Title	形態的なアプローチによるソフトロボットの構造的なダメージへの補償:ウィスカーセンサーの場合
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ABSTRACT

Graduate School of Advanced Science and Technology

Doctoral Dissertation

Morphological Approach for Motor-sensory Compensation of Soft Body with Structural Damages: Case of Soft Whisker

by Nguyen Huu Nhan

After decades of intensive research and creative innovation, modern autonomous machines (robots) now have the capabilities to accomplish pre-programmed tasks with an incredible precision repeatably in multi-thousands (or even millions) cycles. A study of 46 countries and 800 occupations by McKinsey Global Institute has reported that, by 2030, there would be at least 800 million global employees lost their jobs to high-functional robotic systems. Although the process of industrial robot development is still growing fast and strong, as a roboticist, I personally think it is time to bring robotic systems out of their "cozy home" in factory workplaces to more challenging, unstable environments (*e.g,* near humans) where adaptability, robustness, and resilience against all kinds of uncertainties are vitally required. For the last decade, there is a nascent class of robots called *soft robots* that offer flexibility to a few components or even the whole robot's body similar to living organisms. These machines are built with many intriguing abilities of locomotive behaviors, perceptions, and cognition that we have seen a lot from natural species, whilst pretty rare or none existed in rigid robots before. With this spirit, resilience in response to structural changes to the body due to critical damages is an instance.

Researchers in the field have been struggling to develop a new clan of regenerative robots by integrating flexibly adaptable controllers. However, such approaches have never, so far, proved themselves as efficient methods in actual scenarios mostly because the processor can not afford in terms of time for a massive computational burden as they usually assign. Not to mention the expensive cost to build up supportive systems does not ensure successful resilience. Meanwhile, biological counterparts such as rodents or spiders, through millions years of evolution, learn how to couple their variable body's morphology with the brain to facilitate their interaction with the surrounding and enable intelligent functionalities including resilience. Such fascinating intelligence are widely known with the name *embodied intelligence* - or embodiment. This thesis attempts to clarify the use of embodied intelligence for the development of a new generation of resilient robots with a particular focus on soft tactile sensory systems. This work is achieved by summarizing all investigations (which are reported in top-ranked conference proceeding and journals in robotic field) that I have done on an soft whisker-like tactile sensor with variable morphology.

As an inhabitant in unstructured, lack-of-vision environments, rodents such as rats rely much on the sensibility of their vibrissal system for various tactile exploration tasks. However, high frequency of physical impacts to the surroundings poses a critical challenge in maintenance of the sensing function in response to injured whiskers (e.g eroded, broken), so-called resilience process. To successfully mimic such exquisite ability into an artificial whisker, I introduced a novel design of whisker sensor that is able to actively change its morphology (*i.e.,* equivalent to tactile perception) in order to regain the original sensitivity despite being broken. Experimental results shown in this thesis demonstrate the feasibility of the idea of resilience based on adaptive morphology and its possibility to aid in tactile perception in more complex scenarios. It is also expect to reset our common sense in creating intelligent autonomous machines.

Keywords: Soft robots, structural changes, embodied intelligence, resilient robot, soft whisker-like tactile sensor.