“Advanced exploration of extraterrestrial objects through shape-changing robots”

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Background & Significance

Provide an introduction that provides background context and NASA significance for the study. 150 words maximum.

Rigid robots are the standard for task specific space expeditions. While these robots have been very effective on large planetary surfaces, it is difficult for them to traverse high variability terrain on smaller objects such as asteroids, and Kuiper-belt-like objects. These robots generally fail directly or indirectly due to their weight, size, or non-complaint bodies.

Soft robots have unique characteristics absent from rigid machines: low-mass, compact, highly complaint bodies. Soft robots draw heavily from the way in which living organisms move and adapt to their surroundings. Soft robots also allow for increased flexibility, adaptability, and resilience to damage.

Soft robots also provide a unique capability over rigid machines: the ability to change their shape. As demonstrated in nature, this behavior has several desirable properties, including the ability to enter and operate in a wider range of environments than a fixed-shape organism. As our ability to create shape-changing soft robots improves, they may similarly be able to enter and operate in a growing range of environments.

Project Goals

Concisely describe the specific goals of the project. 150 words maximum.

In this research I have worked on the development of a simulation-to-reality pipeline that automatically designs morphing strategies for soft robots, as well as behaviors for each task and shape in each environment. I use the soft-bodied physics engine, Voxelyze, better known by its corresponding graphical interface: VoxCAD. Voxelyze/VoxCAD simulates materials as a set of voxels (3D pixels with user-specified elasticity, density and friction) that can be volumetrically deformed through linear expansion and contraction of internal elastic beams that define their structure. This simulator is used to mimic shape-shifting elastic bilayers in a physically realistic and plausible manner.

For physical hardware I (in conjunction with a team at Yale) have utilized pneumatics for the core of an inflatable robot in a flexible skin with embedded strain limiting fibers, building on the previous work done with their OmniSkins platform.

Summary of Key Findings

Describe the key outcome of your work in terms suitable for an educated, but non-expert reader. 300 words maximum.

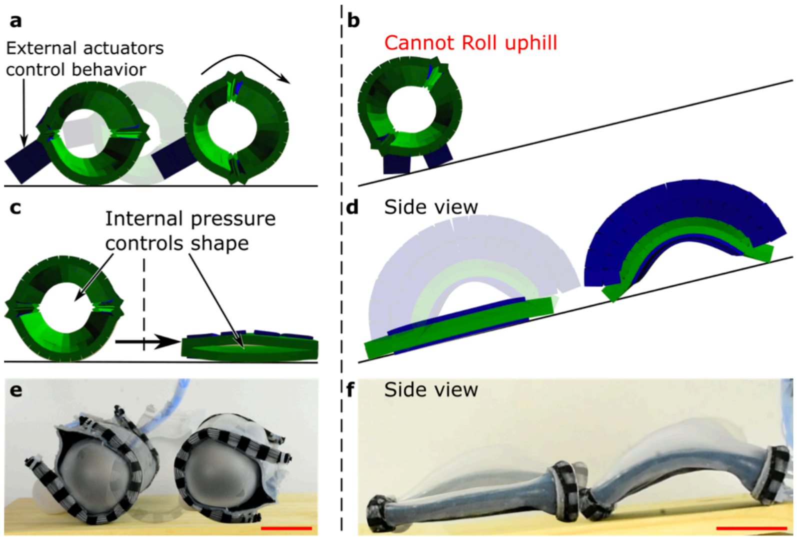

Figure 1: **We tested the hypothesis that shape change could result in faster locomotion speeds than control adaptation, when a robot must operate in multiple environments.** (**a**) Using inflatable external bladders, rolling was the most effective gait on flat ground. However, this gait was ineffective on the inclined surface (**b**). (**c**) The robot's inner bladder allowed it to change shape. (**d**) The most successful locomotion strategy on the incline was crawling while transforming to a flat shape. After discovering these strategies in simulation (**a-d**), we transferred learned strategies to real hardware (**e-f**). Scale bars in **e-f** are 5 cm.

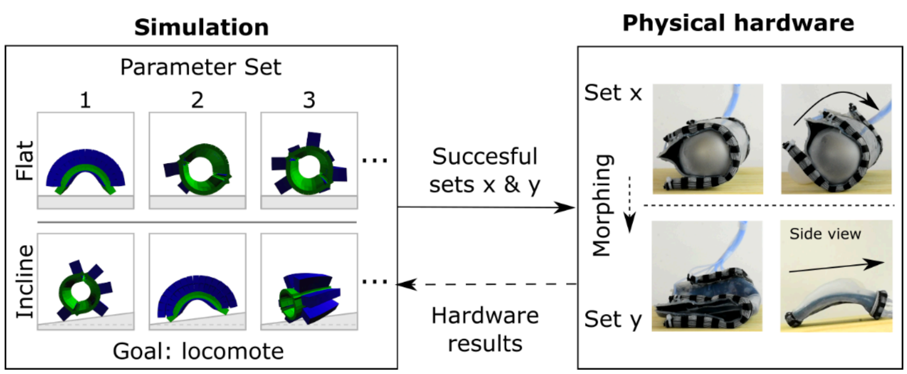

Figure 2: **Simulation revealed successful shapes and controllers, which we attempted to realize in hardware.** Sets consisting of a shape, an orientation, and a controller were found for the robot in simulation. Successful sets were used to design hardware that could attain similar gaits.