TEXAS A&M UNIVERSITY Engineering

6-DOF Prosthetic Ankle (ANKL)

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TEXAS A&M UNIVERSITY
ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Problem Definition

Create a working 6 DOF Stewart Platform robot using inverse and forward kinematics for the use in an advanced below the knee ankle prosthesis.

Methodology

1. Began Studying Modern Robotics
2. Simultaneously explored medical and Hardware
3. Performed literature reviews to inform our approach
4. Evaluated hardware Components
5. Exploring functionality of Raspberry Pi
6. Acquiring knowledge of IMU's
7. Obtaining empirical measurements
8. Explored Simulation Programs
9. Developed Dynamic 3D python simulation to test behavior

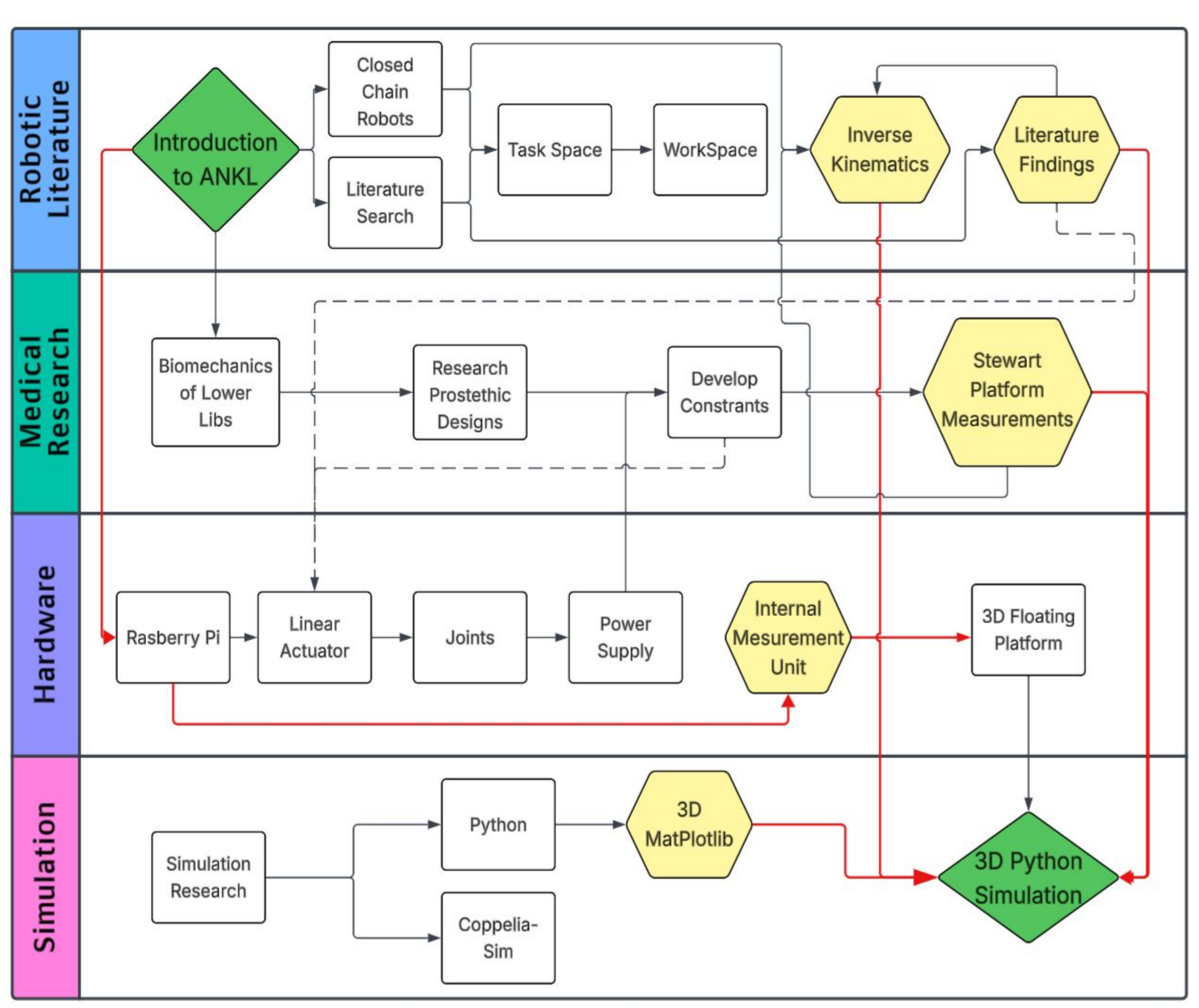

Figure 1 - Methodology Flow Chart

Robotic Kinematics

A. The distance between the two platforms is treated as a vector and Table 1 is used to determine the neutral distance.

B. Using Equation 1, the leg lengths are calculated at any position or rotation the platform is in.

C. Radius of each platform is treated as a vector to the desired leg, and the calculations of each radii was calculated based on Table 1.

D. *R*, the rotation matrix shown below, represents the rotational position of the top platform. This is calculated from the IMU data shown in Figure 4.

$$\begin{bmatrix} \cos\psi\cos\theta & \cos\psi\sin\theta\,\phi - \sin\psi\cos\phi & \cos\psi\sin\theta\cos\phi + \sin\psi\sin\phi \\ \sin\psi\cos\theta & \sin\psi\sin\theta\sin\phi + \cos\psi\cos\phi & \sin\psi\sin\theta\cos\phi - \cos\psi\sin\phi \\ -\sin\theta & \cos\theta\sin\phi & \cos\theta\cos\phi \end{bmatrix}$$

Equation 1. Rotation Matrix R

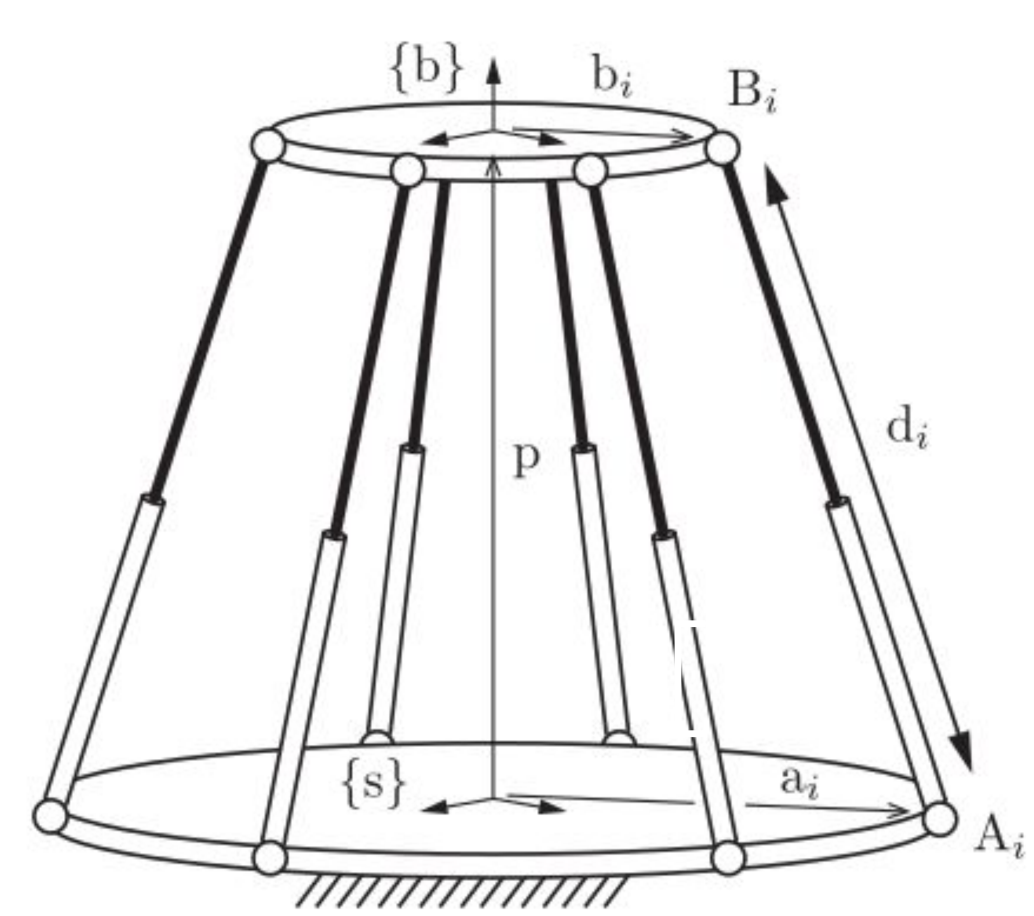

Figure 2. Analytical visualization of a Stewart Platform [1]

$$d_i = p + Rb_i - a_i$$

Equation 2. Stewart Platform Leg Length

Table 1 - Average Stewart Platform Measurements

	Average (mm)
Distance Between Platforms (p)	379.413
Base radius (ai)	189.38875
Platform radius (bi)	127.8571429

Outcomes

The primary outcomes of this semester lied within the research on closed loop kinematics and ankle biology, the IMU programming and functionality, and the visualization simulation. Using the previously described kinematics a Python graph was created to showcase the movement and control of the Stewart Platform.

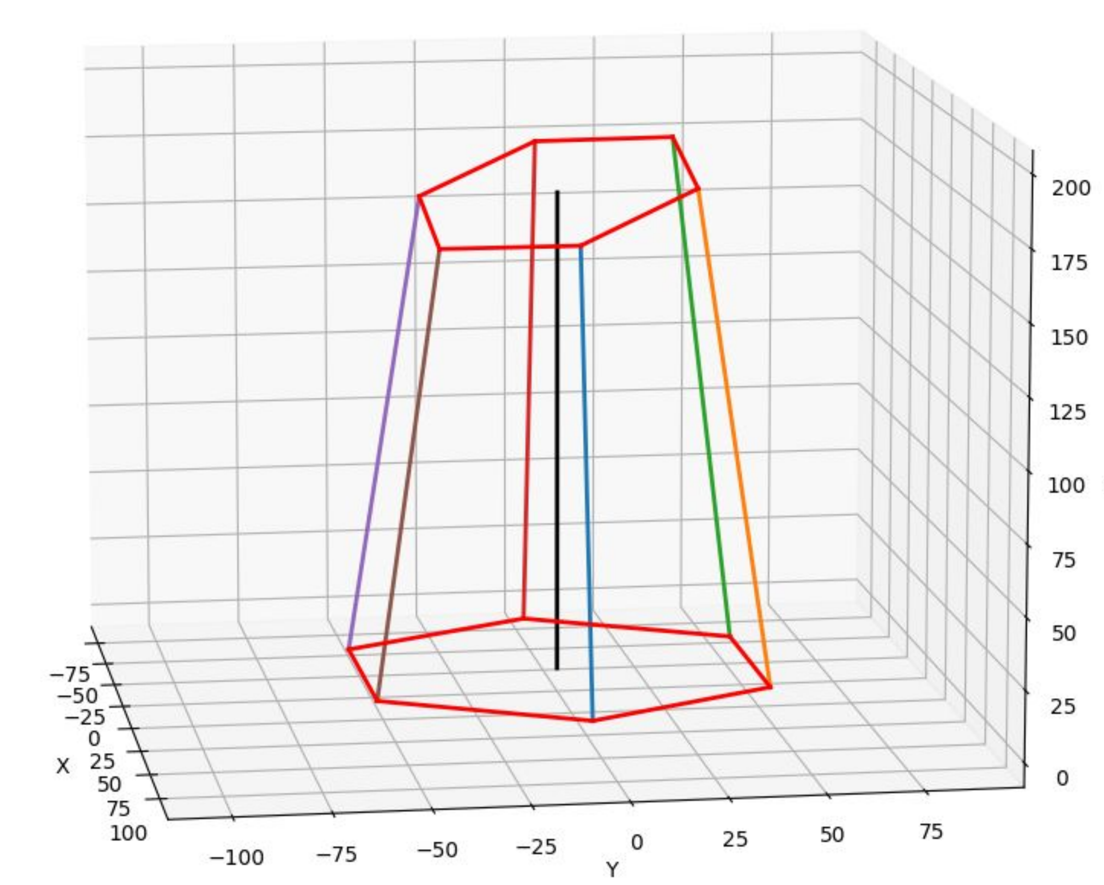

Figure 3. Stewart platform simulation

Currently this simulation actively responds to changes in the pitch, yaw, and roll of the top platform's IMU. This simulation demonstrated the functionality of the Stewart platform and the leg lengths for a given configuration.

The IMU's gyroscope can currently be calibrated and can actively record and output the pitch, yaw, and roll angular velocity and position. The angular position is found using numerical integration methods, and is output in the following graph.

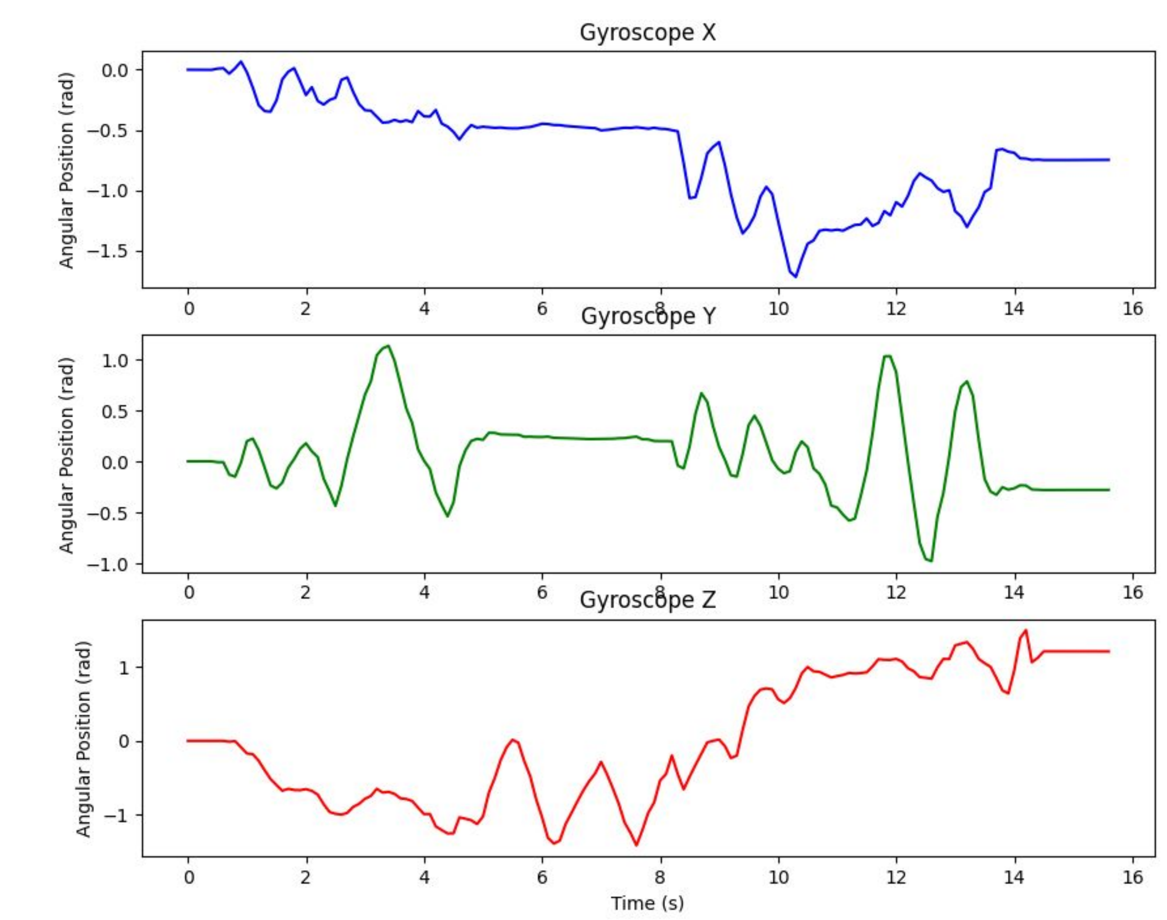

Figure 4. IMU Angular Position Data

Future Goals

- Process IMU accelerometer data to output linear position of the top platform.
- Filter IMU accelerometer and gyroscope data to decrease drift and improve measurement accuracy.
- Reconfigure Stewart Platform simulator to use PyBullet.
- Survey target demographic.
- Model and assemble the physical model of the Stewart Platform.
- Gather gait data to determine force and leg length requirements for the Stewart Platform.

[1] K. M. Lynch and F. C. Park, *Modern Robotics: Mechanics, Planning, and Control*. Cambridge, U.K.: Cambridge University Press, 2017.

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