Metamerism in a Bistable Origami Crawling Robot

Brian H Chien, Oyuna Angatkina, Alex Pagano, Andrew Alleyne, Aimy Wissa, Sameh Tawfick
University of Illinois at Urbana-Champaign

In biology, metamerism is a phenomenon that occurs when an organism possesses multiple segments of similar structure in series. An example of metamerism in biology can be attested to creatures such as the earthworm, as it has several combined segments that have similar structures and organs. Current bio-inspired metameric robots either mimic earthworms or snakes. Both types possess their own inherent advantages, but none of them possess the ability to separate into independent segments. This poster presents the design of a segmented crawling origami robot that is inspired by organisms of the Annelida family, mimicking both their metamerism as well as their crawling gait. The robot moves by expanding and contracting to slide across a surface, and possesses feet that utilize directional friction. By defining a singular robot as a segment, this allows for true metamerism, as multiple robots linked together may perform the same general function of locomotion but may also have several different sub-functions to help the overall metameric robot. A segment can be removed at any time without hindering the performance of the overall robot or the individual segment. Each segment combines via a rotational docking mechanism. This mechanism is actuated using shape memory alloys (SMAs) that engage and rotate the mechanism so the magnets are sheared off. A torsion spring allows for the locking piece to return to its original position to allow for re-segmentation. The crawling robot's expansion motion is attributed to an origami tower consisting of three Kresling origami cells that expand and contract in a screw motion. Properties that the robot's origami also possess include bistability, where the origami structure can snap between open and closed states. This is achieved after the origami is rotated to a critical angle. From running kinematic analysis involving calculation of the elastic energies and stiffnesses, the critical angle can be determined when the elastic energy is at its highest, which is where the overall rotational and translational stiffnesses transition from positive stiffness to negative stiffness. One can change the critical point by folding the origami structure at different strengths or changing the material of the origami structure itself. By implementing bistability into an actuation structure, one can input a small amount of rotational energy in exchange for a large amount of linear displacement. From running dynamic mechanical analysis on the origami cell, we determined the possible theoretical work saved by the crawling robot should it utilize bistability. Future work includes robot performance analysis utilizing the bistable origami structures, as well as a control algorithm that allows for the robots to dock and interact in various environments through swarm robotics. Additional actions such as rolling, jumping, and digging due to the robot's metameric design are also a possible inclusion to a future design iteration.

References

Pagano, T. Yan, B. Chien, A. Wissa, and S. Tawfick, "a Crawling Robot Driven By Multi-Stable Origami," *Smart Mater. Struct.*, vol. In Press, pp. 1–10, 2017.

O. Angatkina, B. Chien, A. Pagano, T. Yan, A. Alleyne, A. Wissa, and S. Tawfick, "A Metameric Robot Enabled By Origami and Smart Materials," *Proc. ASME 2017 Conf. Smart Mater. Adapt. Struct. Intell. Syst.*, p. SMASIS2016-3836, 2017.