Project title: Myriapod Robot: SLAM with Exotic Locomotion

Group number: 25

Group members and majors

- Diego Santiago (CpE)
- Ethan Thomas (CpE)
- Juan Torres Camacho (CpE)
- Axel Maysonet (CpE)

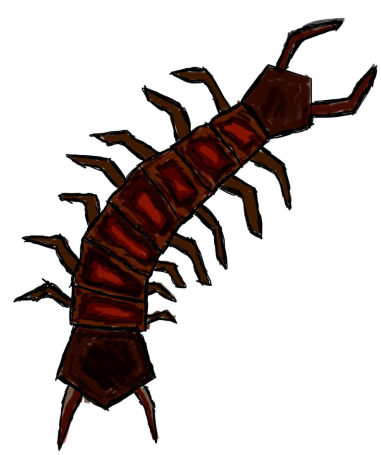
Review Committee

- Aman Behal

Narrative

For as long as it has been feasible, humans have always been fascinated with replicating nature's creatures. From building robot mice that solve mazes, to building robot dogs that can walk up and down stairs, we've always been captivated with the idea of recreating an animal's ability to traverse the world. Alternative mobility robots provide features and capabilities that traditional mobile robots are not able to achieve. This can range from navigating difficult terrain, to climbing walls, to swimming in the ocean. The applications for these innovative technologies are only limited by one's imagination.

Myriapods are of particular interest thanks to their unique ability to maneuver through almost any obstacle on land, thanks in large part to their robust walking mechanism. Myriapods are known for their abundant number of legs, and these legs give them better traction control of their own bodies. Centipedes, being a part of the myriapod family, take advantage of these characteristics as well. They rely on a large quantity of legs to maintain stability and control as opposed to the two or four legs you might find on other animals. The issue with developing a bipedal or quadrupedal robot is that achieving ideal stability while also moving relatively quickly proves to be a very complicated task. Existing solutions have to consistently make adjustments and calculations to make sure they can remain upright and such calculations require a lot of computing power. Instead, we focus on a centipede robot which is able to balance, move, and traverse obstacles mechanically by design, without having to make as many computations. [2]



Fundamentally, centipedes have a head, where they control all of their actions and movements, and a trunk, which consists of numerous segmented body parts. Each segment of the trunk contains two legs, which allows it to move efficiently. Many centipedes are born with only 4 pairs of legs, but they grow one more pair each time they sprout a new segment on their body. The layout of our robot will mirror this closely: One head that controls all/most of the logic, and a trunk that contains modular, segmented body parts that each accommodate a pair of legs. In its modularity, the user would be able to add more segments and legs for additional walking capabilities. Furthermore, each new segment would have the potential and ability to add new functionalities such as sensors or logic units.

Our robotic centipede's goal is to establish a mobile robot platform that intends to address the need for an affordable, durable, expandable robot. The robotic centipede will be able to serve various different applications as needed, offering its ability to be modular and reliable. Its reliability is due to the fact that it relies on less computational power, for example: incase of an electrical failure the robot will have no trouble maintaining its position. Its modularity is due to the fact that we intend to embed technology that allows additional segments to be added to its body. These segments are what will allow it to accomplish different tasks like search and rescue, industrial surveying and being a potential space rover.

With that being said it's important to address how our solution compares to the other current market solutions that are in a similar 'alternative mobility robot' sphere. Number one is cost, one quick look at quadrupedal and bipedal robots and you will notice the high price tag. One of our objectives for our robot is to present a more affordable option. This will be accomplished by using inexpensive computer components since the need for "top of the line" computer hardware isn't really apparent. Number two is expandability, although robots like *Spot* from *Boston Dynamics* offer a peripheral mounting system [1], they can often be very restricting in terms of how many tasks it can perform simultaneously. Once you add one component to *Spot*, it becomes increasingly difficult to add any more. With a robotic centipede, the possibilities truly become limitless. Any functionality one would want to add to the robot, you can essentially join another segment and you're good to go. Need more battery? Add a battery segment. Need a LiDAR sensor? Add a LiDAR segment. This is indeed a remarkable advantage the robotic centipede aims to achieve. Number three is functionality and capability: potential solutions like aerial drones or treaded robots are very good at their jobs but they are just that, 'only good at that one job. Drones over the years have become more affordable, however their functionality is limited due to the fact that any sensors or computer you want to add to it will weigh it down. This then forces the user to construct a larger, more expensive drone to produce more lift. This is without mentioning that many drones are decently fragile in large part due to the fact they have to use lightweight materials. Moreover, a treaded robot is unable to make as many maneuvers or navigate as complicated terrains that a robotic centipede could. With our first iteration of the centipede robot, we hope to prove its advantages over other alternative mobility robots, and continue making it even more robust.

Table of Specifications

Specifications	
Maximum Speed	0.5 m/s
Acceleration to Maximum Speed	0.1 m/s^2
Turning Radius	0.5 m
Supported Terrain	Flat ground, sand, rocks
Connected segments	≥ 4 segments connected to head
Segment add/remove/swap time	≤ 5 minutes
Maximum payload per segment	10 lbs on flat ground
Battery Life	3 hours

- Speed and Agility
    - Maximum Speed: The robotic centipede achieves a maximum speed of 0.5 meters per second on flat surfaces.
    - Turning Radius: It can make a 90-degree turn within a 0.5-meter radius.
- Terrain Adaptability:
    - Terrain Types: The centipede successfully traverses sand, rocks, and stairs without toppling over.
- Energy Efficiency:
    - Battery Life: The robot operates continuously for 3 hours on a single charge.
- Cost and Scalability:
    - Cost-effectiveness: The cost per unit for production is less than $1000.
    - The base design supports connecting at least 4 segments to the head segment
    - Segments should be able to be added, removed, or swapped in less than 5 minutes by an untrained person with minimal instruction
- Durability and Reliability:
    - Robustness: After 72 hours of operation in dusty/sandy conditions, the robot shows no significant damage.
    - Maintenance Frequency: The robot requires maintenance every 500 hours of operation.
- Sensors and Perception:
    - Sensor Range: The sensor has a range of 3 meters.
    - Detection Accuracy: The object detection system has a false positive rate of 3% and a false negative rate of 2%.
- Performance Under Load:

    - Maximum Payload: The robot can carry up to 10 lbs of weight per segment.

Goals

The primary objective for this project is to develop a prototype that demonstrates the potential for myriapod robots as a viable mobile robotics platform. We wish to specifically highlight the affordability, robustness of design, and expandability of a myriapod robot design.

- **Main goals -** These are goals that make up the minimum acceptable progress for the completion of our project.
    - Design and integrate a myriapod robot that, under its own power, can locomote around a human-navigable environment (such as a room), as well as over uneven terrain (such as sand or debris).
    - Have the robot create a map of its environment
    - Have the robot be able to localize itself within its map, and path accordingly
    - Design at least one segment that performs a specialized function to demonstrate modularity (such as an atmosphere sensor module)

- **Advanced goals -** These are goals that our group is confident within reason that we can implement, but are not critical to the demonstration, and can be sacrificed if necessary.
    - Integrate quick connectors for swapping modular body segments
    - Implement wireless control of the robot; i.e. controlling locomotion from a computer, connected via wireless signal

- **Stretch goals -** These are goals that our group will attempt to implement if we have time and resources remaining after completing the above.
    - Implement active motor drive of segment linkages (other than the neck joint) for shape control
    - Implement model predictive control for leg and body pose adjustment

Requirements

Software Requirements

- ROS (Robot Operating System) with SLAM packages and Nav2
- Custom motor control software for metachronal wave locomotion
- Device drivers for all robot components

Hardware Requirements

- Single board computer for high level functions
- Motor controllers for legs
- Leg motors
- Steering servo for head
- Range sensors
- Battery
- Power distribution system
- Battery management system

Anticipated Standards

- ASTM F45 - Committee F45 on Robotics, Automation, and Autonomous Systems
  - This project falls within the committee's scope, as our group aims to design and integrate an autonomous vehicle
  - This committee and its various subcommittees detail various methods and standards for the design and testing of autonomous vehicles.

- ISO 13482 - Safety requirements for personal care robots
  - Though the myriapod robot is not inherently being developed with personal care as a use case, proximity to humans is anticipated.

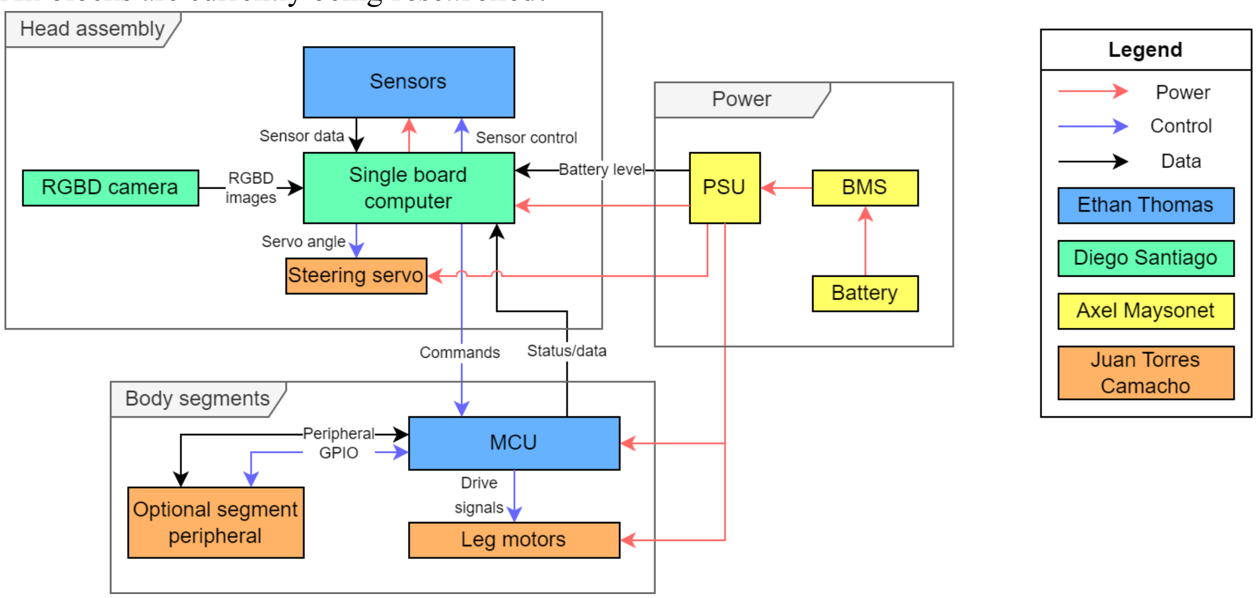
- ISO 10218 - Safety requirements for industrial robots
  - Though our prototype is not intended to be suitable for industrial applications, it is intended to demonstrate the potential for a myriapod robot design to be viable in such applications

- IEC 62133 - Safety testing for Lithium batteries
  - Our robot will have onboard batteries to provide power

Block Diagrams

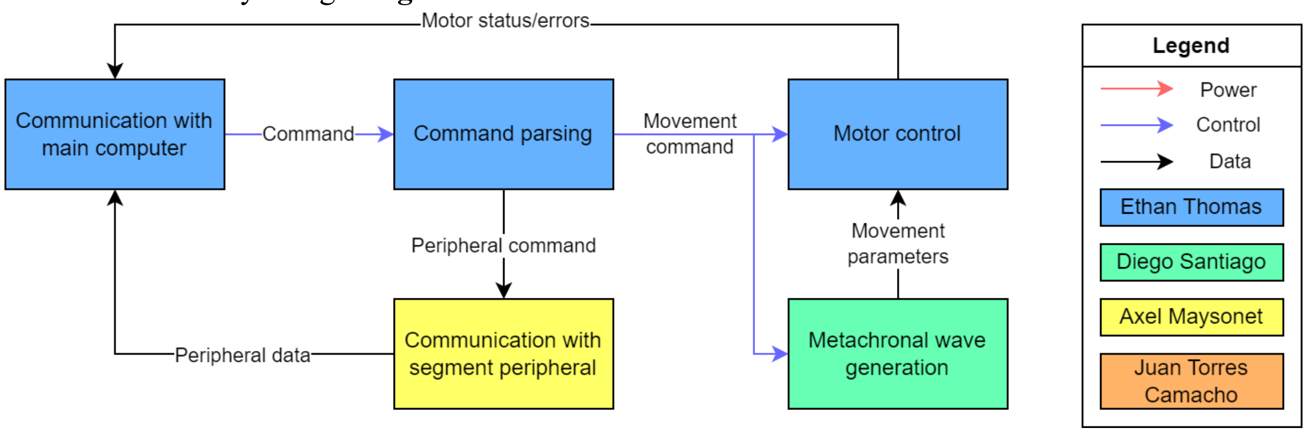
Hardware

All blocks are currently being **researched**.



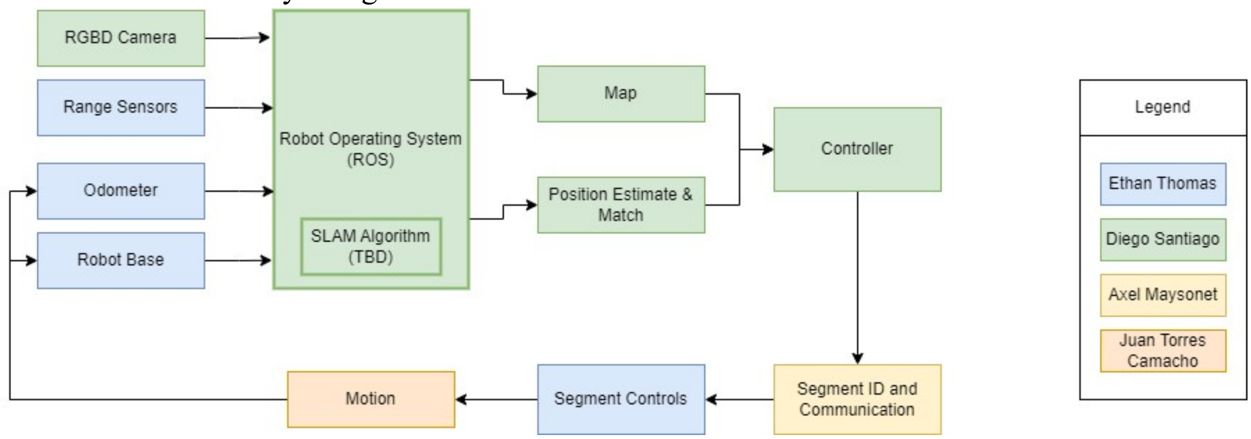
Segment Software

All blocks currently being **designed**.



Robot logic + SLAM

All blocks are currently being **researched**.



Estimated Project Budget

Item Description	Quantity	Cost
Range Sensors	2	$10
Leg Motors	20	$720
RGBD Camera	1	$62
Odometer (optical flow sensor)	1	$17
Turning Servo	1	$16
BMS	1	$22
MCU	5	$45.3
Battery	1	$36

Power Distribution System	2	$27
Total		**$955.3**

Work Distribution Table

Group Member	Primary Responsibility	Secondary Responsibility
Ethan Thomas	MCU programming	PCB design
Diego Santiago	Mechanism design and modeling	SLAM and high-level robot logic
Axel Maysonet	Electrical and PCB design	MCU programming
Juan Torres Camacho	System integration	Mechanism design and modeling

Initial Project Milestones

Category	Milestone	Expected Completion
SEMESTER 1		
Report	Divide and Conquer document completed	Week 4
	60 page document completed	Week 11
	First draft of 120 page document completed	Week 13
	120 page document completed	Week 15
Mechanical	Mechanical design for single segment complete	Week 9
	Mechanical design for head segment complete	Week 10

Hardware	Hardware selection complete	Week 11
	Unit tests complete for single segment	Week 13
	Multiple legs working in parallel	Week 14
Software	Communication with leg motors	Week 12
	Basic robot movement functions	Week 15
SEMESTER 2		
Report	Final report	Week 15
	Team website finalized	Week 15
Mechanical	Segments modified to accommodate PCB(s)	Week 2
	Modular segment connections finished	Week 3
	First full prototype complete	Week 5
	Mechanical design finalized	Week 7
Hardware	All segments working in parallel	Week 4
	PCB design(s) complete	Week 3
	PCB assembly	Week 4
	PCB testing complete	Week 6
Software	Segments controlled by commands from SBC	Week 6
	Basic obstacle avoidance	Week 7
	SLAM	Week 10
	Robot logic finalized	Week 12
Testing	Test terrain constructed	Week 11
	Full system testing complete	Week 13

Appendix

References

1. Boston Dynamics, “Equip the right payload for the job”, BostonDynamics.com, https://bostondynamics.com/products/spot/payload/ (accessed September 10, 2023)
2. “Centipede” portrayed by Axel Maysonet
3. ASTM F45: https://www.astm.org/get-involved/technical-committees/committee-f45
4. ISO 13482: https://www.iso.org/obp/ui/en/#iso:std:iso:13482:ed-1:v1:en
5. ISO 10218: https://www.iso.org/obp/ui/en/#iso:std:iso:10218:-1:ed-2:v1:en
6. IEC 62133: https://webstore.iec.ch/preview/info_iec62133-2%7Bed1.0%7Db.pdf

Acronyms and Definitions

Acronym	Definition
MCU	Microcontroller unit
SLAM	Simultaneous localization and mapping
IMU	Inertial measurement unit
BMS	Battery management system
RGBD	Red-green-blue-depth
SBC	Single board computer
PWM	Pulse width modulation
GPIO	General Purpose Input/Output

LLM Declaration: We hereby declare that we have not used a Large Language Model (LLM) for the creation of this document.