BIPEDAL MOBILE ROBOT

PROJECT DESCRIPTION

The Bipedal Mobile Robot project served as a valuable learning experience in managing and iteratively improving a complex system. The robot features limbs with four revolute joints providing one degree of freedom each, and two revolute joints offering two degrees of freedom each. Throughout the build and testing phases, the primary goal was to apply theoretical knowledge in a practical setting.

Concepts such as Forward Kinematics, Inverse Kinematics, and controller design, extensively studied in theory, were brought to life through this hands-on project.

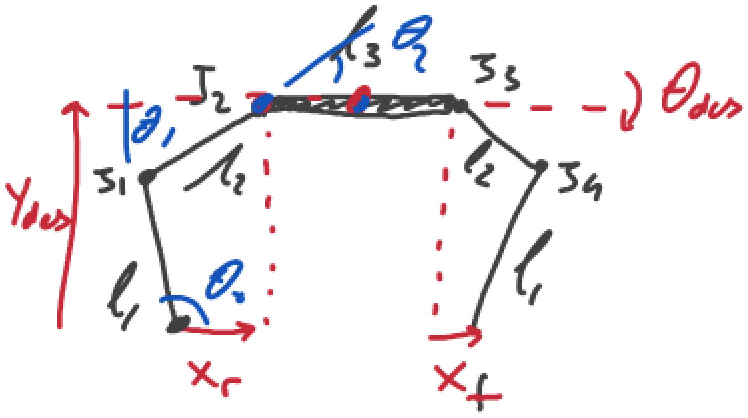
Through the following sections, we present our work and what we have learned!

FORWARD KINEMATICS

In order to calculate locations of each members given joint angles $[\theta_1, \theta_2, \theta_3, \theta_4]$ there are multiple methods, we used Geometric Analysis and Denavit Hartenberg:

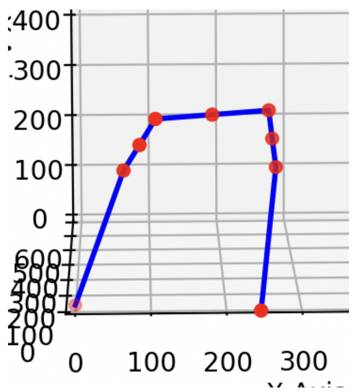
Geometric Analysis

This method involves the use of the geometry of the members and trigonometry to determine the required joint angles needed.



Denavit Hartenberg (D-H Method)

$$
\begin{aligned}
{}^{n-1}T_n &= \mathrm{Rot}(z_{n-1}, \theta_n) \cdot \mathrm{Trans}(z_{n-1}, d_n) \cdot \mathrm{Trans}(x_n, a_n) \cdot \mathrm{Rot}(x_n, \alpha_n) \\
&= \begin{pmatrix} \cos\theta_n & -\sin\theta_n \cos\alpha_n & \sin\theta_n \sin\alpha_n & a_n \cos\theta_n \\ \sin\theta_n & \cos\theta_n \cos\alpha_n & -\cos\theta_n \sin\alpha_n & a_n \sin\theta_n \\ 0 & \sin\alpha_n & \cos\alpha_n & d_n \\ 0 & 0 & 0 & 1 \end{pmatrix}.
\end{aligned}
$$



INVERSE KINEMATICS

In order to calculate joint angles required to achieve certain positions $[y_d, x_r, x_f, \theta_d]$ of the end effector, we use geometric analysis:

$$X_{j2} = X_r \quad [1]$$

$$Y_{j2} = Y_{des} - \frac{l_3}{2} \sin\theta_{des} \quad [2]$$

$$Y_{j3} = Y_{des} + \frac{l_3}{2} \sin\theta_{des} \quad [3]$$

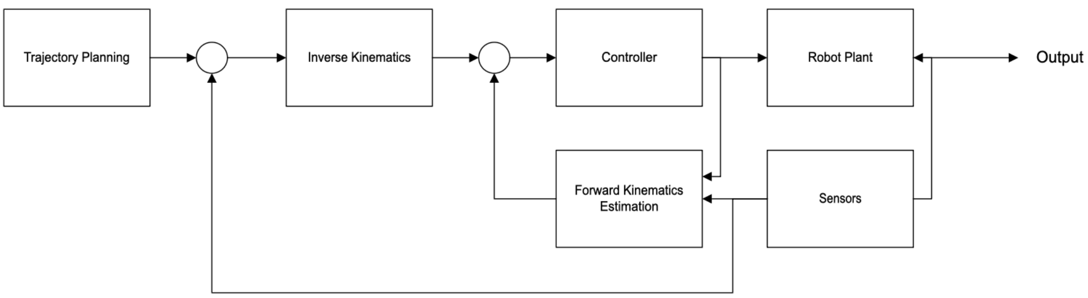
$$\phi_r = \cos^{-1}\left(\frac{l_2^2 - d_r^2 - l_1^2}{-2 d_r l_1}\right) \quad [4]$$

$$\theta_r = \tan^{-1}\left(\frac{Y_{j2}}{X_{j2}}\right) \text{ where } \theta_0 = \theta_r \pm \phi_r \quad [6]$$

$$\delta_r = \cos^{-1}\left(\frac{d_r^2 - l_1^2 - l_2^2}{-2 l_1 l_2}\right) \text{ where } \theta_1 = \pi - \delta_r \quad [5]$$

$$\theta_0 + \theta_1 + \theta_2 = \theta_{des} \quad [7]$$

SENSORS & FEEDBACK CONTROL



Here we have control logic of the robot for desired input $[y_d, x_r, x_f, \theta_d]$. Given desired input, Inverse Kinematics calculate input angles $[\theta_1, \theta_2, \theta_3, \theta_4]$ and after going through PID logic, servo position is set as input for the Robot Plant. The output is measured by the sensors, which with Forward Kinematics, unobserved states are estimated and input angles are used as feedback to controller logic. In addition, measured states are cascaded to trajectory planning such that a new trajectory is sent to achieve the full motion pre-determined.

ABOUT US

Chuba Oraka

Chuba is a self-taught programmer with a background in Civil Engineering. He has a passion for acquiring new skills through a project-based approach and has worked on projects ranging from Structural design and web design to robotics.

chubaoraka.github.io/assets/bin/Résumé.pdf

Kaan Beydüz

Kaan has a mechanical engineering background with a focus on robotics, currently planning to pursue PhD. Currently working at an analog circuit design startup to validate customer specifications through ML.

www.kaanbeyduz.com