University of Central Florida

Department of Electrical & Computer Engineering

EEL4914

Senior Design 1: Group D

Autonomous Soft Worm Robot

Updated Initial Project and Group Identification Document
"Divide and Conquer 2.0"

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Project Narrative

Ever since the conception of robotics, the objective was to always mimic human movements or complete tasks that are difficult to do, reducing the need of humans altogether. However, what if nature, along with animal movement and composition, was the inspiration of robotics? There are various animals and species capable of moving and doing things in ways no human can do, which brings us to the idea of "soft robotics." Soft robotics is a growing area of research that deals with robotics designed with compliant materials, such as fabric, silicone, or other flexible material, along with flexible electronics, instead of the rigid material that is conventionally used, mimicking what animals, fish, bugs, or plants can do. Using this material can improve safety, allow for greater flexibility, and make it easier to access hard-to-reach areas. This new technology could have a variety of great applications in the fields of medicine, construction, disaster relief, or archeology. Moreover, our project aims to study and showcase the potential of soft robotics by bringing to life a soft robot capable of reaching hard to reach places.

The goal of our project would be to design an autonomous soft robotic worm using flexible materials that would be programmed to navigate a maze of obstacles. Using pneumatically controlled tubing, the robot would attempt to navigate through a series of turns, tight areas, sticky surfaces, liquids, rough terrain, and elevations to retrieve a small object at the end. To grab the object, a gripping system will be implemented on one end of the robotic worm, along with a lidar sensor, which would allow the worm to autonomously navigate the maze.

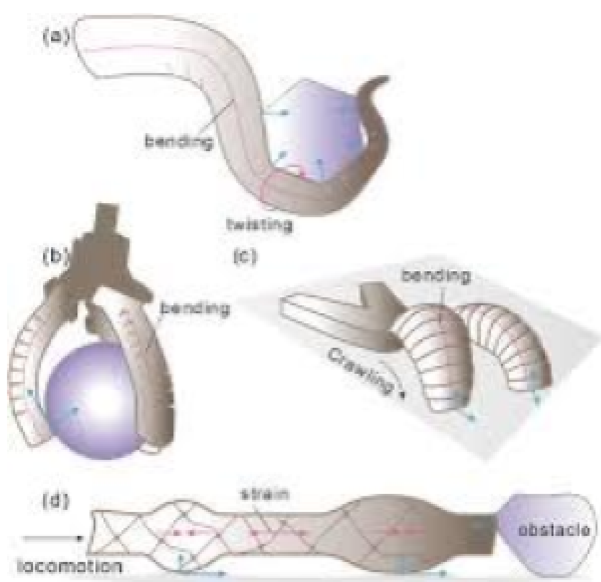

Fig 1: worm & gripper illustration

A camera will also be attached to the tip of the worm, which would be sending footage back to the user. An accelerometer and gyroscope will also be implemented so the worm can detect its orientation and speed when in the maze. The max length of the robotic worm will be kept close to twice the length required to complete the maze, and the diameter will be close to 5 inches so it can navigate hard to reach areas and squeeze through tight places. The material of the robot will be soft and flexible, with the ability to inflate and deflate with pneumatic control.

Furthermore, as this is relatively new technology, there isn't any available input from customers or current marketing analysis on competitive products utilizing soft worm robots. There is, however, research being conducted on how soft robotics can be used in the form of a worm-like design, similar to what we are aiming for in this project. Vine Robots is a soft robotics project supported by Stanford Applied Nanophotonics and the IRiS lab of University of Notre Dame. Their robot, built with flexible material, mimics a vine by retracting and growing with pressurized pneumatics. The robot can also autonomously avoid obstacles with pre-programmed haptic controls. This project serves as one of our inspirations to pursue this idea.

Requirement Specifications

Requirments:

- Robot shall be able to autonomously navigate a maze made up of a series of obstacles.
- Robot shall house lidar sensor, camera, gyroscope, and accelerometer to relay information to the user and be controlled autonomously.
- Maze shall be designed using a combination of: turns, tight areas, sticky surfaces, liquids, rough terrain, and elevations.
- Maze shall be able to be completed using a maximum of 10 feet of robot length.
- Robot body shall be made of flexible material capable of elongating to twice the required length of maze (20 feet maximum) using pneumatic pressure.
- Robot body diameter shall be 5 inches to allow for a navigating tight areas.
- Robot shall turn using artificial muscles that expand using pneumatic pressure, and shall have a maximum turning radius of 1.5 feet.
- Robot shall retract using an internal roller that inverts the base tubing into itself
- Robot shall be able to grip objects of 4cm diameter with a pneumatically controlled soft gripper.
- Robot shall be able to switch to manually control using a smartphone application or web application.
- Users shall be able to select if the robot will be manually driven through a series of rough terrains and obstacles or if the worm will autonomously navigate through the obstacles.
- Users shall be able to see in real time what the light sensors and cameras are reporting back to the robot.
- Robot batteries shall be charged using solar panels.
- Robot shall extend from the tip, and the tail shall holds the body of the worm, the electronics, and the pneumatics.

Feature Specifications:

- Lidar sensor (3D) should detect objects as far as 1m and have a resolution within 1cm for detecting the surroundings and steering autonomously.
- Solar panels should be 2W 12V, and batteries should be 12V 10Ah.
- Camera for manual steering should have night vision capabilities or flashlight.
- Gyroscope will have a range of 450 degree/s to measure and maintain the angular velocity of the robot and assist with steering
- Accelerometer range of (+/-) 2g to record the distance traveled.
- Soft robotic gripper at the head of the robot to grab objects should be capable of 5 psi of gripping strength.
- Material for robot should be flexible, tendon-like tubes that expand upon being applied pressure.
- The lidar camera will process information at a rate of at least 150 frames per second.
- Pressure sensor allows the arm to apply as much as (2 - 2.5) psi for grabbing objects.
- The gripper will have a radius of (4 inches) for its range of motion in all directions.
- Gripper should have at least 2 points of contact.
- Robot should use a Fluid Control Board to regulate pressure flowing into the flexible tendons and the gripper.

- Users should be able to control the pressure distributed to the robot to control its growth rate and speed by using the pressure sensor.
- User should be able to manually turn on and off the air pump using a switch.
- Raspberry Pi board should be used to connect to lidar and get sensor feedback.
- The maze should be at least 10 feet long and made mostly out of cardboard.
- The maze will include deadends for all possible sides and obstacles for the worm.
- The body of the robot will be developed using (ecoflex and silicon elastomer) as well as the artificial muscles.
- Robot body should grow at a maximum rate of 2 in/s.

Constraints:

- **Mobility**: While the robot itself is made for ease of access and mobility throughout a different set of terrains, carrying the pressure tank or dispenser might not be as easy to carry or move when deploying the robot in different environments. Both the body of the robot and the base that houses the pneumatics and electronics will likely be heavy and voluminous. We expect the entire system to have a weight close to 50 pounds.
- **Gripper & Sensors**: The robot has limited space for the features that the team wants to implement. Since the nature of the bot indicates that the head expands, the robot needs to include a cap at its head so the the sensors, camera, and arm grip do not fall off as it expands.
- **Retraction**: The body of the robot allows it to navigate numerous terrains and through or around obstacles because of the pressure being applied. However, when retracting the worm, there is a mobility constraint in narrow spaces which is a key feature of worms. Implementing the artificial muscles, sensors & gripper, and internal roller for retracting will be challenging.
- **Accessibility:** One of the biggest advantages of using this type of robotic structure is accessing tight spaces, which is a feature that will be limited to any space that can fit the head of the worm containing the gripper.

Diagrams

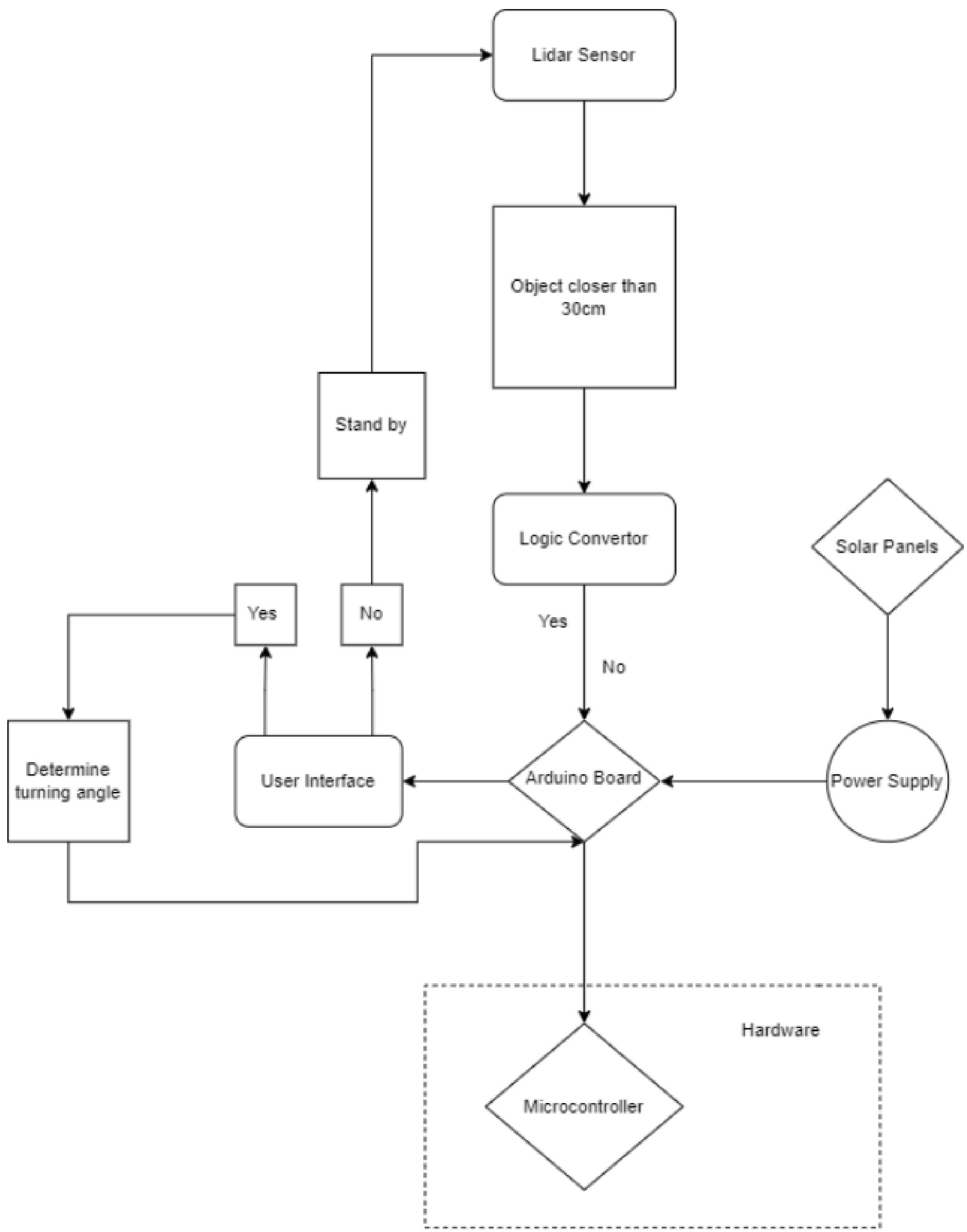

Fig 2: software block diagram

- Kevin will be responsible for the software

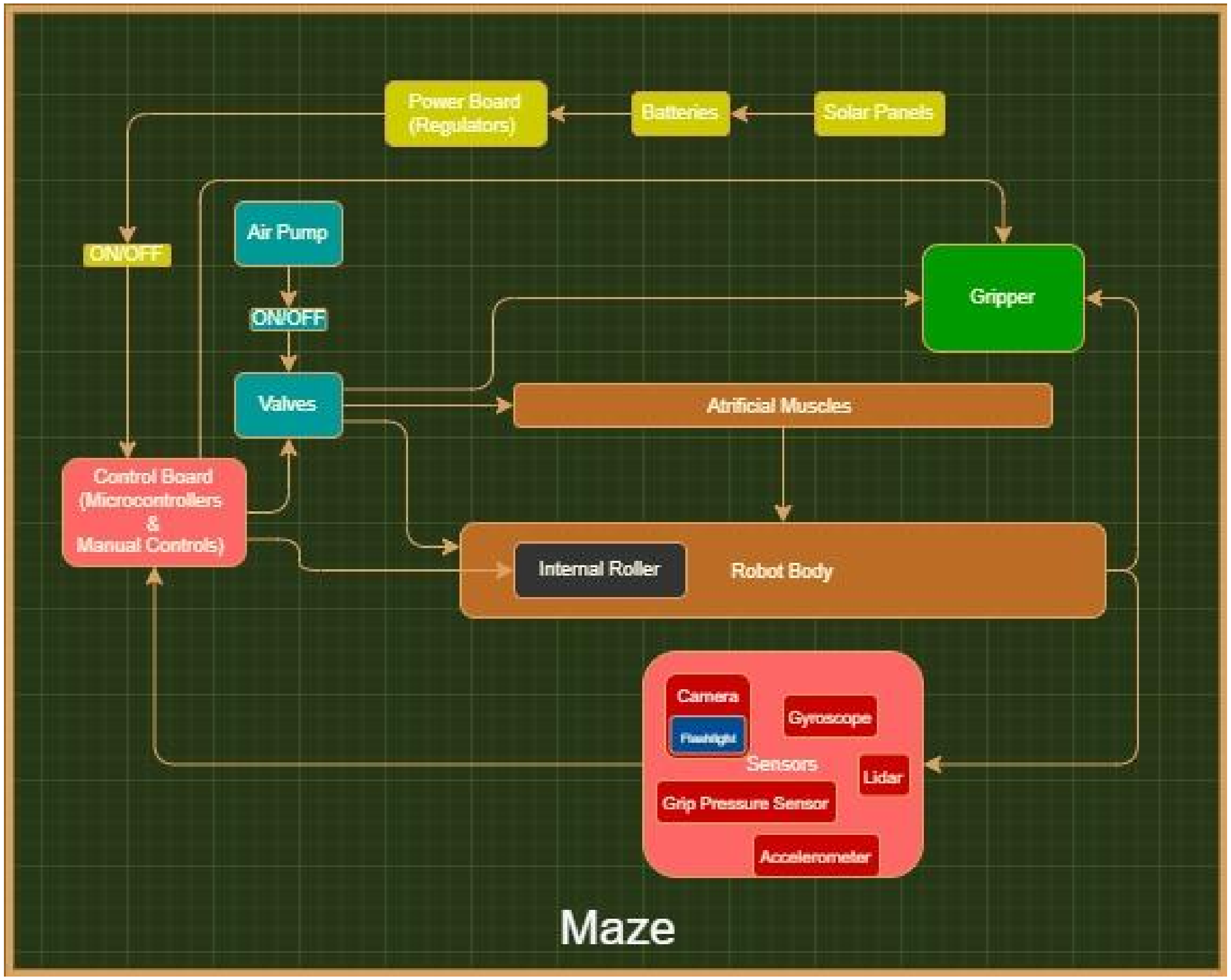

Fig 3: hardware block diagram

- Abdul will be responsible for power (yellow) and pneumatic devices (blue).
- Muhammad will be responsible for the flexible material (orange) and internal roller (black).
- Juan will be responsible for control board & sensors (pink) and gripper (green

Marketing Requirements	Engineering Requirements					
	(-) Dimensions	(-) Processing Time	(-) Weight	(-) Power Consumption	(-) Production Cost	(+) Accuracy
Durable (+)	↑		↑↑			
Easy to Use (+)		↓	↓			↑
Portable (+)	↓↓		↓↓			
Easy to Maintain (+)			↓		↑↑	↑
Reliability (+)		↓				↑↑
Cost (-)		↓		↑↑	↑↑	
	5 in Diameter 10 ft Length	< 150 fps	< 50 lbs	< 200W	< $500	< ±1 in

Strong Positive Correlation	↑↑
Positive Correlation	↑
Negative Correlation	↓
Strong Negative Correlation	↓↓
Positive Polarity	(+)
Negative Polarity	(-)

Fig 4: house of quality

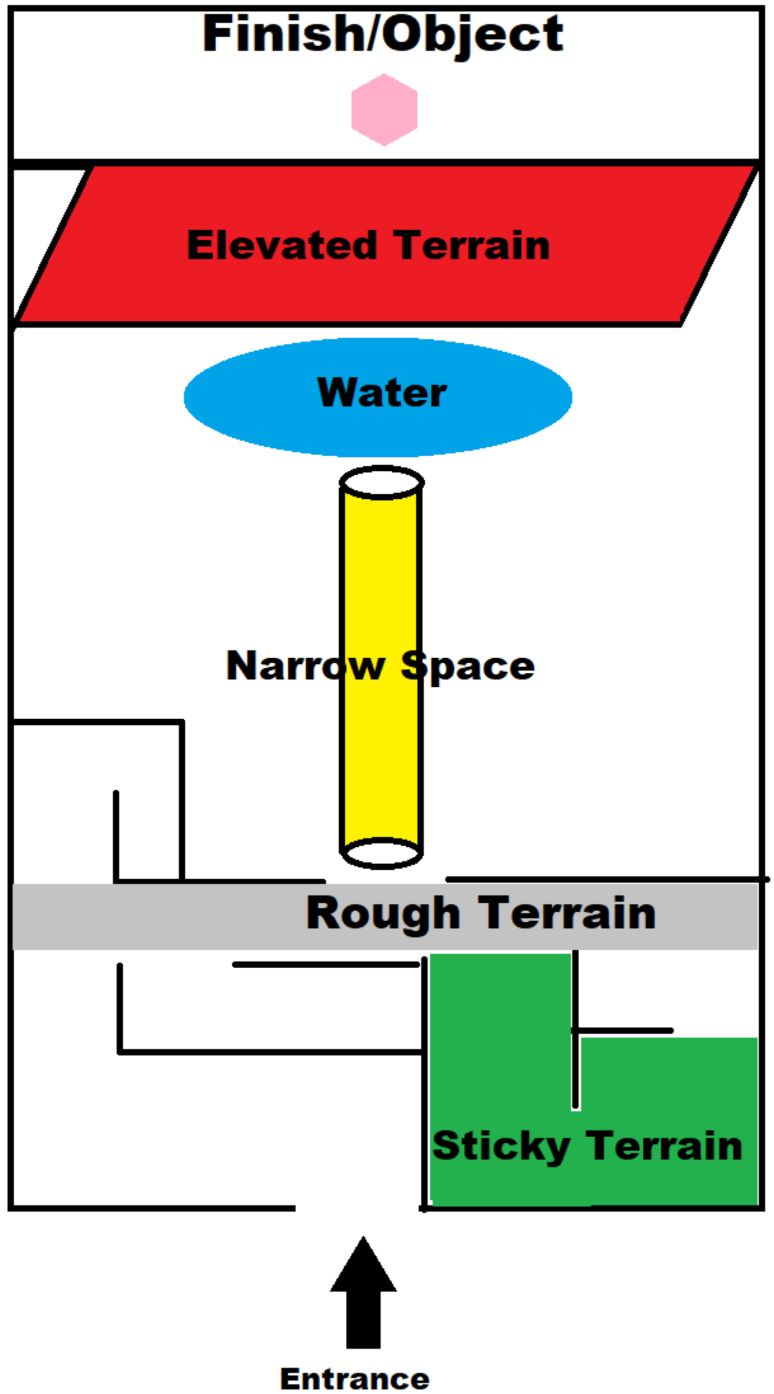

Fig 5: possible maze layout

(Dimensions: L: 15ft, W: 7ft, H: 1ft)

Budget & Financing

The goal for the project's budget would be to keep the cost under $250 and to have funding through the university. Most components we will be using will be SMD and soldered onto a flexible PCB, which should keep our costs low. Below is a cost estimate of our project, along with a range of what our total cost is projected to be with the current components.

Component	Cost	Quantity
Flexible Material / Tubing	$10-15	1
Pneumatics	$15-20	1
Lidar Sensor	$40-50	1
Microcontroller	$5-10	1
Night Vision Camera	$35-45	1
LED Flashlight	$1	1-2
Gripper	$5-10	1
Accelerometer/Gyroscope	$10	1
Pressure Sensor	$20-30	1
PCB	$10-15	1
Roller (Retractor)	$5-10	1
Passive Components	$5	10-20
ICs	$5-10	5-10
Battery pack (Lithium ion)	$5-10	2
Solar Panel	$8-10	1
Logic Converter	$3	1
Unexpected Costs	$300	1
Total Estimated Cost	**$487-664**	

Table 1: budget

Initial Project Milestones

Senior Design I	
Milestone	Timeframe
Presenting idea to faculty members to request funding	February
Research different types of mazes that can provide the most efficient navigation	February
Commence initial project document	February
Finish senior design report draft	March
Building the CAD of the robot/order parts (PCB Design)	March
Final Document Due	April
Integration and testing	April

Table 2: first semester milestones

Senior Design II	
Milestone	Timeframe
Finalize testing of grippers and motion sensors	September
Testing of gyroscope and accelerometer to analyze the distance the robot covers	September
Programming of the robot implemented and tested	October-November
PCB board tested and implemented	October-November
Making necessary hardware changes based on repeated testing	October-November
PCB board tested and implemented	November
Finalize testing of lidar and camera vision	October
Make final presentation	October-November

Table 3: second semester milestones