Soft Robots Using Compliant Tensegrity Structures and Soft Sensors

Lee-Huang Chen[1], Peadar Keegan[1], Michelle Yuen[2], Alice M. Agogino[1], Rebecca K. Kramer[2], Adrian K. Agogino[3],and Vytas SunSpiral[4]

[1]University of California at Berkeley, [2]Purdue University, [3]University of California at Santa Cruz at NASA Ames and [4]Stinger Ghaffarian Technologies at NASA Ames

Tensegrity structures, isolated solid rods connected by tensile cables, are of interest in the field of soft robotics due to their flexible and robust nature. This makes them suitable for uneven and unpredictable environments in which traditional robots struggle. The compliant structure also ensures that the robot will not injure humans or delicate equipment in co-robotic applications [1]. A 6-bar tensegrity structure is being used as the basis for a new generation of robotic landers and rovers for space exploration [1]. In addition to a soft tensegrity structure, we are also exploring use of soft sensors as an integral part of the compliant elements. Fig. 1 shows an example of a 6-bar tensegrity structure, with integrated liquid metal-embedded hyperelastic strain sensors as the 24 tensile components. For this tensegrity, the strain sensors are primarily composed of a silicone elastomer with embedded microchannels filled with conductive liquid metal (eutectic gallium indium alloy (eGaIn), Sigma-Aldrich) (fig.2). As the sensor is elongated, the resistance of the eGaIn channel will increase due to the decreased microchannel cross-sectional area and the increased microchannel length [2]. The primary functions of this hyperelastic sensor tensegrity are model validation, feedback control, and structure analysis under payload. Feedback from the sensors can be used for experimental validation of existing models of tensegrity structures and dynamics, such as for the NASA Tensegrity Robotics Toolkit [3]. In addition, the readings from the sensors can provide distance changed between the ends of the bars, which can be used as a state estimator for UC Berkeley's rapidly prototyped tensegrity robot to perform feedback control [1]. Furthermore, this physical model allows us to observe and record the force distribution and structure deformation with different payload conditions. Currently, we are exploring the possibility of integrating shape memory alloys into the hyperelastic sensors, which can provide the benefit of both actuation and sensing in a compact module. Preliminary tests indicate that this combination has the potential to generate enough force and displacement to achieve punctuated rolling motion for the 6-bar tensegrity structure.

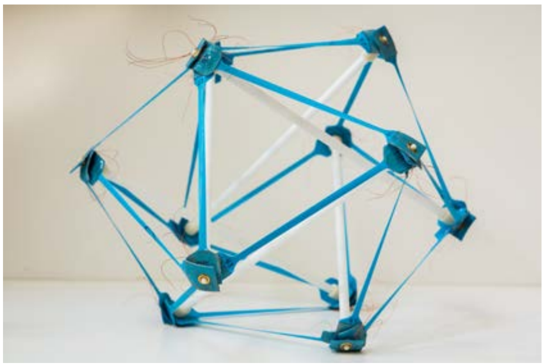

Fig.1 – 6-bar tensegrity structure with 24 liquid metal-embedded hyperelastic strain sensors as the tensile elements.

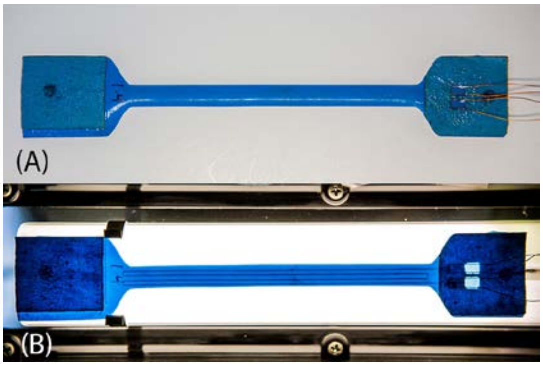

Fig.2(A)(B)– (A) The liquid metal-embedded hyperelastic strain sensor used on the 6-bar tensegrity structure. (B) The embedded eGaIn microchannels shown through fluorescent light.

References

[1] K. Kim, A. K. Agogino, D. Moon, L. Taneja, A. Toghyan, B. Dehghani, V. SunSpiral, and A. M. Agogino, "Rapid Prototyping Design and Control of Tensegrity Soft Robot for Locomotion," *Proc. 2014 IEEE Int. Conf. on Robotics and Biomimetics*, December 5-10, 2014, Bali, Indonesia.

[2] M. Yuen, A. Cherian, J. Case, J. Seipel, R.K. Kramer. "Conformable Actuation and Sensing with Robotic Fabric." *IEEE Int. Conf. on Intelligent Robotics and Systems*, Chicago, USA, 2014

[3] NASA tensegrity robotics toolkit. [Online]. Available: http://irg.arc.nasa.gov/tensegrity/NTRT/