JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY

Abstract

Graduate School of Advanced Science and Technology

Doctoral Dissertation

Study of Tactile Transference from Humans to Robots and Its Applications

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Abstract:

The demand for robots working alongside humans has been steadily increasing over the past decade. While robots have become increasingly popular, traditional robots pose safety risks due to their lack of soft touch and human-like perception. Recently, soft robots have emerged, offering the advantage of safe interaction with humans and the environment. One key component of this technology is the tactile sensor. With its ability to gather rich tactile information and its inherent softness, the tactile sensor presents a promising solution for improving robot interaction with the environment, especially when interacting with humans.

Humans heavily rely on touch to interact with their environment. Transferring this ability to robots operating in complex environments presents a significant challenge. Researchers have addressed this challenge by recording human hand actions to capture human tactile perception. Deep neural networks then analyze this data to extract the underlying perception. However, the availability of human hand action data, especially for large-scale vision-based tactile sensors, is limited. Additionally, the transfer of this tactile perception to robots using large-scale vision-based tactile sensors has not been widely researched.

To overcome this challenge, a method is proposed that involves extracting information about human tactile perception and then transferring it to robots to enable

them to perform tasks. This method relies on data collected through experiments where participants interact with these large-scale vision-based tactile sensors. This tactile sensor consists of two cameras and a soft, silicone interface that mimics human skin. As participants interact with the interface, the cameras capture the deformations, allowing the extraction of physical interaction information from these visual cues using machine learning techniques. By analyzing the knowledge gained from the collected dataset, robots can distinguish between various human-hand interactions. Besides, with the development of the Internet of Things (IoT), robots controlled remotely can explore the environment and interact with surrounding objects through vision-based tactile sensor. To improve the understanding of robot-environment interaction, visualizing tactile sensor data within a virtual environment becomes essential. Deformations in the silicone interface shape during interaction can be visualized in real-time within a virtual environment, providing a clear and intuitive representation of the physical interaction. In addition, the extracted perception can be applied to multi-robot systems to improve their performance in tasks such as navigation. To extend the benefits of tactile perception, this thesis also introduces the development of a tactile sensor specifically designed for multi-robot systems operating in complex environments. The sensor integrates a fish-eye camera with strategically placed markers to capture surface deformations during contact. A key aspect of this research is the sensor's ability to detect multiple contact points simultaneously and its rapid response time under these conditions, achieved by leveraging tactile perception. The proposed system is evaluated by analyzing its sampling rate and its limitations due to processing power and camera constraints. The findings suggest that the sensor achieves a sampling rate between 18Hz and 23Hz, with potential for improvement through hardware upgrades. This research paves the way for robots equipped with a human-like sense of touch, enabling them to navigate and manipulate objects more effectively in intricate settings.

Keywords: Soft tactile sensor, Swarm robotic system, Human robot interaction, Virtual reality, Robot navigation