Multiplexed Force and Deflection Sensing Shell Membranes for Robotic Manipulators

This technology can be used to enhance precision in robotic surgery.

Lyndon B. Johnson Space Center, Houston, Texas

Force sensing is an essential requirement for dexterous robot manipulation, e.g., for extravehicular robots making vehicle repairs. Although strain gauges have been widely used, a new sensing approach is desirable for applications that require greater robustness, design flexibility including a high degree of multiplexibility, and immunity to electromagnetic noise.

This invention is a force and deflection sensor — a flexible shell formed with an elastomer having passageways formed by apertures in the shell, with an optical fiber having one or more Bragg gratings positioned in the passageways for the measurement of force and deflection.

One object of the invention is lightweight, rugged appendages for a robot that feature embedded sensors so that the robot can be more "aware" of loads in real time. A particular class of optical sensors, fiber Bragg grating (FBG) sensors, is promising for space robotics and other applications where high sensitivity, multiplexing capability, immunity to electromagnetic noise, small size, and resistance to harsh environments are particularly desirable. In addition, the biosafe and inert nature of optical fibers makes them attractive for medical robotics. FBGs reflect light with a peak wavelength that shifts in proportion to the strain to which they are subjected. Multiple FBG sensors can be placed along a single fiber and optically multiplexed. FBG sensors have previously been surface-attached to or embedded in metal parts and composites to monitor stresses.

An exoskeletal force sensing robot finger was developed by embedding FBG sensors into a polymer-based structure. Multiple FBG sensors were embedded into the structure to allow the manipulator to sense and measure both contact forces and grasping forces. In order to fabricate a three-dimensional structure, a new shape deposition manufacturing (SDM) process was developed. The sensorized SDM-fabricated finger was then characterized using an FBG interrogator. A force localization scheme was also developed.

A sensor is formed from a thin shell of flexible material such as elastomer to form an attachment region, a sensing region, and a tip region. In one embodiment, the sensing region is a substantially cylindrical flexible shell, and has a plurality of apertures forming passageways between the apertures. Optical fiber is routed through the passageways, with sensors located in the passageways prior to the application of the elastomeric material forming the flexible shell. Deflection of the sensor, such as by a force applied to the contact region, causes an incremental strain in one or more passageways where the optical fiber is located. The incremental strain results in a change of optical wavelength of reflection or transmittance at the sensor, thereby allowing the measurement of force or displacement.

The ability to route a single optical fiber through the passageways of the outer shell of the sensor, combined with the freedom to place Bragg grating-based sensors in desired locations of the shell, provides tremendous flexibility in sensing force in three axes, as well as the possibility of providing a large number of sensors for more sophisticated measurement modalities, such as torque and shell deflection in response to multi-point pressure application.

This work was done by Yong-Lae Park, Richard Black, Behzad Moslehi, Mark Cutkosky, and Kelvin Chau of Intelligent Fiber Optic Systems Corp. for Johnson Space Center. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Intelligent Fiber Optic Systems Corp.
424 Panama Mall
Stanford, CA 94305

Refer to MSC-24501-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Whispering Gallery Mode Optomechanical Resonator

These devices can be used for remote and inertial sensing, and mass detection.

NASA's Jet Propulsion Laboratory, Pasadena, California

Great progress has been made in both micromechanical resonators and micro-optical resonators over the past decade, and a new field has recently emerged combining these mechanical and optical systems. In such optomechanical systems, the two resonators are strongly coupled with one influencing the other, and their interaction can yield detectable optical signals that are highly sensitive to the mechanical motion. A particularly high-*Q* optical system is the whispering gallery mode (WGM) resonator, which has many applications ranging from stable oscillators to inertial sensor devices. There is, however, limited coupling between the optical mode and the resonator's external environment. In order to overcome this limitation, a novel type of optomechanical sensor has been developed, of-