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| A Novel Bio-inspired Soft Pneumatic Parallel Manipulation System  *Baugh L.1, Halani R. 1, Baskaran, A. 1, Haley, R. O. 1, Shulze1, Rose C. G. 1* |
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| **Abstract** |
| Soft robots are inherently compliant and can maneuver in rough, irregular environments with greater ease than their rigid counterparts. Further, the compliance of soft robots make them ideally suited for Human Robot Interaction (HRI) applications, as human operators can more safely interact with flexible elements that provide multiple degrees of freedom (DoF) as opposed to compound rigid structures. Taking inspiration from biological systems in the design of soft robots has further allowed engineers to take intuitive and organic design approaches to solve complex problems. Bio-inspired soft mechanisms, including grippers used in industrial robotic systems for handling fragile products, are thereby becoming robust and ubiquitous in society, including in medical and therapeutic settings, industrial automation environments, and exploration of dangerous terrain.  An area of research in soft robotics that has yet to be fully explored is the role that parallel compliant mechanisms can play in supporting or supplanting traditional rigid robotic systems. The Stewart platform is a conventional rigid mechanism that relies upon a complex chain of parallel actuators to provide multi-DoF positional control. We have designed a novel compliant mechanism that takes inspiration from the neuromuscular structure of invertebrate organisms, such as octopuses, to mimic the function of a rigid Stewart platform using a simple system of compliant actuators. The system described herein uses three pneumatic spherical chambers to control the position and angular orientation of a platform, whereas the traditional Stewart platform relies on six rigid actuators to accomplish similar motion paths. The compliant mechanism we designed can replace the complex rigid actuation chain of the Stewart platform to achieve multi-DoF positional control.  In this research work, we present the design and construction of the aforementioned system of spherical chambers which constitute a novel compliant parallel manipulation mechanism. We further detail the microelectronics used to control the pressure in each spherical chamber, and thus the angular orientation of the platform. This system allows for the direct control of the angular orientation of the platform through a pneumatic circuit driven by solenoid valves, by which the pressure in the chambers may be varied through binary modulation. This novel, yet relatively simple approach allows for the serial linking of multiple soft Stewart platforms end-to-end, which can allow the robot to perform locomotion, among other complex movements.  The soft robotic mechanism presented herein represents a significant advancement on the state of the art, in that it utilizes geometric relationships between tangent spheres, material properties of silicone-based soft materials, and sensor-fusion based robotic control mechanics to achieve compliant actuation. This research has a variety of significant applications, including in therapeutics and rehabilitation. Wearable robotic rehabilitation systems, which have traditionally relied on rigid links and motors constrained to the human body can instead interface with the body via the spherical chamber actuators presented herein. Such wearable devices would allow for compliant, organic actuation of muscles and could help enhance blood flow to affected areas for comfortable and effective rehabilitation. | |
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