Robot fingers: Spatially resolved pressure sensor array based on deformable optical nanostructures

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The goal of the proposed work is to build a preliminary prototype demonstration of thepressure sensor array system based on optical readout of nanostructures in a deformable optical material. This demonstration will serve as a proof-of-concept validation of the design approach, provide preliminary information concerning the scalability and applicability of this method for robotic touch sensing applications, and enable future funding proposals to NASA and other sponsors for funding to develop targeted prototype systems. One of the challenges in robotics today is the realization of "Dexterous Manipulators" (i.e. "fingers") that can grasp a variety of objects without breaking or dropping them. A key enabling technology for this task is suitable high-performance two-dimensional pressure sensor arrays. We propose to investigate such sensors based on the synthesis of three proven technologies: (1) nanostructured waveguides implemented in deformable optical materials to transduce small mechanical stresses into modulation of optical properties; (2) multi-wavelength optical heterodyne detection to enable accurate measurement of small variations in optical properties with spatial and temporal resolution; and (3) high-performance reconfigurable computing to implement the requisite signal processing and data analysis. The nanostructured waveguides will be realized in Polydimethylsiloxane (PDMS), a common silicone material with suitable optical properties. This material provides several important advantages, including the ability to cast the waveguides even with nanoscale features, a pressure-to-optical properties transduction mechanism compatible with two-dimensional sensor arrays, the ability to vary stiffness to change sensitivity levels, and extremely low cost, which makes the waveguides practically disposable. Optical heterodyne detection enables high-sensitivity pressure measurements as well as extensive sensor multiplexing, while the use of reconfigurable computing tools provides the required signal processing capacity at relatively low cost. The overall goal of this project is to optimize each of the above technologies for this purpose, and to develop a prototype demonstration of this sensing approach. This method provides a scalable platform for implementing pressure sensor arrays that can be adapted to a broad range of applications, including robotics.

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