Seeing without Seeing through Bioinspired Soft Touch

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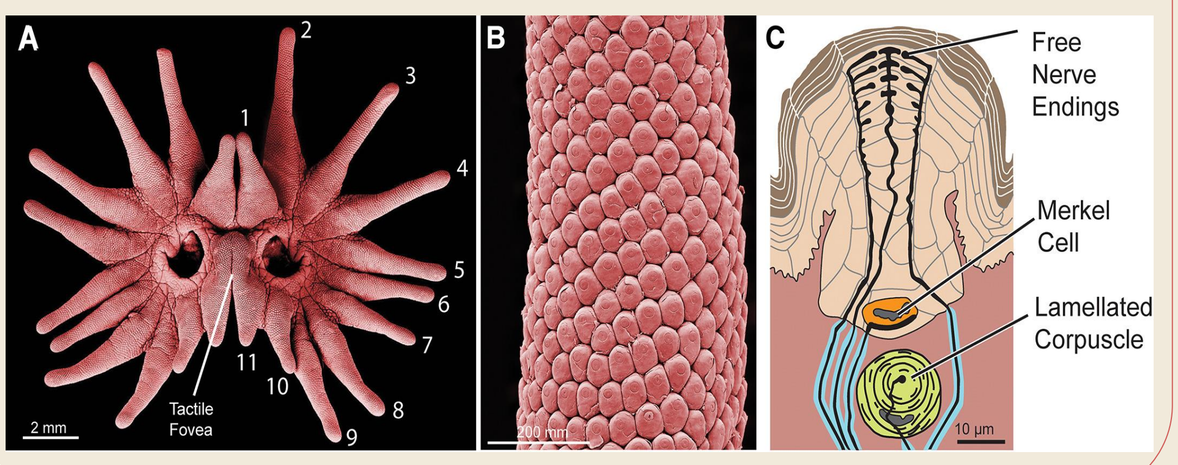
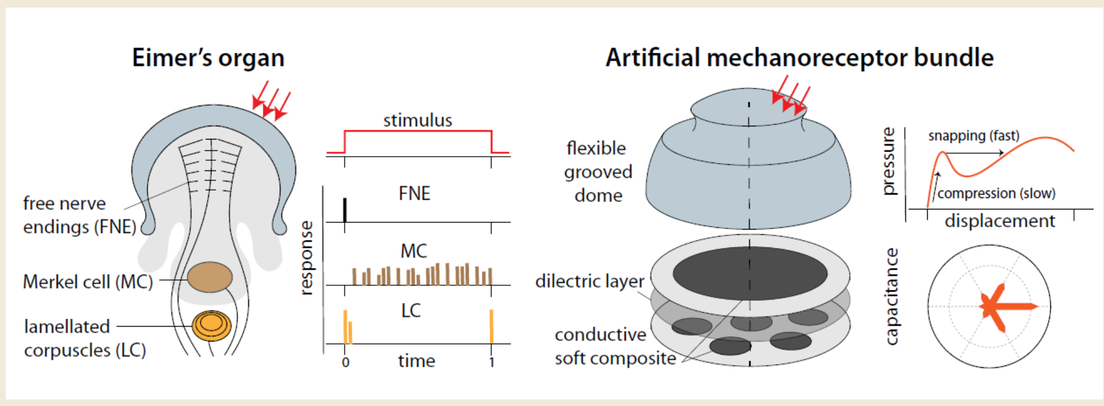
Background

Dominance of sight in human feedback often lead robotics community to focus on computer vision as the primary sensing approach. However, vision fails to provide the sufficient feedback in dark environment or collect information on surface texture [1]. In nature, animals widely use other senses such as touch to compensate lack of visual data. One primary example is the star-nosed mole which detect environmental texture in great detail thanks to its distinctive tactile perception [2]. The hyper performance sensing is due to thousands of microscopy dome-shaped epidermal sensors called Eimer's organ [3]. Each organ contains three different receptors: the laminated corpuscle for vibratory sensation, Merkel's cell for pressure sensation, and the free nerve for light pain and touch [4]. Such a unique organism and set of receptors enable the mole to collect at such high resolution that it is unprecedented compared to other animals. Therefore, emulating the mole's sensory structure into robotics design provides a new generation of bio-inspired soft sensors that actively detect delicate objects and collect subtle textural information.



Methodology

Inspired by the Eimer's organ, a dome-shaped sensor will be fabricated and tested. The dome will be constructed from a grooved elastic hemispherical shell which allows the filtering of two sensing regimes by just measuring its internal pressure. Moreover, the dome will be sat on top of a soft, flexible capacitive sensor that transduces directional information when the dome undergoes asymmetric deformation. The mechanoreceptor will be fabricated using a combination of silicone molding, lamination, and 3D printing methods. Moreover, various materials will be tested for the conductive and dielectric layers to find the best response and least noisy materials for the capacitive sensor. After successfully fabricating a single mechanoreceptor, the bubble wrap manufacturing technique will be adopted to develop an array of dome-shaped structures in complex configurations to emulate the star-nosed mole's ray. Finally, the single and array bundle will be characterized under different touch scenarios. A machine learning method will be applied to reduce the required wiring and enhance the read from the sensor. In the final stage, the sensor array will be assembled on a soft actuator to create an active system, and the response will be compared against static sensors.



Objectives

The objective of this study is to create a novel soft sensor inspired by the star-nosed mole's active tactile sensing abilities, capable of transducing mechanical and textural information. We aim to address a significant challenge in robotics: integrating a sense of touch into robots. The main objectives are:

Objective 1 Sensor Design: Developing a single mechanoreceptor bundle consist of multi-sensor reading to replicate the three touch receptors in Eimer's organ.

Objective 2 Fabrication: Fabricating the designed mechanoreceptor at a micro-scale level and later scaling up the fabrication to create an array of sensors similar to the mole's rays.

Objective 3 Testing: Characterizing the developed sensors' performance as a single unit and array of sensors under different touch scenarios.

References

[1]- B. Shih et al., "Custom soft robotic gripper sensor skins for haptic object visualization," 2017 IROS.

[2]- Catania, K.C. and J.H. Kaas, The Unusual Nose and Brain of the Star-Nosed Mole. BioScience, 1996.

[3]- Catania, K.C., Epidermal Sensory Organs of Moles, Shrew Moles, and Desmans. Brain, Behavior and Evolution, 2000.

[4]- Catania, K.C., Ultrastructure of the Eimer's organ of the star-nosed mole. Journal of Comparative Neurology, 1996.

Project Period

June 2023- May 2026