Multiple Degree of Freedom Pneumatic Actuation for an Untethered Soft Robotic Quadruped

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I. Introduction

Soft robotic systems utilize compliance to adapt to their environment. Recently, researchers have used soft lithography as a promising approach for fabricating mobile soft robotic systems [4]. We have used a similar method to develop an untethered soft robot with single degree of freedom limbs [5]. However, this design used elastic energy stored during actuation to provide the restoring force after actuation. This limited the actuation speed and the ability for the robot to lift its legs over obstacles. Antagonistic actuation, by contrast, has been demonstrated in soft robotic systems for gripping [1], serpentine locomotion [3], and swimming [2]. Here we present a multi-degree of freedom soft robotic limb with antagonistic actuation for agile walking with the goal of emulating the complex, versatile behavior of a gecko.

II. Design

Using antagonistic pneunets, we control the actuation for each direction independently. A pneunet is a pneumatic network connecting air chambers that expand when pressurized. By adding a strain limiting layer, we constrain the expansion of the chambers to create the desired motion.

Pairing air chamber networks on both sides of the strain limiting layer enables antagonistic actuation; when one side of the actuator inflates, the other side compresses. Designing the cross-section of each chamber to be triangular alleviates the interference of the chambers that are under compression.

To control the motion in four directions (i.e. left, right, up, and down) individually, two of these dual layer pneumatic networks are paired orthogonally. To access the two channels on the far end of the appendage, air channels flow through the central strain limiting layer. When inflating combinations of the four actuators, we can obtain the lift and swing degrees of freedom required to achieve the gait similar to a gecko (Fig. 1).

III. Experimental Results

Experimentally, we built a prototype leg and actuated the proximal and distal antagonistic pairs to achieve lift and swing (Fig. 1). Each leg is made using a soft silicone elastomer (Ecoflex 0030, Smooth-On). This soft elastomer requires low pressure for actuation and is thus compatible with small portable pressure sources.

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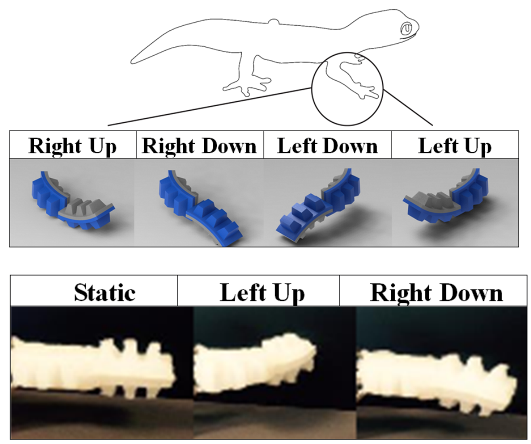

Fig. 1. Pictured at the top of the figure is a rendering for the planned actuation sequence used to reproduce a gait similar to that of the gecko, below is the experimental prototype pictured in several actuation states.

Each actuator is manufactured by soft lithography using 3D printed molds. Each pneunet unit is molded independently. Once cured, a polyester sheet infused with silicone acts as the strain limiting layer and is used to mechanically connect and pneumatically separate opposing pneunets. Two of these bidirectional actuators are attached in series in a perpendicular orientation with a thin layer of silicone.

IV. Conclusion

We have presented a soft robotic leg composed of a pair of orthogonal antagonistic actuators. This leg design will enable a small, agile, untethered, soft robot to have capabilities beyond those of other soft robots, including overcoming obstacles or climbing walls.

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