JAIST Repository
https://dspace.jaist.ac.jp/

Title	ソフトロボティクスにおける感覚及び把握を促進する適応形態学の研究
Author(s)	QI, Qiukai
Citation	
Issue Date	2021-03
Type	Thesis or Dissertation
Text version	ETD
URL	http://hdl.handle.net/10119/17474
Rights	
Description	Supervisor:HO, Anh Van, 先端科学技術研究科, 博士

JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY

Japan Advanced Institute of Science and Technology

Abstract

The past few decades have seen a rapid growth of robotic research in many fields including, for example, industry, medical care, entertainment and education. Conventional robots are typically fabricated with metals and plastics that are resistant to deformation. While these robots can perfectly complete their jobs in closely structured environment because of speed, precision and predictability, they raise severe challenges in those scenarios characterized by human interactions due to concerns about safety.

Soft robotics has been expected to compensate the situations where their rigid cousins fail to function, as they usually employ compliant and adaptive materials that could potentially serve as a safety layer when interacting with humans. Therefore, safety, adaptability and autonomy have long been preferred to achieve with soft robotics. However, despite the ubiquitous research on soft robotics during last decade, there is yet an effective principle or methodology to design soft robots with adaptive behavior. Embodied intelligence, or embodiment, in this situation delivers profound insights on robot intelligence. It considers that the intelligence of robotics lies not merely in the control domain ("brain"), but in the combination of brain, body, and the interaction with environment. In this sense, the morphology of robotic body is a source of intelligence that can potentially shape the functionality of soft robots. Consequently, morphology that is adaptive, coined as adaptive morphology, has been a popular theme for soft robotics.

Adaptive morphology has the potential to enable adaptive behavior of soft robots. It can either optimize the performance or add new functions to existing robotic agents. Despite the numerous successful demonstrations, adaptive morphology has been dominantly investigated in terms of robotic actuation. The kingdom of robotic sensing, however, has remained largely unexplored. Even within the actuation, there are still many questions to be answered, for example, the role of adaptive behavior in improving the energy efficiency. To this end, this thesis attempts to bridge the gap by studying how adaptive morphology can influence, or facilitate in specific, sensing and grasping of soft robotics, based on our work on two prototypes, "WrinTac" and "RetracTip".

WrinTac is a soft tactile sensor that has been formed in wrinkle morphology. When actuated by stretching or bending, the wrinkle morphology can change its wavelength and magnitude continuously thus varying the sensing property of the sensing element embedded in the wrinkle bump. The fabrication process was simulated using finite element method (FEM) to show the effectiveness, and the morphological changes were characterized by analytic and FEM modeling. It was found that the more it is stretched or bent, the longer the wavelength is and the stiffer the overall structure becomes, which all affecting the sensing ability of the sensor. In order to find out how the morphological changes influence the sensing functionality, we examined the sensitivity to normal and tangential force. Further, we implemented two tasks, shape discrimination and texture detection, to study the influence by the adaptive morphology. In shape classification, we adopted machine learning (decision tree, k nearest neighbors and supporting vector machine) and deep learning techniques (convolutional neural network) as the "brain" to perceive the difference. In texture detection, we used Fast Fourier Transform (FFT) to analyze the performance and found the optimal morphology for this task. Finally, we found out that there is always an optimal morphology for different task and the adaptive morphology offers promising opportunity to adapt the sensor morphology to different tasks and environments based on the specific performance.

RetracTip is a universal and energy-efficient gripper coupled with sensing functionality. It is capable of gripping objects of arbitrary size and shapes. The design was initially inspired by the sea anemone while can find its artificial ancestor that is a tactile sensor with dome shape fingerprints on the external surface. By comparing RetracTip with its artificial predecessor, we demonstrated that how the morphology can be utilized and optimized in order to augment the original design with gripping functionality. Additionally, we demonstrated how the energy efficiency was improved by integrating a bistable morphing dome structure thus eliminating the requirement for continuous power input during object-holding action that is a common posture for pick and place scenario. Specifically, we investigated the sensing and gripping functionality individually by implementing tasks including self-state sensing, direction and terrain detecting, and gripping force testing and object gripping testing. Then, by implementing an autonomous gripping system, we validated the potential of this design towards future autonomous robots.

The findings in this thesis demonstrate the potential of adaptive morphology in shaping the sensing behavior, maximizing the information gain, and bringing about autonomous and energy efficient gripping functionality of soft robotics. It is shown that adaptive morphology could be utilized to design future soft robotics with adaptive sensation and energy efficient actuation.

Keywords: Adaptive morphology, Soft robotics, Tactile sensors, Soft grippers, Morphological computation