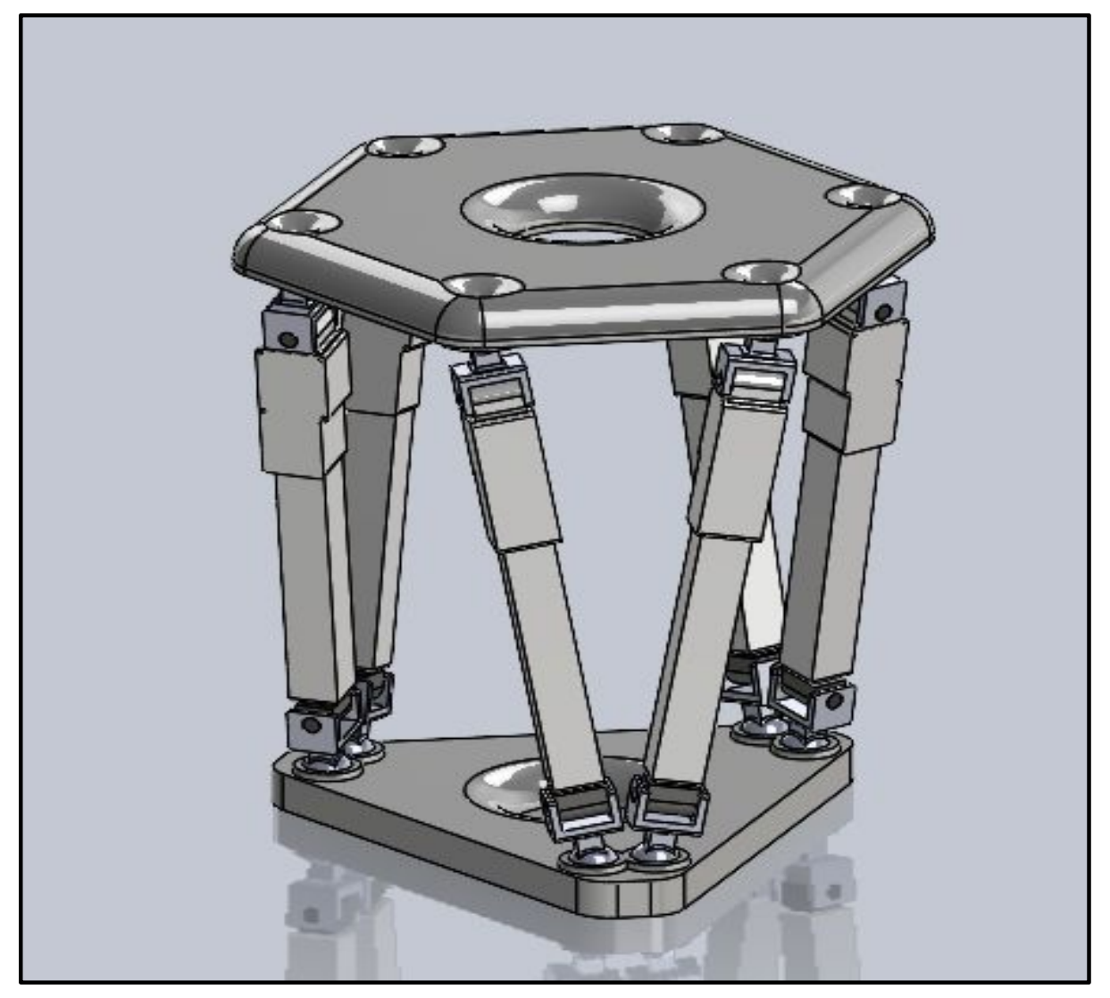
Project Objectives

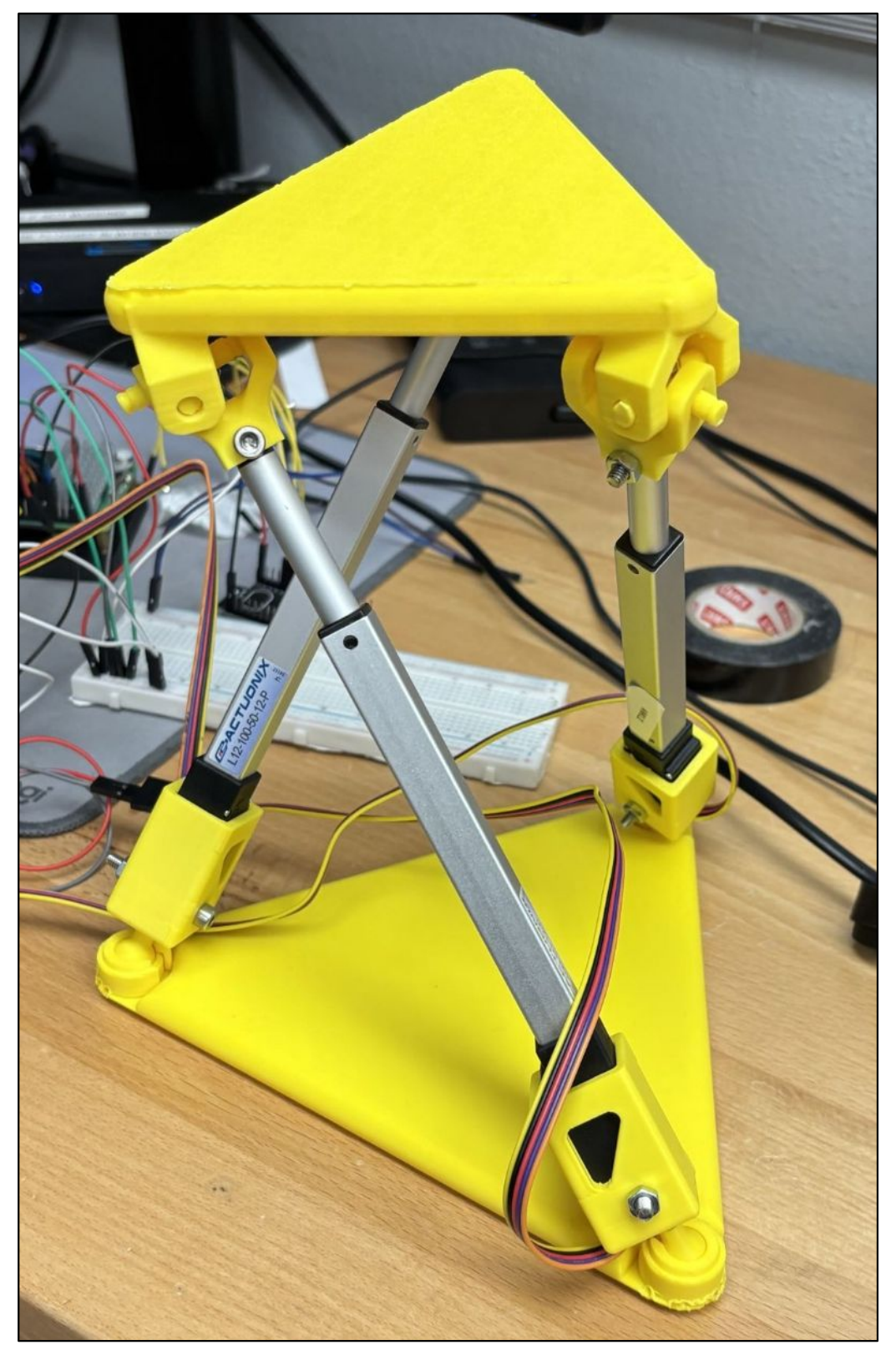
- Replicate the RoM of the human ankle within ±10% of their average values.
- Have an overall weight and footprint comparable with existing lower-leg prosthetics
- Actively acquire gait data (shank angle, shank velocity, thigh angle, thigh velocity) from a functioning leg to phase shift movements to prosthetic.
- Develop a custom controller for the modified kinematics and dynamics of the prosthesis

Platform Design

Our previous design was based on a 6x3 stewart platform design (left) due to its stability and extensive research. This semester, the design shifted to a 3x3 Stewart platform (right) with a central supporting joint due to:

- 3 DOF having closer semblance to the modeling of the biological ankle
- Simplified controls algorithm
- More dispersed loading

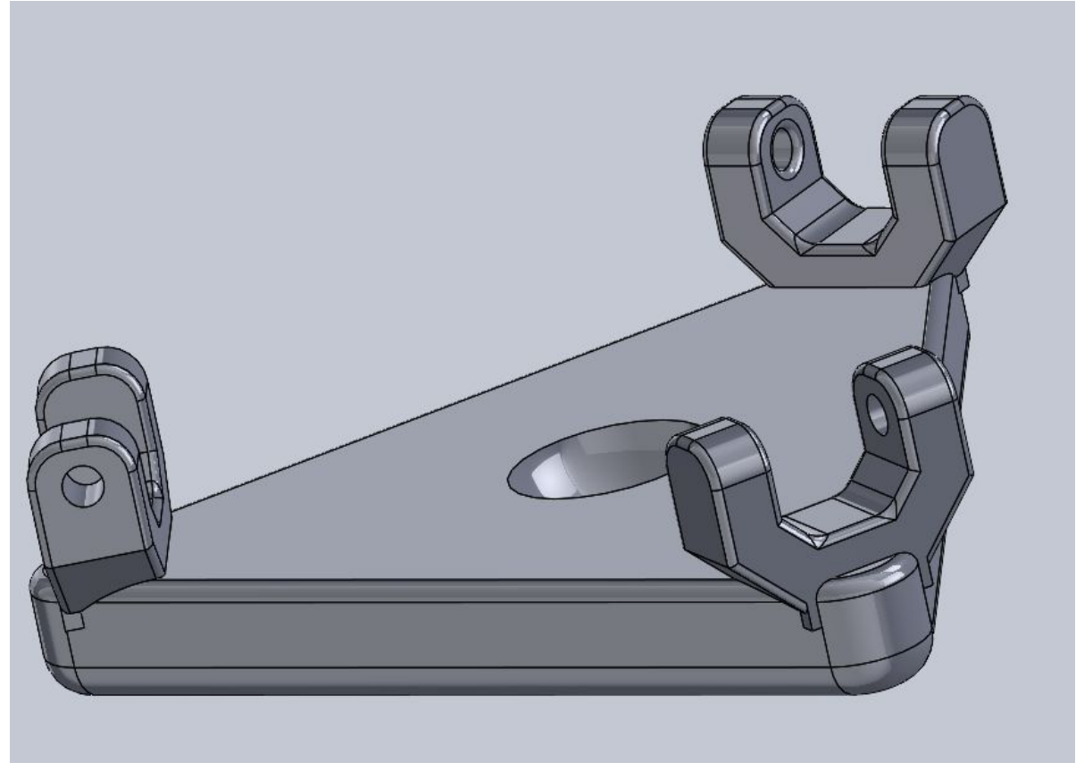


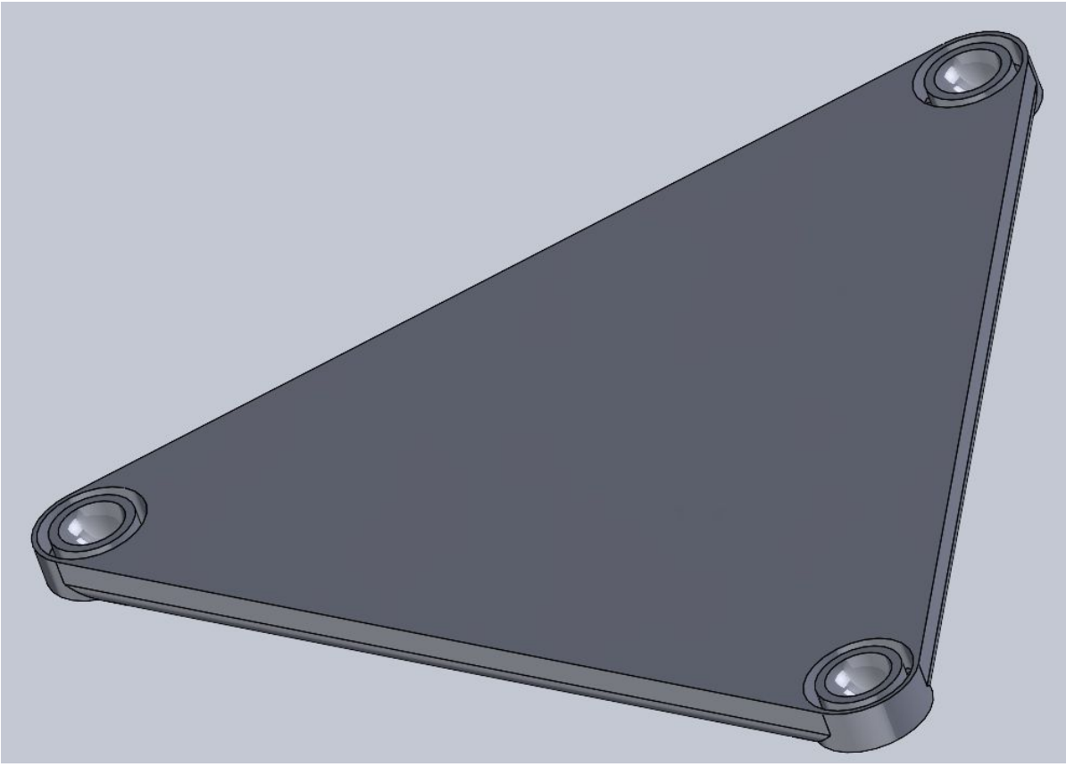


Plates and Linkage Joints

These plates serve as the main support structure for the prosthetic and are designed mimic the circumference of human calves and ankles, so as not to impede the user's walking pattern. These plates serve two additional purposes:

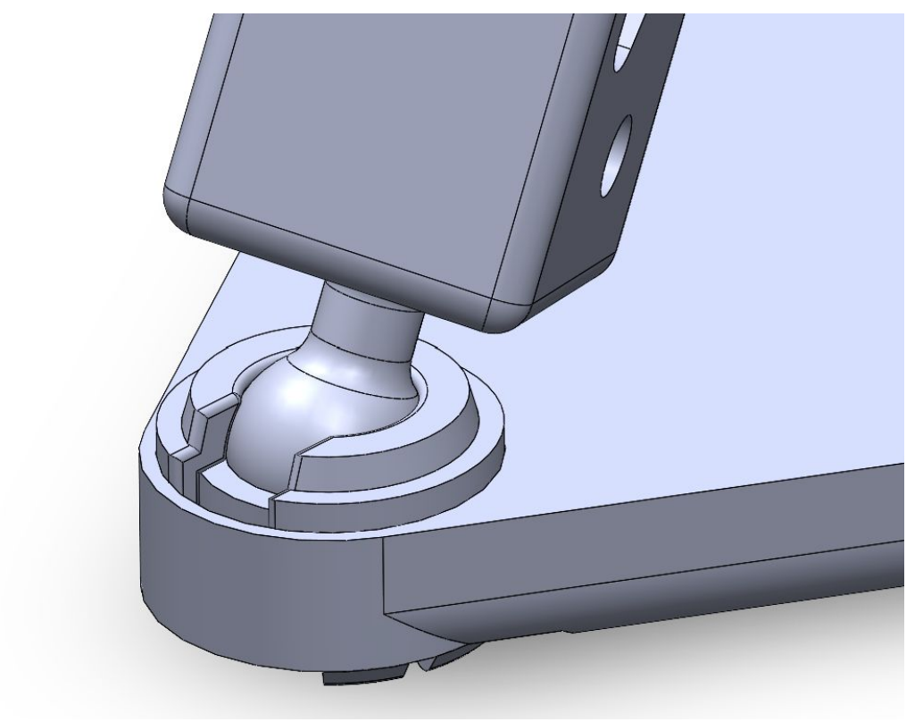
- Socket attachments for the actuators
- Base housing for the electronics

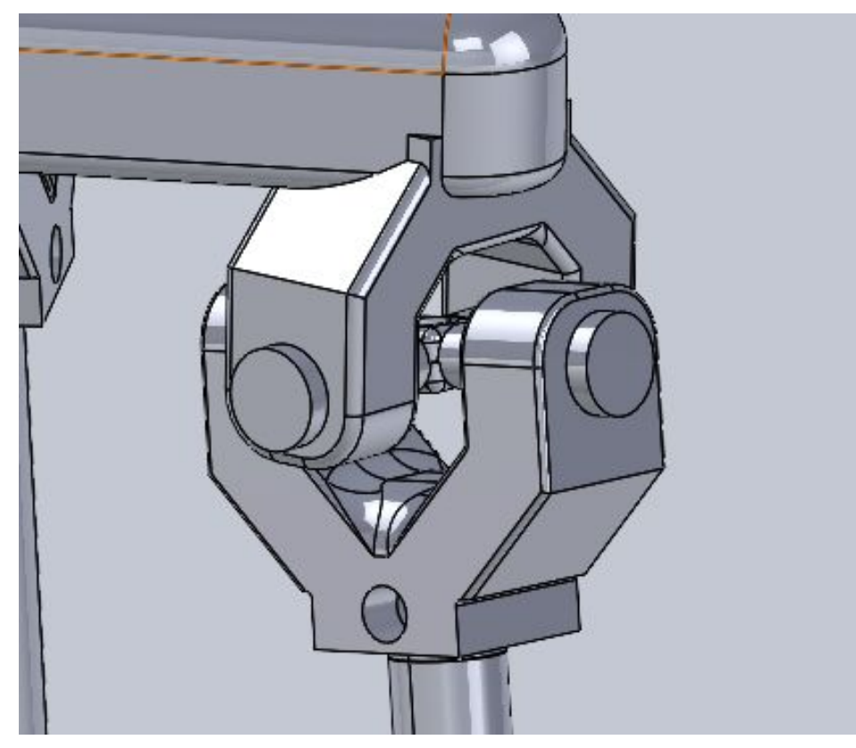




The of the platform consist of universal joints on the top platform and ball and socket joints on the bottom platform:

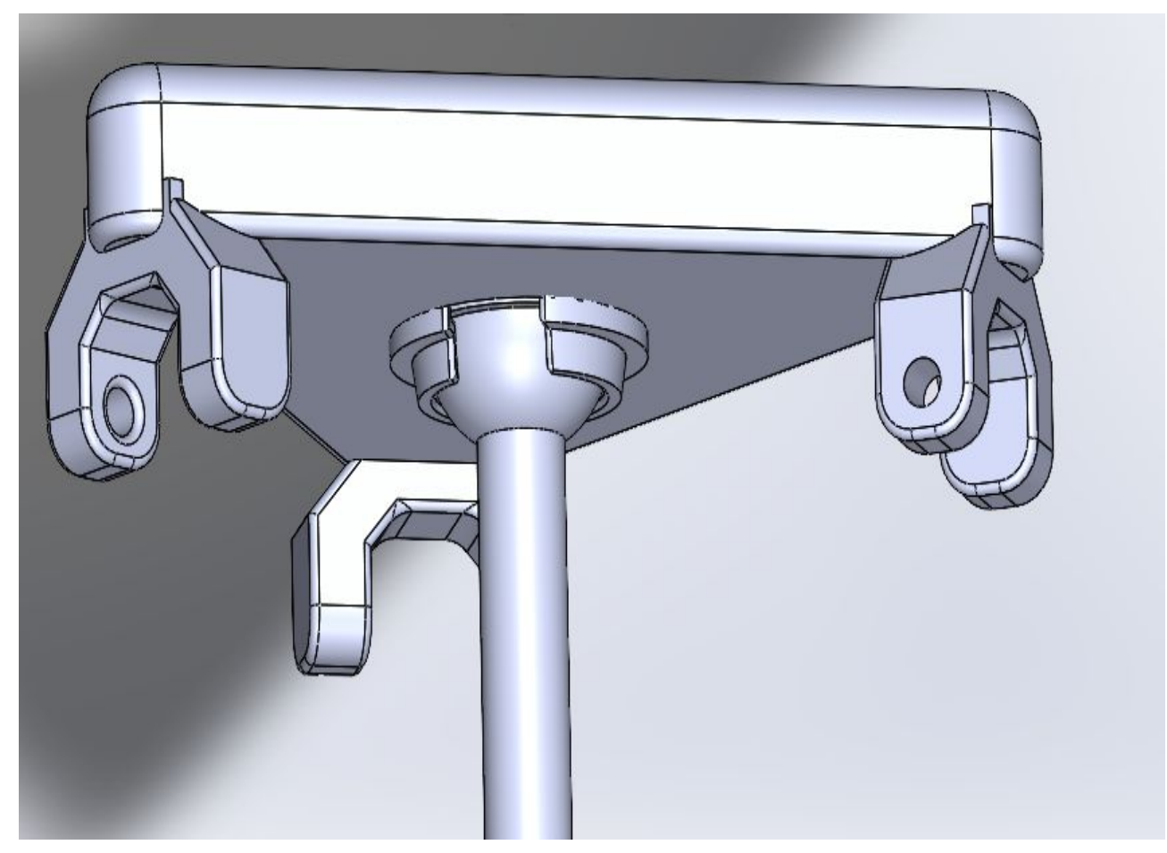
- The ball and socket joints have the 3 degrees of freedom necessary for platform rotation.
- Universal joints have 2 degrees of freedom and are used to prevent actuators from rotating axially and tangling electrical wires.

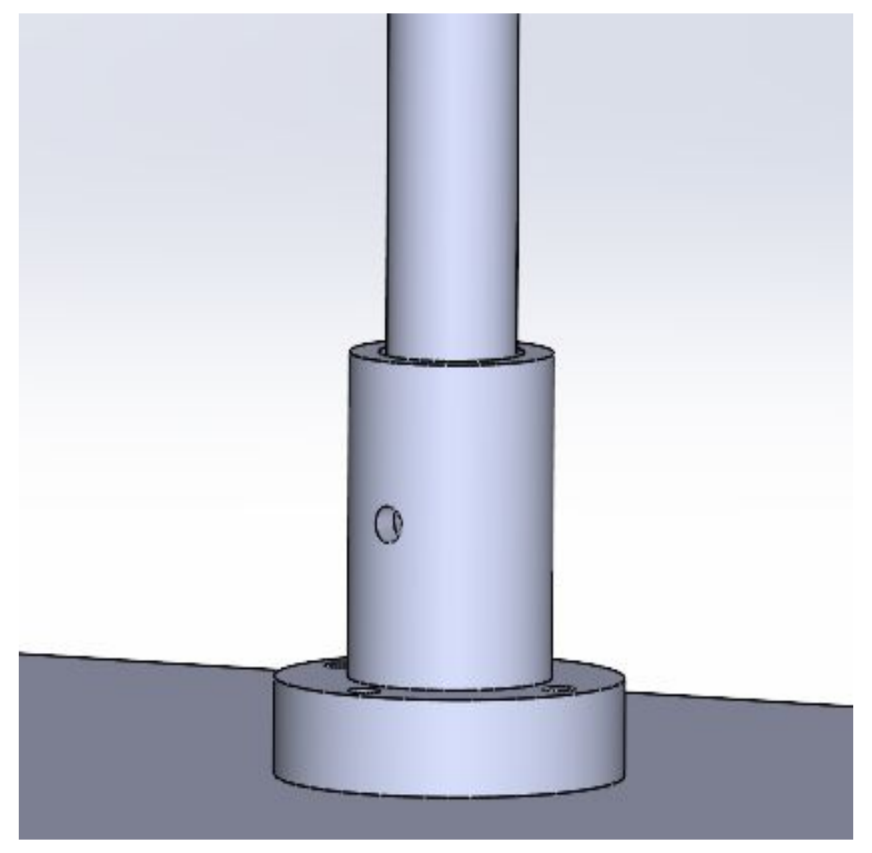




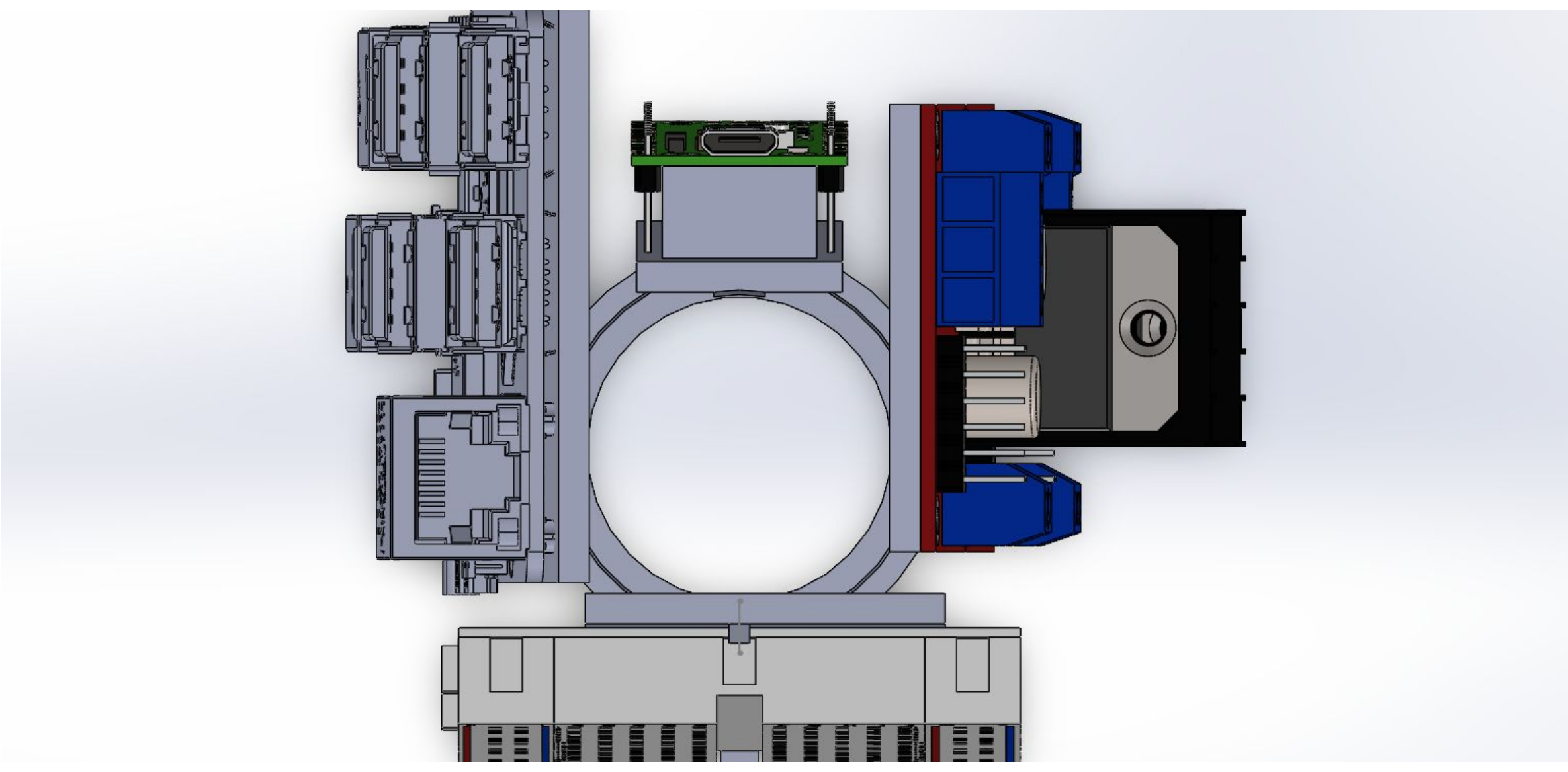
Center Joint

A central joint is created to limit it to the three degrees of freedom similar to a human ankle. This joint serves to support the bulk of the user's weight, allowing us to use lower power actuators





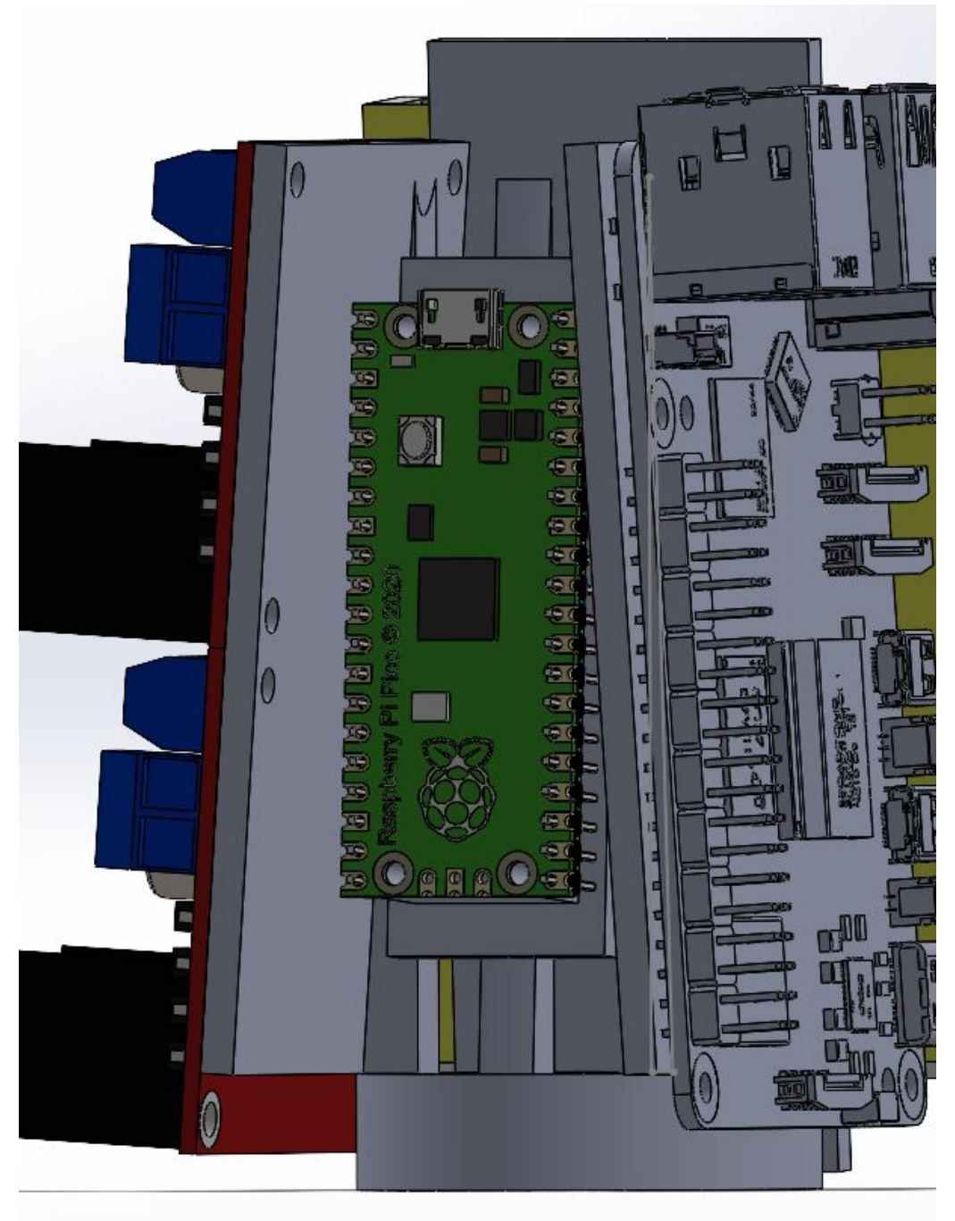
Electronics/Electronic Housing

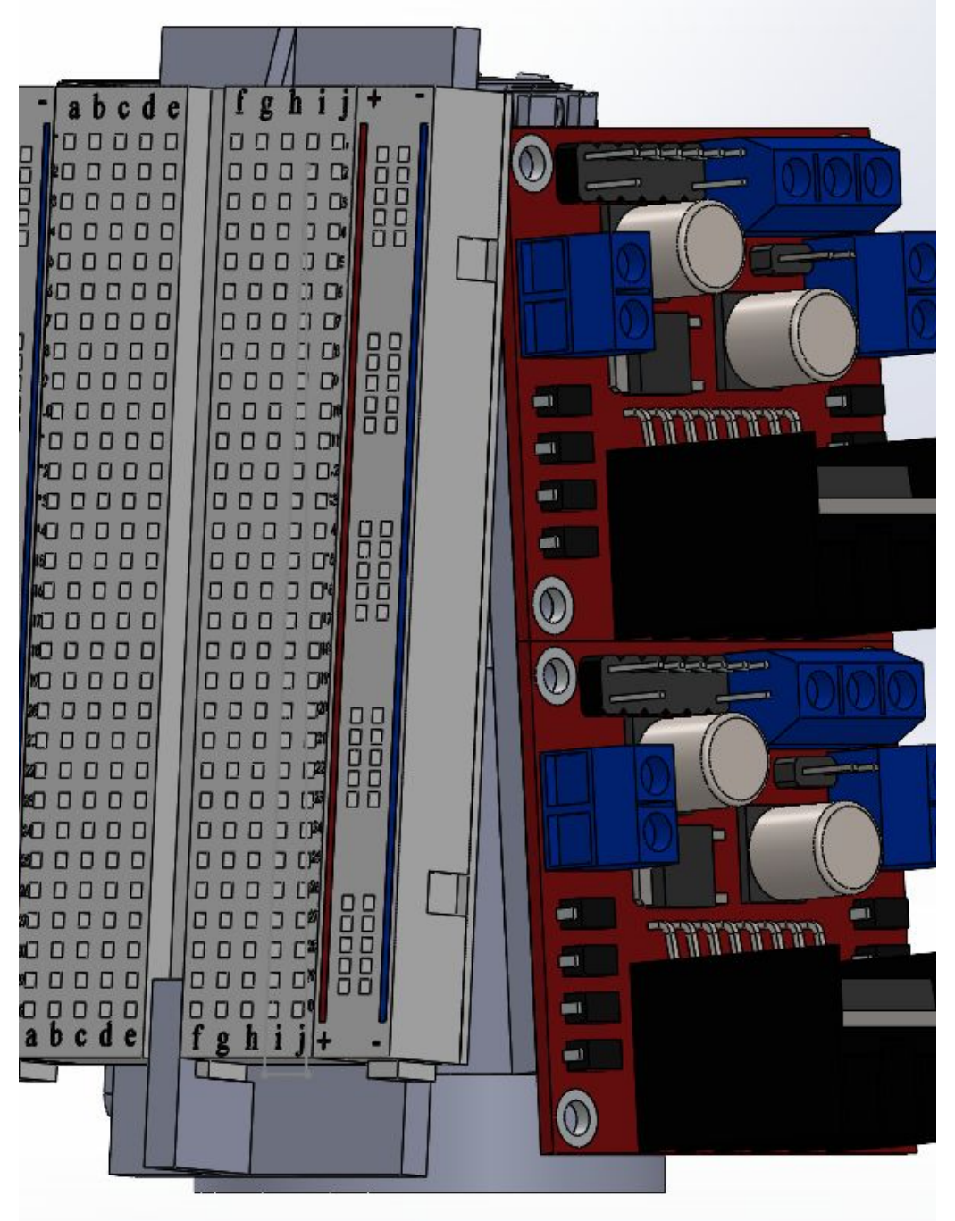


Components:

- Linear Actuators
- L298N Motor Drivers
- Raspberry Pi Pico
- Raspberry Pi 5

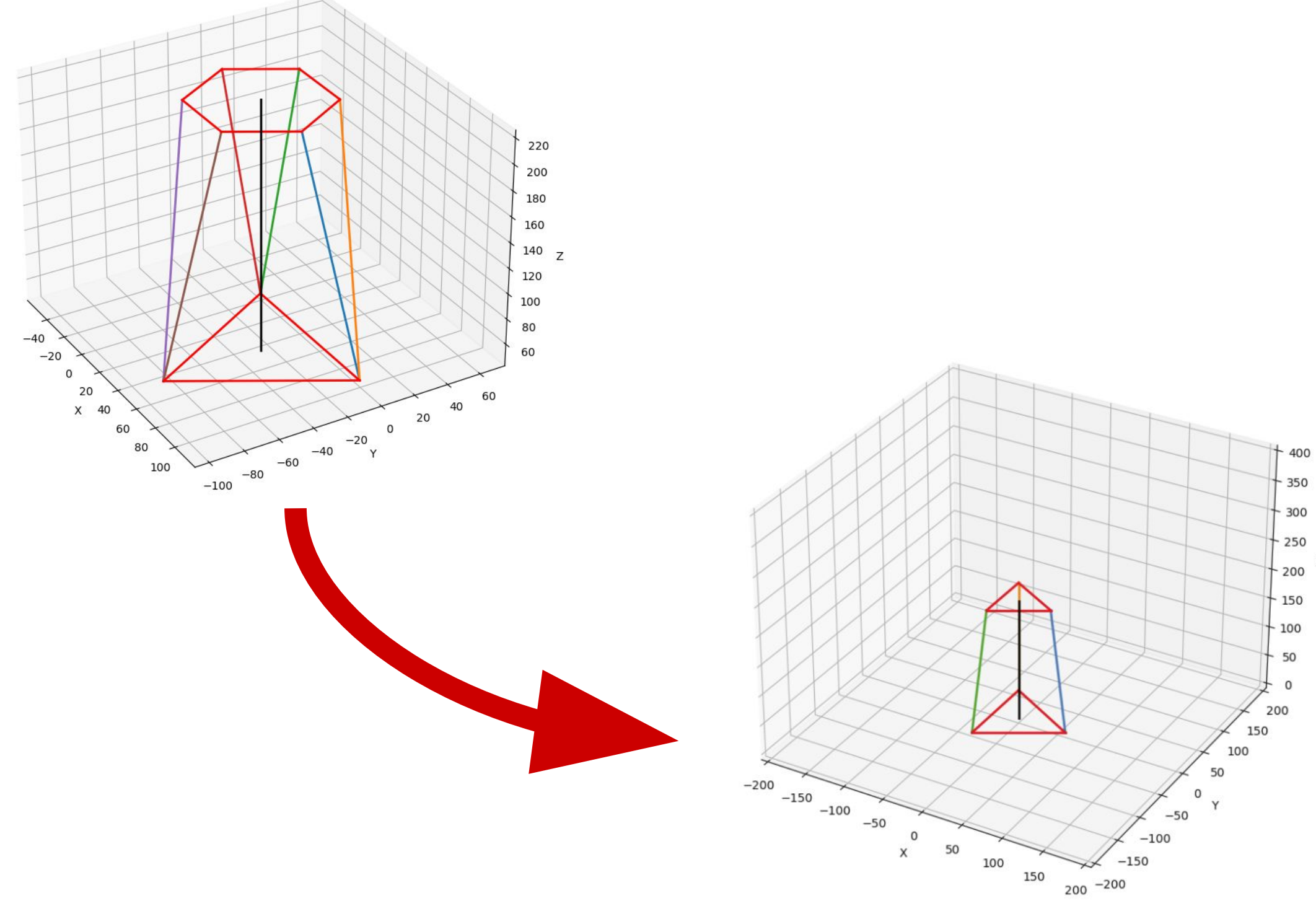
The electronics will be mounted on platforms surrounding the central joint and secured to the plate to mitigate strain.





Simulation Updates

Updated simulation, along with our robotic kinematics to use the 3-3 platform configuration.



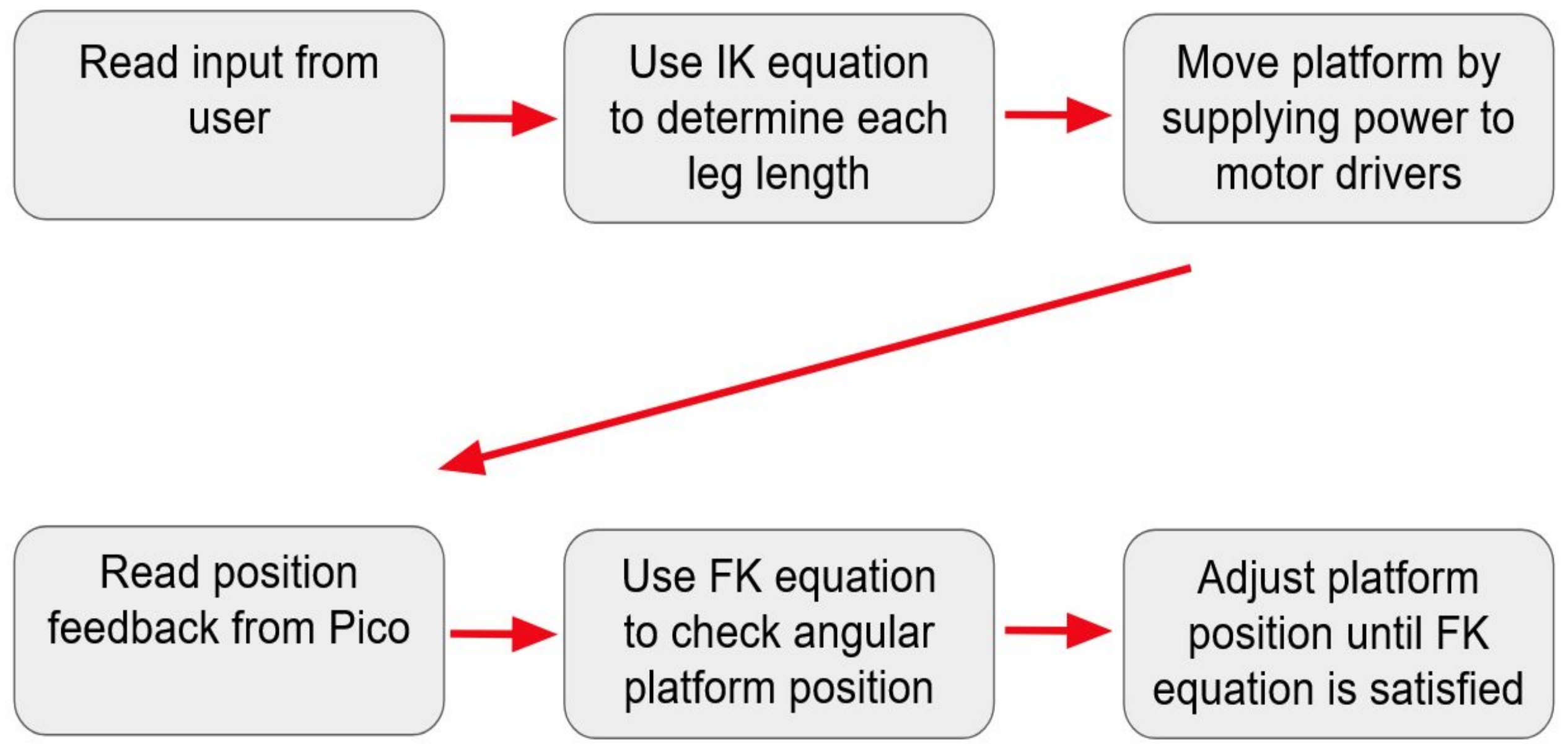
Software and Robotic Kinematics

Using the known leg lengths of each actuator, the unknown angular position of the floating platform can be determined. Due to Stewart Platforms containing nonlinear geometry, the forward kinematics cannot be solved analytically and require the use of numerical methods [1].

$$F(q) = \begin{bmatrix} f_1 \\ f_2 \\ f_3 \end{bmatrix} = \begin{bmatrix} \sqrt{L_1^T L_1} - l_{m1} \\ \sqrt{L_2^T L_2} - l_{m2} \\ \sqrt{L_3^T L_3} - l_{m3} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$q_{n+1} \approx q_n - J^{-1}(q_n)(L_{in} - L_m)$$

The ESP32 acts as an analog-to-digital converter (ADC), transmitting position data to the Raspberry Pi, where it is fed into robotic kinematic equations to determine the angular position of the platform. Based off the position of the platform, the linear actuators can be moved while continuously sending feedback to the Raspberry Pi until a desired position is reached.



Read input from user

Use IK equation to determine each leg length

Move platform by supplying power to motor drivers

Read position feedback from Pico

Use FK equation to check angular platform position

Adjust platform position until FK equation is satisfied

Future Goals

- Automated calibration and verification of linear actuators.
- Implementation of dynamics within the platform controller.
- Fully battery powered operation.
- Professionally manufactured aluminum parts.

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[1]L. Huang, H. Pang, and H. Zhang, "Research on the Forward Kinematics of Stewart Platform based on Broyden Algorithm and Newton-Raphson Algorithm," pp. 402–406, Oct. 2023, doi: https://doi.org/10.1109/icnisc60562.2023.00013.

Texas A&M University Robotics Team and Leadership Experience (TURTLE)