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The First Steps of a Robot Based on Jamming Skin Enabled Locomotion

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***Abstract*—A soft, controllably morphable mobile robot is an ideal platform for traversing complex terrain and navigating small holes. iRobot Corporation and the University of Chicago have made use of a phenomenon known as particle jamming to create such a robot. The robot presented in this work uses jamming skin cells to enable controlled morphing and locomotion.**

I. Introduction

This work, funded under the DARPA Chemical Robots program [1], has a goal of creating a soft controllably morphable mobile robot. iRobot Corporation and the University of Chicago have used the phenomenon of vacuum pack jamming to construct such a robot [3]. Jamming is a unique and interesting phenomenon that could prove to be an ideal technology for a soft robot platform. To the authors' knowledge the only other use of jamming in a robotic context is in a haptic device where jamming is used as a mechanical constraint [2].

A. Jamming

Vacuum pack jamming is the mechanism by which particulate material can transition between a liquid-like and a solid-like state with only a small change in confining volume [1]. To illustrate vacuum pack particle jamming, a flexible bladder is filled with a granular material, such as sand, and a fluid, such as air. When no pressure differential exists between the inside and outside of the bag, the sand-air slurry is very compliant. If the air is removed from the bag, the pressure differential causes the walls of the bag to squeeze the sand. The grains of sand jam against one another, and the bag becomes non compliant. In addition to vacuum pack jamming, other forms of liquid-like to solid-like transitioning substances exist, including electrorheological, magnetorheological, photorheological, and shear thickening fluids. Each of these jammable fluids is activated by different means but the principle remains the same. When activated the fluid enters a solid-like state; when deactivated the fluid returns to its liquid-like state. These other forms of jamming are important as it is the intention of this project to replace vacuum jamming with one of these other forms of jamming, specifically electrorheological jamming.

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II. Jamming Modulated Work

While the phenomenon of transitioning between liquid-like and solid-like states is interesting, jamming alone does not solve the problem of constructing a soft robot. Jamming itself cannot perform work on its surrounding environment. However, jamming can be used as a modulation device to direct the work performed by other actuators. Therefore, it is important to differentiate between the modulators (jamming cells) and the actuators which perform the work. This is important because this means that many degrees of freedom (DOF) can be created from only a few, or a single, actuator(s). When jamming is used as a modulator, it allows for a reduction of actuators which are, in many cases, rigid devices. This work demonstrates a robot with 19 DOF yet only 1 actuator.

A. Jamming Skin Modulated Work

Jamming Skin enabled locomotion (JSEL) makes use of the jamming modulated work concept to enable controlled morphability and consequently locomotion of a mobile robot. In JSEL's architecture a hyper-elastic skin composed of multiple cellular compartments is constructed. Each cellular compartment is filled with a vacuum pack jammable slurry.

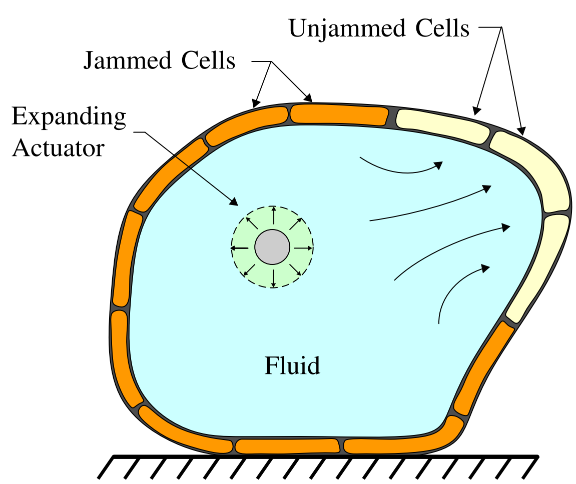

Fig. 1. A side view showing jamming skin enabled morphing. 3 cells are unjammed and the internal actuator is partially inflated causing deformation at the unjammed cells.

Fig. 2. Composited figures of the JSEL prototype rolling over one revolution.

The center cavity is filled with a fluid and a single actuator capable of volumetric variation. Morphing is realized by unjamming a subset of the outer cells and changing the internal volume of the robot through the expansion of the volume varying actuator, as in Fig. 1 [3].

III. Construction

The JSEL prototype was constructed from 20 triangular silicone rubber cells. Each cell was filled with a jamming slurry composed of 100 mesh glass spheres (Class IV soda lime glass spheres) and air. Though all granular materials exhibit jamming behavior, these particular glass spheres were chosen due to their ability to flow well in an unjammed state yet remain fairly rigid in a jammed state [3].

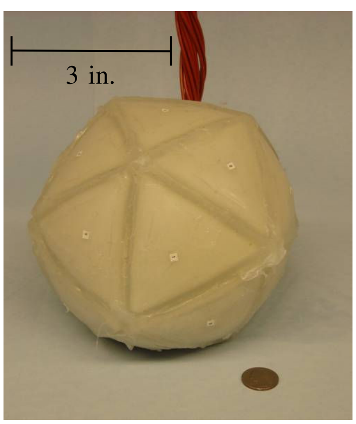

Fig. 3. JSEL prototype alongside a U.S. quarter for scale. The robot is tethered and each of the 20 cells on the robot are numbered as shown.

The jamming cells were assembled into a regular icosahedron, a 20 sided polyhedron composed of equilateral triangular faces, thereby forming a jamming skin with a hollow central cavity (see Fig. 3). Silicone rubber pneumatic tubing was used to tether the jamming cells and central cavity (volume varying actuator) to a pneumatic control board.

IV. Results

Morphing was realized by jamming the cells desired to remain in place and unjamming a subset of the cells to be morphed into or out of the robot through inflation or deflation of the central cavity. Examples of this robot's morphing capabilities can be seen in [3]. A simple locomotion gait was achieved by jamming all but a subset of cells at the rear of the robot and inflating the volume varying actuator. This inflation caused a foot to protrude out of the main body of the robot which caused it to roll in the opposite direction. Through repeating this roll inducing mechanism, this extremely soft and controllably morphable robot, enabled through the use of particle jamming, was able to roll over 360 degrees.

References

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