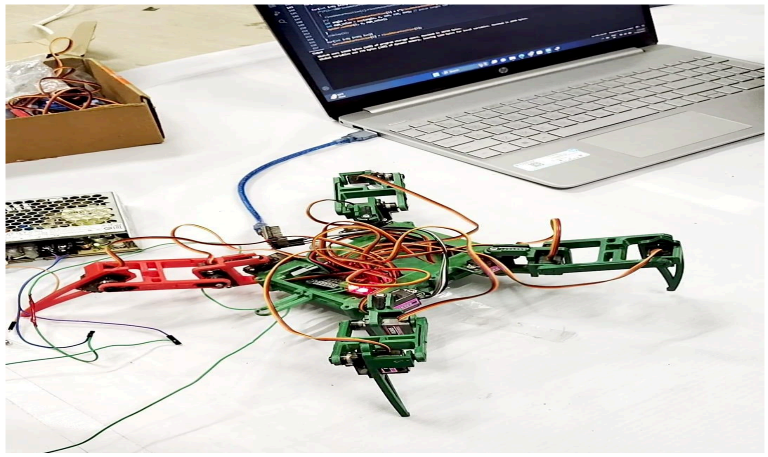
Project report

SPIDERBOT



CONTRIBUTORS-

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AIM- The aim of this project is to design and build a basic spider robot that can move and navigate on flat surfaces.The end goal of this project would be to create a functional and reliable spider robot that can move and navigate its environment.

TECH STACK -

Microcontroller: Arduino

Programming Language:C++

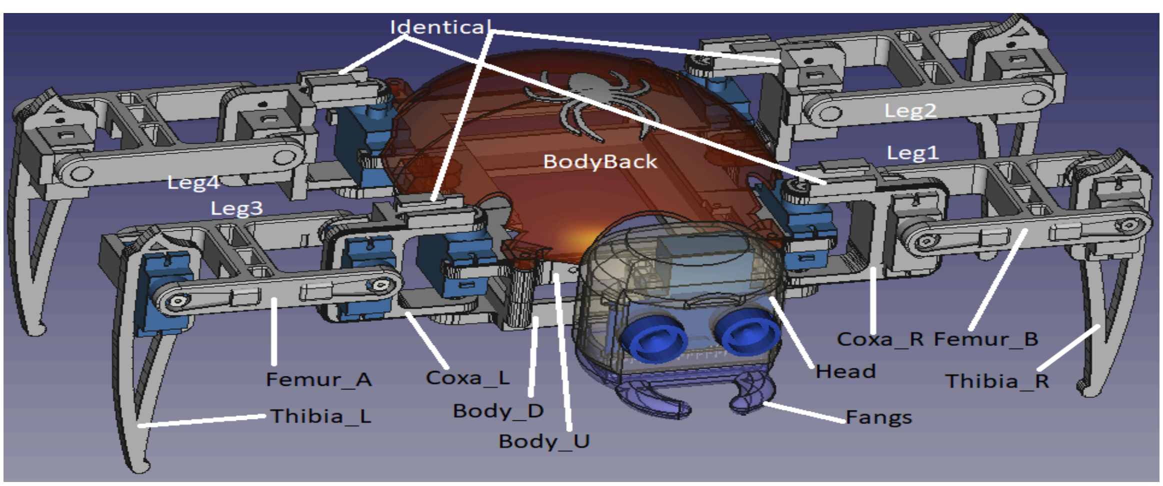
Libraries:Adafruit_PWMServoDriver

Hardware:Servo Motors,Chassis,Power Supply,Jumper Wires,PCA9685 Servo Motor Driver

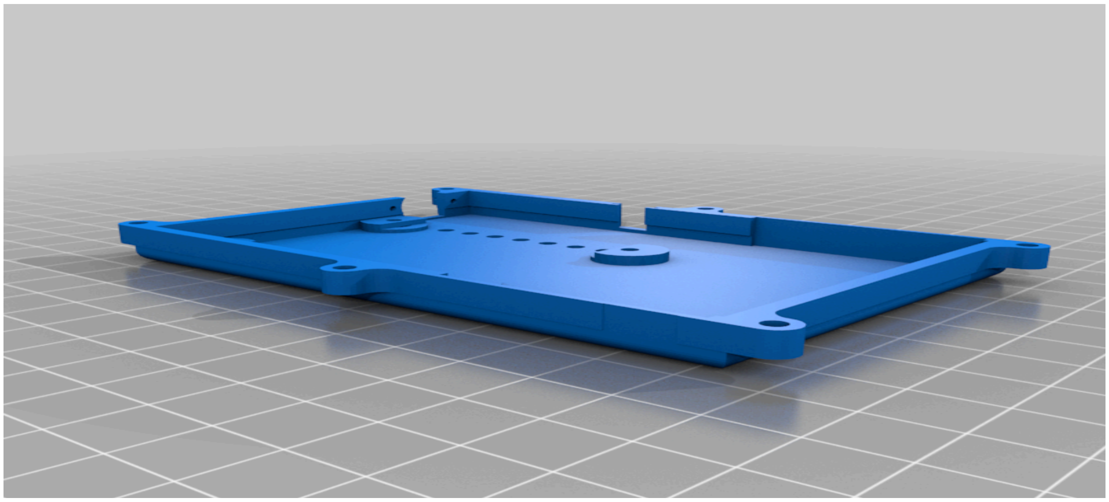
INTRODUCTION -

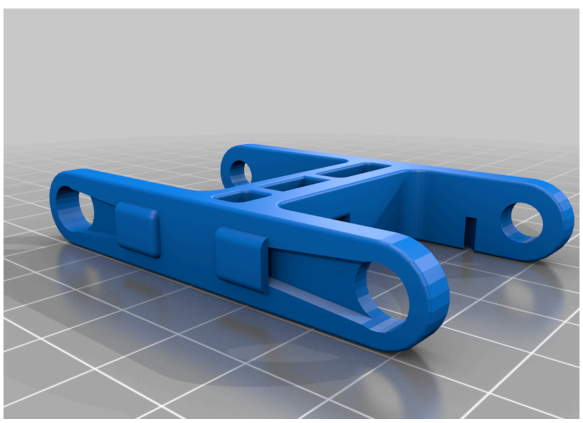
The Quadrupled Spider Robot is a four-legged walking robot inspired by the movement of spiders. It uses servo motors for each leg to achieve precise control and coordinated movement. The Arduino microcontroller is employed to control the servo motors, and the Adafruit_PWMServoDriver library is used for PWM signal generation.

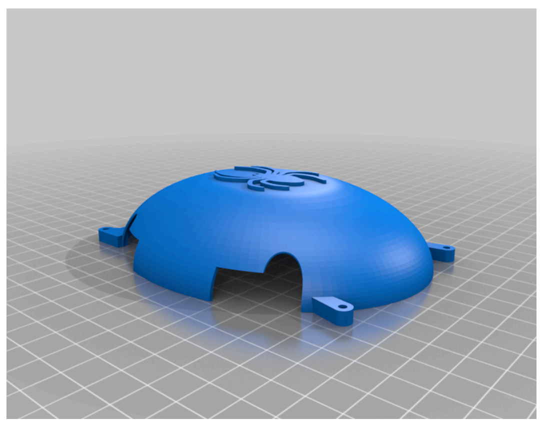
ROBOT STRUCTURE

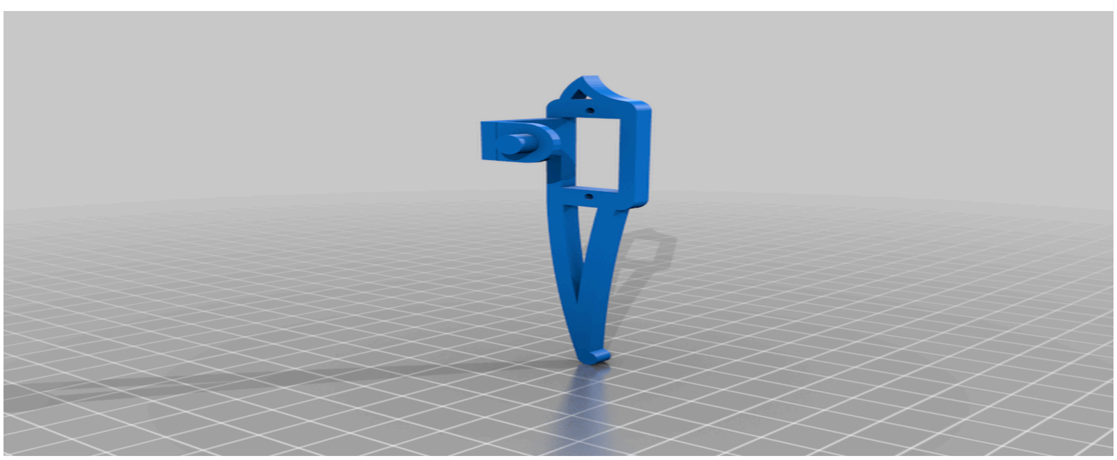


SPIDER BOT PARTS-









COMPONENTS -

1. Arduino Nano Board:

The Arduino Nano is a compact and versatile microcontroller board. It serves as the brain of the Spider Bot, responsible for processing instructions, controlling servo motors, and coordinating the overall motion. The Nano's small form factor makes it suitable for robotics projects, providing a balance between functionality and size.

2. Adafruit PWM Servo Driver:

The Adafruit PWM Servo Driver is a dedicated controller for managing multiple servo motors. It simplifies the process of controlling a large number of servos simultaneously, as it extends the limited number of PWM pins on the Arduino. This component is crucial for managing the numerous SG90 Mini Servo Motors used in the Spider Bot.

3. SG90 Mini Servo Motor (12):

The SG90 Mini Servo Motors are compact, lightweight motors with the capability to rotate within a specific range. In the Spider Bot, these servos actuate the various joints and limbs, enabling precise control over the movement of each leg. With 12 servos in total, distributed across the legs and body, they play a central role in achieving the spider-like motion.

4. Chassis and Legs:

The chassis forms the structural framework of the Spider Bot, providing support for attaching the servo motors and legs. The legs are designed to mimic the multi-jointed structure of a spider, facilitating agile and stable locomotion. The combination of a well-designed chassis and articulated legs contributes to the overall stability and functionality of the Spider Bot.

5. Power Supply (Battery):

The power supply, typically in the form of a battery, provides the necessary electrical energy to drive the Arduino Nano, Adafruit PWM Servo Driver, and the servo motors. The choice of an appropriate power supply is crucial to ensure that the Spider Bot operates reliably and has sufficient power to drive all its components during various movements.

6. Jumper Wires:

Jumper wires are used for establishing electrical connections between different components on the breadboard or within the circuit. In the Spider Bot, jumper wires play a vital role in connecting the Arduino Nano, PWM Servo Driver, and servo motors, enabling the seamless flow of control signals and power.

These components work in tandem to create a sophisticated robotic system. The Arduino Nano processes control signals, the Adafruit PWM Servo Driver manages servo motors efficiently, and the SG90 Mini Servos drive the leg movements, collectively contributing to the Spider Bot's dynamic and lifelike motion. The chassis and power supply provide the structural and electrical foundation for the entire system, while jumper wires facilitate the necessary connections to ensure smooth communication and operation.

WORKING OF THE BOT -

The Spider Bot's motion and functionality are achieved through a combination of trajectory planning, inverse kinematics, and the coordinated movement of its servo motors. Below is an elaboration of its working:

Initialization and Setup:

_____The Spider Bot uses an Arduino Nano board as its microcontroller.

- ❖ An Adafruit PWM Servo Driver is employed to control the numerous SG90 Mini Servo Motors efficiently.
- ❖ Twelve(12) SG90 Mini Servo Motors are distributed across the four legs(3 per leg) and body of the Spider Bot.
- ❖ The default, normal, and current positions of each servo motor are defined in arrays.

Standing Position:

- ❖ The Spider Bot is initially positioned in a stable standing position using inverse kinematics.
- ❖ The servo motors are tuned for stability while the robot is suspended above the ground with a rope.**Walking Steps:**

The walking cycle involves a series of steps, and each step is described as follows:

Leg Movement: The robot bends its knees, allowing one leg to swing above the ground while the other supports its weight.

Body Tilt: The upper body tilts in the opposite direction to provide enough height for the swinging leg.

Leg Placement: Both legs are placed on the ground to support the robot for further walking steps.

Leg Swing: The free leg swings forward, and the hip center trajectory is controlled using trajectory planning equations.

Body Re-Centering: Both legs come together, and the body re-centers to its normal standing position.

Trajectory Planning:

- ❖ Trajectory planning involves determining the time series of successive joint angles for coordinated leg and body movements.
- ❖ Hyperbolic, elliptical, and straight-line trajectories are used for the hip center, providing controlled, stable, and agile motion.

Inverse Kinematics:

- ❖ Inverse kinematics is employed to calculate the required joint angles for the robot to achieve specific positions or motions.
- ❖ Joint configurations are determined using closed-form solutions, ensuring stable motion of the Quadrupled Spider Bot.

Turning and Shifting:

- ❖ The Spider Bot can execute turns and shifts using a combination of trajectory planning and inverse kinematics.
- ❖ Specific functions(user defined), such as turnRight and centerShift, are utilized for controlled turning and lateral movements.

Walking Sequence:

The Spider Bot executes a sequence of leg movements, including lifting, swinging, and placing, to achieve forward motion. Coordinated movements of all legs are orchestrated to mimic the walking cycle.

User Interaction:

- ❖ The Spider Bot can respond to user commands received through the serial interface.
- ❖ Users can adjust the position of individual servo motors in real-time to control the Spider Bot's motion.

Power Supply and Components:

The Spider Bot is powered by a battery, and its components include an Arduino Nano, Adafruit PWM Servo Driver, SG90 Mini Servo Motors, chassis, legs, and jumper wires.

In summary, the Spider Bot's intricate motion is achieved through a combination of precise trajectory planning, inverse kinematics, and coordinated control of its servo motors. The provided code defines various functions and sequences that enable the Spider Bot to exhibit lifelike movements, resembling the walking pattern of a spider.

METHODOLOGY -

Steps involved:

Setup:

- ➔ Initialize Communication and Servo Motor Settings
- ➔ Set Initial Position using setMotors and standing functions

Basic Motions:

- ➔ Implement standing, moveUpDown, turnRight, etc.
- ➔ Use inverse kinematics functions for precise control

Inverse Kinematics Functions:

- ➔ Implement invKin for calculating joint angles
- ➔ Consider spiderbot geometry and servo motor constraints

Trajectory Generation:

- ➔ Develop Trajectory and moveLeg functions
- ➔ Define smooth trajectories for leg motions

Center Shift and Turn Functions:

- ➔ Implement centerShift for lateral movement
- ➔ Implement turn for turning
- ➔ Adjust spiderbot position by modifying joint angles

Walking Algorithm (moveBot):

- ➔ Integrate trajectory planning and motion functions
- ➔ Move each leg independently for coordinated walking

Serial Communication:

- ➔ Implement serial communication for dynamic updates
- ➔ Read input values and update FinalMotorPosition accordingly

Testing and Debugging:

- ➔ Test each motion independently
- ➔ Use serial communication for debugging and dynamic adjustments

Trajectories for Spider Bot:

Trajectory planning is instrumental in orchestrating the motion of the Spider Bot, dictating a sequential series of joint angles over time to seamlessly transition the robot from an initial configuration to a goal configuration, effectively accomplishing various tasks.

Trajectory Equations:

We employ diverse trajectory equations to enhance the stability and efficiency of the Spider Bot. A third-order polynomial function with variable time (t) is utilized to articulate the trajectories of the robot, ensuring that factors such as distance, speed, and acceleration are all taken into consideration during trajectory planning. The equation is defined as follows:

$X = a0 + a1(t) + a2(t)^2 + a3(t)^3$

Trajectory of Leg Joints:

The trajectory of the leg joints plays a pivotal role in controlling the Spider Bot's movement. Various trajectory patterns are utilized to achieve specific characteristics in motion.

- **Hyperbolic Trajectory:** This involves moving the leg joints in a pattern resembling a hyperbola, allowing controlled and agile movements. Inverse kinematics is employed to calculate the joint angles required for executing this trajectory.
- **Elliptical Trajectory:** Moving the leg joints in a circular or oval pattern, providing stability. Inverse kinematics is used to calculate the joint angles for executing the elliptical trajectory.
- **Straight Line Trajectory:** Involves moving the leg joints in a straight line, ideal for quick, efficient, stable, and controlled movements. Joint angles for this trajectory are calculated using inverse kinematics.

Trajectory of Foot:

During the Spider Bot's walking steps, the trajectory for its foot involves an elliptical pattern. The choice of an elliptical trajectory contributes to better stabilization and agile walking.

Various Motions:

Leg Movement Sequences:

- *Left Leg Starting:* The robot bends its knee, tilts towards the right, and re-centers its hips for balance.
- *Right Leg Walking:* The robot swings its right leg, tilts left for walking steps, and re-centers hips.
- *Left Leg Walking:* Similar to right leg walking, with swings and tilting towards the right.
- *Right Leg Stopping:* Swings right leg, tilts left, aligns the right leg parallel to the left, and re-centers hips to stop.

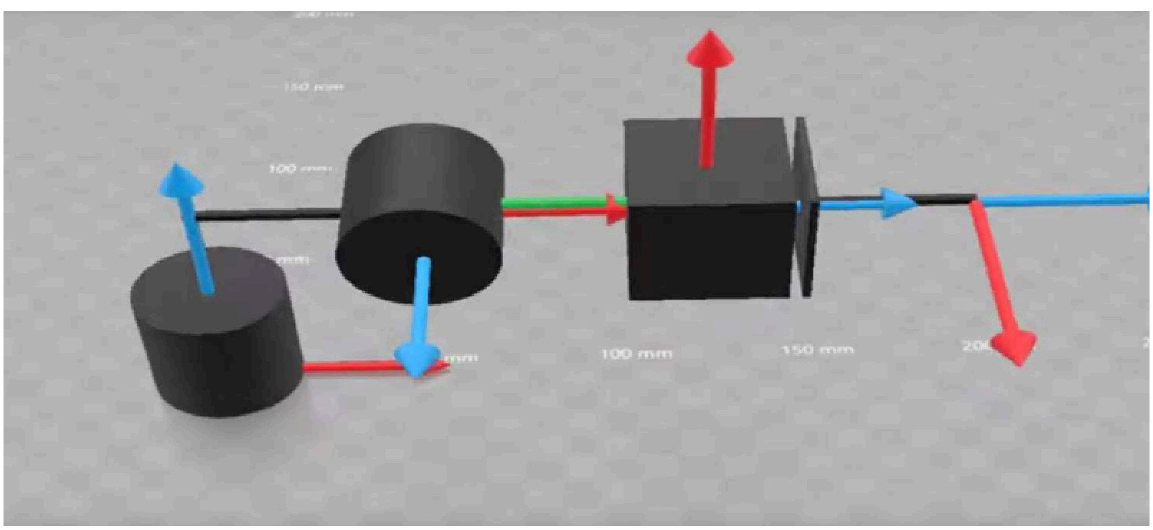
Inverse Kinematics:

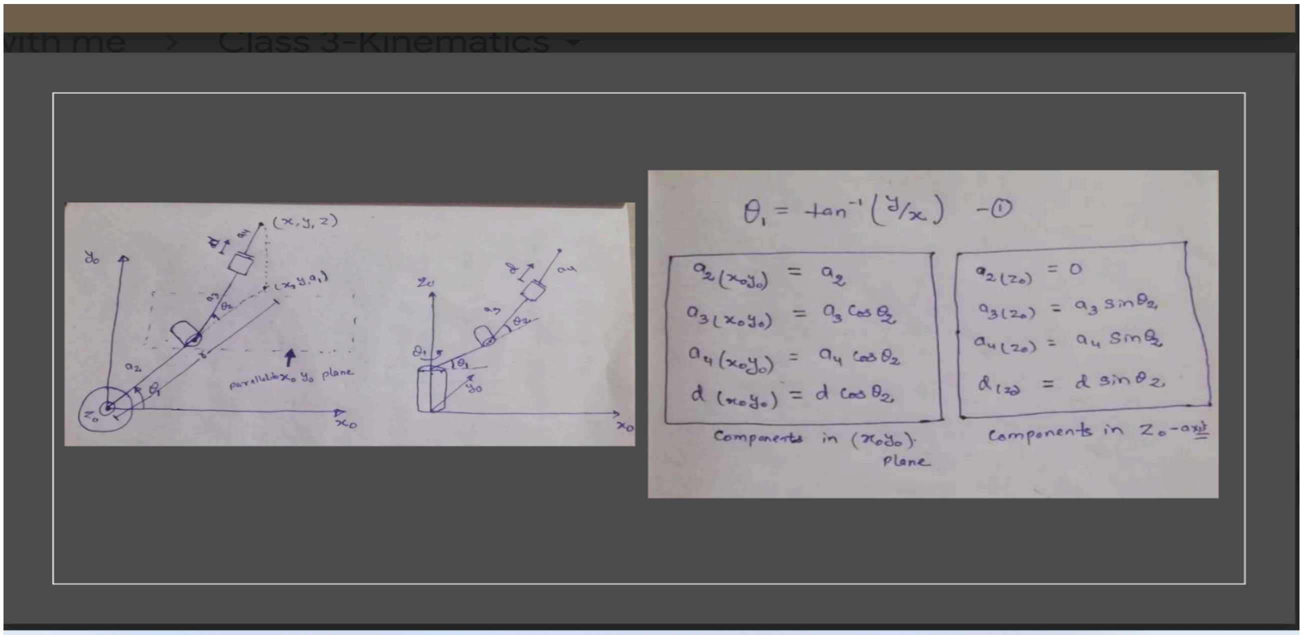
Inverse kinematics is crucial for determining the joint angles required to achieve specific positions or motions. By employing inverse kinematics, we calculate the precise joint configurations needed for stable and controlled motion.

Joint Angle Positioning:

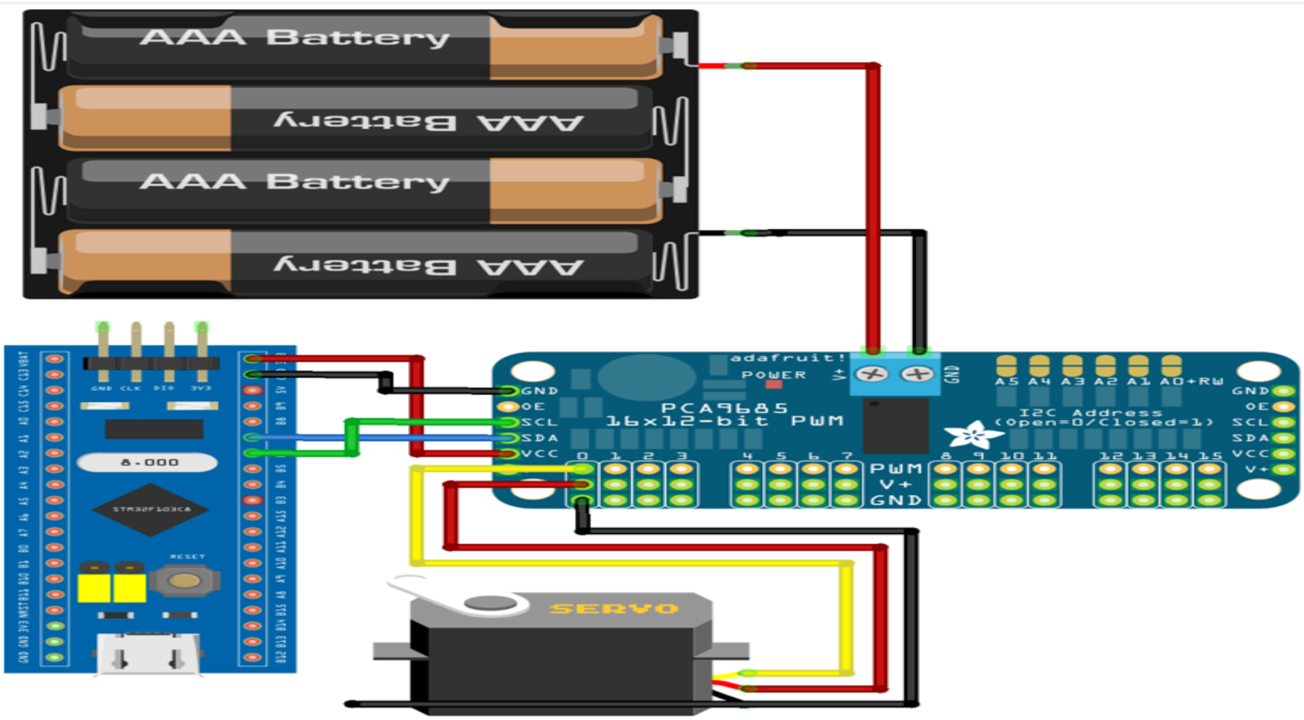
Once the trajectory pattern is established, inverse kinematics is utilized to calculate the required joint angles for the Spider Bot to seamlessly follow the desired trajectory. This involves leveraging the geometric properties of the robot and the target position or motion in three-dimensional space.

By integrating these trajectory planning techniques, inverse kinematics, and joint angle positioning, the Spider Bot achieves sophisticated and stable motion, making it adaptable to diverse scenarios and tasks.





CIRCUIT DIAGRAM -



Resources-

1.Arduino Official Website: https://www.arduino.cc/

Adafruit_PWMServoDriver Library Documentation:
https://www.arduino.cc/reference/en/libraries/adafruit-pwm-servo-driver-library/

2.Servo Motor Datasheets: https://datasheetspdf.com/pdf/791970/TowerPro/SG90/1

3.PCA9685 Datasheets:
https://cdn-learn.adafruit.com/downloads/pdf/16-channel-pwm-servo-driver.pdf

4.Forward and Inverse Kinematics:

Lec1 - Class 1-Kinematics

Lec2 - Class 2-Kinematics

Youtube Link:

➔ https://www.youtube.com/playlist?list=PLT_0lwItn0sDBE98BsbaZezflB96ws12b

(Video: Video7-Video 23)

➔ https://www.youtube.com/playlist?list=PLT_0lwItn0sAfi3o4xwx-fNfcnbfMrXa7
(Video:Video1-Video9)

5.Trajectory Planning

Lecture 11: Trajectory Planning

VIDEO LINK -

REAL-LIFE APPLICATIONS -

1. **Search and Rescue Operations:**

   ➔ **Capabilities:** Climbing, versatile locomotion.
   ➔ ·**Implementation:** Deployment in disaster-stricken areas for exploring complex terrains, locating survivors, and aiding rescue efforts.

2. **Exploration in Unknown Environments:**

   ➔ **Capabilities:** Adaptability, sensor integration.
   ➔ **Implementation:** Planetary exploration, underground exploration in caves or mines, leveraging climbing abilities for navigation.

3. **Surveillance and Monitoring:**

   ➔ **Capabilities:** Stealth, maneuverability, 360-degree vision.
   ➔ **Implementation:** Security surveillance in complex environments, environmental monitoring in challenging or remote areas.

PROBLEM FACED -

1)Servo Attachment to Chassis

2)Chassis Integrity Issues

3)Code Debugging

4)Circuit Connection Challenges

5)Power Supply Optimization

6)Leg Coordination and Movement Calibration

Thank you

TEAM SPIDERBOT