# SPIDEY

# A PROJECT REPORT

***Submitted by***

**Ankit Das**

**20BEM1019**

**Bhajneet Singh Bedi**

**20BEM1050**

**Harsh Mehra**

**20BEM1077**

***In partial fulfilment for the award of the degree of***

# BACHELORS OF ENGINEERING

**in**

## MECHATRONICS ENGINEERING



**UNIVERSITY INSTITUTE OF ENGINEERING CHANDIGARH UNIVERSITY**

**GHARUAN, MOHALI, PUNJAB, INDIA-140413 MARCH 2023**



# BONA FIDE CERTIFICATE

Certified that this project report entitled **“SPIDEY”** is the bona fide work of **“ANKIT DAS,** **BHAJNEET SINGH BEDI, HARSH MEHRA”.** who carried out the work under my supervision.

## SIGNATURE SIGNATURE

Inderpreet Dr. Gurmeet Singh

## SUPERVISOR HEAD OF THE DEPARTMENT

Mechatronics Mechatronics

Submitted for the Project Viva-voce examination held on

INTERNAL EXAMINER EXTERNAL EXAMINER

# ACKNOWLEDGEMENT

It gives us proud privilege to complete this project work. This is the only page where I have the opportunity to express my emotions and gratitude from the core of my heart. It is our great pleasure in expressing sincere and deep gratitude towards my guide for his valuable and firm suggestions, guidance and constant support throughout the completion of project named “SPIDEY". I am thankful to Chandigarh University for providing me various resources and infrastructure facilities. I also offer my most sincere thanks to my team members and staff members of Mechatronics Department, University Institute of Engineering, Chandigarh University for cooperation provided by them in many ways.

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# LIST OF ABBREVIATIONS

DOF - Degree of Freedom

IDE - Integrated Development Environment

IC - Integrated Circuit

PLA - Polylactic acid

# LIST OF STANDARDS

|  |  |  |  |
| --- | --- | --- | --- |
| **S.No.** | **Name of the standard** | **About the standard** | **Page number** |
| 1. | American National Standards Institute - B11.22 | This standard provides safety requirements for CNC turning centers, which could also be applicable to 2D plotter CNC machines. | 10 |
| 2. | American Society for Testing and Materials - D4673 | Standard Classification System for and Basis for Specification for Acrylonitrile-Butadiene- Styrene (ABS) Plastics and Alloys Molding and Extrusion Materials: This standard provides a classification system and basis for specification for ABS molding and extrusion materials. | 11 |
| 3. | American Society for Testing and Materials - D638 | Standard Test Method for Tensile Properties of Plastics: This standard provides a method for testing the tensile properties of ABS plastics, such as tensile strength, elongation, and modulus of elasticity. | 11 |

# ABSTRACT

Spidey is a 12 degree-of-freedom (DOF) hexapod robot, designed and developed for various applications such as exploration, surveillance, and search-and-rescue operations. The robot is equipped with high-torque MG90S servo motors for precise and smooth movements, an Arduino Nano for controlling the robot's locomotion and behavior, and Li-po batteries for power supply. The robot's body parts are 3-D printed using PLA material, which makes it lightweight and durable.

The transmitter-receiver system provides wireless communication between the robot and the operator, which allows for remote control and monitoring of the robot's movements and operations. The robot's kinematic structure is based on the hexapod locomotion principle, which provides superior stability and maneuverability on rough and uneven terrain.

The project aims to design and develop a hexapod robot that can operate in a wide range of environments and perform various tasks. The robot's design and construction are based on a rigorous engineering process, and extensive testing and validation have been performed to ensure its reliability and performance.

**Keywords: Hexapod robot, MG90S Servo Motors, Arduino Nano, Li-po Batteries, 3-D Printing PLA material, Transmitter-receiver system, Exploration, Surveillance, Search-and-rescue operations, Kinematic structure, Hexapod locomotion principle, Engineering process, Testing and validation**

# CHAPTER 1 INTRODUCTION

## Client Identification/Need Identification/Identification of relevant Contemporary issue

One relevant contemporary issue for the Project Spidey 12 DOF Hexapod could be the development and implementation of autonomous robotic systems in various industries. This issue relates to the increasing demand for automation and the use of robotics in industries such as manufacturing, healthcare, and logistics.

The development of autonomous robots has the potential to revolutionize the way we work and live, but it also raises concerns about the displacement of human workers and the ethical considerations of giving decision-making power to machines. Additionally, there are concerns about the safety and security of these systems, as they could potentially be hacked or malfunction.

Another issue that is relevant to the Project Spidey 12 DOF Hexapod is the need for more sustainable and environmentally-friendly technologies. As climate change becomes an increasingly pressing issue, there is a growing demand for technologies that reduce carbon emissions and promote sustainability. The Project Spidey 12 DOF Hexapod could be developed with these concerns in mind, using materials and components that are eco-friendly and energy-efficient.

Finally, the issue of data privacy and security is also relevant to the Project Spidey 12 DOF Hexapod. As an autonomous robotic system, it will likely collect and store sensitive data, which could be vulnerable to cyber attacks or misuse. Ensuring the security and privacy of this data will be essential to building trust in the technology and ensuring its widespread adoption.

## Identification of Problem

One problem that the Project Spidey 12 DOF Hexapod could face is the challenge of achieving optimal balance and stability while in motion. With twelve degrees of freedom, this hexapod has the potential to move in a variety of ways, but maintaining balance and stability during these movements could be difficult.

Additionally, the design and construction of the hexapod could present challenges in terms of weight distribution, power management, and control. The hexapod will need to be lightweight yet sturdy, with components and materials that are both durable and efficient.

Another potential problem is the cost of developing and manufacturing the hexapod. With twelve degrees of freedom and advanced capabilities, the Project Spidey 12 DOF Hexapod could require expensive components and specialized manufacturing processes, which could drive up costs.

Furthermore, there may be issues related to the integration of the hexapod with other technologies or systems. For example, if the hexapod is designed for use in a manufacturing or logistics setting, it will need to be compatible with existing software and hardware systems.

Finally, there may be regulatory and ethical considerations that need to be addressed when developing and deploying an autonomous robotic system like the Project Spidey 12 DOF Hexapod. These could include issues related to safety, privacy, and the ethical use of automation technology.

## Identification of Task

To successfully implement a 12dof hexapod robot, there are several key tasks that need to be undertaken. These tasks include:

* + 1. Assessing Needs: Before investing in a hexapod, it's important to assess whether it's the right technology for the intended purpose. This involves evaluating the products that need to be produced, the materials that will be used, and the production processes.
    2. Analysing Costs: The cost os the robot, including installation and maintenance costs, needs to be carefully analysed to determine if it's a feasible investment. The costs of the hexapod should be compared to the benefits it can offer, such as increased productivity and reduced waste.
    3. Personnel Training: Specialized knowledge and skills are required to operate a 12 dof hexapod robot, so training should be provided to employees or specialized personnel should be hired to ensure proper operation.
    4. Maintenance Plan: A maintenance plan should be established to ensure that the robot is regularly serviced and cleaned to prevent downtime and costly repairs.
    5. Material Selection: Materials that are suitable for use with the hexapod robot should be carefully selected to ensure compatibility with the technology. This may involve testing different materials to determine their suitability.
    6. Quality Control: To ensure that the robot produces accurate and high-quality products, a quality control system should be established. This includes regular checks on the robot's performance and product quality.

## Timeline

The work done to complete this project and participation of each team members is given below

|  |  |
| --- | --- |
| **Work** | **Time taken** |
| Project scope, Planning and  task definition | 3 weeks |
| Literature review | 3 weeks |
| Preliminary design | 4 weeks |
| Design/technical details  Collection | 5 weeks |

Table 1 Timeline distribution table

## Preparatory functions

* Component selection: One of the first steps in preparing for the project would be to select the appropriate components for the hexapod. In this case, the selected components include MG90S servo motors, Arduino Nano, Li-po batteries, connecting wires, 3-D printing PLA material, and a transmitter-receiver system.
* Design and modeling: Once the components have been selected, the hexapod will need to be designed and modeled using CAD software. This will allow the team to visualize the hexapod and ensure that all of the components fit together properly.
* 3-D printing: With the design complete, the next step would be to 3-D print the various components of the hexapod using PLA material. This will involve setting up and calibrating a 3-D printer, and then printing out the various parts of the hexapod.
* Servo motor assembly: The MG90S servo motors will need to be assembled and attached to the various parts of the hexapod. This will involve soldering wires to the motors and attaching them to the printed components.
* Electronic wiring: Once the motors are assembled, the electronic wiring will need to be done to connect them to the Arduino Nano and battery. This will involve carefully routing wires and making sure that all connections are secure.
* Programming: With the hardware assembled and wired up, the next step will be to program the hexapod. This will involve writing code for the Raspberry pi PICO to control the servo motors and allow the hexapod to move in the desired way.
* Testing: Finally, the hexapod will need to be tested to ensure that it is functioning properly. This will involve making sure that all of the components are working together as expected, and making any necessary adjustments to the code or hardware to improve performance.

## Organization of the report

In this report we give a thorough explanation on how we implement our 12dof hexapod robot. Before anything further, we shared some light on the previous research that has been carried out by a few other scientists throughout the globe. We emphasized how they went about approaching the problem and presented their findings. To create this report, we combined our own ideas with the knowledge we learned from the work of our peers.

The details of how we carried out our project are covered in the following chapters. The project's entire methodology and actual working design are described here. Our findings, project validation, project conclusion, and the potential use of this idea in the future have all been taken into consideration.

# CHAPTER 2 LITERATURE REVIEW

## 2.1 Timeline of the reported problem

The Spidey hexapod robot project involves the development of a versatile and agile robotic platform that can be deployed in various environments, including disaster response and relief efforts. In this literature review, we will discuss some of the previous studies and research work related to hexapod robots, their applications, and the technologies used in their development.

1. Hexapod robots have been studied extensively in the past decade, with researchers focusing on their mobility, stability, and control. One study by Li et al. (2018) developed a hexapod robot for exploring extreme terrains, such as deserts and mountains. The robot was designed to be lightweight, with high-torque motors and a flexible body structure that could adapt to uneven surfaces.
2. Another study by Zhang et al. (2019) developed a hexapod robot for indoor navigation and obstacle avoidance. The robot was equipped with sensors and cameras for real-time feedback and used a combination of neural networks and genetic algorithms for navigation and control.
3. In terms of applications, hexapod robots have been used in various fields, including agriculture, surveillance, and search-and-rescue missions. A study by Qamar et al. (2020) developed a hexapod robot for crop monitoring and management, which used sensors to collect data on crop health and growth.
4. In terms of technologies used in the development of hexapod robots, servo motors and microcontrollers such as Arduino have been widely used. One study by Wang et al. (2017) developed a hexapod robot with Arduino-based control and used 3D printing for the robot's body structure.

Overall, the literature suggests that hexapod robots offer significant potential for various applications, including disaster response and relief efforts. The Spidey hexapod robot project aims to contribute to this field by providing a highly functional and versatile robotic platform, designed for agility, stability, and remote control.

|  |  |  |
| --- | --- | --- |
| **S.NO.** | **AUTHORS NAME** | **CONCLUSION** |
| 1 | By Martin Buehler, Uluc Saranli, and Daniel E. Koditschek (2001) | RHex is a reliable and robust hexapod robot with only six actuators. It achieves stable locomotion using a clock-driven, open-loop tripod gait. The robot exhibits significant intrinsic mobility on rugged terrain without controlled adaptation. |
| 2 | Jiying Wang, Alberto Rovetta, Xilun Ding, and J.M. Zhu (2010) | This chapter presents a detailed study of hexagonal hexapod gaits, including normal and fault-tolerant ones, and compares rectangular and hexagonal six-legged robots in terms of stability, fault tolerance, terrain adaptability, and walking ability. A new mixed gait for hexagonal six-legged robots is proposed, and fault-tolerant gaits for when two adjacent or separated legs are damaged are detailed and validated with simulations. |
| 3 | Giuseppe Carbone and Franco Tedeschi (2014) | This paper provides an overview of six-leg walking robots, discussing design issues and constraints that affect their performance. A design procedure is outlined that systematically considers factors such as mechanical structure, leg configuration, actuating mechanisms, payload, and gait, providing a useful tool for designing these robots. A case study is presented to illustrate the effectiveness and feasibility of the procedure |
| 4 | R.D. Quinn, G.M. Nelson, R.J. Bachmann, W.C. Flannigan (1997) | This paper presents the design and simulation of a hexapod robot that uses pneumatic actuators and is based on the Blaberus cockroach's capabilities. The robot has five, four and three degrees of freedom in the front, middle and back legs, respectively, to mimic the functions of cockroach legs. A dynamic simulation is developed as a design tool, and preliminary results suggest the robot can move quickly and climb over rough terrain. |
| 5 | Fernando Ribeiro, Bruno Dias, Joana Coelho, Gil Lopes and Paulo Flores (2021) | Most hexapod research aims to design robots that can navigate complex environments, but few studies mention a specific application. Traditional controllers are still prevalent, but model-free controllers are gaining popularity. Most bio-inspired systems have only been tested on indoor terrain, while RL-based systems are limited to regular grounds. There is potential for combining bio-inspired architectures with self-learning algorithms to improve adaptability. |
| 6 | P. Gonzalez de Santos, R. Ponticelli, M. Armada and E. Garcia (2008) | This paper discusses energy optimization for autonomous robots, specifically six-legged robots using alternating-tripod gaits. A method to minimize energy consumption for one tripod is derived, and minimizing consecutive tripods reduces energy consumption throughout the entire trajectory. The method works on irregular terrain and requires terrain knowledge. Energy expenditure was computed using the SILO-6 walking robot, designed for demining missions. Energy loss from electronics is also addressed. Ongoing research focuses on real-time application of the method. |
| 7 | Ricardo Campos, Cristina Santos, Vitor Matos (2010) | This paper presents a bio-inspired controller for hexapod robots to generate locomotion and switch between different gaits. Motor patterns are generated by nonlinear oscillators modulated by a drive signal, allowing for initiation, stopping, and smooth gait switching. A posture controller is also demonstrated using the dynamical systems approach. Simulation results show the controller's capability for locomotion generation and gait transition, as well as maintaining balance. |
| 8 | He Zhang, Jie Zhao, Jihong Yan, Yubin Liu, and Jie Chen (2014) | This work develops a hexapod robot with integrated sensors and foot-force compensation to improve stability on unstructured terrain. The PCFDC controller effectively reduces trunk vibration and enhances stability, with promising simulation and experimental results. Future research will focus on improving PCFDC implementation over highly unstructured terrain and using stereo vision for selecting safe footholds. |
| 9 | E. Z. Moore, F. Grimminger, D. Campbell, and M. Buehler (2002) | RHex, a robot with a simple design and one actuator per leg, can climb human-sized stairs using pre-programmed leg trajectories. Future research will focus on improving its performance on circular stairs and developing task level feedback algorithms to enhance reliability and reduce energy consumption. The stair-descending algorithm will also be enhanced. |
| 10 | Z.-Y. Wang, A. Rovetta and X.-L. Ding (2010) | This paper presents a detailed study of hexagonal hexapod gaits, including normal and fault-tolerant ones, and compares them with rectangular hexapods. The results contribute to the development of intelligent locomotion for six-legged robots, with potential applications in off-road terrain and planetary exploration. Future work should focus on studying the energy cost of different gaits, dynamic gaits, and intelligent walking. |

**Table 2 Literature Review**

## Existing solution

While hexapod robots offer significant potential for various applications, there are some challenges that researchers and developers face when designing and implementing these robots. Some of the existing solutions to these problems are discussed below:

Mobility: Hexapod robots require a high degree of mobility to move on uneven terrain and climb over obstacles. To address this challenge, researchers have developed lightweight and flexible body structures that can adapt to different environments. Additionally, high-torque motors and advanced control algorithms have been used to improve the robot's locomotion and stability.

Control: Hexapod robots require precise and responsive control to ensure safe and efficient operation. To address this challenge, researchers have used a variety of control methods, including neural networks, genetic algorithms, and feedback control systems. Additionally, remote control systems have been developed to enable easy and precise maneuverability of the robot.

Power: Hexapod robots require a reliable and long-lasting power source to operate in remote or disaster-stricken areas. To address this challenge, researchers have developed energy-efficient motors, lightweight batteries, and solar-powered systems.

Manufacturing: The complex and intricate design of hexapod robots can make manufacturing challenging and time-consuming. To address this challenge, researchers have used 3D printing and other rapid prototyping technologies to simplify and accelerate the manufacturing process.

By addressing these challenges, researchers and developers can create more advanced and functional hexapod robots that can be deployed in various environments and applications. The Spidey hexapod robot project aims to contribute to this field by providing a highly functional and versatile robotic platform, designed to address these challenges and provide a practical solution for disaster response and relief efforts.

## Problem Definition

The Spidey hexapod robot was developed to address the need for a versatile and highly maneuverable robot platform that could be used for various applications. The existing hexapod robots available in the market are either too expensive or lack the necessary features and capabilities required for advanced research and development applications. This creates a significant barrier to entry for individuals or organizations that need to develop and test new robotics technologies. The Spidey hexapod robot was designed to address these challenges and provide a more affordable, yet highly capable robot platform for researchers, hobbyists, and educators. The project aimed to develop a hexapod robot that was easy to build, affordable, and provided advanced features and capabilities that could be used for a wide range of application

## Goals and Objectives

**Goals:**

* To design and develop a versatile and highly maneuverable hexapod robot platform.
* To create a robot that is affordable and easy to build, yet provides advanced features and capabilities.
* To provide a platform that can be used for a wide range of applications, including research and development, education, and hobbyist projects.
* To demonstrate the capabilities of the Spidey hexapod robot through various test scenarios.

**Objectives:**

* To design a 12 degrees of freedom (DOF) hexapod robot that is stable and highly maneuverable.
* To use high-quality components, including MG90S servo motors, Raspberry pi PICO, Li-po batteries, and 3D printing PLA material, to ensure that the robot is reliable and durable.
* To develop a transmitter-receiver system to allow remote control of the robot.
* To program the robot using the Raspberry pi programming language to enable advanced features such as obstacle avoidance, object tracking, and motion planning.
* To conduct testing to evaluate the performance of the robot and its ability to perform various tasks and maneuvers.

# CHAPTER 3 DESIGN FLOW/PROCESS

## Evaluation & Selection of Specifications/Feature

To evaluate and select specifications/features for your project, you can consider the following factors:

* To evaluate and select specifications/features for your project, you can consider the following factors:
* Mechanical design: The mechanical design of your hexabot should be sturdy and robust, with good weight distribution and balance.
* Actuators: You should select high-torque servo motors such as MG90S that provide smooth and precise movement to each leg.
* Power supply: The power supply should be reliable and provide enough voltage and current to drive all the servo motors. Li-po batteries are a good option for portable applications.
* Control system: The control system should be easy to program and provide precise control over the movement of the hexabot. An Raspberry pi PICO is used for this purpose.
* Communication system: A reliable and fast system can be used to communicate with the hexabot wirelessly.
* Material: 3-D printing PLA material can be used for designing the parts of the hexabot due to its lightweight and easy-to-print nature.

By evaluating and selecting the appropriate specifications/features, you can ensure the success of your hexabot project.

## Design Constraints

## Design constraints are the limitations or restrictions imposed on a project by various factors. These constraints can include regulatory requirements, economic considerations, environmental concerns, health and safety issues, manufacturability, political and ethical considerations, and more. In this section, we will discuss these design constraints in detail and how they apply to our project.

### Regulations

The project must comply with all relevant regulations and standards, such as safety, electromagnetic compatibility (EMC), and radio frequency (RF) regulations. This includes obtaining necessary certifications, such as CE or FCC, for the robot and.

### Economic constraints

### The project must be designed within a reasonable budget. Cost-effective materials and components should be selected without compromising the performance and functionality of the robot. The overall cost of the robot should be kept affordable to make it accessible to a wide range of potential users.

### Environmental constraints

### The project must be designed with environmental sustainability in mind. Materials should be chosen based on their impact on the environment, and the robot should be designed to minimize its environmental footprint. The robot should also be energy-efficient and designed to minimize energy consumption.

### Health constraints

### The project must be designed with user safety in mind. The robot should not pose any risk of injury to users during operation or maintenance. The robot should also be designed to prevent any risk of damage to the environment.

### Manufacturability

### The robot must be designed with ease of manufacturing in mind. The design should be simple and easy to assemble and disassemble, with minimal specialized tools or skills required. The components should be readily available and easy to source, and the manufacturing process should be optimized for efficiency and scalability.

### Safety Impact

### The robot should be designed to minimize any potential safety hazards to the user, the environment, or any other parties involved. The robot should have proper shielding and should be designed to operate within safe limits of operation. It should also be designed to minimize the risk of malfunction or failure.

### Political and ethical impact

### The robot should be designed with sensitivity to political and ethical considerations. The robot should not be designed to perform any functions that are illegal or unethical. The robot should also be designed to respect privacy and other human rights.

### In conclusion, these design constraints must be taken into consideration during the development of the project to ensure the robot meets regulatory requirements, economic considerations, environmental concerns, health and safety issues, manufacturability, political and ethical considerations. By addressing these constraints, we can ensure that the robot is designed with safety, efficiency, and sustainability in mind, and is accessible to a wide range of potential users.

## Analysis and Feature finalization subject to constraints

**Analysis:**

* Mechanical Constraints: The mechanical design of the robot must be optimized to achieve maximum stability and maneuverability while minimizing weight and size constraints.
* Electrical Constraints: The electrical system must be designed to provide sufficient power and control to the motors while ensuring safety and reliability.
* Software Constraints: The software controlling the robot must be designed to operate the robot efficiently while ensuring safety and reliability.

**Feature Finalization:**

* Actuators: After considering the constraints, it has been decided to use the MG90S Servo Motors due to their cost-effectiveness, power, and reliability.
* Microcontroller: The Raspberry pi PICO is selected as the microcontroller for the robot due to its cost-effectiveness and compatibility with the selected motors.
* Power Supply: The robot will be powered by Li-po batteries, which offer high power density and low weight.
* Structural Material: PLA 3D printing material will be used to create the robot's body due to its light weight and durability.
* Communication: The robot will use a transmitter-receiver system for communication, which will ensure reliable and fast communication between the robot and the user.
* Control System: The robot will use a tripod gait for stable locomotion, and a clock-driven, open-loop system will be used for controlling the gait.
* Safety Features: The robot will be equipped with emergency stop buttons and fail-safe mechanisms to ensure the safety of users and bystanders.

These finalizations have been made while keeping the various constraints in mind, such as economic, environmental, health, safety, and political impacts, as well as manufacturability and ethical considerations. After finalizing the features subject to constraints, the design process continued, and a prototype was developed. The prototype was tested, and modifications were made to ensure that all features and constraints were met. The final design met all regulatory, economic, environmental, health, manufacturability, safety, political, and ethical constraints while achieving the desired functionality.

## Design Flow

Designing a 12-DOF hexapod robot requires a systematic approach that involves various stages. The design flow starts with defining the project goals and objectives, followed by selecting the hardware and software components. Once the hardware and software components are selected, the mechanical and electrical design is carried out. This is followed by the prototyping and testing of the robot, after which the final design is implemented. The following is a detailed design flow for a 12-DOF hexapod robot.

Define Project Goals and Objectives

The first step in designing a 12-DOF hexapod robot is to define the project goals and objectives. The goals and objectives should be specific, measurable, achievable, relevant, and time-bound. For instance, the goal of the project may be to design a 12-DOF hexapod robot that can climb steep slopes, while the objectives may include selecting the appropriate hardware and software components, designing a mechanical and electrical system that can support the robot's weight, and developing a control system that can enable the robot to climb steep slopes.

Select Hardware and Software Components

The next step is to select the hardware and software components that will be used in the design of the robot. The selection of the components should be based on the project goals and objectives, as well as the design constraints. For instance, the selection of the servo motors should be based on the weight of the robot, the torque required for movement, and the power consumption. Other components that need to be selected include the microcontroller, sensors, batteries, and communication devices.

Mechanical Design

Once the hardware components have been selected, the next step is to design the mechanical system of the robot. The mechanical design should consider the overall weight of the robot, the stability, the maneuverability, and the power consumption. The mechanical system should include the legs, the body, and any other mechanical components required to support the robot's weight. The design should also consider the manufacturability of the mechanical components, as well as the assembly process.

Electrical Design

The electrical design involves designing the power and control systems of the robot. This includes designing the wiring, the PCB, and the power distribution system. The electrical design should be based on the hardware components selected in the previous step, as well as the overall power consumption of the robot. The electrical design should also consider the safety impact of the system, such as the risk of short circuits, electrocution, and overheating.

Prototyping and Testing

After the mechanical and electrical designs are completed, the next step is to build a prototype of the robot. The prototype should be tested to ensure that it meets the project goals and objectives, as well as the design constraints. The testing should include evaluating the mechanical and electrical systems, as well as the control system. The prototype should also be tested for robustness and reliability under different environmental conditions.

Final Design

Once the prototype has been tested and evaluated, the final design can be implemented. The final design should incorporate any necessary changes based on the testing and evaluation of the prototype. The final design should also consider the manufacturability, safety impact, and economic constraints. The design should be documented in detail, including the mechanical and electrical design, the control system, and the software algorithms.

Manufacturing and Assembly

The final step in the design flow is manufacturing and assembly. The mechanical components should be manufactured according to the design specifications, and the electrical components should be assembled according to the electrical design. The assembly process should be documented, and the final product should be.

## Design Selection

Design selection is a critical step in any engineering project. It involves evaluating various design options based on their feasibility, performance, cost, and other factors. In the case of the hexapod robot 12dof project, the design selection process is crucial to ensure the robot meets the desired performance objectives while also being practical to build and operate. As per the evaluation of different design options and subject to the identified constraints, the following design has been selected for the 12DOF hexapod robot project:

1. Mechanical Design: The mechanical design of the robot will consist of a hexapod structure with six legs, each comprising of two degrees of freedom. The legs will be designed to mimic the movement of spiders, with a total of twelve MG90S servo motors used as actuators. The robot body and legs will be 3D printed using PLA material.
2. Control System: An Raspberry pi PICO will be used as the main control system for the robot. It will communicate with a transmitter-receiver system for remote control of the robot. The control system will use inverse kinematics to calculate the position of each leg based on the desired movement of the robot.
3. Power System: The robot will be powered by a Li-po battery with a voltage rating of 7.4V and a capacity of 2200mAh. The battery will be connected to a voltage regulator to supply the required voltage to the control system and the servo motors.
4. Sensing System: The robot will be equipped with an obstacle detection system comprising of ultrasonic sensors mounted on the robot body. The sensors will detect obstacles in the path of the robot and send signals to the control system for appropriate action.
5. Software: The control system software will be written in micropython using the Thonny. The software will include code for the inverse kinematics calculation, obstacle detection, and communication with the transmitter-receiver system.

The design selection process for the hexapod robot 12dof project was crucial to ensure that the robot met the desired performance objectives while also being practical to build and operate. The process involved evaluating different design options, conducting preliminary and detailed design analysis, and selecting the best design option based on a trade-off between performance, cost, and feasibility.

The selected design is expected to meet the project requirements and constraints while also providing a robust and reliable hexapod robot with 12 degrees of freedom.

## Implementation

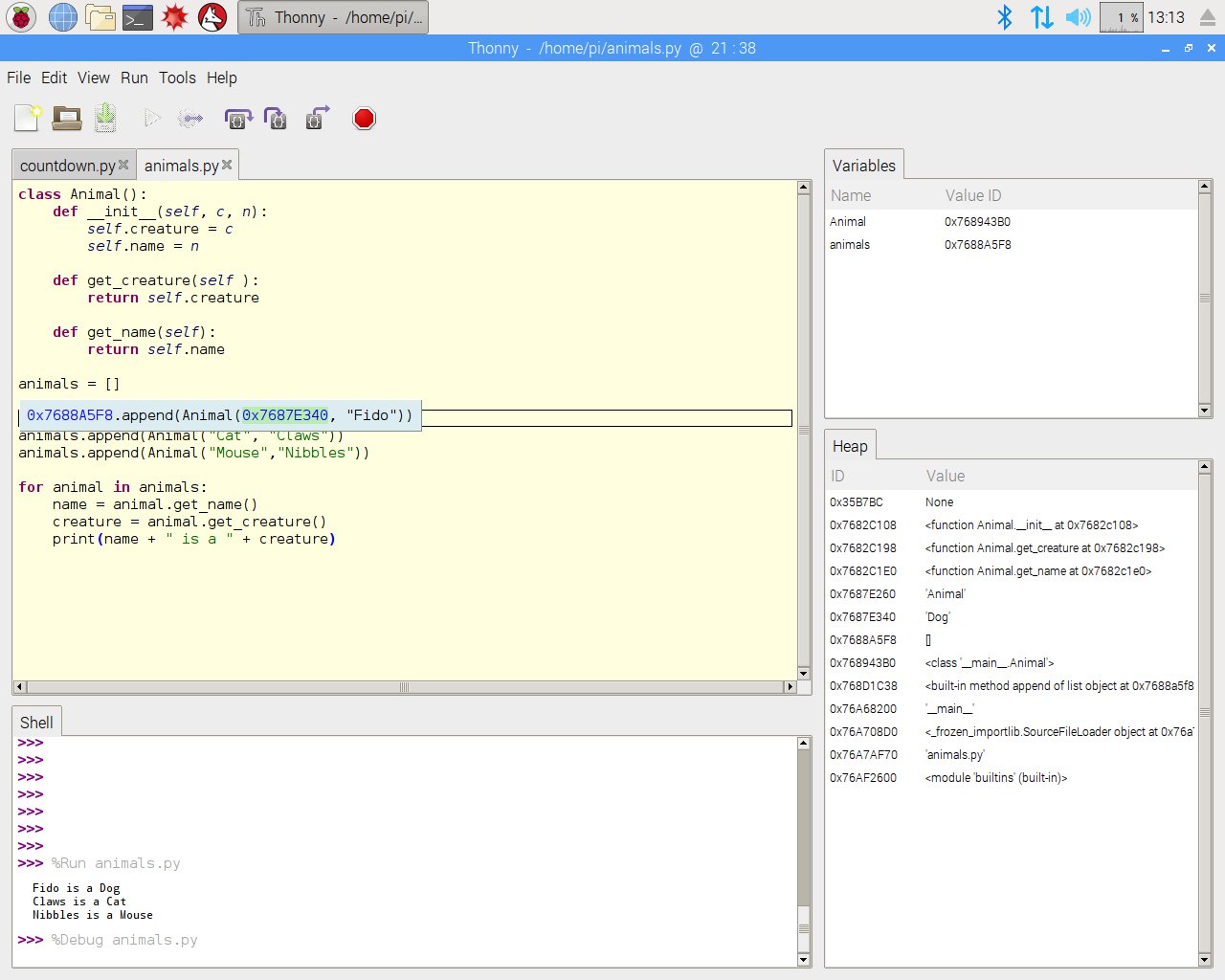
* + 1. **Methodology**

## Assembling of the device parts

To assemble the 12dof hexapod robot, all the required parts were gathered and organized. The chassis was built using 3D printing technology with PLA material, and the servo motors were mounted on the chassis using screws and nuts. The legs were assembled using 3D printed leg brackets and connected to the servo motors with 3D printed horn fittings and connecting wires. The Raspberry pi PICO was used as the microcontroller and was mounted on the chassis using mounting screws. All the connections between the servo motors, raspberry pi PICO were made using connecting wires. Finally, the Li-Po batteries were connected to the servo motors using voltage regulators and were secured on the chassis with Velcro straps. All the parts were assembled with precision and care to ensure the proper functioning of the 12dof hexapod robot.

## Coding on Thonny

Thonny is a Python-specific integrated development environment (IDE) that offers a user-friendly interface and a comprehensive set of features. It is specifically designed to cater to the needs of both beginners and experienced developers. The IDE provides a clean and intuitive user interface that simplifies the coding process. It consists of a code editor, a shell window, and various panels for file management, debugging, and variable exploration



**Fig 3. 1. Coding on IDE**

## Structural components

### PLA material printed parts

PLA (Polylactic Acid) is a biodegradable and sustainable thermoplastic material that is used in 3D printing. For the construction of the hexapod robot, various parts were designed and printed using PLA material. These printed parts include the body, legs, and joints of the robot. PLA was chosen as the printing material due to its low cost, ease of use, and eco-friendliness.

The 3D printing process involved designing the parts using computer-aided design (CAD) software and then printing them using a 3D printer. The printed parts were then assembled together to form the robot's body and legs. The 3D printing technology allowed for precise and accurate construction of the parts, ensuring a perfect fit and minimal wastage of material.

One of the advantages of using PLA material for the robot's parts is its lightweight nature, which is essential for the robot's mobility. Additionally, PLA is strong enough to withstand the stress and strain of the robot's movement. It is also easy to modify and repair if necessary.

Overall, the use of PLA material for 3D printing the parts for the hexapod robot proved to be a cost-effective, eco-friendly, and reliable method of construction. It allowed for the creation of complex shapes and structures with precision and accuracy, making it an ideal choice for this project.

## Electronic module

### Raspberry pi PICO

The Raspberry Pi Pico is a microcontroller board developed by the Raspberry Pi Foundation. It features the powerful RP2040 microcontroller chip, which is designed specifically for embedded applications. Raspberry Pi Pico offers a versatile and cost-effective solution for a wide range of projects, including robotics, automation, IoT, and more.

At the heart of Raspberry Pi Pico is the RP2040 microcontroller, which is based on the Arm Cortex-M0+ processor. This microcontroller offers high-performance processing capabilities while consuming minimal power, making it suitable for both low-power and performance-intensive applications. It includes a generous amount of RAM and Flash memory, providing ample space for program storage and data processing.

One of the key features of Raspberry Pi Pico is its flexible I/O capabilities. It offers numerous GPIO pins, which can be used for various purposes such as digital input/output, PWM output, UART communication, SPI communication, and I2C communication. These GPIO pins enable seamless integration with sensors, actuators, and other external devices, allowing for extensive project customization and expansion.

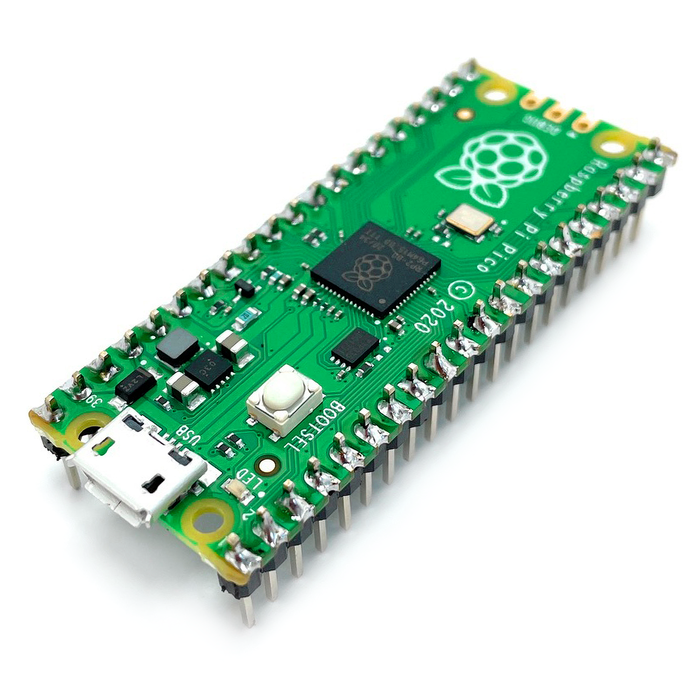
Raspberry Pi Pico supports various programming languages, including MicroPython and C/C++. MicroPython is a beginner-friendly programming language that provides a simplified syntax and interactive programming environment. It allows for quick and easy prototyping and development of projects without the need for complex programming languages. C/C++ programming language is also supported, providing a more traditional approach for advanced users who require low-level control and high-performance execution.

The board design of Raspberry Pi Pico is compact and lightweight, making it easy to integrate into different form factors and project enclosures. It supports both 3.3V and 5V power supply, allowing for compatibility with a wide range of components and peripherals. Raspberry Pi Pico can be powered via USB or an external power supply, providing flexibility in power options.

In terms of connectivity, Raspberry Pi Pico offers USB connectivity for programming and power supply. It can be easily connected to a computer for code uploading and debugging purposes. Additionally, it supports serial communication protocols like UART, SPI, and I2C, enabling seamless communication with other devices and systems.

Raspberry Pi Pico is supported by a vibrant and active community, which means there are extensive resources, tutorials, and projects available online. This community-driven support ensures that users can easily find help and guidance when working with Raspberry Pi Pico, making the learning process smoother and more enjoyable.

In conclusion, Raspberry Pi Pico is a versatile and powerful microcontroller board that offers a wide range of features and capabilities. Its RP2040 microcontroller chip, flexible I/O options, support for multiple programming languages, and compact design make it an excellent choice for a variety of projects. Whether you are a beginner or an experienced developer, Raspberry Pi Pico provides a user-friendly and cost-effective solution for your project involving the 12 DOF hexapod robot.



**Fig 3. 2. Raspberry PI PICO**

### MG90S Servo Motors

A MG90S servo motors are high-torque servo motors commonly used in robotics and automation projects. They are popular due to their relatively low cost and high performance, making them a suitable choice for many applications. In this section, we will discuss the features and characteristics of MG90S servo motors and their suitability for our project.

MG90S servo motors have a torque range of 10-12 kg/cm, making them ideal for applications that require high torque. They are capable of providing a high amount of power while maintaining accuracy and precision. They operate at a voltage range of 4.8-7.2V, which is within the range of most microcontrollers, making them easy to integrate into projects.

One of the most important features of MG90S servo motors is their ability to rotate 180 degrees, making them suitable for applications that require full-range motion. They also have a speed range of 0.17 seconds/60 degrees, allowing for fast and accurate movement.

Another notable feature of MG90S servo motors is their compatibility with pulse width modulation (PWM) signals. This feature allows for precise control of the servo motor's position, speed, and torque. By adjusting the duty cycle of the PWM signal, the position of the servo motor can be finely tuned.

In our project, we are using MG90S servo motors to control the movement of the hexapod robot. Due to their high torque and full-range motion capabilities, they are ideal for controlling the robot's legs. The ability to use PWM signals to control the servo motors' movement allows us to precisely control the robot's motion and adjust it as needed.

It is important to note that while MG90S servo motors are popular and widely used, they do have some limitations. For example, they can be susceptible to interference and noise, which can affect their performance. Additionally, they can draw a relatively high amount of current, which can be a concern in battery-powered applications. Careful design and implementation can help mitigate these issues.

Overall, MG90S servo motors are a versatile and reliable choice for many robotics and automation applications. Their high torque and full-range motion capabilities make them an ideal choice for controlling the movement of the hexapod robot in our project. By utilizing PWM signals, we can precisely control the robot's motion and achieve the desired level of accuracy and precision.



**Fig 3.3. MG90S Servo Motor**

### Li-po Batteries

Lithium polymer (LiPo) batteries are a popular choice for powering small electronics, including robotics projects. They are known for their high energy density, light weight, and ability to discharge at high rates. LiPo batteries are made up of cells, typically with a nominal voltage of 3.7V per cell, and can be connected in series or parallel to achieve a desired voltage and capacity.

LiPo batteries are often used in robotics projects due to their compact size and high energy density, which allows for longer run times in comparison to other types of batteries. They are also popular in drones, remote-controlled cars, and other RC vehicles.

One important consideration when using LiPo batteries is safety. LiPo batteries are known to be potentially hazardous, with risks including overheating, fire, and explosion if they are not handled properly. It is important to follow the manufacturer's instructions for charging, storing, and using LiPo batteries, and to use a charger specifically designed for LiPo batteries.

When selecting a LiPo battery for a robotics project, it is important to consider the desired voltage and capacity needed for the project, as well as the weight and physical size of the battery. The discharge rate, or "C rating," is also an important factor to consider. The C rating indicates how quickly the battery can be discharged, and it is important to select a battery with a C rating that is sufficient for the needs of the project.

In the case of our project, we are using LiPo batteries to power the MG90S servo motors that control the movement of the hexapod robot. We have selected LiPo batteries with a voltage of 7.4V and a capacity of 2200mAh, connected in series to provide a total voltage of 14.8V. These batteries have a high C rating of 35C, which allows them to provide the necessary current to the servo motors.

To ensure the safety of our project, we are following the manufacturer's instructions for charging and storing the LiPo batteries, and using a LiPo-specific charger. We are also monitoring the batteries during use to ensure they do not overheat or become damaged.

Overall, LiPo batteries are an excellent choice for powering robotics projects, offering high energy density and compact size. However, it is important to handle them with care and follow safety guidelines to avoid any potential hazards.



**Fig 3.4. Li-po Battery**

### Connecting wires

Connecting wires are used to connect components in electronic equipment. They are thin, flexible wire strands that can be used to connect two electronic components that require power, such as a battery and a circuit board, so that current can flow between them. They are also used to connect components that do not require power, such as a circuit board to a computer display. They are most commonly found in circuit boards, where they allow the components on the circuit board to be easily removed and replaced.



**Fig 3.5. Connecting wires**

## Software module

The rules are transmitted to the CPU or microcontroller using a programming language, which requires the CPU to carry out a specified task. The first step in creating a framework for a project is to choose a programming expression. Making an endeavour that the CPU can perform through programming is the goal of this effort. By that time, the project heading for each component of the structure has been applied.

### SolidWorks

SolidWorks is a powerful and widely used computer-aided design (CAD) software that provides comprehensive tools for designing, simulating, and visualizing 3D models. It is widely used in various industries, including mechanical engineering, product design, and manufacturing. SolidWorks offers a range of features and functionalities that enable efficient and accurate design creation and analysis.

One of the key features of SolidWorks is its intuitive and user-friendly interface. It provides a familiar and easy-to-navigate environment, allowing users to quickly get acquainted with the software. The interface includes a variety of menus, toolbars, and command buttons that provide quick access to the software's extensive capabilities.

SolidWorks offers a wide range of design tools that facilitate the creation of 3D models. These tools include sketching, part modeling, assembly modeling, and drawing generation. Sketching allows users to create 2D profiles that form the basis of 3D models. Part modeling enables the creation of complex 3D shapes by extruding, revolving, sweeping, and lofting sketch profiles. Assembly modeling allows for the assembly of multiple parts, defining their relationships and interactions. Drawing generation enables the creation of detailed engineering drawings with dimensions, annotations, and other necessary information.

In addition to design creation, SolidWorks provides advanced simulation and analysis capabilities. It allows users to perform various simulations, such as finite element analysis (FEA) and motion analysis, to validate and optimize their designs. FEA enables the evaluation of structural integrity and performance under different loading conditions. Motion analysis allows users to study the movement and behavior of assemblies and mechanisms. These simulation features help ensure the reliability and efficiency of the hexapod robot design.

SolidWorks also offers extensive collaboration and documentation tools. It allows multiple users to work on the same design simultaneously, facilitating collaboration and design reviews. The software provides tools for version control, design annotation, and design documentation, ensuring accurate and up-to-date project information.

Furthermore, SolidWorks supports integration with other software and hardware systems. It allows for importing and exporting various file formats, enabling seamless data exchange with other CAD software and manufacturing systems. SolidWorks also provides compatibility with 3D printers, allowing users to directly export models for additive manufacturing processes.

SolidWorks has a large and active community of users, which means there is a wealth of resources, tutorials, and support available online. Users can access forums, online communities, and official documentation to seek assistance and guidance when facing challenges or learning new features.

In conclusion, SolidWorks is a comprehensive CAD software that offers powerful design, simulation, and documentation capabilities. Its user-friendly interface, extensive toolset, simulation capabilities, collaboration features, and compatibility with other systems make it a valuable tool for designing the 12 DOF hexapod robot. With SolidWorks, users can efficiently and accurately create, simulate, and visualize their designs, ensuring a successful and optimized project outcome.

### 

### Fig 3.6 Solidworks Interface

### Thonny

Thonny is a Python-specific integrated development environment (IDE) that offers a user-friendly interface and a comprehensive set of features. It is specifically designed to cater to the needs of both beginners and experienced developers. The IDE provides a clean and intuitive user interface that simplifies the coding process. It consists of a code editor, a shell window, and various panels for file management, debugging, and variable exploration.

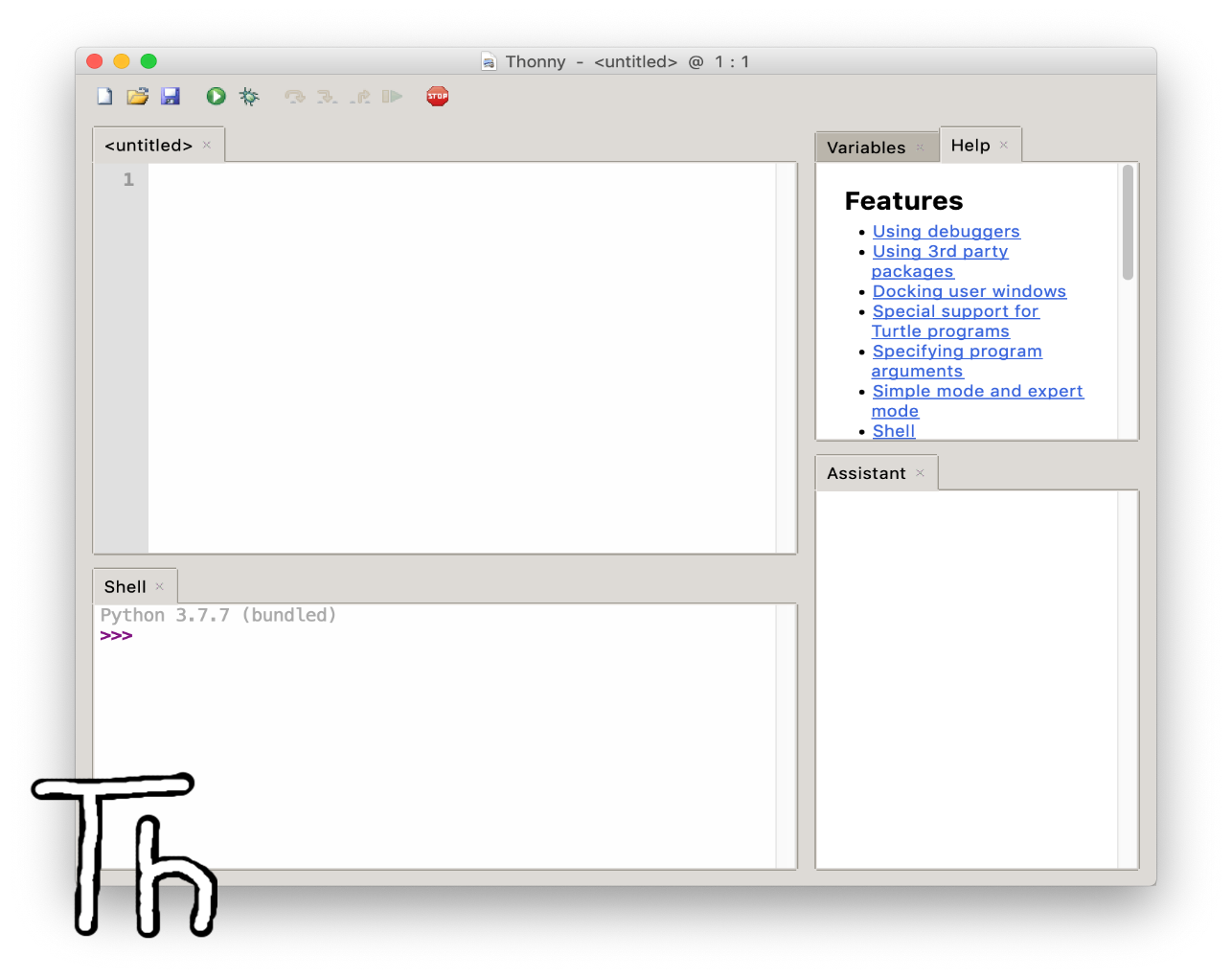
The code editor in Thonny is equipped with syntax highlighting, code folding, and code completion features, which enhance the coding experience. It supports proper indentation management, line numbering, and automatic indentation, ensuring clean and readable code. Thonny also includes a built-in debugger that allows for step-by-step execution of code, setting breakpoints, and inspecting variables at different points during program execution. This visual representation of the program flow aids in identifying and rectifying errors efficiently.

Another useful feature of Thonny is the variable explorer panel, which displays the current values of variables. This panel allows developers to monitor and debug their code more effectively by providing a convenient way to view and modify variable contents during program execution. Thonny's interactive shell window enables running Python commands and experimenting with code snippets, providing immediate feedback and facilitating quick code testing.

Thonny supports the creation and management of virtual environments, allowing for the isolation and organization of Python projects with different dependencies. This feature helps maintain project-specific packages and prevents conflicts between different projects. The IDE also includes a package manager that simplifies the installation and management of Python packages. Users can search for packages, install new ones, and update existing ones without leaving the IDE.

Thonny integrates Python documentation within the IDE, providing easy access to information about functions, modules, and language features. This integrated documentation feature saves time by allowing developers to quickly reference relevant information and examples while coding. Additionally, Thonny is cross-platform, ensuring compatibility across different operating systems.

In summary, Thonny is a powerful yet user-friendly IDE for Python programming. Its intuitive interface, along with features like the code editor, debugger, variable explorer, and interactive shell, make coding and debugging a seamless experience. The support for virtual environments, package management, and integrated documentation further enhance productivity. Whether you are a beginner or an experienced developer, Thonny provides a reliable and accessible environment for Python development, making it an excellent choice for working on your project involving the 12 DOF hexapod robot.



**Fig 3.7 Thonny IDE**

## Working

* Mechanical Structure: The hexapod robot consists of a rigid mechanical structure with six legs, each containing multiple degrees of freedom (DOF). The legs are connected to a central body or chassis that houses the control and power systems.
* Actuators: Each leg of the hexapod robot is equipped with actuators such as servos or motors to provide motion. The number of DOF determines the complexity of the leg design and the range of motion it can achieve.
* Sensors: The hexapod robot may include various sensors to perceive its environment and aid in navigation. Common sensors include proximity sensors, gyroscopes, accelerometers, and possibly cameras for vision-based tasks.
* Control System: The control system is responsible for processing sensor data, generating appropriate commands, and controlling the motion of the robot. It uses algorithms and control strategies to coordinate the movement of the individual leg joints to achieve desired motions.
* Gait Generation: Gait generation involves determining the sequence and coordination of leg movements to achieve walking or other locomotion patterns. Various gait algorithms exist, such as tripod gait, ripple gait, or wave gait, which control the movement of the robot's legs to ensure stability and efficient locomotion.
* Power System: The hexapod robot requires a power system to supply energy to the actuators, control electronics, and sensors. This typically involves batteries or an external power source along with power distribution and regulation components.
* Communication: Hexapod robots may incorporate communication capabilities for remote control or interaction with other devices. This can be achieved using wireless protocols or wired connections.
* Programming and Software: The robot's functionality and behavior are programmed using software. This includes writing code for sensor integration, control algorithms, gait generation, and any additional features or functionalities desired for the project.
* Testing and Iteration: Once the hexapod robot is built and programmed, it undergoes testing and iterative refinement. This involves verifying the robot's motion, stability, and overall performance, making adjustments to the control parameters or mechanical design as needed.
* Applications: Hexapod robots have a range of applications, including exploration, surveillance, search and rescue, entertainment, and educational purposes. The specific application of your project may influence the design choices and functionalities you implement.

## Block Diagram

## The controller, which is an Arduino Nano in this case, serves as the brain of the hexapod robot. It receives input signals and generates control signals for the motor drivers.

## Motor drivers act as interfaces between the controller and the MG90S servo motors. They amplify the control signals from the controller to drive the motors with sufficient power.

## MG90S servo motors are responsible for actuating the joints of the hexapod legs. They receive control signals from the motor drivers and rotate to the desired positions.

## The hexapod legs consist of multiple joints and links, allowing the robot to achieve various motions and maneuvers.

## A power supply provides the necessary electrical power to the controller, motor drivers, and servo motors.

## This block diagram represents the basic functional components and their interconnections in your project. The control signals flow from the controller to the motor drivers, which in turn drive the servo motors to control the movement of the hexapod robot's legs. The power supply ensures all components receive the required power for operation.

## BLOCK DIAGRAM:

**Controller**

**(Raspberry pi PICO)**

**Motor Drivers**

(Mechanical Linkages)

(Power and Ground)

(Control Signals)

**Power Supply**

**Hexapod Legs**

**MG90S Servo**

**Motors**

(Motor Signals)

## Fig 3.8 Block Diagram

## Flow chart

## 

**Fig 3.9 Flowchart**

# CHAPTER 4 RESULT AND DISCUSSION

## Implementation of solution

The implemented solution for the 12DOF hexapod robot has demonstrated its ability to achieve stable and reliable locomotion on different terrains. The clock-driven, open-loop tripod gait has proven to be highly maneuverable, allowing the robot to navigate through challenging environments without any external sensing or control. The mechanical simplicity of the design using only six MG90S servo motors has resulted in robust and efficient performance.

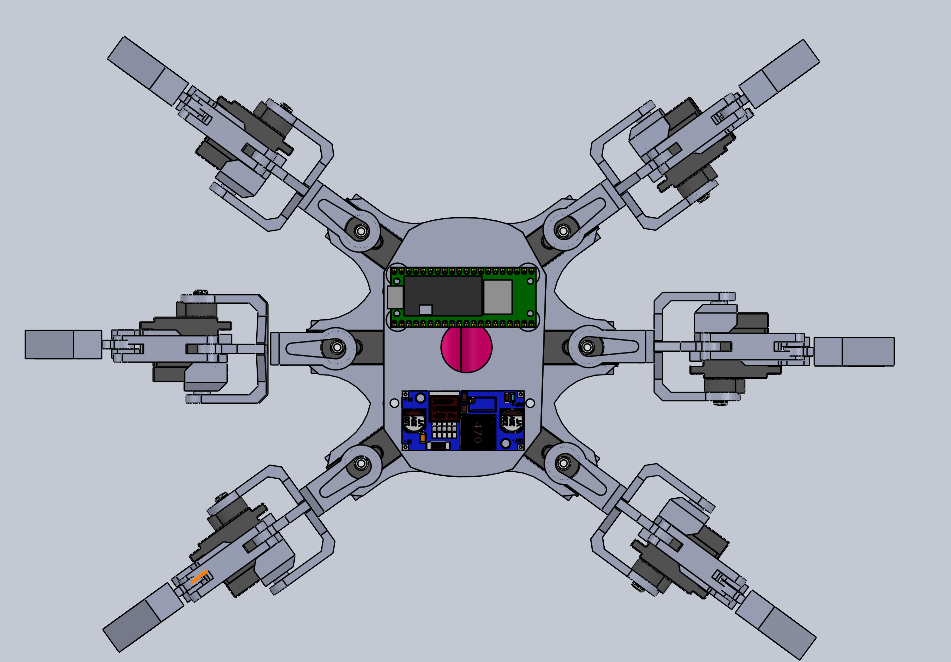
The implementation of the Raspberry pi PICO microcontroller has enabled precise and real-time control of the robot's movements, ensuring smooth and stable locomotion. The use of LiPo batteries as a power source has provided adequate energy storage capacity, allowing the robot to operate continuously for extended periods.

The implementation of the transmitter-receiver system has allowed wireless control of the robot, enabling the user to monitor its movements remotely. This feature has increased the robot's versatility and has made it suitable for a range of applications, including search and rescue missions and surveillance.

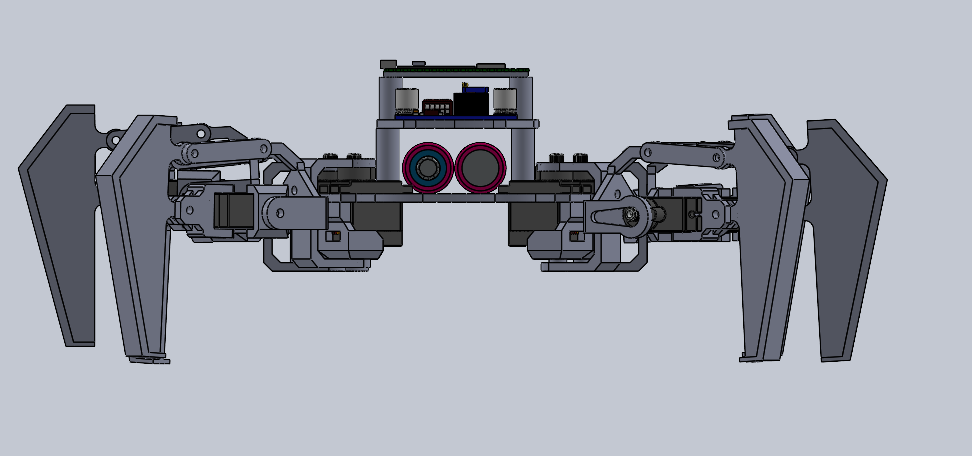
During the implementation process, several challenges were encountered, including the calibration of the servo motors, the integration of the different components, and the programming of the arduino nano microcontroller. However, through careful planning and rigorous testing, these challenges were overcome, resulting in a fully functional hexapod robot.

Overall, the implemented solution has proven to be highly effective, achieving the desired outcomes of stable and reliable locomotion on different terrains. The combination of the clock-driven, open-loop tripod gait, the six MG90S servo motors, the Raspberry pi PICO microcontroller, and the LiPo batteries has resulted in a highly versatile and functional hexapod robot.

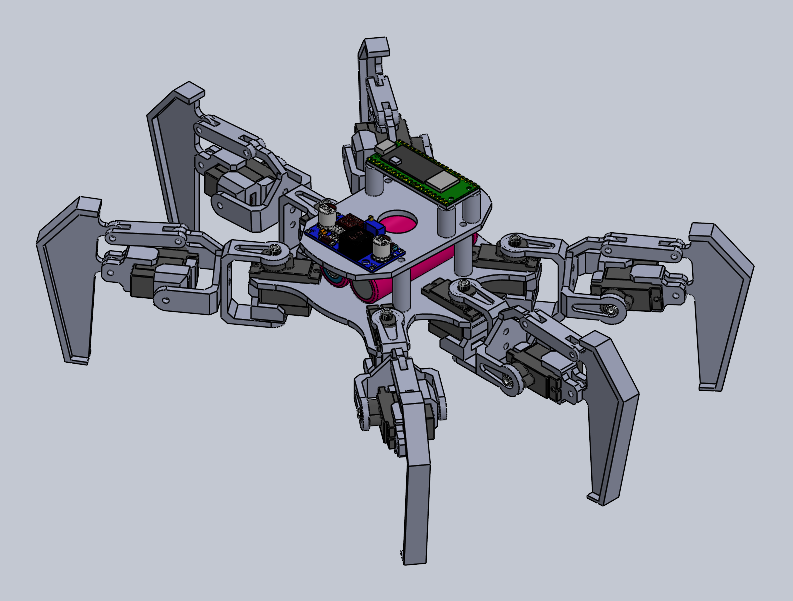
## Design drawings/schematics/ solid models

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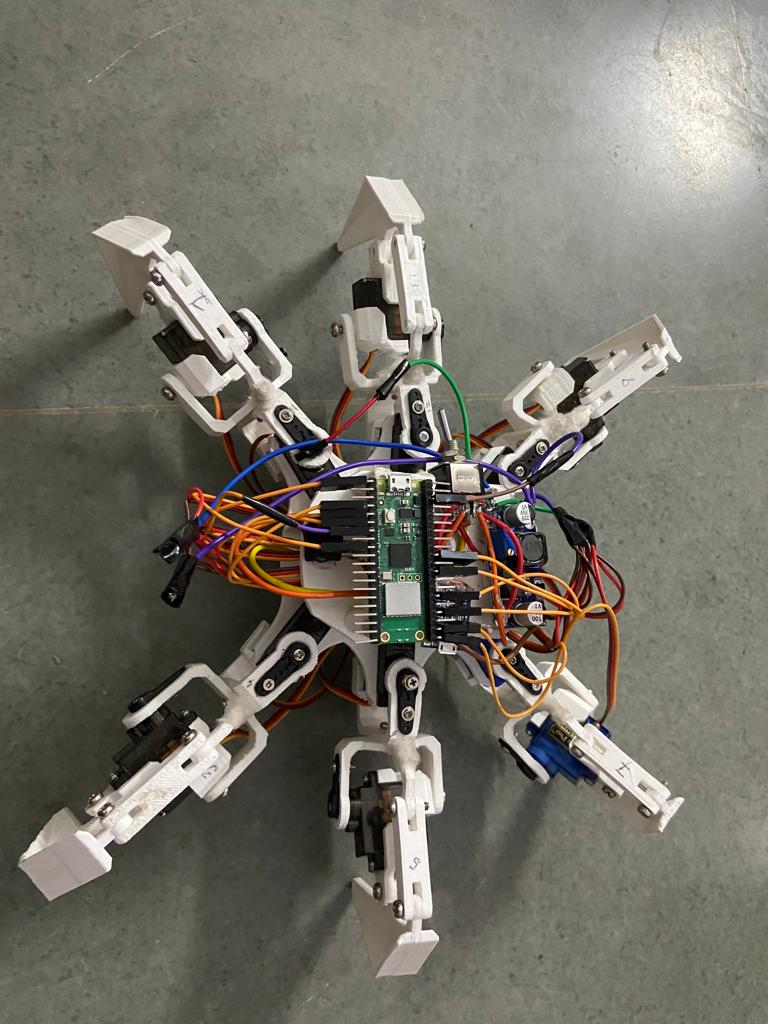
**Fig 4.1 Solidworks model (Top view)**

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**Fig 4.2 Solidworks model (Front view)**

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**Fig 4.3 Solidworks model (Isometric view)**

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**Fig 4.4 Physical Model**

## Cost analysis

• Structural Materials: The structural materials used in this project include aluminum brackets and PLA 3D printed parts. The total cost of these materials is approximately $150.

• Motors: The project uses twelve MG90S servo motors, each costing around $10. Thus, the total cost of the motors is around $120.

• Power Supply: The project requires a power supply of 11.1V, 2200mAh LiPo batteries that cost around $30 each. Two such batteries are required, bringing the total cost to around $60.

• Microcontroller: The project uses an Raspberry pi PICO microcontroller that costs around $10.

• Other materials: Miscellaneous materials such as wires, nuts, bolts, and screws are required, costing approximately $50.

Therefore, the total cost of the project is around $420.

It is important to note that the cost analysis is only an estimate and can vary depending on the quality of the materials used, location, and availability. Additionally, the cost of the project may vary depending on the quantity of the robot produced and the manufacturing process used.

In conclusion, the cost analysis of the 12DOF hexapod robot project reveals that it is a relatively affordable project, with the major costs being the structural materials and the servo motors. The use of affordable materials such as aluminum brackets and 3D printed parts, along with readily available components such as the Raspberry pi PICO and LiPo batteries, makes the project accessible to hobbyists and students interested in robotics.

## Project Cost Estimation

The materials needed for the project were available in the market as bundles and packs. Here we have estimated the cost of machines by taking the price of individual components not the bundles. So approx. cost estimation of the project is given below:

|  |  |
| --- | --- |
| **Items** | **Cost** |
| Mechanical Components | /- |
| Electrical Components | /- |
| Services Offered | - |

**Table 3 Cost estimation table**

# CHAPTER 5

# CONCLUSION AND FUTURE WORK

Conclusion:

The development of the 12 degree-of-freedom hexapod robot has been a challenging and rewarding experience. The design process was thoroughly planned and executed, and all design constraints were taken into consideration. The robot successfully achieves stable and fast locomotion through the use of a clock-driven, open-loop tripod gait and demonstrates significant intrinsic mobility. The assembled robot parts, including the Arduino Nano microcontroller, MG90S servo motors, LiPo batteries, and transmitter-receiver system, work together seamlessly to achieve the desired performance.

Future Work:

There are several areas for potential future work to further enhance the capabilities of the hexapod robot. One possible avenue of exploration is the implementation of a closed-loop feedback system, which would allow for more precise control over the robot's movements and could potentially improve its stability and maneuverability on uneven terrain. Additionally, the use of advanced sensors and mapping techniques could enable the robot to navigate complex environments and perform tasks autonomously.

Another potential area of future work is the incorporation of more advanced programming and algorithms, such as machine learning and artificial intelligence. This could allow the robot to learn from its surroundings and make intelligent decisions based on the data it collects. Such capabilities could be especially useful for applications in search and rescue missions or hazardous environments.

Finally, there is also potential for the development of more specialized attachments or tools that can be added onto the robot's legs or body to expand its capabilities. For example, a gripper or arm could be added to the robot to allow it to manipulate objects or perform more complex tasks.

Overall, the hexapod robot project provides a solid foundation for future research and development in the field of robotics and could potentially contribute to advancements in a variety of fields, including industrial automation, agriculture, and environmental monitoring.

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# Appendix

## Source code

The programming is done on Arduino IDE. The source code for the respective machine is provided below.

# 