LUCS Haptic Hand II

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Abstract

The Lucs Haptic Hand II has been built as a step in a project at LUCS aiming at studying haptic perception. In this project, several robot hands together with cognitive computational models of the corresponding human neurophysiologic systems will be built. Grasping tests with LUCS Haptic Hand II were done with two different objects in order to get a comprehension of the signal patterns from the sensors provided while grasping. The results from these preliminary grasping tests suggest that LUCS Haptic Hand II provides signal patterns rich enough to serve in our current haptic models.

1 Introduction

Computational models of haptic perception is not a very well explored area, but there are several reasons why it should be interesting to build such a system, especially if it is modeled with the human system as a blueprint. One reason is that from a pure scientific viewpoint the model might constitute support and yield new insights into the cognitive and neuroscientific theories it is founded on. Another reason is that from an applications perspective it is interesting because it might provide new knowledge about robot haptics.

It is hard to simulate all parts of a haptic model. Simulations of all parts of the system might be enough if the system only deals with passive tactile stimuli, e.g. when exploring the best way to give tactile stimulation in order to optimize the recovery after nerv injuries between the hand and the brain with the aid of simulations (Johnsson, 2004a). But a model of haptic perception is a model of active tactile perception, and thus it is best to implement the hand physically since it would be hard to simulate the intricate interactions between manipulation of and the sensory feedback from the objects.

The ability of the human hand to manipulate grasped objects is very sophisticated, and it has receptors for several submodalities, especially cutaneous and proprioceptive mechanoreceptors. Depending on the level of sophistication of the haptic model a robot hand that to some extent emulate the properties of the human counterpart has to be built.

Modeling of haptic perception is not a very well researched subject. However, some research has been done. A prototype of a five finger human-like robot hand with its fingers actuated by shape memory alloy artificial muscle wires has been designed by DeLaurentis and Mavroidis (2000).

Sugiuchi, Hasegawa, Watanabe and Nomoto (2000) have developed a robot hand with five fingers and 22 degrees of freedom. Each articulation is actuated by an RC servo and the surface of the robot hand is covered by a distributed touch sensor consisting of 64 x 16 lines of electrodes placed on both sides of a pressure sensitive rubber sheet.

A system for the categorization of objects with the aid of touch and vision has been developed by Dario et al. (2000). This system mimics the human ability to integrate sensory information from multiple modalities into low-level perceptions.

Laschi et al. (2002) and Dario et al. (2003) have developed human-like manipulation systems consisting of a hand together with a head with a binocular vision system. The systems are founded in neurophysiologic models of the haptic as well as visual systems in humans. Basic human-like sensory data processing is implemented in software. The systems have yielded encouraging results in preliminary experiments.

Our previous research in haptic perception consists of the design and implementation of some fairly simple haptic systems. These systems consisted of a robot hand, the Lucs Haptic Hand I (Johnsson, 2004b, 2005; Johnsson et al., 2005a, 2005b, 2006), together with some experimental models of the relevant neurophysiologic sites in the human brain implemented in software as Ikaros modules (http://www.ikaros-project.org/).

The aim of the Lucs Haptic Hand I and its haptic systems was to identify important principles of design for our future haptic systems, and to gain experience and knowledge before designing more potent versions.

The Lucs Haptic Hand I has three fingers out of which only one is moveable with one degree of freedom. Each finger is equipped with three push sensors. A Basic Stamp II, (Parallax Inc.), works as an interface between the robot hand and the computer.

Analyses of the signal patterns generated while the robot hand was grasping objects were done, and used as a starting point in the design of the haptic systems for the robot hand.

The haptic models for the Lucs Haptic Hand I consist in principle of two modules. One module represents the primary somatosensory cortex and in most of the models it consists of a non-adaptive neural network of leaky integrator units. The other module represents the secondary somatosensory cortex and it consists of a self-organizing neural network of Kohonen type.

Tests with the Lucs Haptic Hand I and its haptic models, in summary, showed an ability to learn to categorize the test objects (balls and cubes) according to size.

The rest of this report will consider the technical construction of the Lucs haptic hand II. The Lucs Haptic Hand II is sophisticated enough to enable us to build and explore a system capable of haptic perception, i.e. a system that actively explores the object with touch. This is true even though the robot hand is not able to manipulate an arbitrarily shaped object so that it is relocated in an arbitrary way. For that ability at least three fingers, each with three degrees of freedom, are needed (Bicchi, 2000).

2 LUCS Haptic Hand II

Lucs Haptic Hand II , Fig. 1., is equipped with three similar fingers symmetrically mounted at the corners of an equilateral triangle made of a plastic material. Each finger consists of two finger segments. The proximal finger segment is articulated against the triangular plastic plate, and the distal finger segment is articulated against the proximal finger segment. Each finger segment contains an actuator and it is therefore able to apply force in its proximal articulation.

The triangular plastic plate is mounted on a wrist consisting of a bearing, and an actuator connected to a stick for force transmission. The wrist enables horizontal rotation of the robot hand. The wrist is in turn mounted on a lifting mechanism consisting of an actuator and a splint. The lifting mechanism makes it possible for the robot hand to be lifted and lowered to change the grip of the object. To enable experimentation with the robot hand, it has been mounted on a frame at a suitable height. The frame was built of aluminum pipes.

Altogether, the Lucs Haptic Hand II has eight degrees of freedom. The actuators are constituted by RC servos. These RC servos are controlled by a servo controller (SSC-32 version 2.0, Lynxmotion Inc.). The computer and the servo controller communicate via an USB-port.

The finger segments are equipped with push sensors mounted with glue. Some of the sensors are partly mounted on top of a part of other sensors, see Fig. 2. for details about how the sensors are mounted. This means that some of them are slightly bent over a part of other sensors. Due to this there will be a sensor registration for some sensors even when the finger segment is not pressed onto an object. For theses sensors the registration may also decrease when the plates are pressed onto the object. However, this has no practical implications since the only thing that is important is that the sensors registration varies when in contact with the object.

In total the Lucs Haptic Hand II has 45 push sensors. The status of the sensors is read by the aid of a NiDaq 6008, (National Instruments), which includes an AD-converter. The NiDaq 6008 device also controls three multiplexer chips that are used in order to switch between different sensor signals during reading. See Fig. 3. for details of the circuits involved in the sensory part of the Lucs Haptic Hand II.

All software for LUCS haptic hand II is developed and will continue to be developed in the future as Ikaros modules (http://www.ikaros-project.org/). Ikaros provides a kernel and an infrastructure for computer simulations of the brain and for robot control. The current software consists of three modules, one module that controls the movements of the actuators and another module that handles the reading of the sensors status. These two modules communicate with the SSC-32 and the NiDaq 6008 via USB-ports.

In every iteration of an Ikaros simulation, the servo-controlling module takes as input an array with elements corresponding to the desired positions of the servos and the desired time for reaching these positions. The Ikaros module transform these positions and the desired reaching time into appropriate commands for the SSC-32 and transmit them with the aid of a USB-port.

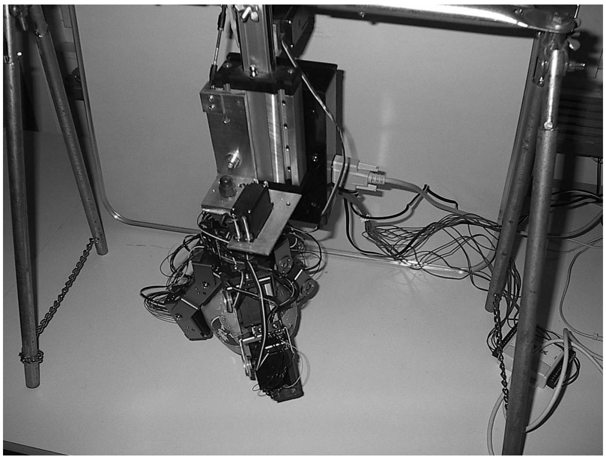

FIGURE 1: *The Lucs Haptic Hand II while grasping a soft ball. The 8-dof robot hand has three fingers, each consisting of two segments symmetrically mounted on a triangular plastic plate. The hand is equipped with a wrist and a lifting mechanism. The finger segments are built with RC servos together with so-called servo brackets. All the actuators of the Lucs Haptic Hand II are controlled via a SSC-32. At each finger segment there is a plate mounted. The plates are equipped with push sensors.*

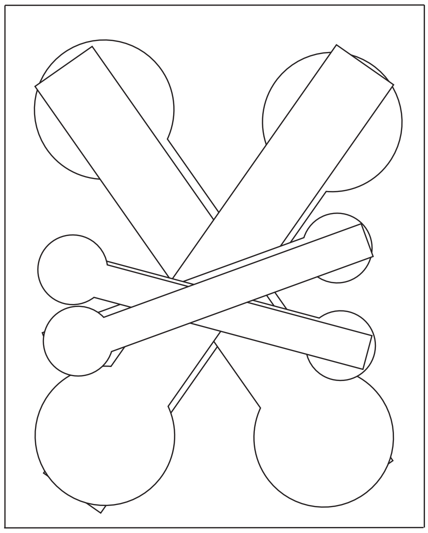

FIGURE 2: *The inner side of each finger segment is equipped with a sensor plate. The sensor plates are equipped with 8 push sensors on the distal finger segments. The push sensors are mounted as depicted. The sensor plates of the proximal finger segments are almost similar. The only difference is that the uppermost right sensor is excluded. The circular region of the sensors is sensitive to pressure*

During execution the control remains with the module until the SSC-32 signals that commanded the movements are finished. The sensor status module reads the status of each sensor in every iteration.

The third module uses the other two and takes care of a single grasping movement. In principle it works in the following way. It starts by moving the proximal finger segments. The status of the sensors are measured individually for each finger segment, and the movement of a certain finger segment comes to an halt when the change of the sensors, in total, on that particular finger segment exceeds a certain limit, or a maximal position has been reached. When the proximal segment for a finger comes to a halt, the distal segment starts to move until the change of the sensors status exceeds a certain limit or the finger segment reaches a maximal position. The idea here is, of course, to enable the hand to grasp around the object in such a way that it takes a shape that is in accordance with the object.

A movie showing the Lucs Haptic Hand II in a grasping task is available on the web site (http://www.lucs.lu.se/People/Magnus.Johnsson/HapticPerception.html).

3 Grasping Tests

The Lucs Haptic Hand II will be used in a series of computational models of the human haptic system. It will also be used to model the haptic system together with models of other modalities, e.g. vision.

So far we have tested the Lucs Haptic Hand II by letting it grasp two objects, a plastic sphere and a block made of wood. This has been done to get a comprehension of what the signal patterns generated while grasping look like.

The grasping tests show that the signal patterns generated are significantly different when the Lucs Haptic Hand II grasps nothing (Fig. 4 A.), when it grasps a plastic sphere (Fig. 4. B), and when it grasps a block of wood (Fig. 4. C).

As can be seen in the diagram in Fig. 4 A. there is a registration on some sensors even while the robot hand is not grasping anything. This is due to the way the sensors are mounted on the plates of the finger segments.

However, this is of minor significance besides from a pure esthetical viewpoint. What is important is that the sensors registration will vary with the grasped object

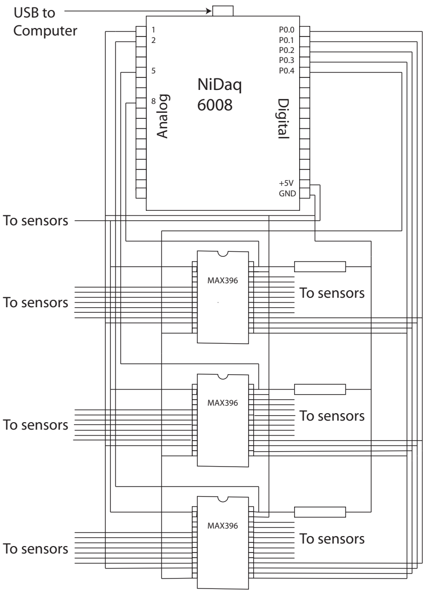

FIGURE 3: *The circuits involved in the sensory part of the Lucs Haptic Hand II. The NiDaq 6008 converts multiple analog input signals to digital signals that are conveyed to the computer via a USB-port. The MAX396 chips are multiplexor circuits for selection of sensor channels.*

and with the way the object is grasped. The variation of the sensors registration is quite good, at least for these two objects (Fig. 4 A - 4 C).

Judging from these tests the Lucs Haptic Hand II should serve its purpose quite well.

4 Future Work

In the future we plan to develop new and better sensor plates for the Lucs Haptic Hand II. In addition, we may also mount microphones at the fingertips in order to sense vibrations, and variable resistors at each joint to increase the proprioceptic sense of the system.

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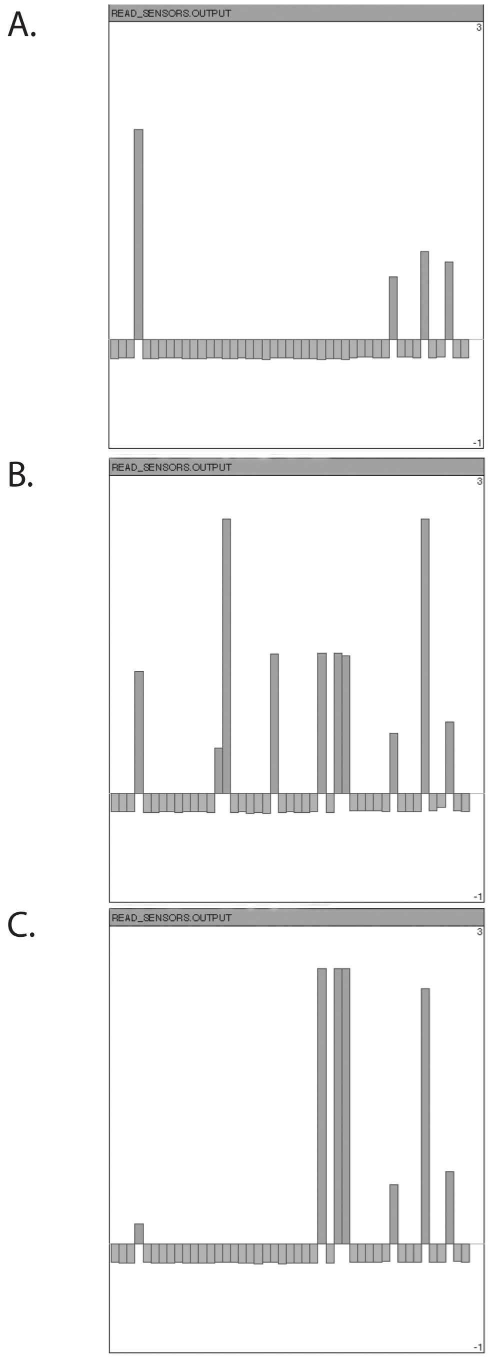

FIGURE 4: *The sensors status. A. The status of the sensors while not grasping anything. B. The status of the sensors while grasping a hard plastic sphere. C. The status of the sensors while grasping a block of wood.*

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