Bioinspired Soft Actuator Capable of Self-sensing Displacement and Force

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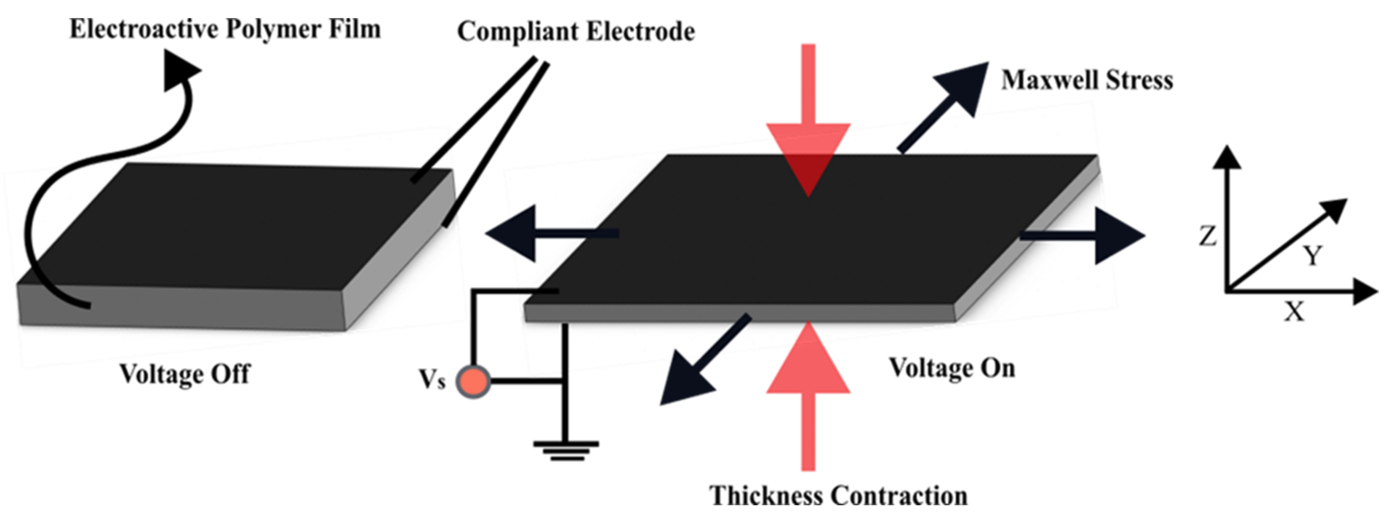
Objective

To develop a bio-inspired fully untethered conical dielectric elastomer actuator with simultaneous force and displacement strain sensing ability.

Introduction

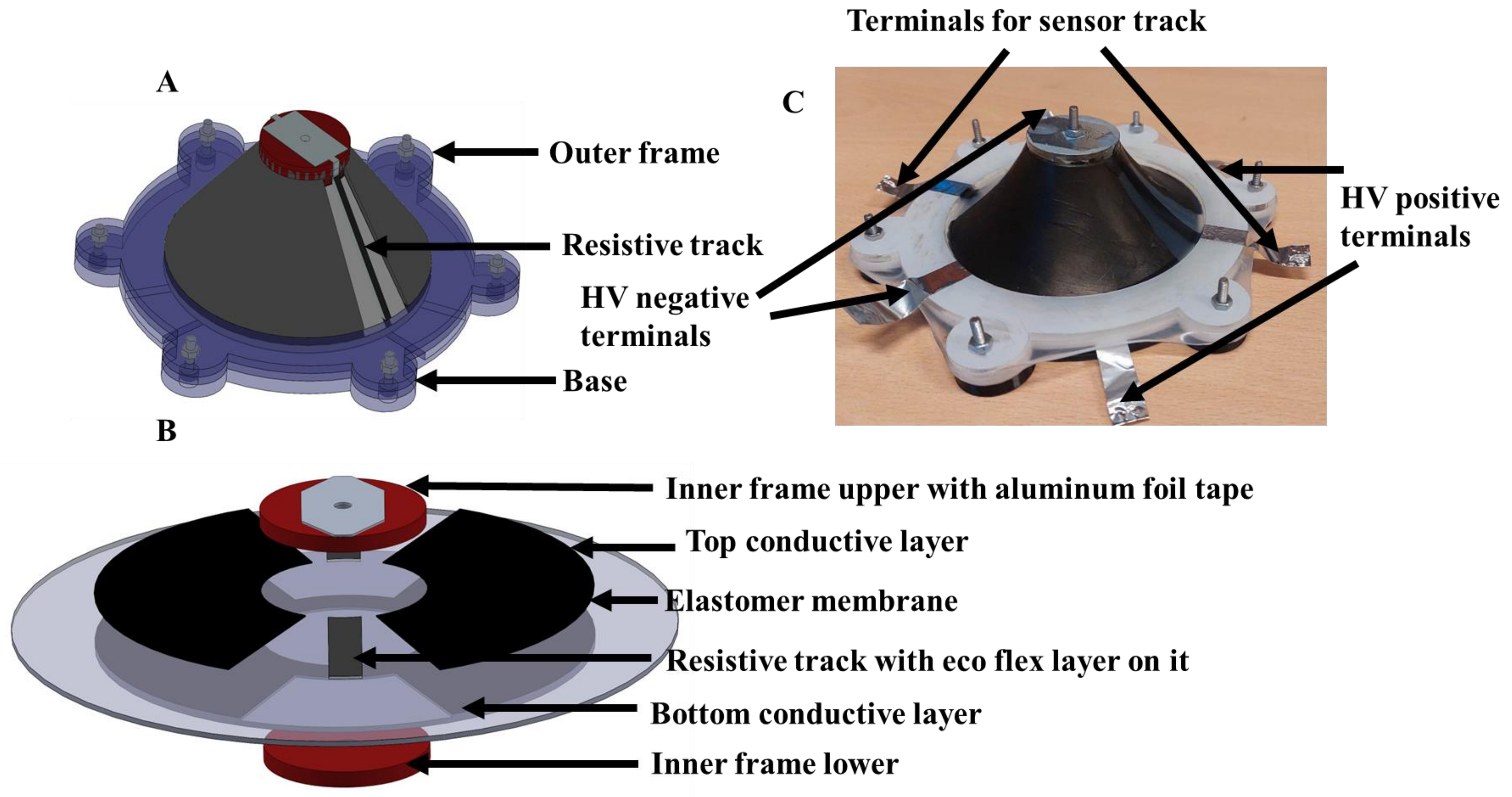
Dielectric elastomer actuators, also known as **Artificial Muscles,** are a class of electroactive polymers which undergo deformation when voltage is applied [1]. The areal expansion of the polymer membrane can be converted into vertical linear actuation using a biasing element spring.



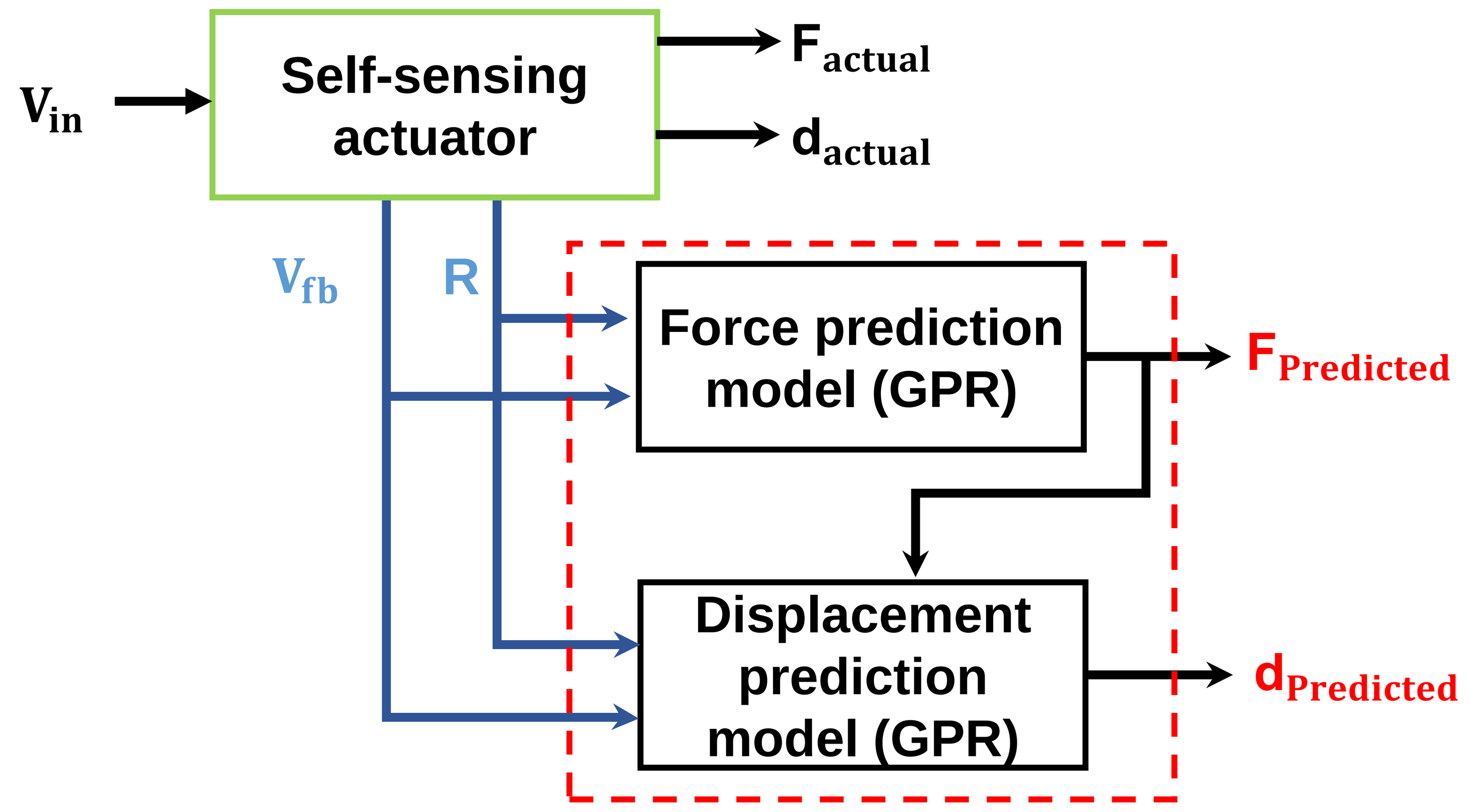
Bioinspired actuator design

1. Human muscles are capable of both actuation strain and force sensing.
2. Muscle spindles embedded in the skeletal muscle act as stretch receptors to detect change in length of muscle [2].
3. Golgi tendon organs measure the force applied by the muscles [3].
4. Joint receptors are sensory receptors located within joint capsules and ligaments that provide feedback about joint position, movement, and forces applied to the joint.
5. In this project, a methodology for embedding piezoresistive track (analogous to stretch receptors) and a model to make use of the applied voltage (action potentials) and stretch receptor information to estimate external force real time is developed.

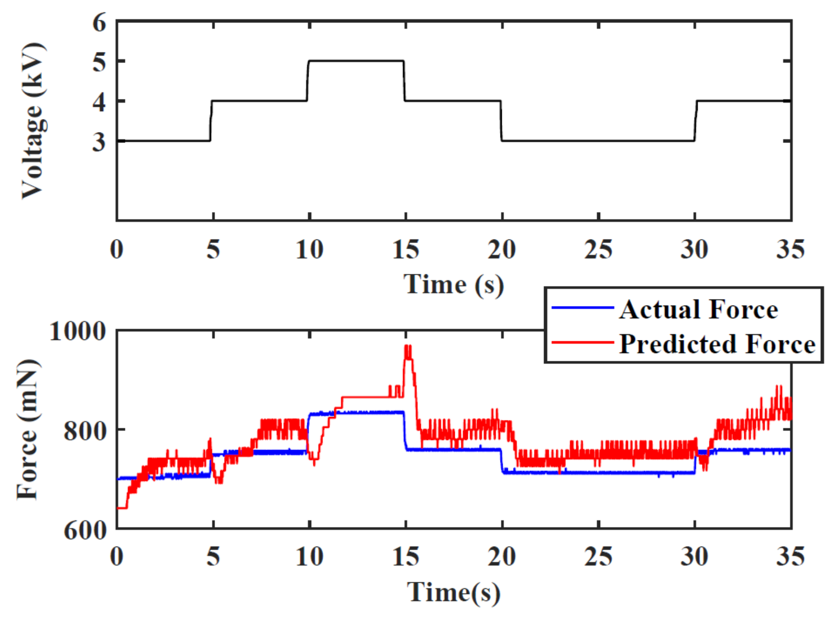
Actuator Design

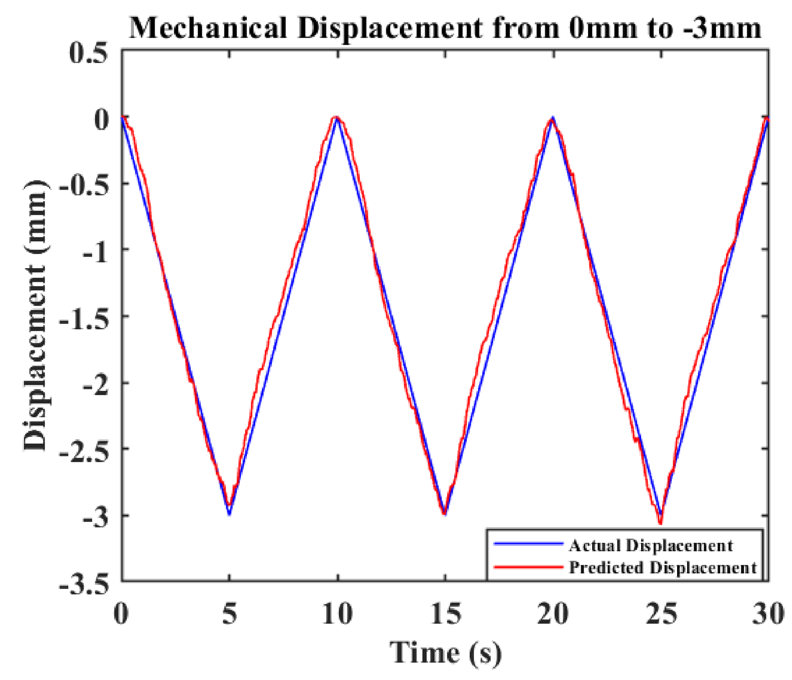


Prediction Models



Estimation Results

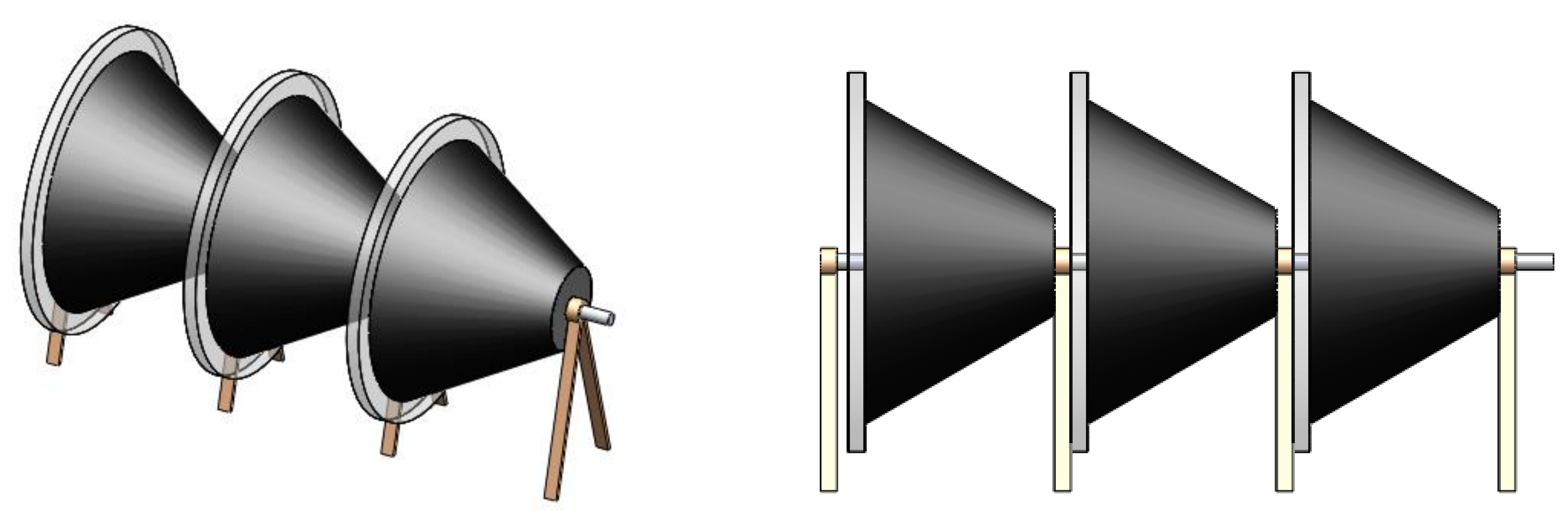




Model Performance Results				Model Validation Results	
Test condition	RMSE	MAE	R-Squared	RMSE	NRMSE
Force prediction (0 to -3mm)	65.453 mN	46.217 mN	0.99	72.99 mN	0.0751
Force prediction (1.5 to -1.5mm)				96.57 mN	0.1099
Displacement prediction (0 to -3mm)	0.0661 mm	0.0398 mm	1.00	0.2364 mm	0.1089
Displacement prediction (1.5 to -1.5mm)				0.3281 mm	0.1092

Conclusions and Discussions

1. In this project, we proposed a new methodology for simultaneous self-sensing of force and displacement of soft actuators with reasonable accuracy.
2. A fully untethered operation and real-time communication have been realized.
3. The proposed actuator can be used as a building block for developing a self-responsive multiple stable crawling robot for obstacle detection as well as decision-making during navigation.



References

1. J. H. Youn et al., “Dielectric elastomer actuator for soft robotics applications and challenges,” Appl. Sci., vol. 10, no. 2, 2020, doi: 10.3390/app10020640.
2. Knott, R., & Voss, D. (2013). proprioception and Muscle Spindles. In Clinical Anatomy of the Spine, Spinal Cord, and Ans (3rd ed., pp. 56-59). Elsevier.
3. Gajdosik, R. L. (2001). Passive extensibility of skeletal muscle: review of the literature with clinical implications. Clinical Biomechanics, 16(2), 87-101. https://doi.org/10.1016/S0268-0033(00)00061-9.