VIRTUAL EVOLUTION OF 2D SOFT ROBOTS

NT Conradie[a] & Dr. MP Venter[b]

Department of Mechanical and Mechatronic Engineering, University of Stellenbosch, Stellenbosch, South Africa

The project aims to virtually evolve efficiently represented two-dimensional (2D) soft robotic bodies using a genetic algorithm. These soft bodies are accurately modelled using real-world materials and physics, and the results should thus be physically replicable. Initial testing using a simple model is done to verify the accuracy of the non-linear FEM models used. Unit cells from which the soft bodies are built are defined with unique and specific behaviours. Innovative techniques are used to represent entire complex 2D bodies in a computationally efficient manner.

Introduction: Soft robotics is an emerging and fast-growing field with many potential applications[1]. However, traditional design methodologies are not well-suited to the design of many aspects of soft robots, as their surfaces are often contoured, compliant and complex, and advanced FEM is usually required to accurately model and predict their behaviour[2].

This project proposes to alleviate these issues by using new, more efficient methods to design and model soft robots.

Objectives: The project aims to demonstrate the viability of virtual evolution as a design methodology for soft robots. The project aims to show that it is computationally efficient and practical, resulting in designs that can be translated into the real world.

Genetic algorithms are robust and capable of exploring large design spaces with relative ease. Due to the difficulty of manually attempting to design soft robots for new and different tasks, these algorithms are a promising solution to this dilemma[3]. If the models of the soft bodies can be made more computationally efficient, this could vastly improve the genetic algorithms' performance, and by extension, allow for soft robotic design to become easier and more accessible. This project aims to do so.

The project also aims to make its work replicable and easy to continue with for further research. Stepping up from 2 dimensions to 3 dimensions, while requiring more intensive computations, should be achievable, and modifying the objective functions of the genetic algorithm should be straightforward, to allow for the easy reuse and further development of the project.

Investigative Approach: Virtual bodies are composed of hollow 2D unit cells with distinctly defined behaviours. Example behaviours, although not necessarily the final behaviours, can be seen in Figure 1 below. The initial shape is indicated with solid black lines and the transformed shape with dotted lines. Unit cells are deformed first according to their defined behaviours, and the resultant strain energy will then be computed. Deformations are defined as occurring due to an internal pressure increase.

Figure 1: Unit Cell Example Deformations

Two approaches are considered to model the soft bodies as a whole.

One approach is the usage of Lindenmayer systems (L-systems), as they have been shown to be very promising as representation methods for complex soft bodies. L-systems are composed of recursive grammar rules, replaceable symbols and constants, which are then applied to an initial set of symbols and constants. Using this approach, a complete soft body can be modelled using only the rules, symbols, constants, initial set and a specified level of recursion, where symbols and constants are representative of specific unit cells.

The other approach involves the usage of Compositional Pattern-Producing Networks (CPPNs), a type of neural net, as a more efficient method of the representation of soft bodies.

The project potentially uses a genetic algorithm to evolve a randomly generated population to best fit some goal.

Virtual bodies and their behaviours are modelled using non-linear FEM. Different FEM software packages are tested in order to determine which is sufficiently accurate, applicable and supportable. The

[a] 19673418@sun.ac.za
[b] mpventer@sun.ac.za

different packages considered are Siemens NX, LSDyna and Marc Mentat.

A material model of Mold Star 15 is used. It is modelled as a non-linear, hyper-elastic material.

As a proof of concept, physical replicas of unit cells and complete bodies are manufactured. In order to mimic the 2D virtual models, these replicas are manufactured at some constant thickness. The assumption is made that there is similar behaviour throughout the material's thickness. Internal pressure as with the virtual models is applied. The replicas are kept in place between two glass plates. At the unit cell level, the physical replicas are compared to the unit cell virtual models to determine if the same shapes result. At the body level, the physical replicas are compared to the virtual bodies to determine if the same behaviours result.

Limitations: The bodies are modelled in two dimensions, so as to severely reduce complexity and computational costs.

Expected Findings: There are no findings yet.

The project is expected to accurately and efficiently evolve and simulate soft robotic bodies in 2 dimensions, in an easily replicable and modifiable manner. The project is also expected to do so in a much more computationally efficient manner than previous attempts.

Conclusions: The field of soft robotics has a lot of potential for discovery. This project aims to explore some of that potential in a more computationally efficient manner, resulting in tools that can be used to further develop this field and design interesting solutions to complex problems.

References:

1. G. M. Whitesides, "Soft Robotics," *Angew. Chemie - Int. Ed.*, vol. 57, no. 16, pp. 4258–4273, 2018.
2. N. Cheney, J. Bongard, and H. Lipson, "Evolving Soft Robots in Tight Spaces," pp. 935–942, 2015.
3. N. Cheney, R. MacCurdy, J. Clune, and H. Lipson, "Unshackling evolution: evolving soft robots with multiple materials and a powerful generative encoding," *Heal. Psychol.*, vol. 24, no. 4, Suppl, pp. 167–174, 2013