Anthropomorphic Robotic Finger Platform Based on Shape Memory Alloy

Jessica Lauren Banks

The Problem: The human hand can serve as a paradigm for a robotic interface with the environment. Thus, its morphology has provided impetus for manipulator research and its functionality remains a benchmark for engineering sophistication. One of the challenges of this line of research is that too close an emulation of human anatomy often proves cumbersome, while a severe divergence from it sacrifices dexterity [1, 2, 3, 4].

The goal of this work is to develop the primitive basis of an anthropomorphic manipulation platform based on shape memory alloy (SMA) [5]. We pursue this objective through the fabrication and control of a single robotic finger inspired by human analogy, self-containment, and functional diversity. The final product should be an appropriate end effector for a humanoid robot.

Motivation: Many industrial manipulator systems, in being designed primarily for a specific utility, do not elicit natural movement. This is largely due to the fact that they are constrained by ungainly actuator hardware. However, when considering a component for a humanoid robot, function and form are of commensurate priority, especially for establishing social credence.

This project is a fusion of sensory, actuation, and design modalities chosen to enhance the portrayal of organic interaction with the world. Such behavior displays a quality of unity, characterized by fluid movement that integrates multiple links into a continuous articulated body. Furthermore, it is initiative of internal propulsion and responsive to external force application for tasks such as grasping, pushing, and investigating.

The use of SMA contributes directly to these capacities. Because the material can be made to plastically stretch and contract with heat modulation, it can be employed as active wires and springs in actuator designs. Therefore, SMA relaxes the requirements of proximally located motors and large drives.

Previous Work: There has been research into and experimentation with sensor technologies (tactile, force, position), human anatomy, and shape memory alloy implementation. We have also investigated many compliant skin-like materials (eg. silicone and polyurethane variants) with which to cover the finger. This will provide surface friction for grasping and be a substrate in which to embed tactile sensors. Pre-fabricated SMA actuators are being considered and a secondary actuator design is underway. The structure of the finger has been designed in SolidWorks and fabricated using stereolithography (SLA) (Figure 1).

Figure 1: SolidWorks assembly of robot finger. Actuators and sensors not included.

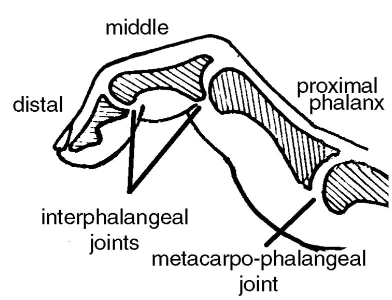

Figure 2: Bones and joints of the human finger [6].

Approach: The project is an attempt to work within the limitations of today's inorganic muscle, ligament, and tendon mediums to parallel their biological counterparts and mimic human hand functionality. The physical construction of the robot includes a hollow "bone" framework inside which the actuators, microcontroller, connections, and torque cells will be positioned. It is made of a lightweight resin and is 4.5" tall and 1.0" in diameter. The three links of the robot correspond to those of the human index finger (Figure 2). It also has two 1DOF hinge joints (interphalangeal articulations) which couple the middle and distal links and one 2DOF condyloid joint representing the metacarpo-phalangeal joint.

The remotely located joint control that SMA avails will be exploited to convert linear translation of tendon/muscle mechanisms in the links into angular movement of the finger joints. Digitally phased inputs from a microprocessor will modulate the current through the SMA to effect the thermoelastic transformation. Force feedback from tactile and proprioceptive sensors will be used to moderate the response.

Difficulty: The incorporation of SMA actuation introduces problems regarding power consumption, cooling, hysteresis, and torque output. Many of these issues have no documented optimal solutions and have prevented SMA from becoming widely used in the macrorobotics arena. It is also very difficult to find affordable tactile sensors that can be adapted to a curved surface, have high enough resolution, and can distinguish multiple pressure points.

Impact: Such a comprehensive manipulation system that is integrated with other sensory systems has far reaching implications- from the study of humanoid interactions to industrial applications and prosthetics. Furthermore, a self-contained digit could be used in a variety of configurations. For instance, many of them could be arranged upside-down on a surface to act as legs.

Future Work: After the previously described fabrication and control of the finger is complete, other sensory submodalities (eg. pain/reflex, temperature detection) may be added to the platform. Also, we will further elaborate on the somatic qualities corresponding to human proprioception and touch sensation. Ultimately, the hope is that this robot can be easily adapted and integrated with other functionally and mechanically similar versions into an engineered analogue of the human hand.

Research Support: Support for this research is provided by NTT.

References:

[1] Y. Matsuoka. Embodiment and Manipulation Learning Process for a Humanoid Robot. Master's thesis, Massachusetts Institute of Technology, May 1995.

[2] M. Rosheim. *Robot Evolution: The Development of Anthrobotics.* John Wiley & Sons, Inc., 1994.

[3] Y. Nakano, M. Fujie, and Y. Hosada. Hitachi's Robot Hand. *Robotics Age,* 6(7), July 1984.

[4] M. Mason and J. Salisbury, Jr. *Robot Hands and the Mechanics of Manipulation.* MIT Press, Cambridge, Massachusetts, 1985.

[5] R. Gilbertson. Muscle wires project book: A hands-on guide to amazing robotic muscles that shorten when electrically powered.

[6] I. A. Kapandji. *The Physiology of the Joints,* volume 1. E&S Livingstone, Edinburgh and London, 2nd edition, 1970.