A Magnetically Transduced Whisker Sensor Array with Heterogeneous Morphologies

Description

Rodents rhythmically move their vibrissae (whiskers) to sense contact within their near-field environment and tactually explore surrounding objects. Contact and applied forces are detected through deformation of the whisker shafts and their embedded follicles. As a non-intrusive, tactile-based perception method, artificial whiskers offer capabilities such as contour and texture extraction, as well as active collision avoidance, that can be adopted to enhance the robotic perception and agility [1, 2]. Typically, these whiskers are arranged in arrays with specific spatial patterns and varying curvature profiles or lengths. Several previous researches [3, 4] have attempted to configure artificial whiskers from different aspects, incorporate realistic morphology [5] of the rat whisker array to predict the time-varying mechanical signal generated at each whisker base, which however is either simulated or hard to implement in practical to form a sizable array. In our previous work, we have developed a tapered whisker sensor with configurable slope and a planar flexure-based suspension. Despite this, several major issues remain: **1)** The mechanical mismatch between the suspension's flexure body and the whisker shaft, due to differing materials and fabrication methods, limits performance; additionally, an easily configurable curvature along the whisker shaft remains a pressing need. **2)** A biomimetic whisker sensory array with a well-defined spatial pattern and heterogeneous configurations is still required, along with a scalable support structure and integrated signal communication system. Furthermore, with the ultimate goal of integrating the whisker sensor into our biomimetic mouse robot, the overall system design and installation protocol remain underdeveloped.

Tasks

In this project, you will focus on developing a whisker-inspired tactile sensor and constructing a sensory array using heterogeneous whisker configurations. The goal is to enhance robustness, accuracy, and adaptability across various robotic platforms. Specifically, you can start your thesis with one of the following tasks:

1. **Design and develop a PCB board** that enables simultaneous acquisition of instantaneous deflection measurements from multiple whisker sensors. The sensing point should be arranged in well-defined spatial patterns to support a bionic whisker structure.
2. **Establish a fabrication procedure** for whiskers with varying configurations, such as length, taper slope, curvature, orientation, and material properties. This includes investigating how these physical characteristics affect sensing performance.
3. **Conduct a thorough evaluation** of the current sensor design, including analysis of basic whisker mechanics, performance of the magnetically transduced sensing system, hysteresis behavior, and long-term degeneration of the flexure suspension body.

For further discussion on specific tasks, welcome to direct contact me via email.

Technische Universität München

TUM School of Computation, Information and Technology

Lehrstuhl für Robotik, Künstliche Intelligenz und Echtzeitsysteme

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Type:
MA,SA,BA

Research area:
tactile sensor, biomimetic rodent, soft robotics

Programming language:
C++ or Python

Requirements:
High self-motivation and passion for robotics; At least six-month working time; With experience on mechanic structural design, fast 3D prototyping and PCB design (optional).

Language:
English

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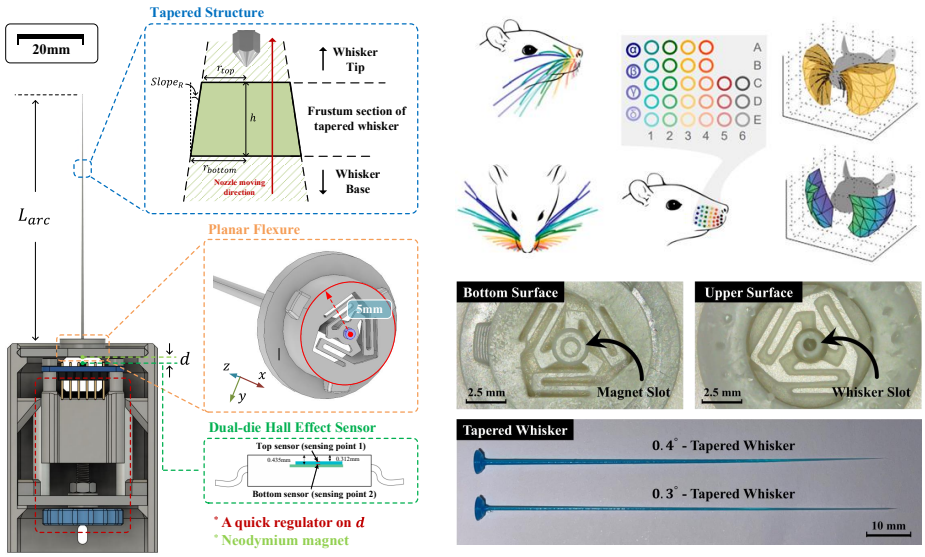

A). The basic structure for our magnetically transduced tapered whisker sensor with details B). The array of an average rat is organized in rows and columns with specific pattern and different dimensions for each single whisker. C). Microscopic images of the fabricated results, including suspension flexure and the tapered whisker structure.

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[1] Adaptive Cancelation of Self-Generated Sensory Signals in a Whisking Robot[J]. IEEE Transactions on Robotics, 2010; [2] Whisker-Inspired Tactile Sensing for Contact Localization on Robot Manipulators[C]. 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS); [3] Identifying Contact Distance Uncertainty in Whisker Sensing with Tapered, Flexible Whiskers[C]. 2023 IEEE International Conference on Robotics and Automation (ICRA); [4] Artificial whisker sensor with undulated morphology and self-spread piezoresistors for diverse flow analyses[J]. 2023 Soft Robotics; [5] A dynamical model for generating synthetic data to quantify active tactile sensing behavior in the rat[J]. Proceedings of the National Academy of Sciences, 2021;