INTERNATIONAL CONFERENCE ON POWER, ELECTRICAL, ELECTRONICS AND INDUSTRIAL APPLICATIONS (PEEIACON) 2024

PAPER TITLE - DESIGN AND DEVELOPMENT OF LEO: AN AFFORDABLE BIOMECHANICALLY INSPIRED QUADRUPED ROBOT WITH COGNITIVE ABILITIES

Paper ID - 200

Authors:

Jubaer Tanjil Jami

Taskin Mehereen

Munirul Alam

Mir Tahmidur Rahman

Authors' Affiliation:

Department of Mechanical Engineering

Bangladesh University of Engineering and Technology (BUET)

Presenting Author: Taskin Mehereen

Contents

INTRODUCTION

Quadruped Robots: Mimic 4-Legged Animals

Quadruped Robots: Mimic 4-Legged Animals

Military Use

Image courtesy: Spot

Terrain Exploration

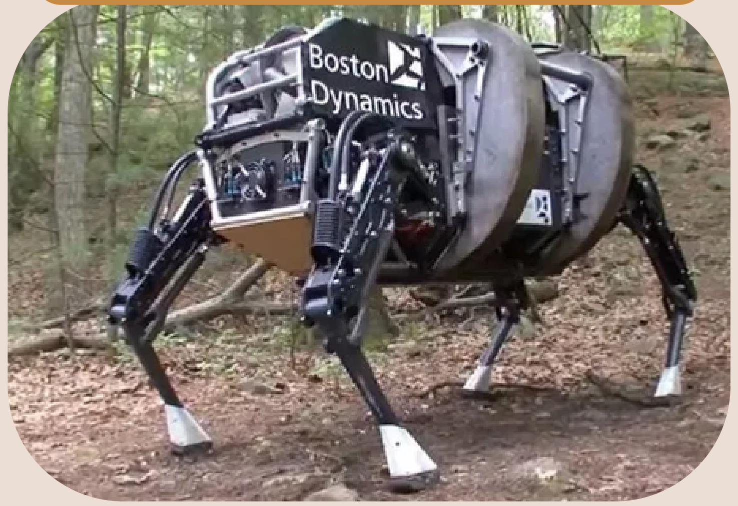


Image courtesy: BigDog

Industry Exploration

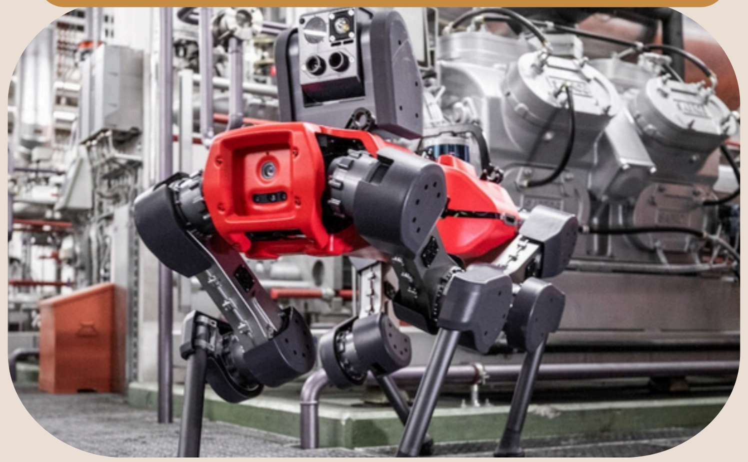


Image courtesy: ANYmal

Stair Climbing

Image courtesy: MIT Cheetah

Quadruped Robots: Mimic 4-Legged Animals

Military Use

Image courtesy: Spot

Terrain Exploration

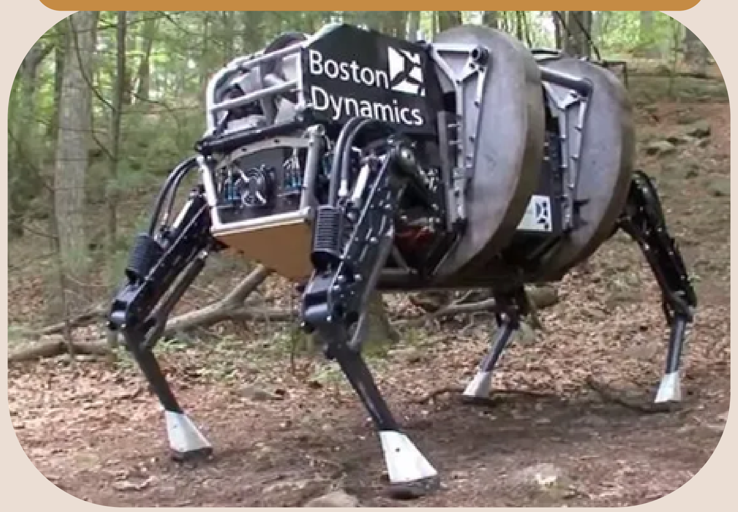


Image courtesy: BigDog

Industry Exploration

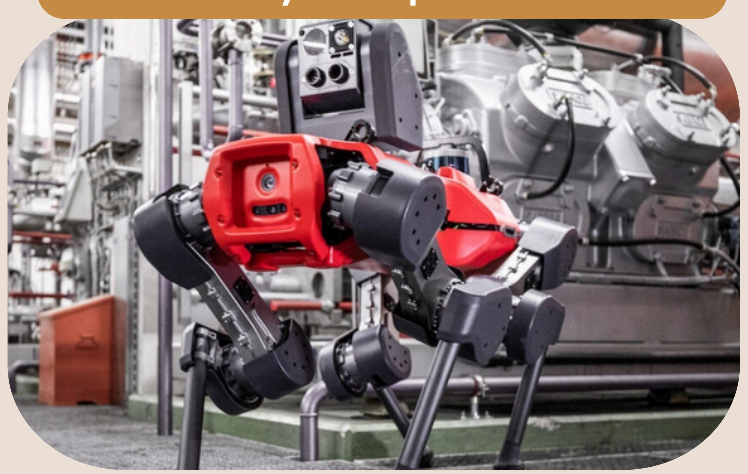
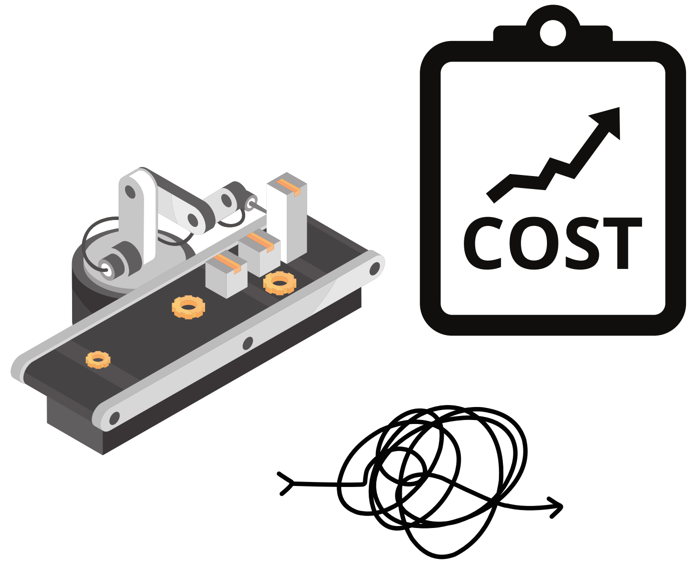


Image courtesy: ANYmal

Stair Climbing

Image courtesy: MIT Cheetah

High Development Complexity & Cost



Limited accessibility for research and education.

Objective: Development of Leo, a Quadruped Robot

Scope of the Research:

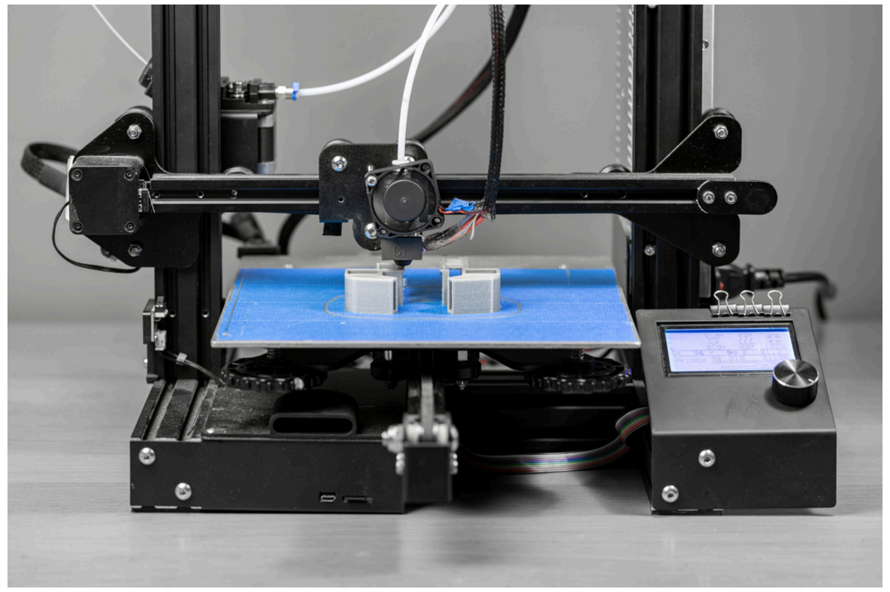
- Low-cost, light-weight
- Biomechanically inspired design.
- Equipped with cognitive abilities.

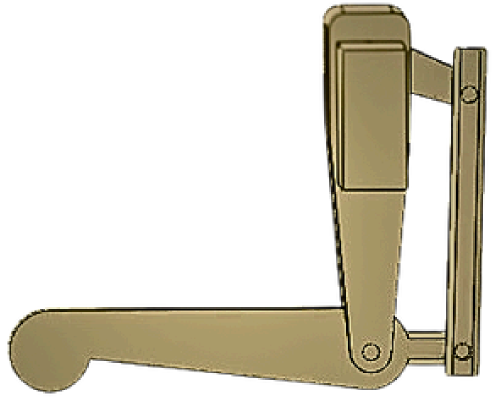
Explore potential applications in research, education, and small-scale tasks.

METHODOLOGY

MECHANICAL DESIGN

- **Materials:**

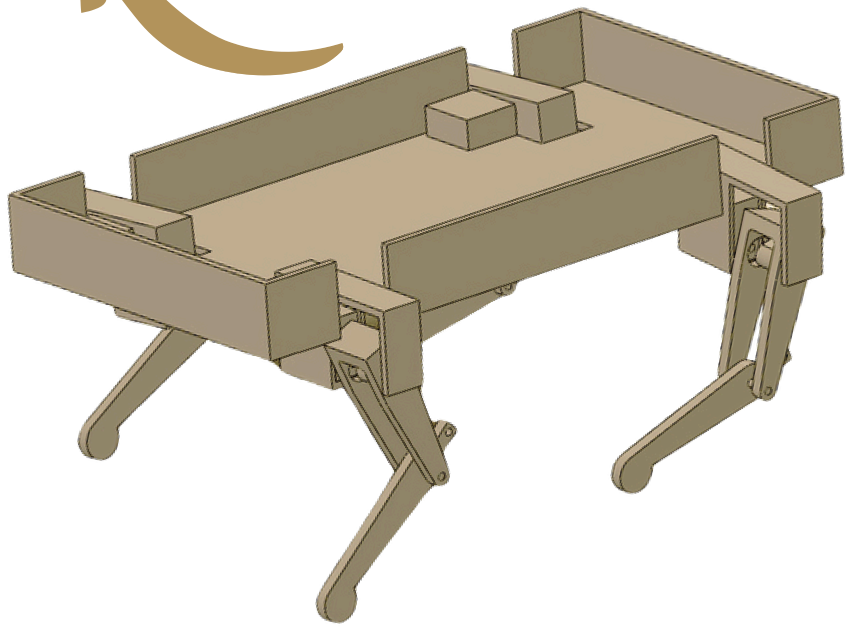




Leg: 3D-printed

Polylactic Acid (PLA)

Torso : Laser-Cut Poly Methyl Methacrylate (Acrylic Plastic) sheet

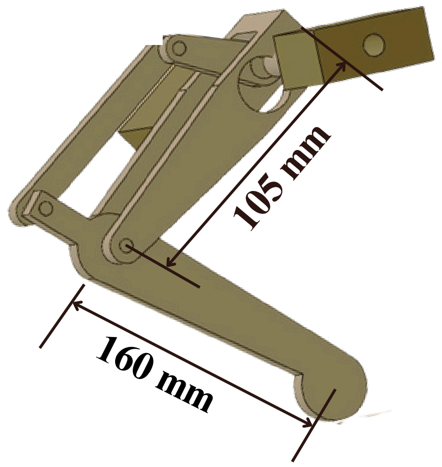


MECHANICAL DESIGN

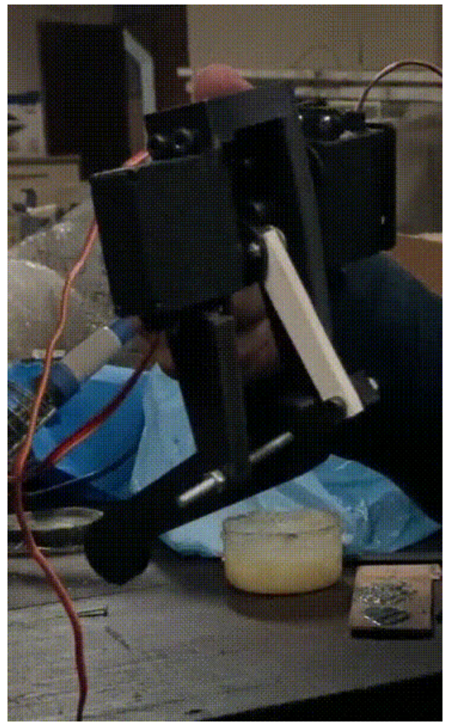
- **Leg Design**

LEO DESIGN SPECIFICATIONS

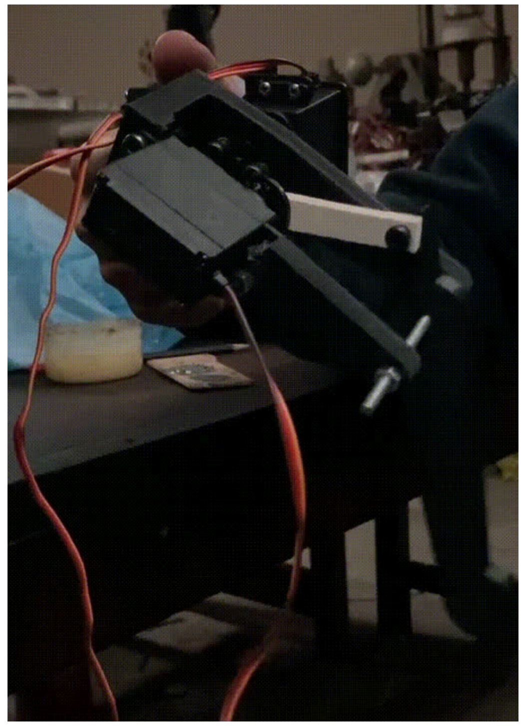
Length	550 mm
Width	400 mm
Height	100 mm
Foot Distance	350 mm
Thigh Length	105 mm
Calf Length	160 mm
Freedom	12



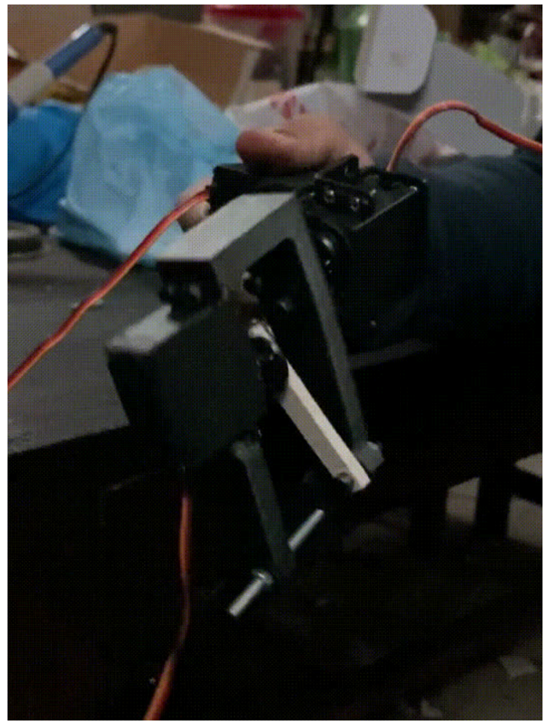
- **Degrees of Freedom**



crank shaft motion



pitching

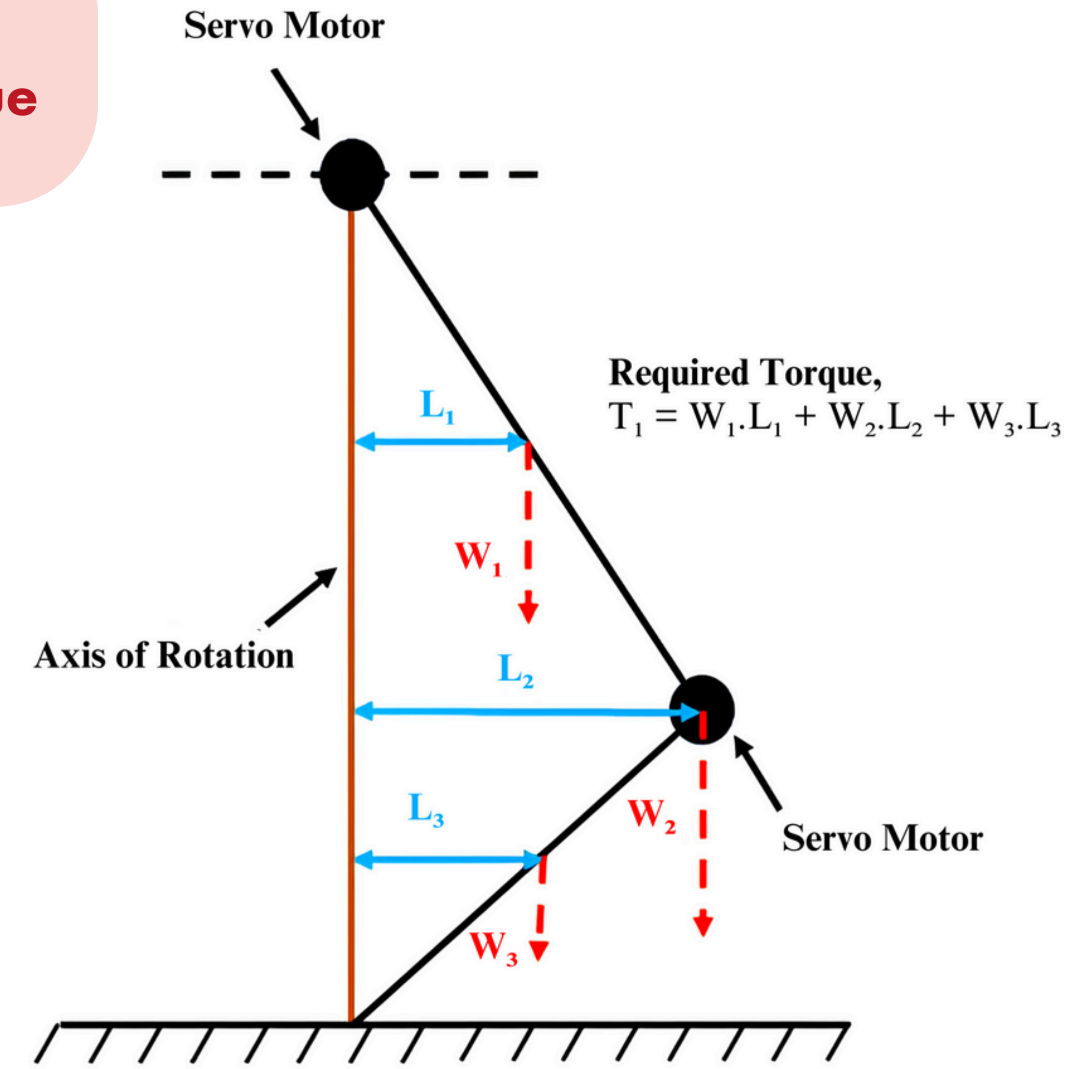


rolling

Crankshaft Mechanism to reduce **Torque Requirement**

Knee Motor:

Greater Torque

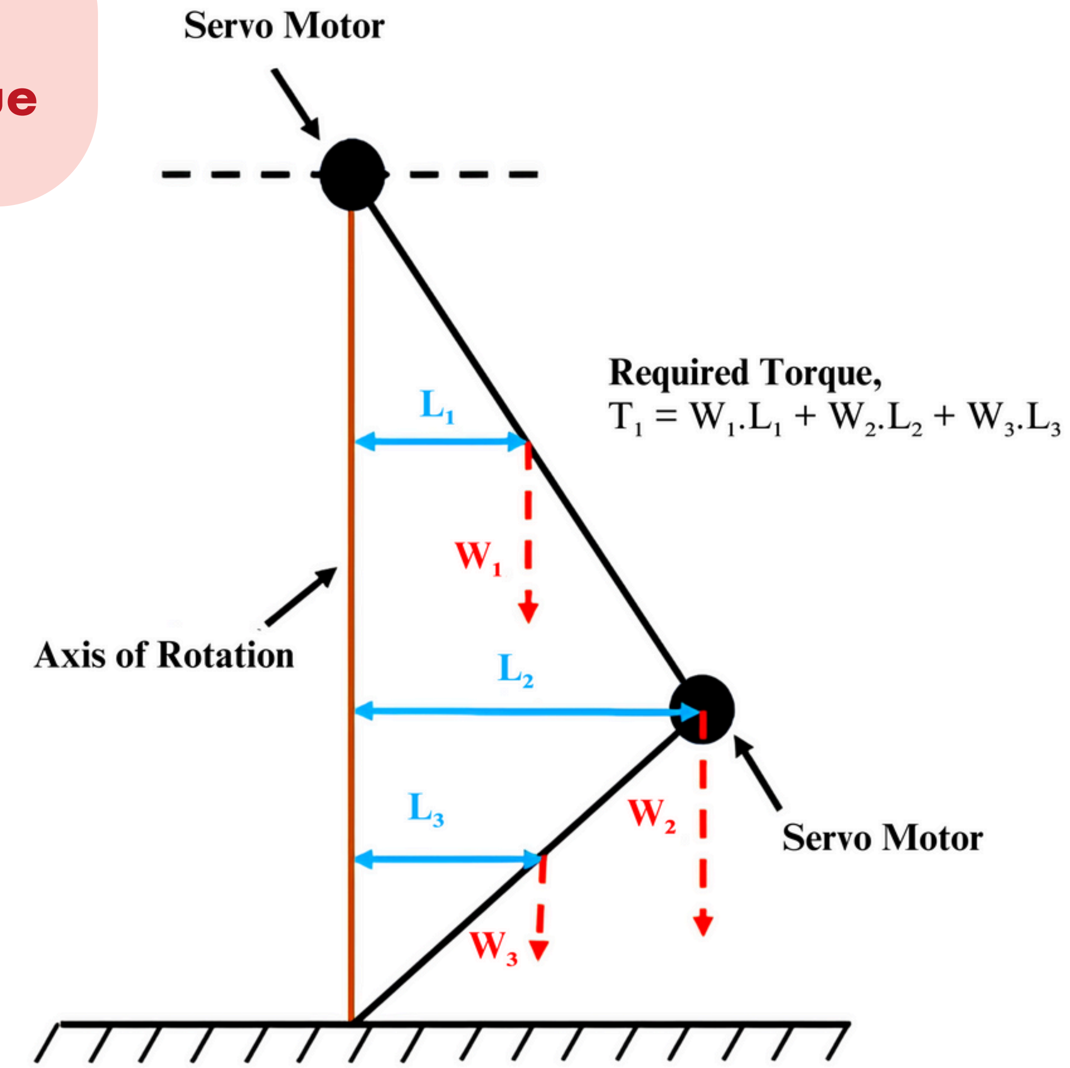


METHODOLOGY

Crankshaft Mechanism to reduce **Torque Requirement**

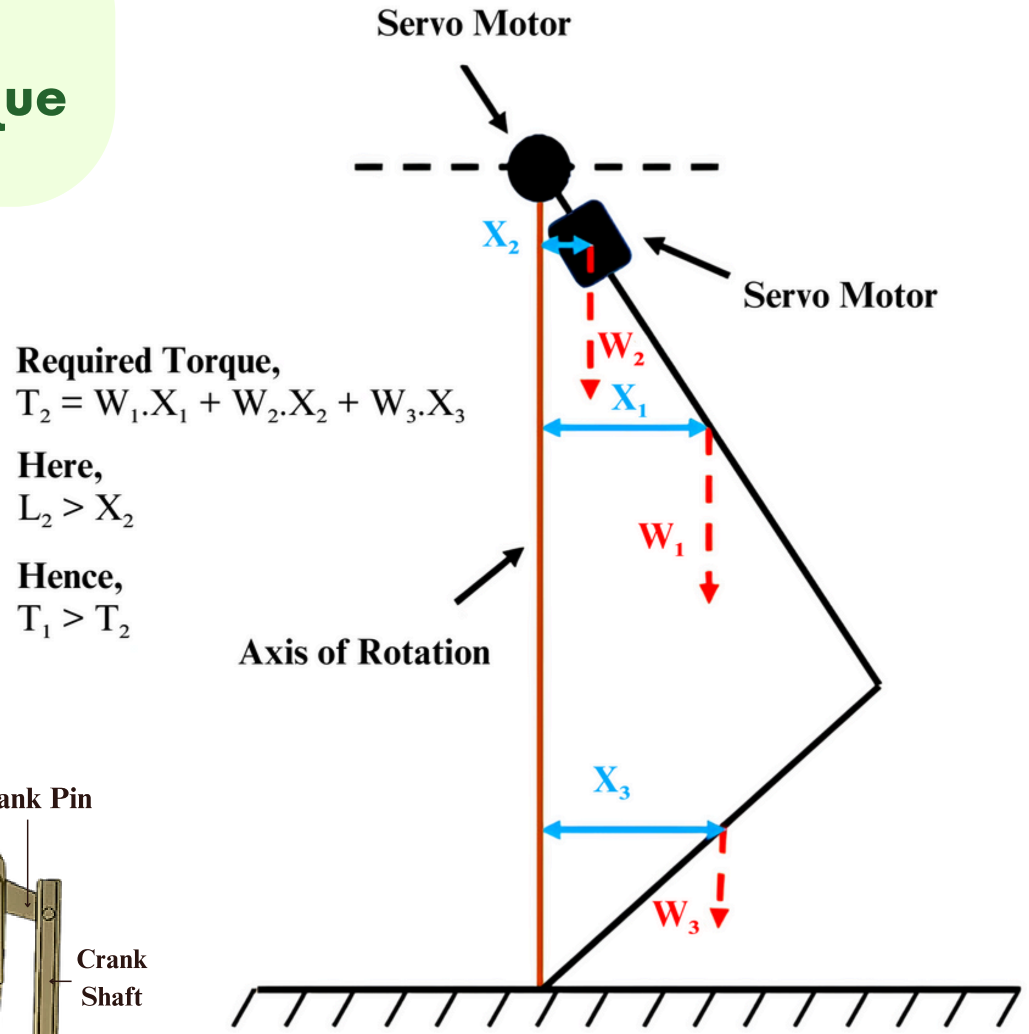
Knee Motor:

Greater Torque

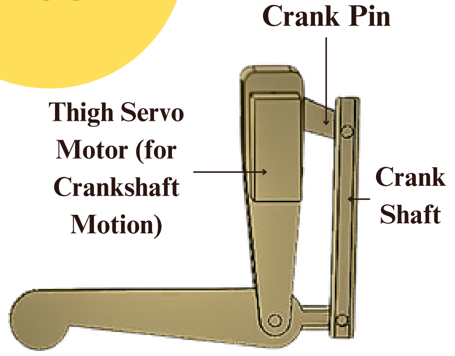


Hip Motor:

Reduced Torque



Used by Leo



METHODOLOGY

GAIT ANALYSIS

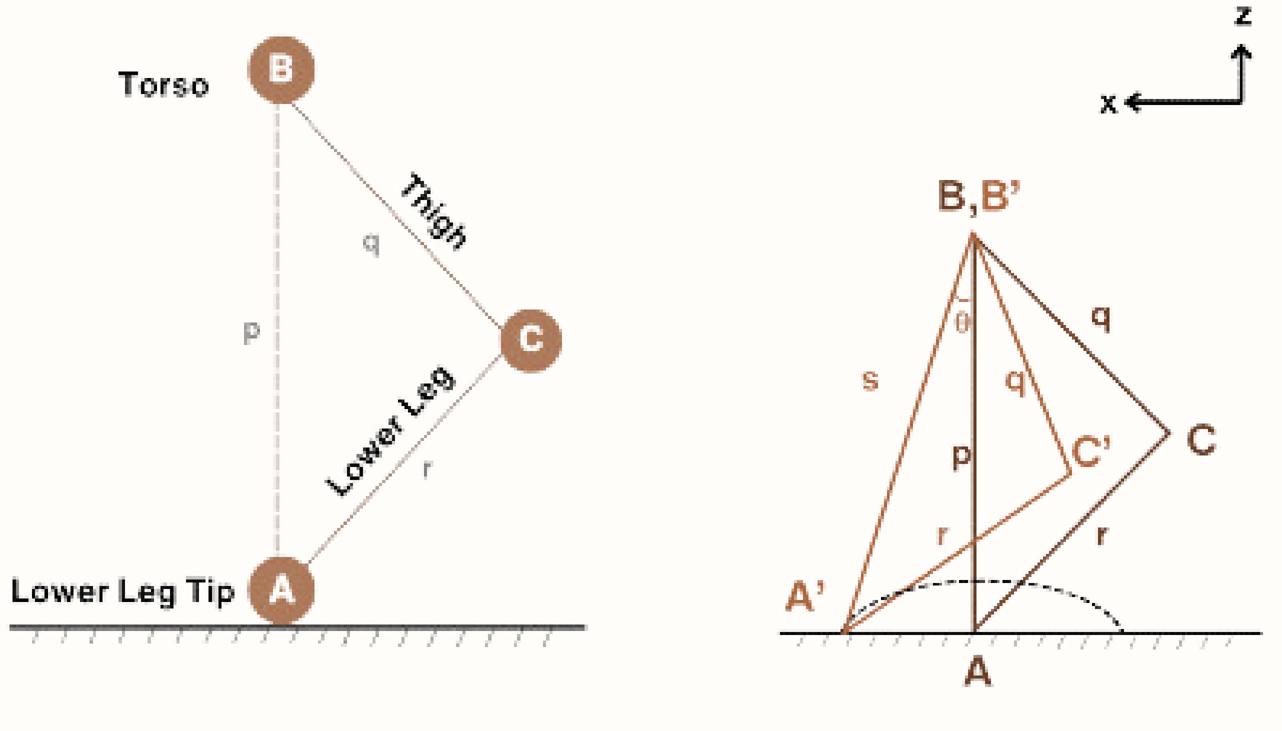


Figure: (a) Standing algorithm (b) Walking algorithm

Elliptical trajectory

$$A' = cos^{-1}\frac{s^2 + r^2 - q^2}{2sr}$$

$$B' = cos^{-1}\frac{q^2 + s^2 - r^2}{2qs}$$

$$C' = cos^{-1}\frac{q^2 + r^2 - s^2}{2qr}$$

$$tan\,\theta = \frac{x}{p}$$

$$s = \frac{p}{cos\,\theta}$$

$$\frac{x^2}{q^2} + \frac{z^2}{r^2} = 1$$

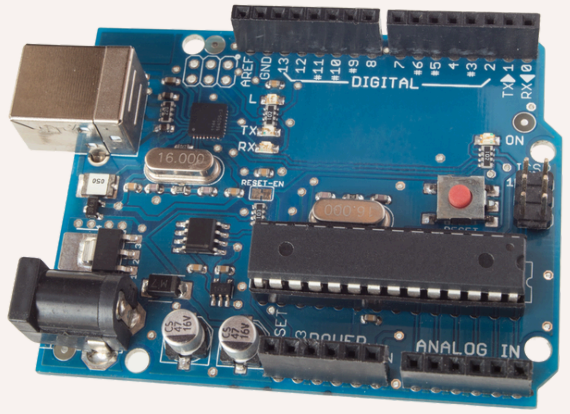
- The algorithm syncs **lower leg**, **torso**, and **thigh.**

↓ **Vertical movement** maintains balance.

→ **Horizontal movement** drives forward motion.

CONTROL SYSTEM

ROS +



$$A' = \cos^{-1}\frac{s^2 + r^2 - q^2}{2sr}$$

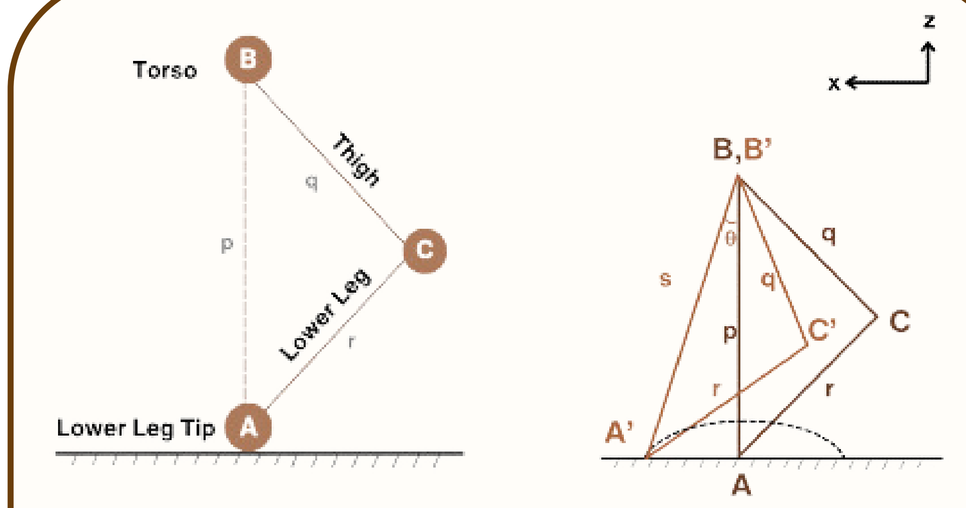
$$B' = \cos^{-1}\frac{q^2 + s^2 - r^2}{2qs}$$

$$C' = \cos^{-1}\frac{q^2 + r^2 - s^2}{2qr}$$

$$\tan\theta = \frac{x}{p}$$

$$s = \frac{p}{\cos\theta}$$

$$\frac{x^2}{q^2} + \frac{z^2}{r^2} = 1$$

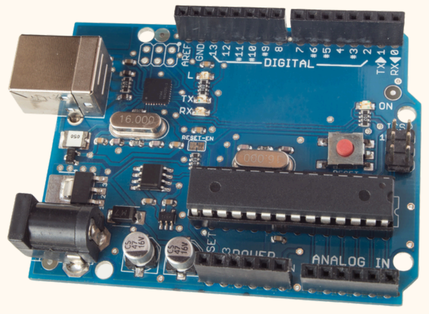


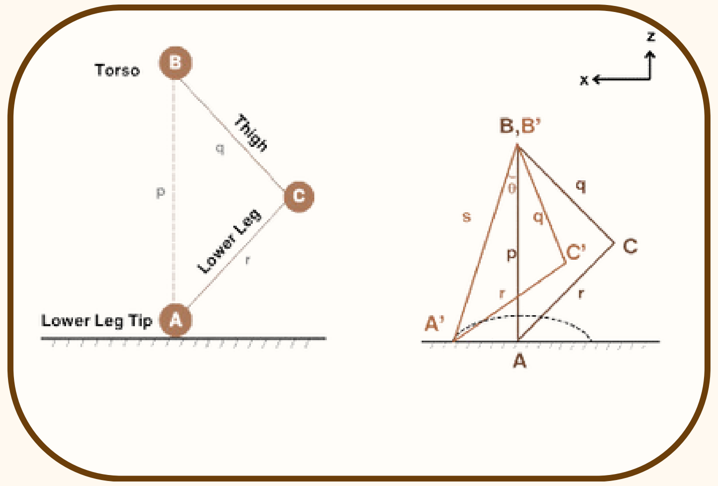
- Motion control driven by ROS and Arduino interfacing.
- Custom gait algorithm for locomotion.
- Twelve servo motors calibrated at startup for proper stance.
- Trigonometric calculations for natural quadruped gait.
- Elliptical pathway determines 3D leg coordinates.

METHODOLOGY

CONTROL SYSTEM

ROS +

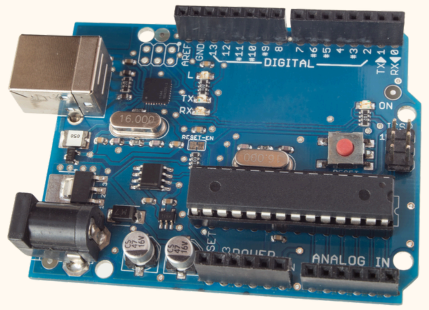


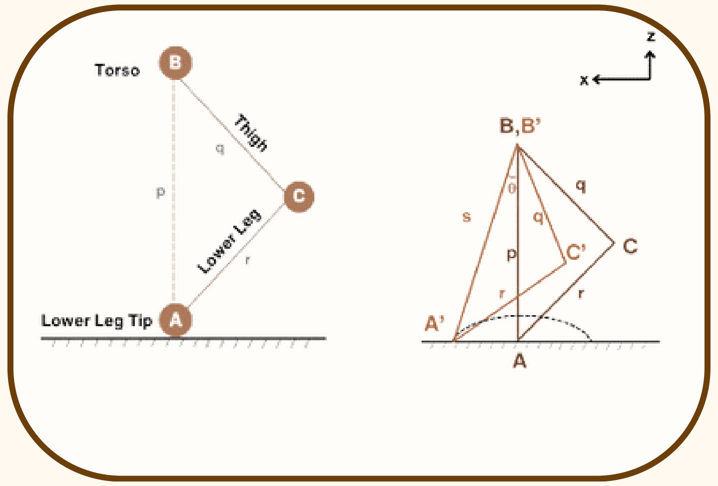


METHODOLOGY

CONTROL SYSTEM

ROS +





Manual Mode

Bluetooth Command

↓

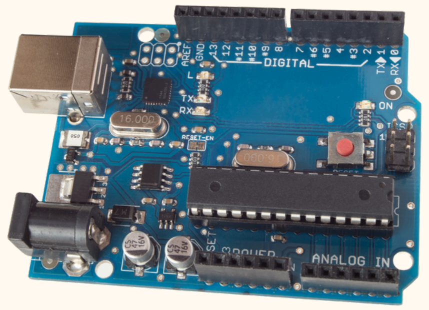
Gait Algorithm

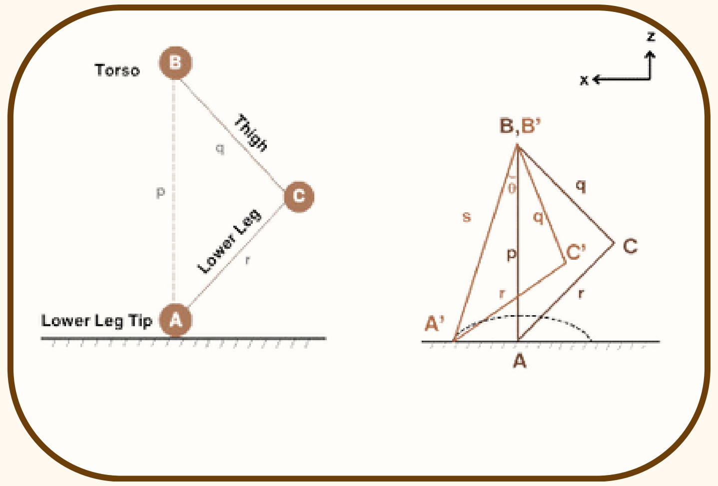
↓

Leg Angles adjusted for Standing & Walking

CONTROL SYSTEM

ROS +





Manual Mode

Bluetooth Command

↓

Gait Algorithm

↓

Leg Angles adjusted for Standing & Walking

Semi-Autonomous Mode

Audio Command

↓

alphacep/ros-vosk

Vosk node for ROS Robot Operating System

Text Command

↓

ChatGPT API

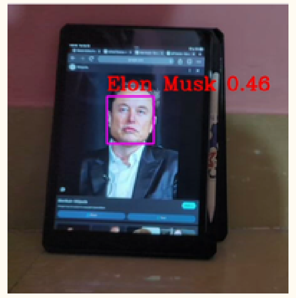
↓

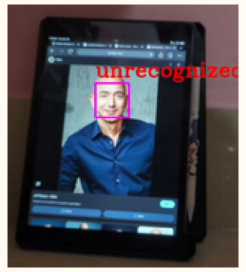
Gait Algorithm → Leg Angles adjusted for Standing & Walking

METHODOLOGY

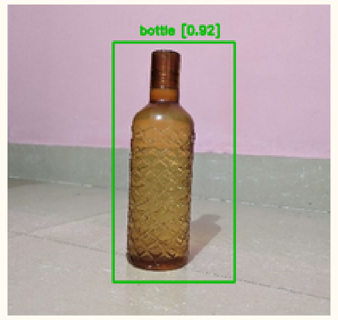
CONTROL SYSTEM

Object Detection & Face Recognition





Face Detection



Object Detection

Sonar Sensor

Camera

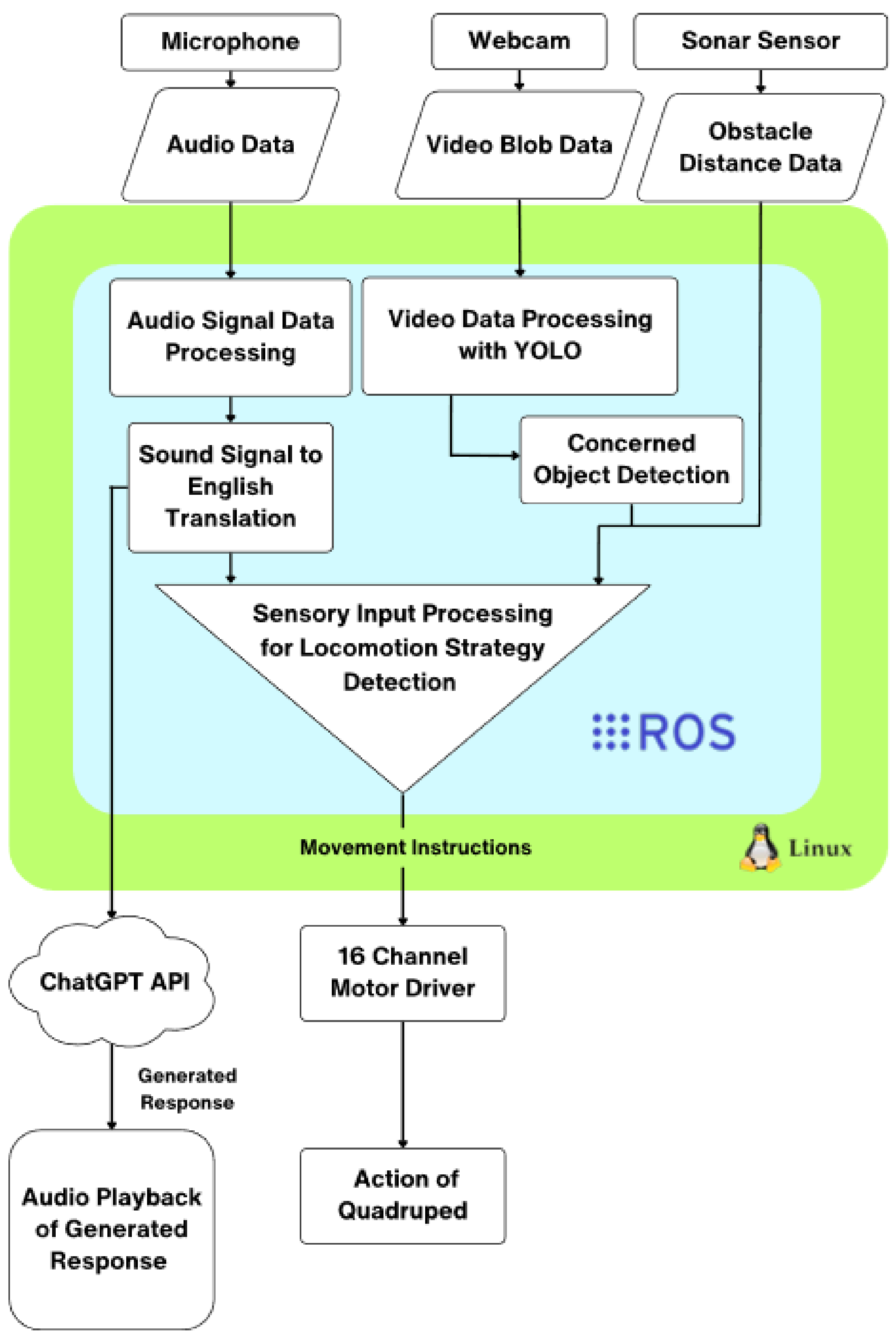
Data Sensing → Real-Time Object Detection & Face Recognition using YOLO v4 → Environmental Awareness →

- Obstacle Avoidance
- Move to Owner

YOLO

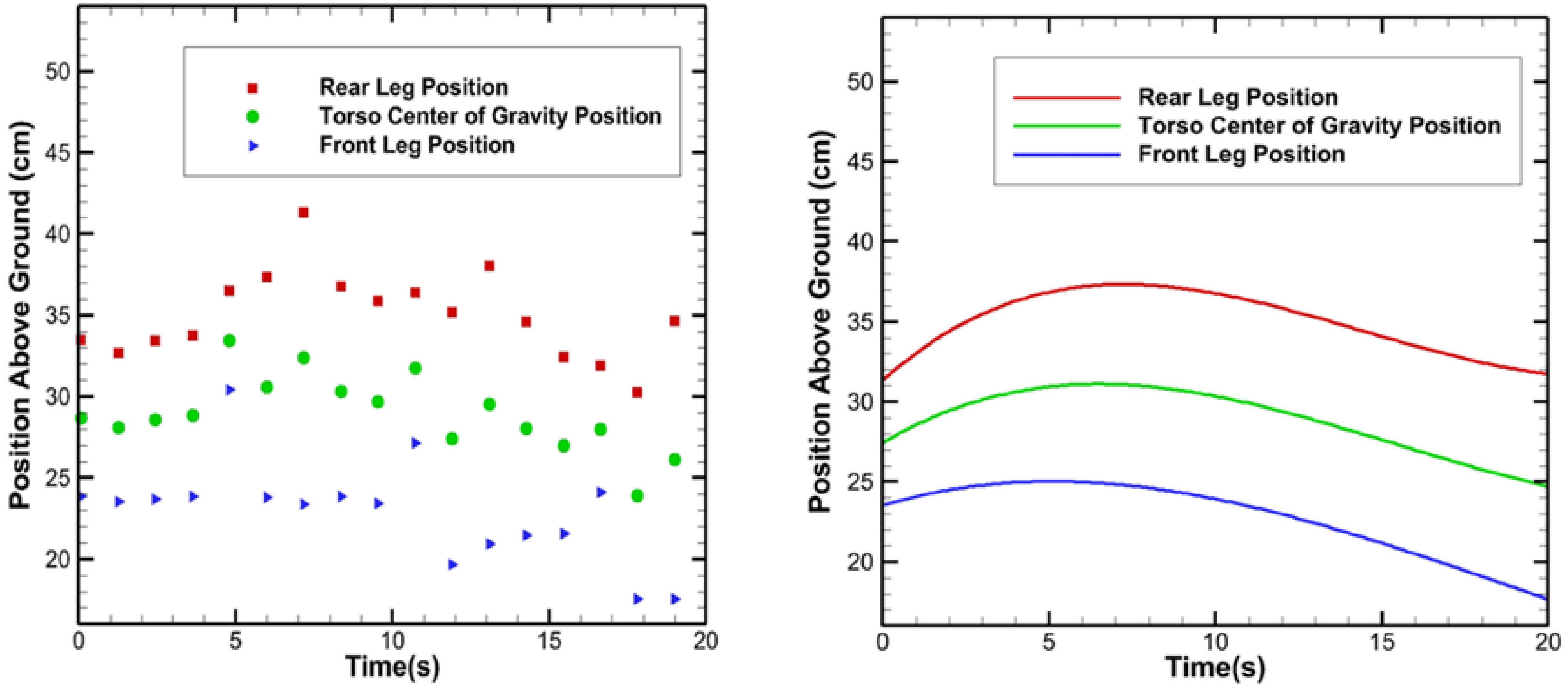
CONTROL SYSTEM

System architecture of the semi-autonomous control mechanism of Leo



KEY FINDINGS AND DISCUSSION

Variation of Rear Leg, Torso Center of Gravity, and Front Leg Positions Over Time During One Complete Step



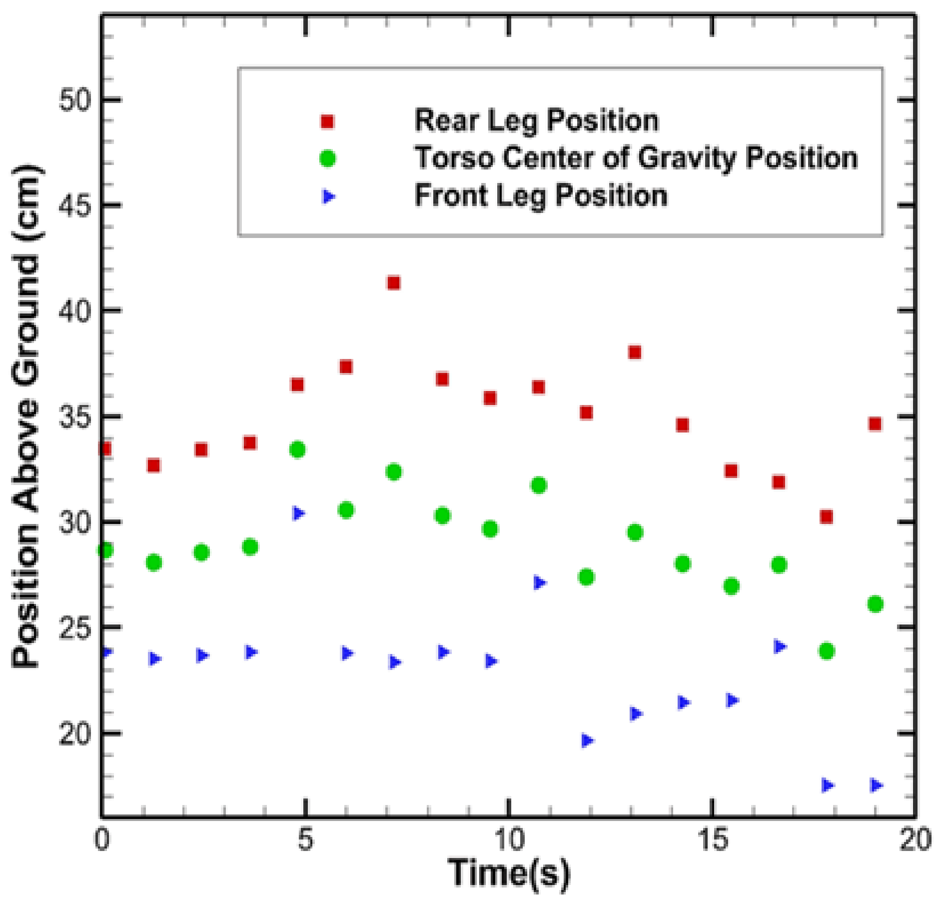
(a) Measured Data Points

(b) Fitted Curve Denoting an Elliptical Trajectory

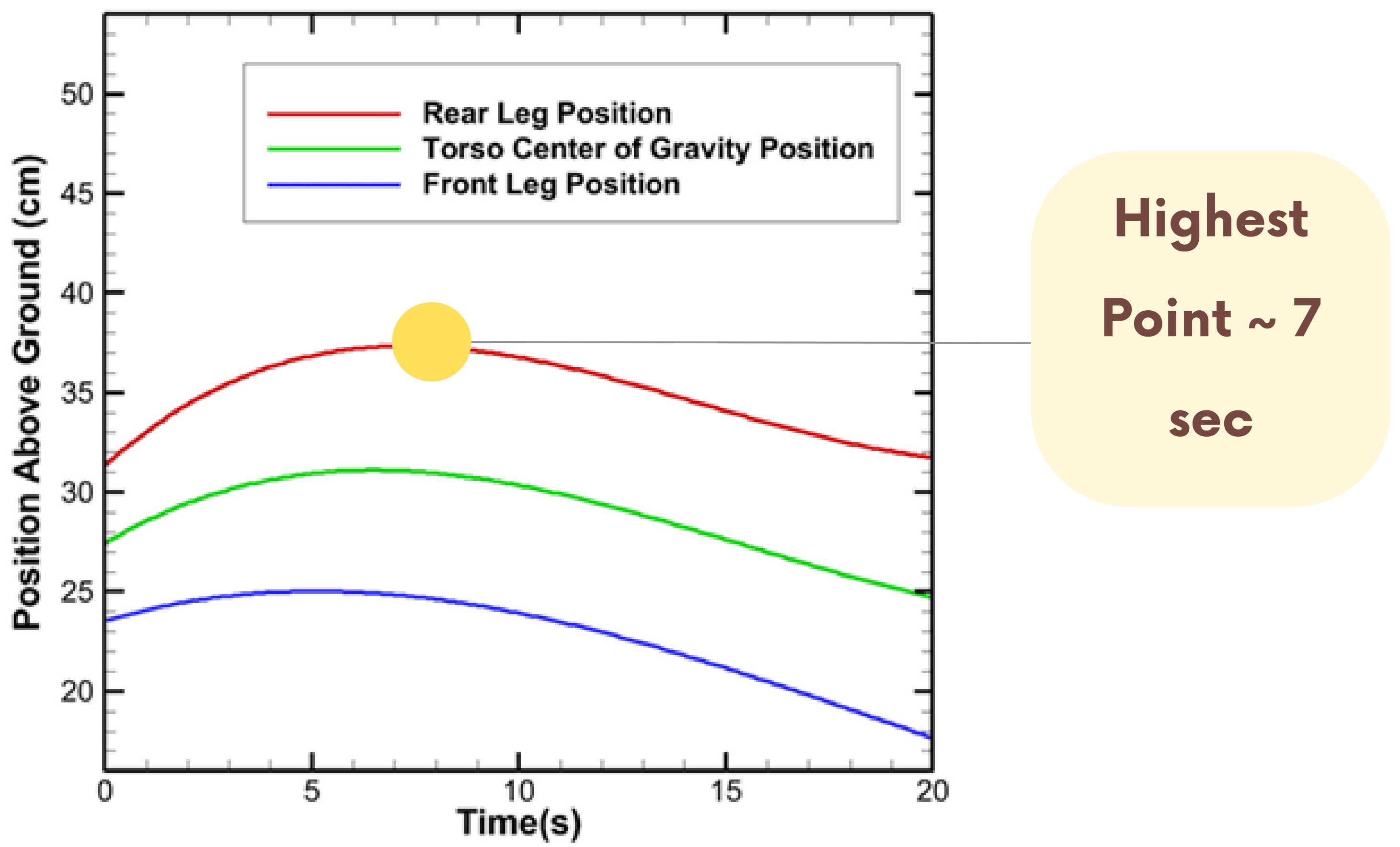
Gait analysis revealed an elliptical trajectory with a walking cycle of 19-20 seconds.

KEY FINDINGS AND DISCUSSION

Variation of Rear Leg, Torso Center of Gravity, and Front Leg Positions Over Time During One Complete Step



(a) Measured Data Points

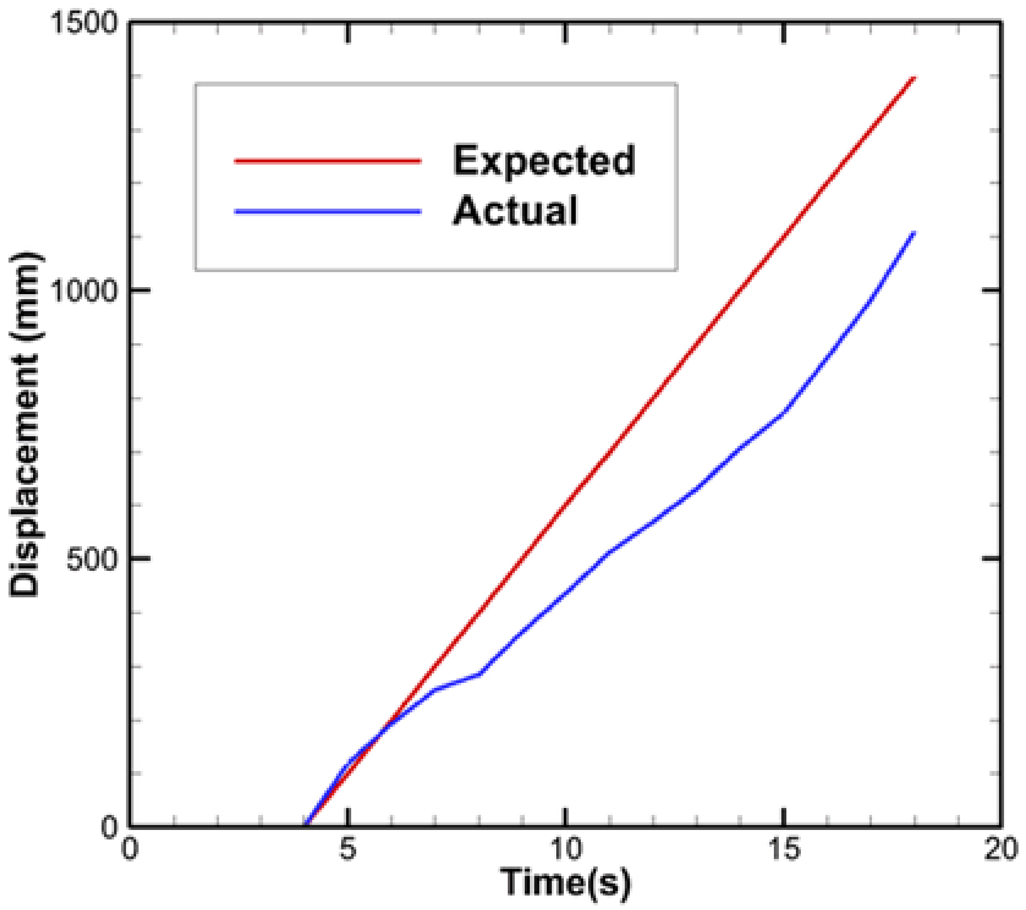


(b) Fitted Curve Denoting an Elliptical Trajectory

Gait analysis revealed an elliptical trajectory with a walking cycle of 19-20 seconds.

KEY FINDINGS AND DISCUSSION

Variation of expected versus actual displacement of Leo with time



Real-world conditions introduce approximately 25% deviation from the intended path due to various losses and environmental factors compared to ideal controlled environments

FUTURE WORK

- Transition to more rigid body materials and metal servo gears for increased durability.
- Enhance gait control algorithms using Machine Learning and Deep Learning for improved outdoor performance.
- Implement Simultaneous Localization and Mapping (SLAM) for full autonomous navigation.
- Develop dynamic voice control features with advanced Natural Language Processing.
- Improve gait and balancing algorithms to increase load capacity for industrial applications.
- Adapt design for operation in industrial, military, and polluted environments.

THANK YOU!