Gait Control of Lower Body Exoskeleton

B. Tech Final Year Project Review

Project Members

Adithya Venkata Narayanan – 111120001
R Charan Bhardhwaj – 111120109

Project Guides

Dr. N Siva Shanmugam (Internal Guide)
Dr. D Ezhilarasi (Co – Guide)

Introduction

What is Gait?

Gait refers to the movement pattern of the limbs during locomotion, commonly associated with walking. It involves a coordinated sequence of movements of the legs and arms to propel the body forward.

What happens to gait under load?

Adding weights alters the biomechanics of gait by increasing the load on muscles and joints. It may lead to changes in stride length, step frequency, and overall stability as the body adapts to the added load.

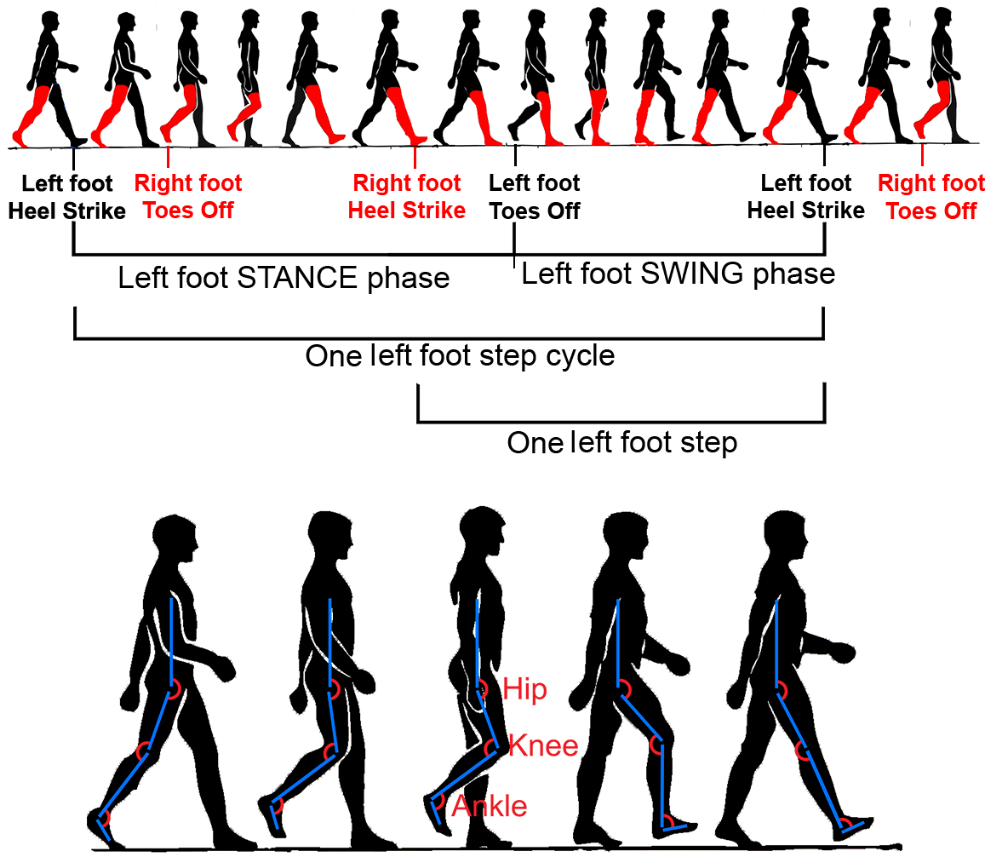


Image Source: Georgiou, T., et.al (2020)

Introduction (Continued)

What are Exoskeletons?

Exoskeletons are wearable robotic devices (over specific regions or overall, of the body) designed to enhance physical performance. They augment power by providing mechanical assistance to muscles, reducing fatigue, and increasing endurance.

How do exoskeletons help?

Exoskeletons distribute weight more evenly across the body, changing the load path and thus reducing the strain on muscles and joints during weight-bearing activities. By supporting the load, exoskeletons enable individuals to carry heavier objects with less effort, improving overall mobility and productivity.

Image Source: DRDO developing exoskeleton for the Indian soldiers posted in high altitudes, Financial Express

Literature Review

S.No	Source	Title	Inference
1	Kinoshita, H. (1985). Ergonomics, 28(9), 1347–1362.	Effects of different loads and carrying systems on selected biomechanical parameters describing walking gait	Significant change of body posture and gait pattern observed when lifting heavy weights , indicating that the risk of encountering stress-related injuries is considerably greater as the load increased in magnitude.
2	Al-Shuka, et. al (2019).International Journal of Dynamics and Control, 7(4), 1462–1488.	Biomechanics, actuation, and multi-level control strategies of power-augmentation lower extremity exoskeletons: an overview	Factors such as interaction force wrench for control purpose, among others required for force augmentation to be considered for design of a control strategy for power augmentation in exoskeletons were discussed.
3	Grimmer, et. al. (2020). Frontiers in Robotics and AI, 7.	Human Lower Limb Joint Biomechanics in Daily Life Activities: A Literature Based Requirement Analysis for Anthropomorphic Robot Design.	A study of the range of motion and joint parameters (velocity, acceleration, torque, and power)exhibited by healthy subjects alongside a motion study of actions (such as walking, jogging, running, climbing, and sitting to standing) was presented.

Literature Review

S.No	Source	Title	Inference
4	Zoss, A, et. al. (2006). IEEE-ASME Transactions on Mechatronics, 11(2), 128–138.	Biomechanical Design of the Berkeley Lower Extremity Exoskeleton (BLEEX)	Introduces the 14 DOF (7 DOF per leg) lower extremity exoskeleton for power augmentation that anthropomorphic in design.
5	Amiri, M. S, et. al. (2019). IEEE Access, 7, 167210–167220.	Initialized Model Reference Adaptive Control for Lower Limb Exoskeleton	A comparative study of IMRAC and non-IMRAC rule on a closed-loop PID controller detailing the mathematical expression of the control schemes' LLE structure, transfer function, and convergence rates

Literature Gap

Augmentative exoskeletons are available in the market, and the research sector covers the entire leg with hip, knee, and ankle actuators (at least 6 DOF). The under-actuated exoskeletons (4 DOF, hip, and knee) in literature are still in the research phase, with their dynamic models either being treated as ones with single-point contact at the foot between the unit and the ground or having no contact with the ground (model, ends at above the ankle joint). A gap exists in the literature where the exoskeleton is underactuated, having a complete metallic sole unit in contact with the ground (multi-point contact).

Aim

Our work involves designing a controller for an underactuated Lower Limb Exoskeleton (4 DOF, only hip and knee joint control) that enhances the user's load-bearing capacity and testing the unit's efficacy on a flat plane. Thus, the feasibility of an underactuated system to provide power augmentation like traditional higher DOF exoskeletal systems is determined.

- Literature Gap

The approach for designing controller for exoskeletons has been to complete system information, modeling and dynamics based optimal controller design or frequency and time response based parameter tuning.

Aim

We aim to work on an approach that strikes a balance between extensive modelling and model free PID approaches. Studying kinematics and dynamics to design compensators for over/undershoots on top of a PID architecture

Objectives

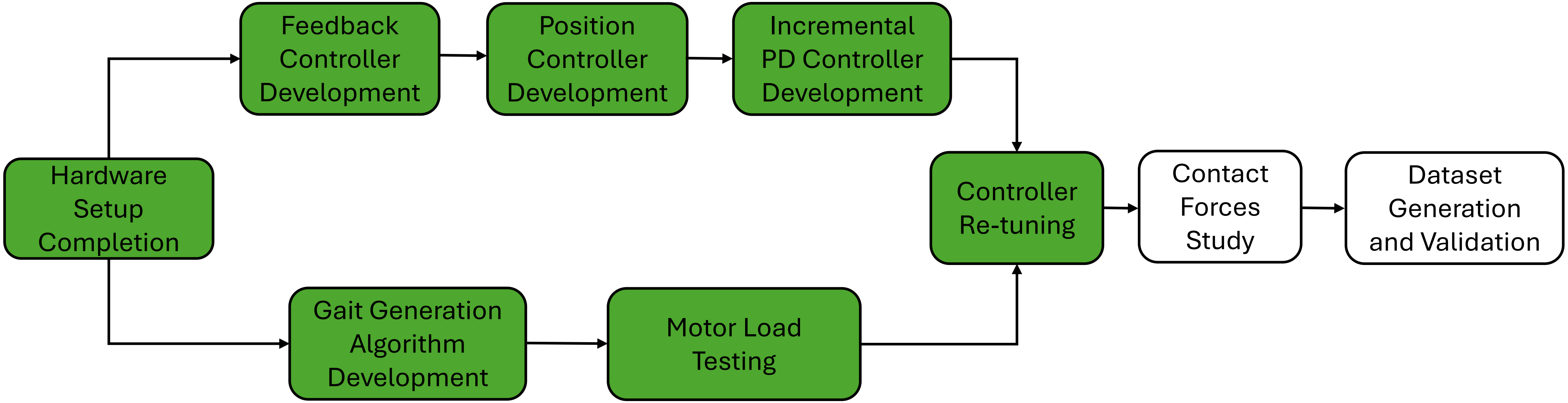
To configure torque controller and design position controller for a BLDC motor to reach and hold the position.

To analyze the differences in gait patterns and study contact forces at foot with and without load when using an exoskeleton and when not using an exoskeleton.

To deploy an PD + Bang Bang controller to trace a desired gait pattern on both external weight-loaded and without external weight-loaded conditions.

To test the developed controller's efficacy in augmenting the user's strength by studying the spikes in forces at the foot when using the exoskeleton.

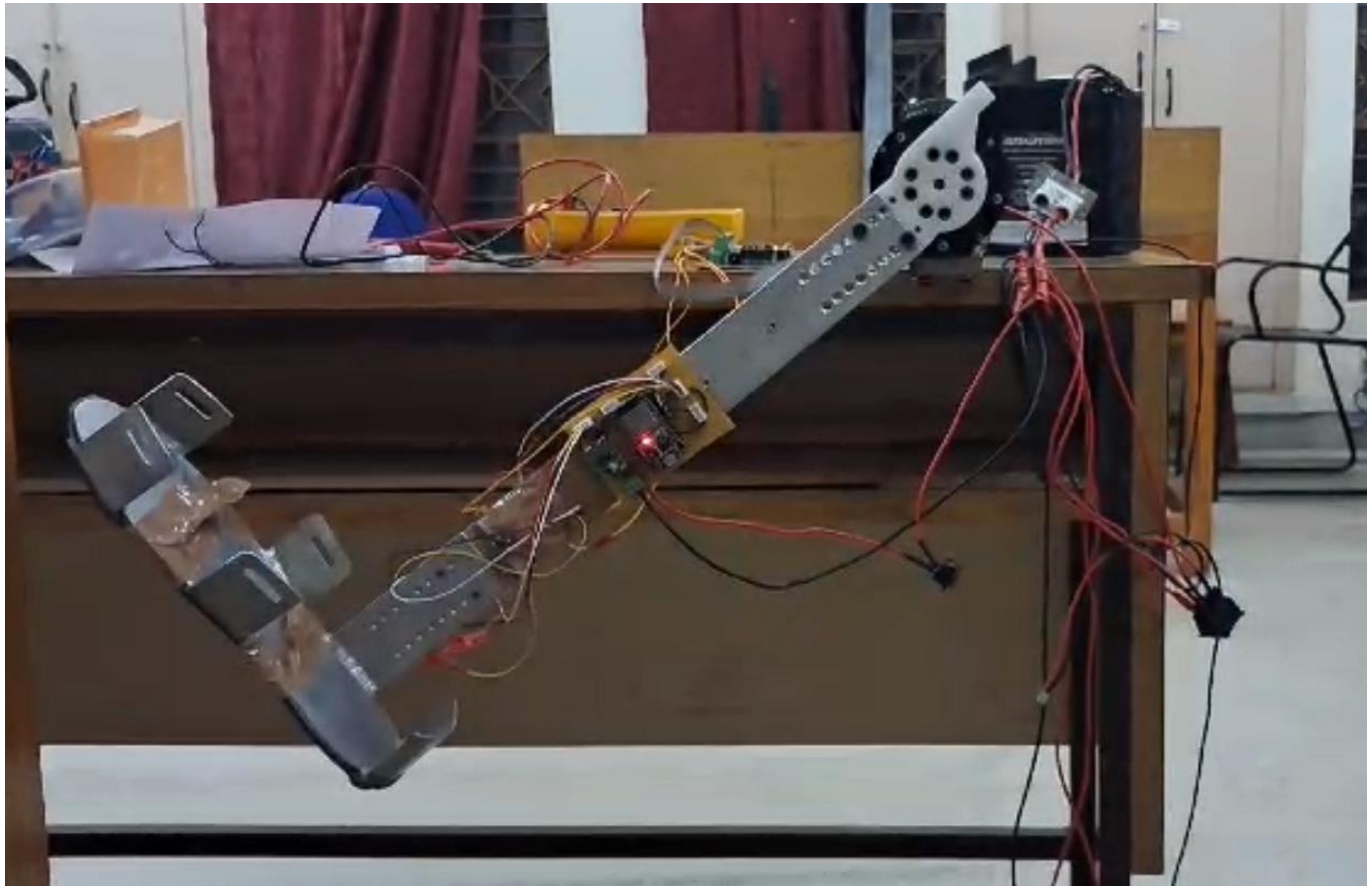
Methodology



Experimental Setup

- (Insert Photo of the test setup and the individual components)

Results – Single DOF Position Controller



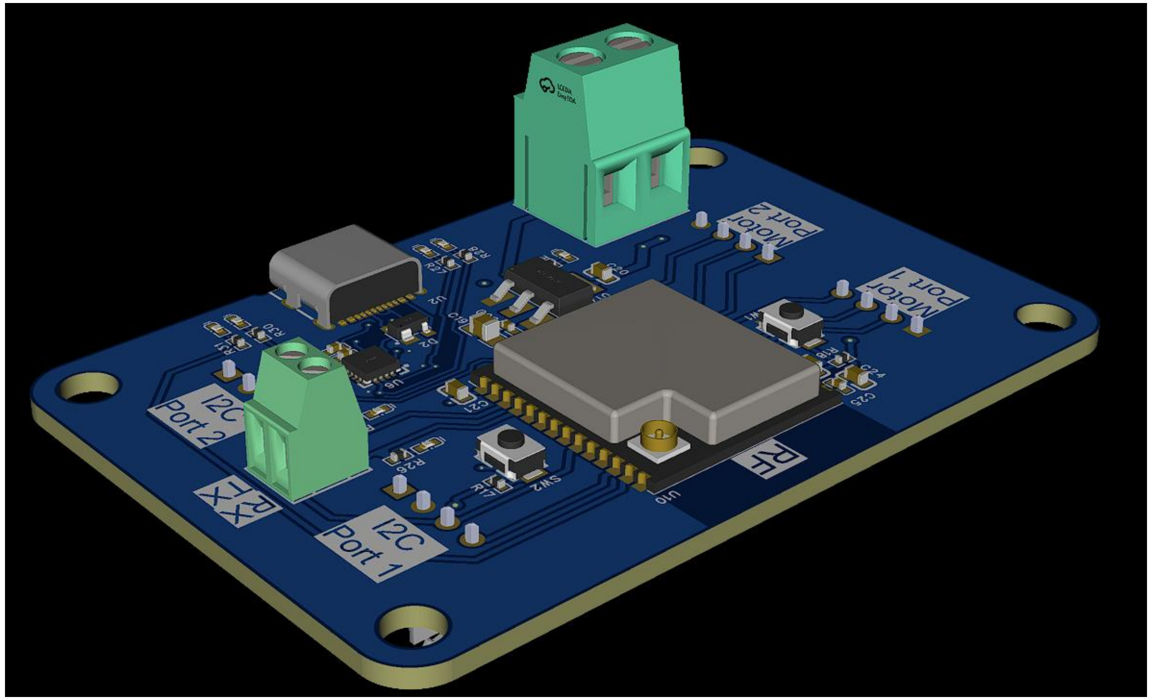
Results – Gait Data Study and Visualization

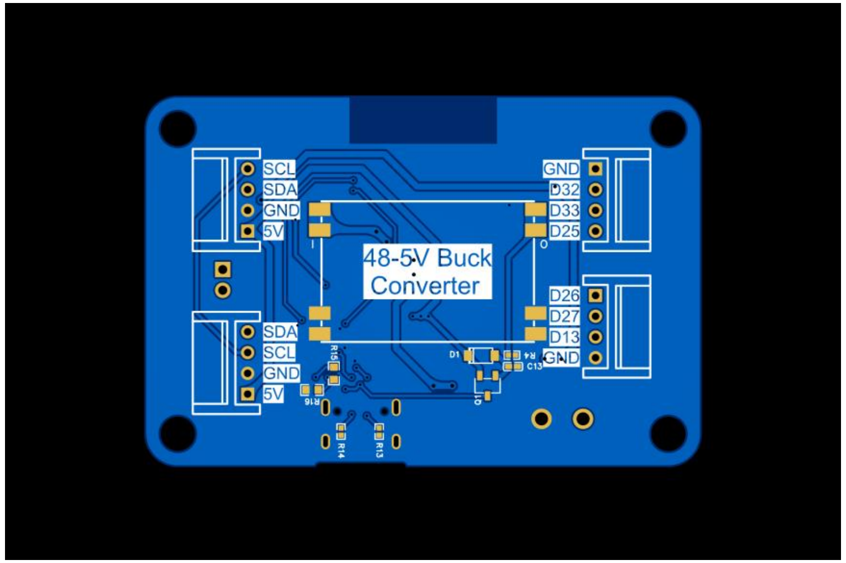
Results – Single Leg Gait Cycle

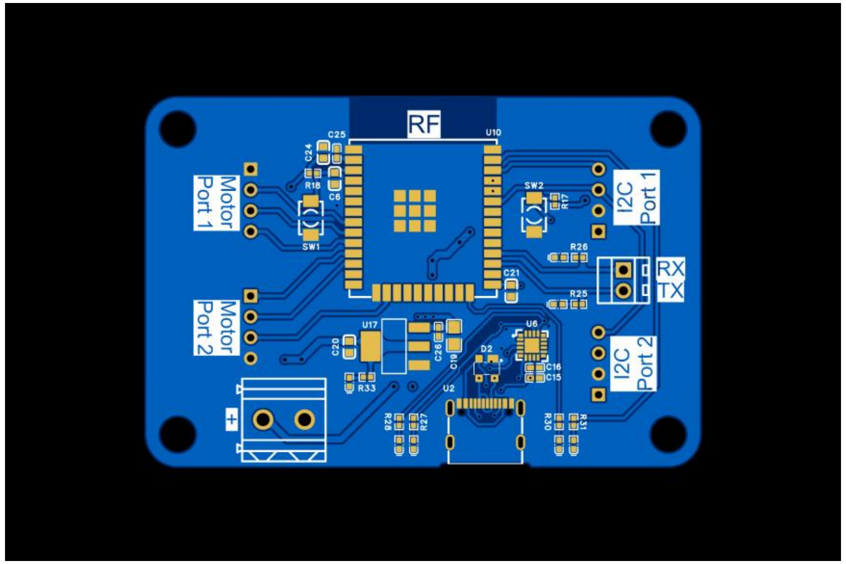
Results – Controller Response

Results – EMG data

PCB Design




SCL
SDA
GND
5V
GND
D32
D33
D25
48-5V Buck
Converter
SDA
SCL
GND
5V
D26
D27
D13
GND


RF
Motor
Port 1
I2C
Port 1
RX
TX
Motor
Port 2
I2C
Port 2

Code Base

Conclusion

References