Design and Control of an Anthropomorphic Robotic Finger with Multi-Point Tactile Sensation

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The Problem: The human hand is the principal organ for the reception of and reaction to tactile stimuli, a perception that guides our repertoire of manual functions. However, the integration of an analogous sensing suite into a robotic platform poses a major technological challenge. Our goal is the design and control of a prototype for anthropomorphic manipulation research based on high resolution artificial taction. The problem is constrained to the active detection of multi-point pressures applied to the surface of a robot finger.

Motivation: Cutaneous and kinesthetic neural afferent relays provide humans with information about physical parameters of the world and the state of our bodily interactions within them. We can, for example, acquire data about the dimensionality, weight, position, composition, shape, and thermal conductivity of objects we touch. When exploited by our sensorimotor system, this tactilo-kinesthetic, or haptic, perception leads to the manual dexterity which appears to have been intrinsically related to hominid evolution [2, 1].

Likewise, the continuous measurement of variable contact forces that occurs during a robotic manipulator's interaction with the environment has become increasingly important in medical, industrial, service, and research applications. The integration of such tactile perception is imperative to the realization of robotic systems which organically interact with the world. This natural behavior is characterized by compliant performance that can initiate internal, and respond to external, force application in a dynamic environment. Prosthetic and tele-operated manipulators must possess these manual faculties because their control greatly relies on the mapping of a human user's natural conduct. Hands for humanoid robots must also express such compatibility if they are to promote intuitive human interaction that is essential to learning.

Previous Work: Most of the groundwork on the subject dealt with processing *static* tactile images, following in the footsteps of early machine vision work. But much of our aptitude for manual exploration, recognition, and retention relies on *active* tactile sensing, especially in situations where visual input is restricted. Furthermore, if a manipulator *does* support such active sensing, it is usually limited to the mechanical fingertips. This runs counter to the distributed nature of our tactile apparatus. Furthermore, only a class of human grasp configurations involves just the fingertips. Thus, even from developments in active sensing, a definitive technique for multi-point superficial force detection has yet to emerge. Though system performance specifications [4] have been delineated and many materials, devices, and data analysis methodologies have been surveyed [7, 3, 5], the present market for robot tactile sensing devices remains marginal and expensive.

Approach: We investigate this problem through the fabrication and simple control of a planar 2-DOF robotic finger inspired by anatomic consistency, self-containment, and adaptability (Figure 1). The robot is equipped with a tactile sensor array based on optical transducer technology whereby localized changes in light intensity within an illuminated foam substrate correspond to the distribution and magnitude of forces applied to the sensor surface plane [6]. Light is transferred to and from the surface of the robot via fiber-optic cables.

In this work we emphasize the role of full-finger tactile feedback in the refinement of manual capabilities. To this end, we propose and implement a control framework for sensorimotor coordination analogous to infant-level grasping and fixturing reflexes (Figure 2). Our approach details the mechanisms used to achieve these sensory, actuation, and control objectives, along with the design philosophies and biological influences behind them.

Impact: The robot serves as a stepping stone for implementation of other, more complex actions that involve sensing and actuation of multiple fingers. Use of this compact, flexible tactile sensor would increase the prospect for actualizing general-purpose manipulators. Forms of tactile feedback can also be used to model a robotic analog

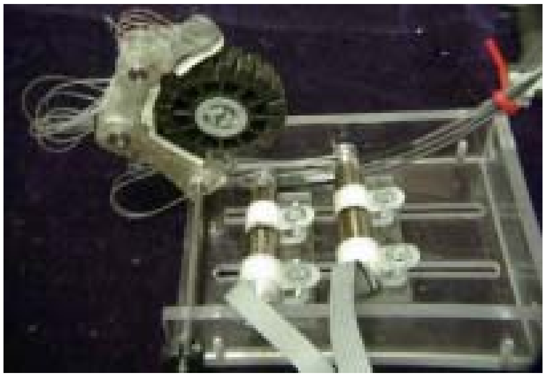

Figure 1: Photo of the robot grasping an object.

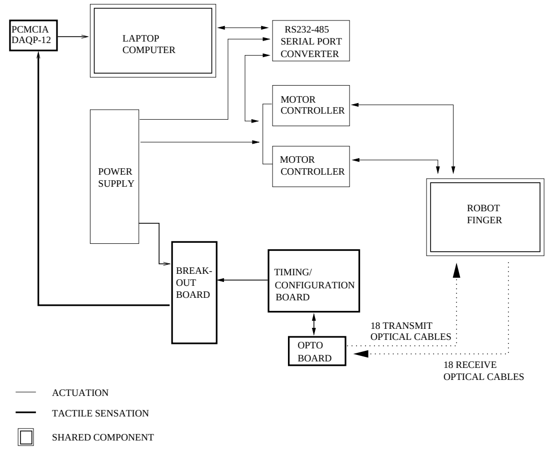

Figure 2: Sensorimotor control modules of the robot.

of pain, defined as the perception of a stimulus that may incur damage to the sensor or other mechanical parts. This along with other reflex-derived control schemas can be used as developmental learning mechanisms for more complex actions and functions. Furthermore, the sensor need not be constricted to a manipulator. It can be extended as a skin to any part of a robot platform for more comprehensive behaviors.

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References:

[1] Kai-Nan An and Edmund Y.S. Chao. Activities at the mayo clinic biomechanics laboratory. In *Proc. of the 24th Rocky Mountain Bioengineering Symposium*, volume 23, pages 1–7, 1987.

[2] Antonio Bicchi. Hands for dextrous manipulation and powerful grasping: A difficult road towards simplicity. In *IEEE Trans. Robotics and Automation*, volume 16, December 2000.

[3] R. A. Grupen, T. C. Henderson, and I. D. McCammon. A survey of general-purpose manipulation. *Int. Journal of Robotics Research*, 8(1):38–61, February 1989.

[4] L. D. Harmon. Automated tactile sensing. *The Int. Journal of Robotics Research*, 1(2):3–31, 1982.

[5] M.R. Nicholls and M.H. Lee. A survey of robot tactile sensing technology. *Int. Journal of Robotics Research*, 8(3):3–30, 1989.

[6] Ernest M. Reimer and Lee Danisch. Us5917180: Pressure sensor based on illumination of a deformable integrating cavity. Delphion Intellectual Property Network, June 1999. Patent.

[7] D. De Rossi. Artificial tactile sensing and haptic perception. *Meas. Sci. Thec.*, 2:1003–1016, 1991.