Proceedings of the 6th International Conference of Control, Dynamic Systems, and Robotics (CDSR'19)
Ottawa, Canada – June, 2019
Paper No. CDSR 143
DOI: 10.11159/cdsr19.143

On the Development of a Compliant Sensor Shell for use in Robot Safety

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Extended Abstract

Over the past few decades, robotics research has sought to incorporate physical human-robot interaction (pHRI) with applications including medical robotics and human-robot co-manufacturing [1,2]. This trend is reflected in the development of safety standards, such as the ISO/TS 15066:2106 [3], specific to human-robot interaction. To meet the needs of these applications, commercial collaborative robots have been developed [4]. While these new manipulators address safety needs, safety is ensured through lightweight design. This method is not applicable to existing manipulators. Ensuring safety without redesign requires the ability to interact along the length of the robot and a means to mitigate impact forces. Compliant tactile sensors could address these issues. While tactile sensor arrays for robot safety have been developed in the past, sensor arrays face inherent challenges with respect to wiring, ensuring a high sampling rate and processing the data [5]. In contrast, sensor shells that use few sensors to cover a large area offer a simpler solution at the cost of reduced spatial resolution [6]. Previous research by the author had developed a planar sensor consisting of a rigid shell compliantly connected to the sensor base with light-to-voltage (LTV) sensors employed to measure the position of the external shell with attached LEDs and so determine the deformation of the compliant connection [6].

To improve upon the previous sensor, the current work develops a second-generation planar sensor based on clusters of LTV sensors. Each cluster was designed to be capable of inferring the direction LED that illuminated the cluster. To form a sensor using these clusters, two clusters were attached to a base that was compliantly connected to a ridged shell on which was attached an LED. During operation, the direction of the LED with respect to the two clusters can be used to determine the position of the LED in the plane. The sensor was capable of deforming on the order of 3 cm.

Using an Optotrak motion capture system as reference, a calibration set of LTV sensor voltages for given LED directions was collected for each cluster. The calibration sets were then used to train a regression tree for each cluster. Using the regression trees to infer LED direction with respect to the cluster using the LTV sensor outputs, the ability of the sensor to track the motion of the external shell was compared to that of an Optotrack system for five 40-second trials. Results of the experiment indicate an average position error of 0.23 mm with a standard deviation of 0.336 mm; however, peak errors did reach 18.7 mm. However, it was noted that the errors occurred when the angle of incidence was large and so the LED was not capable of fully illuminating the LTV sensor cluster. It is proposed to impose mechanical constraints in future to prevent such cases. Excluding these cases, the average position error was 0.219 mm with a standard deviation of 0.126 mm and peak error of 2.22 mm.

Considering the soft nature of the compliant connection, deformation errors on the order of 0.2 mm represent a negligible difference between measured and applied force and so the current results indicate the sensor is capable of being used for safety in pHRI. This paper will discuss the construction of the sensor and the preliminary results.

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