LUCS Haptic Hand III
An Anthropomorphic Robot Hand with Proprioception

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Abstract

The Lucs Haptic Hand III 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 the LUCS Haptic Hand III were done with six different objects in order to get a comprehension of the signal patterns from the proprioceptive sensors provided while grasping. The results from these preliminary grasping tests suggest that the LUCS Haptic Hand III provides signal patterns rich enough to serve in our current haptic models.

1 Introduction

There is an ongoing research project at Lund University Cognitive Science (LUCS) that aims at modelling human haptic perception. In this project increasingly advanced models are built that are modelling different aspects of the human haptic perception, e.g. haptic size perception and haptic shape perception (stereognosis). To implement accurate haptic models robot grippers have to be physically implemented. Moreover, these robot grippers have to be equipped with sensor of one kind or another to serve their purpose as parts of models of the human haptic system. One example of such sensors is touch sensitive sensors mounted on the surface of the gripper, thus emulating the cutaneous sensors in the human skin. Another example could be proprioceptive sensors, i.e. positioning sensors for different parts of the robot gripper. The latter is the kind of sensors so far used for the anthropomorphic robot hand described in this paper.

The modeling of haptic perception as well as the implementation of haptic perception in robots are neglected areas of research. Robot hand research has mainly focused on grasping and object manipulation (Dario et al, 2003; DeLaurentis & Mavroidis, 2000; Rhee et al, 2004; Sugiuchi et al, 2000), and many models of hand control have been focused on the motor aspect rather than on haptic perception (Arbib et al, 2000; Fagg & Arbib, 1998). There are exceptions, though (Allen & Michelman, 1990; Dario et al, 2000; Heidemann & Schöpfer, 2004; Hosoda et al, 2006; Jockusch et al, 1997; Natale & Torres-Jara, 2006; Petriu et al, 2004; Stansfield, 1991; Taddeucci et al, 1997).

Our previous research in haptic perception has resulted in the design and implementation of a number of versions of two different working haptic systems. The first system (Johnsson, 2004; Johnsson et al, 2005a; Johnsson et al, 2005b; Johnsson & Balkenius, 2006a) was a system for haptic size perception. It used a simple three-fingered robot hand, the LUCS Haptic Hand I, with the thumb as the only movable part. The LUCS Haptic Hand I was equipped with 9 piezo electric tactile sensors. This system used self-organizing maps, SOMs, (Kohonen, 1988) and a neural network with leaky integrators and it successfully learned to categorize a test set of spheres and cubes according to size.

The second system (Johnsson & Balkenius, 2006b; Johnsson & Balkenius, 2006c; Johnsson & Balkenius, 2006d; Johnsson & Balkenius, 2007) was a system for haptic shape perception and used a three-fingered 8 dof robot hand, the LUCS Haptic Hand II, equipped with a wrist for horizontal rotation and a mechanism for vertical re-positioning. This robot hand was equipped with 45 piezo electric tactile sensors. This system used active explorations of the objects by several grasps with the robot hand to gather tactile information. The LUCS Haptic Hand II was not equipped with any proprioceptive sensors. Instead it used the positioning commands to the actuators to this end, which is less accurate than real proprioceptive sensors since the wanted positions are not necessarily the same as the actual positions. Depending on the version of the system, either tensor product (outer product) operations or a novel neural network, the Tensor Multiple Peak SOM, T-MPSOM, (Johnsson & Balkenius, 2006c; Johnsson & Balkenius, 2006d, Johnsson & Balkenius, 2007) were used to code the tactile information in a useful way and a SOM for the categorization. The system successfully learned to discriminate between different shapes as well as between different objects within a shape category when tested with a set of spheres, blocks and cylinders.

The remaining part of this paper will provide a technical description of the LUCS Haptic Hand III, which is an anthropomorphic robot hand with proprioceptive sensors (potentiometers with resistance proportional to the angles of the joints), and discuss some initial grasping tests that have been carried out.

2 The LUCS Haptic Hand III

The LUCS Haptic Hand III, Fig. 1 A and Fig. 1B. is an anthropomorphic robot hand equipped with 11 proprioceptive sensors. The robot hand has five fingers and in total 12 dof. As the human hand, the robot hand has a thumb, which consists of two phalanges whereas the other fingers comprise three phalanges. The thumb can be flexed/extended in its proximal joint as well as in its distal joint. The other fingers can also be separately flexed/extended in their proximal joints whereas the middle and the distal joints are flexed/extended together. This is similar to the human hand. The thumb can also be adducted/abducted and the wrist can be flexed/extended as a human hand. The phalanges are made of plastic pipe segments and the force transmission from the actuators, which are located in the forearm, are handled by cords inside the phalanges in a similar way to the tendons of a human hand. All fingers are mounted directly on the palm made of plastic, except the thumb, which is mounted on a RC servo for the adduction/abduction. The RC servo is mounted on the proximal part of the palm. The actuators of the fingers and the wrist are located in the forearm.

There are boxes that comprise the electronics for the scanning of the proprioceptive sensors and a controller for the RC servos mounted on the rear part of the forearm. The RC servo controller, which communicates with the computer via an USB-port, is a SSC-32 version 2.0 manufactured by Lynxmotion Inc. The scanning electronics, see Fig 2, for the proprioceptive sensors consists of a multiplexor that enables switching between different sensors and a NiDaq 6008, (National Instruments), which includes an AD-converter. There are actually two multiplexor circuits, which means the robot hand is prepared to be equipped with up to 21 more sensors, e.g. tactile sensors. The robot hand was also tested with 18 very sensitive binary tactile sensors of our own design, Fig 1 B, but this turned out to be an unsuccessful approach because they almost never reacted due to that the contact points between the objects and the robot hand usually differed from the mounting points of the tactile sensors. This means that we have to come up with another approach when equipping the LUCS Haptic Hand III with tactile sensors. To get proprioceptive sensors the internal potentiometers in the RC servos have been included in the sensory circuit. This is done for every RC servo except the one that actuates the wrist. The forearm is mounted on a holder.

The software for the LUCS haptic hand III is so far developed as stand alone C++ applications but in the future the simulation infrastructure Ikaros will be employed (Balkenius, & Morén, 2003; Balkenius et al, 2007; http://www.ikaros-project.org/). Ikaros provides a kernel and an infrastructure for computer simulations of the brain and for robot control.

Movies and additional pictures of the LUCS Haptic Hand III are available on the web site http://www.lucs.lu.se/People/Magnus.Johnsson.

3 Grasping Tests

The LUCS Haptic Hand III will be used in a series of computational models of the human haptic system. It might also be used in multimodal models where haptic perception is one modality, e.g. models of haptic perception together with vision.

So far the LUCS Haptic Hand III has been tested by grasping six different objects, Fig. 3, a wine bottle, a spice bottle, a plastic bottle, a rectangular bottle, a coffee package and a foil package. This was done to get a comprehension of what the proprioceptive signal patterns look like.

As can be seen in Fig. 3 the proprioceptive signal patterns are different which should enable some computational model to learn to discriminate the different objects according to the proprioceptive information. We

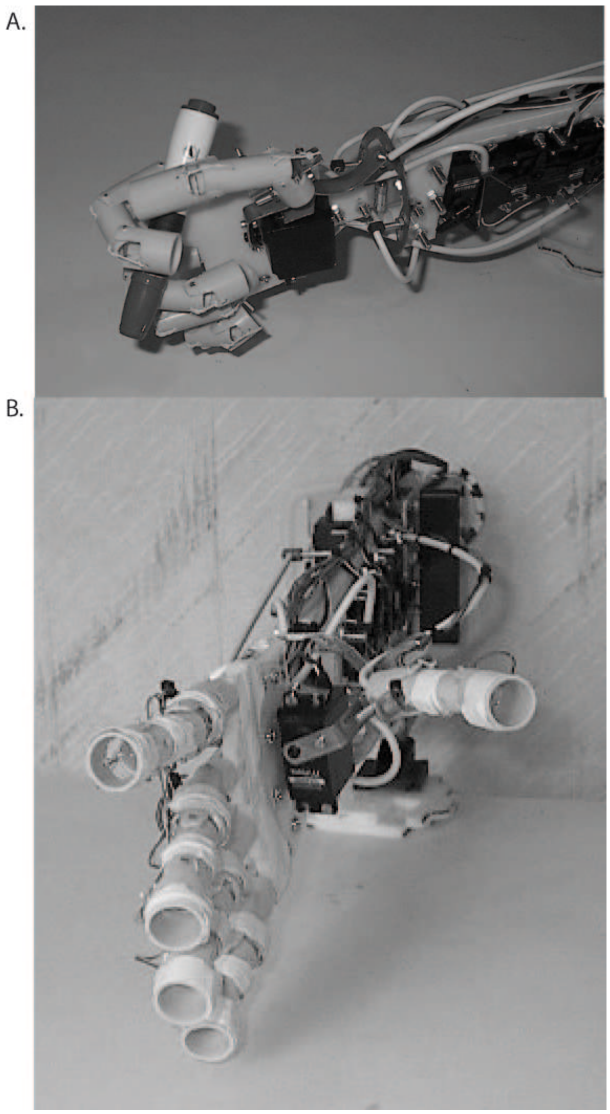

FIGURE 1: *A: The LUCS Haptic Hand III while holding a pen. The 12-dof robot hand has five fingers, is of the same size as a human hand and all its parts have approximately the same proportions as their counterparts in a human hand. Each finger can be separately flexed/extended in the proximal joint, whereas the medial and distal joints are flexed/extended together as real human fingers. As a human hand the thumb has only a proximal and a distal phalang. These can also be separately flexed/extended. In addition the thumb can also be adducted/abducted in a way similar to the human thumb. The wrist is capable of flexion/extension. B: The LUCS Haptic Hand 3 equipped with 18 tactile sensors.*

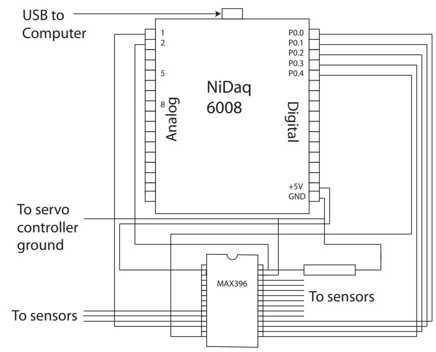

FIGURE 2: *The circuits involved in the proprioceptive part of the LUCS Haptic Hand III. The NiDaq 6008 converts multiple analog input signals to digital signals that are conveyed to the computer via an USB-port. The MAX396 chip is a multiplexor circuit for selection of sensor channels.*

also hope that the proprioceptive information contains enough information for categorization of objects according to shape and that this will enable an artificial system for haptic shape perception that is less sensitive to the sizes and the exact location of the objects in the hand when compared to our previous systems for haptic shape perception (Johnsson & Balkenius, 2006c; Johnsson & Balkenius, 2006d; Johnsson & Balkenius, 2007). We think that the signal patterns might contain such information, perhaps hided in the ratio between different joints. However, this is not obvious and further analyzes and experimentation will be necessary to settle this question.

The LUCS Haptic Hand III is able to carry out a more active exploration than simply grasping the object in only one way. This can be done by adducting/abducting the thumb to vary the way of grasping. This can probably be used to detect whether an object is equally thick all over or not, e.g. if it is a bottle or a cylinder. This is so because the joint angles of the thumb should differ for those adduction/abduction angles where the thumb will get in contact with the bottleneck. Another way of varying the grasps is by flexing/extending the wrist differently in different grasps.

4 Future Work

The LUCS Haptic Hand III will be used in several models of haptic perception. In the nearest future we will use it in experimentation with haptic models with

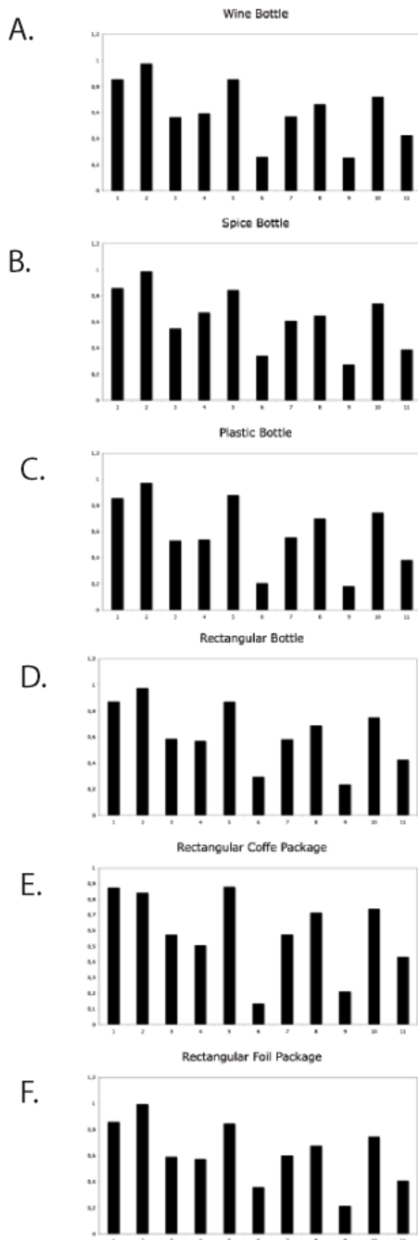

FIGURE 3: *The status of the proprioceptive sensors. The status of the sensors while grasping a wine bottle (A), a spice bottle (B) a plastic bottle (C), a rectangular bottle (D), a coffee package (E) and a foil package (F). The bars in the bar charts represents, from left to right, the registration of the proprioceptive sensor for: index finger proximal joint, index finger middle and distal joints, middle finger proximal joint, middle finger middle and distal joints, ring finger proximal joint, ring finger middle and distal joints, little finger proximal joint, little finger middle and distal joints, thumb proximal joint, thumb distal joint, and thumb abduction/adduction*

a somewhat unconventional approach, which means models that only employ proprioception to see how far this can get us. Further into the future we plan to develop useful tactile sensors for the LUCS Haptic Hand III and use it for more advanced and anthropomorphic models of haptic shape perception than those models that employed the LUCS Haptic Hand II. Perhaps we will also equip the fingertips of the robot hand with tiny microphones or a kind of vibration sensitive sensor of our own design based on Hall effect sensors, and use it to explore haptic texture perception.

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