FINAL REPORT: Whole Skin Locomotion

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***Abstract***

Whole Skin Locomotion (WSL) is a project that hopes to further the research of an interesting problem’s solution. The problem is, how to make a robot that is well suited for traversing tight spaces such as collapsed buildings or humane gastrointestinal tracts. By nature a wheel or tank tread rotates with the top and the bottom effectively going different directions. This can create dangerous and unstable conditions in confined spaces. Additionally wheels and tank treads can only use half of its available surface for forward motion. These are significant problems, and rich area for research. This semester I continued the WSL research project that had been started last semester.

The base of this project was inspired by the movement of an amoeba, whose locomotion heavily depends pseudopods and cytoplasmic streaming. The endoplasm flows through the amoeba causing growth forward and away from the cell body. We aim to mimic this affect by creating the WSL robot’s forward motion from an inverting torus. As the torus inverts the entire exterior facing membrane moves in the same direction and returns though the center. This is contrary to a wheel or tank tread as we discussed earlier. WSL allows the robot to move in as long as the robot is in contact with the surface.

***Introduction***

The robot developed last year achieved forward motion through the continuous inversion of a toroidal membrane. The membrane was push through itself via the activation of shape memory alloy coils. These coils were attached via mounting points along the membrane. By sending small electric currents through the shape memory alloy coils, we were able to apply enough force for the torous to invert.This resulted in proven forward motion, one body length of the torus.

This semester the project was continued with the questions: could we achieve multiple body lengths of movement, and could we achieve 2-directional (forward and backward)? By design, the previous prototype could not move multiple body lengths. The prototype did not have a method for expanding the shape memory after it had been constricted. This was the root of the research I did over the semester.

***Literature Review***

The first step of this research was to conduct a literature review. This was important because there were no recurring members on the team. The most important material was the source material recorded by last year’s research group. THe WSL team won the collegiate category award from the Soft Robotics Toolkit website. Thus their work was well documented, and included videos. This year’s research began by recreating a fully functional robot from last year. Additionally, the literature review included finding external papers that could help advance the project. The most useful papers were about shape memory alloy and the unique features/applications of it. These papers helped guide the research towards a reasonable solution. What this project is trying to achieve is quite nuanced and interesting; after researching the wholistic topic, I’ve realized only a few people are woking in this field. This is promising for any future research Olin students want to conduct.

***Direction of Research and Experiments***

The first direction I would suggest the continued pursued of is the idea of adding spring material as part of the contractile ring or as a separate ring directly behind it. The contractile rings can (by human standards) be easily opened by applying force to them. The idea behind this is to force the contracted rings open by combining the force of moving the WSL forward, and the spring force. This could work is the shape memory alloy (SMA) spring was strong enough to overcome the force of the spring when closing, which would hopefully be considered a neutral force, since the same spring force will be forcing the opposing side open.

This direction is one I find to be most promising. I believe after calculating the forces being applied on the membrane, an experiment would be easy to conduct. The main difficulty I had with conducting this experiment was the difficulty in creating the SMA coils, which took weeks to learn how to do correctly. Additionally, I had a difficult time connecting the spring sections to the SMA section. Ideally, I wanted to connect the spring material at 3 places. However, the system proved too delicate for it; this should not be taken as a universal fact and more a reflection on my shaky hands.

To complete this direction of research testing needs to be done get quantitative results for a variety of questions. For example how much force needs to be applied to achieve forward motion on the membrane? How much force the SMA currently exerts, what the maximum force the SMA can apply, and what's the minimum force that can be applied to the SMA for it to open up. These experiments can all be conducted in the MatSci Lab after receiving training from Matt Neally.

The second direction that could lead to good results is to have a second SMA ring embedded in another SMA coil. One of the rings would contract close and one would open. The one that opens would be on the outside, the one that contracts closed would be on the inside. On one side of the toros the SMA would contract, while on the other side the ring would expand. The combined force of two SMA rings will be enough to open the closed coils up, and close the open coils. Additionally, the extra force should reduce the amount of force each SMA ring would have to exert. The rings would be almost the same diameter with a layer of insulation in between them.

To complete this direction, the same quantitative results must be found as those listed above from direction one. Significant experimentation with the insulation and size of the contractile rings also must be experiments with. This would be an excellent project for an incoming team member to work on, however it does have the same steep learning curve for making the SMA coils.