Engineering Project Detailed Research Plan

Please complete the information/questions begun/seen below in red ink. Save this document to your computer, and add a printed hardcopy to your application.

Student Name: Leo Dai
Project Title: `Underwater Soft Robot for Navigating Underwater Surfaces

Parts of the generic engineering project are listed below with descriptions to the students in the boxes. Students may provide a detailed research plan by describing their specific project in response to each box below.

Engineering Goal: PROBLEM BEING ADDRESSED: All engineering projects solve a problem or fill a need. This goal should be a simple statement that describes the product being designed, the customer it is for and the problem or need it satisfies. Example" "The goal is to design a solar powered lawn mower for inexpensive automated lawn care for homeowners"

Soft robotics provide an interesting alternative to rigid robots for underwater exploration. If constructed properly, they could prove to be far more resilient to pressure and physical impact than the pressurized, rigid robots commonly in use. In addition, they could navigate and access confined spaces far better than any rigid robot could. In current research, there are some prototype underwater soft robots but all of them are built to float or swim in some way. None have demonstrated the capability of moving on an underwater surface. By being grounded, this design could resist underwater currents, it would be better suited for exploring tight areas, and it could provide a more stable platform for repairs. If successful, this device would be well suited for underwater exploration in caves, as well as observation and basic repairs on rigs or pipelines.

My Project Goal is: The goal of this project is to design, fabricate, and test a soft robot capable of moving on underwater surfaces and operating under significant water pressure for exploration and mobile observation on dangerous underwater surfaces.

Design Criteria: Design criteria define the product's required performance . Examples: " It will have a minimum speed of 10 KPH", The output will be within 15% of the mean of the experimental data". "It must withstand 15 repetitions of a 10N impact" The International System of units (SI) required.

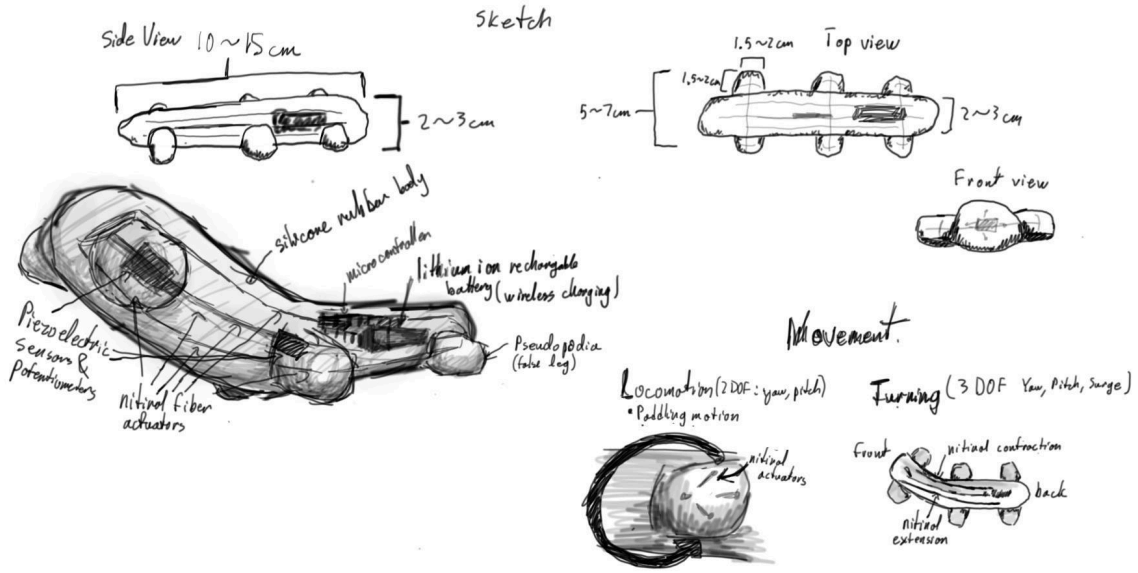
My Project Design Criteria are the following: The device must survive pressure up to 50 meters of water, and move forward with a speed of at least 1m/15 min, as well as turn 360 degrees within 1 minute with a turning radius of less than 20 cm on sand, pebbles, and glass. It will be approximately 10 cm long, and will have an overall density slightly greater than pure water. It will be remotely controlled, and battery powered, with no additional human interference after it is deployed. The robot must be completely flexible with little to no hard surfaces. The design must also incorporate sensors in a way that does not compromise flexibility, while also giving enough data to track robot movement and performance on a computer.

Constraints: Constraints are factors that limit the engineer's flexibility such as size, cost, and time limitations. Examples: "It must fit in a box no larger than 10x20x50 cm" "The maximum cost is $50" "The software must run in real time on a Raspberry Pi"

My Project Constraints are the following: The robot must not be more than 15 cm in length, it must be able to be modeled in real time on a computer using sensory data. It must be completely waterproof up to 50 meters of water pressure. The robot must contain its own power supply. The electronic components must either be flexible or small enough to not hamper flexibility.

Provide your chosen design. For hardware, provide a sketch. For software, provide a flowchart. Indicate the components you will develop, and the libraries you are using.

My Project Design is shown below: insert photos, diagrams, or illustrations below.



Test and evaluate your prototypes against the design criteria listed above to show how well the product meets the need/goal. Provide a test plan describing how you will test the design criteria and constraints you listed above., How will you analyze the data? If the product requires human testing please fill out and append https://science-fair.org/wp/wp-content/uploads/2015/10/Research-Plan-Human-Participants.docx

I test and analyze my prototypes using the following methods:

The robot's movement and turning speed will be measured using a shallow glass tank filled with water at 21 degrees celsius, at least 1.1m in length, and with a grid on the bottom with 5 cm increments. There will be a camera above the center of the tank that can record the tests. For speed, I will record how long it takes for the robot to move 1 meter forward, using the camera and the grid for measuring. For turning, I will use the same setup to find turning time and turning radius for 45, 90, 180 and 360 degrees both left and right. The speed and turning tests will run again on both pebbles and sand, in order to test terrain adaptability. The results will be compared to the test on the flat bottom to see if the design can meet the design criteria. Load cells inside the robot will measure the force output of the actuators, and that information will be used to map actuator performance over time. An internal sensor system using multiple potentiometers and piezoelectric sensors at different points along the center of the robot will perform internal position tracking. The potentiometers measure linear displacement, and the piezoelectric sensors measure bending, and thus can be used to produce a rudimentary 3D skeleton that matches with the robot's movements. Water pressure will be simulated using a sealed container and a pump to reach a pressure analogous to 50 meters of freshwater at 21 degrees celsius, and data from the internal sensor system under pressurized conditions will be compared to data gathered in shallow water to determine differences.

Bibliography: List at least five (5) major references (e.g. science journal articles, books, internet sites & dates of review) from your literature review. If you plan to use vertebrate animals, one of these references must be an animal care reference.

1. Coevoet, E., Morales-bieze, T., Largilliere, F., Zhang, Z., Thieffry, M., Sanz-lopez, M., Carrez, B., Marchal, D., Goury, O., Dequidt, J., & Duriez, C. (2017). Software toolkit for modeling, simulation, and control of soft robots. *Advanced Robotics*, *31*(22), 1208-1224. https://doi.org/10.1080/01691864.2017.1395362

2. Hao, L., Xiang, C., Giannaccini, M. E., Cheng, H., Zhang, Y., Nefti-meziani, S., & Davis, S. (2018). Design and control of a novel variable stiffness soft arm. *Advanced Robotics*, *32*(11), 605-622. https://doi.org/10.1080/01691864.2018.1476179

3. Laschi, C., Cianchetti, M., Mazzolai, B., Margheri, L., Follador, M., & Dario, P. (2012). Soft robot arm inspired by the octopus. *Advanced Robotics*, *26*(7), 709-727. https://doi.org/10.1163/156855312X626343

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5. Yin, H., Tian, L., & Yang, G. (2020). Design of fibre array muscle for soft finger with variable stiffness based on nylon and shape memory alloy. *Advanced Robotics*, *34*(9), 599-609. https://doi.org/10.1080/01691864.2020.1738272