Control of a Powered Prosthetic Hand via a Tracked Glove

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1 Background

Although commercially available robotic prosthetic limbs now provide fingers with multiple degrees of freedom (DOFs), closely resembling the human hand, the amount of control channels provided by typical biological signals (EMG or neural electrodes) [1] [2] limit the usability of the prosthetic limb. On the other hand, the Virtual Reality field has had the technology to digitize hand kinematics via a "dataglove" for several decades [3], enabling interactions in virtual environments.

Thus, by combining the two technologies, we developed a system to teleoperate the TouchBionics RoboLimb™ device with a custom-built 6DOF glove worn on the sound hand. The RoboLimb hand is a 6DOF prosthetic device which weighs under 500 g and can be controlled via a protocol based on the Controller Area Network (CAN) [2].

The purpose of this system is to support on-going work in our laboratory to benefit unilateral amputees who have a sound hand with which they can teleoperate or otherwise interact with a robotic prosthetic device. Specifically, we are investigating the use of this system in 1) The performance of Activities of Daily Living (ADLs) that will benefit from the mirroring of movements between the sound hand and the prosthetic device (e.g., folding a towel, moving a table, picking up a laundry basket, etc.) 2) Allow the user to pose the prosthetic hand in any desired configuration before performing a task 3) Enable the recording of task specific grasping motions that can be defined and played back by the user in the field

2 Methods

Tracking Glove

We have built a tracking glove using six SparkFun 2.2" flexion sensors (SparkFun Inc.), a glove, an Arduino [4] Uno microcontroller, and Velcro™ to hold the Arduino device on the glove. The flexion sensors were attached to the glove through the use of custom-sewn sleeves which reduce the stress on the sensor attachment point by allowing the sensor to slide during movement. The flexion sensors were soldered to flexible multi-strand wires, and the contact areas were encased in moldable thermoplastic (InstaMorph ™) in order to prevent the soldered connections from failing during use. The resulting glove prototype is shown in Figure 1.

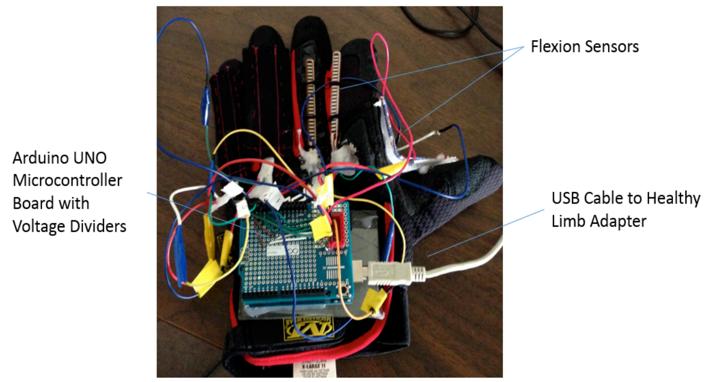

Figure 1: Tracking glove with Arduino microcontroller

The thermoplastic encased ends of the sensors were also molded into sewable buttons by a process involving laser-cut acrylic molds described in Figure 2.

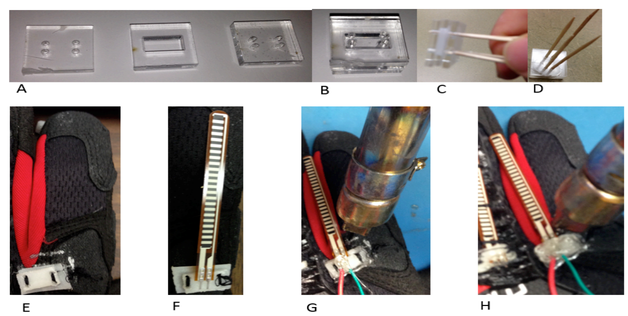

Figure 2: Steps involved in making a sewable sensor holder. A-D: Three layer acrylic mold created with CNC laser cutter used to mold a button with InstaMorph ™. E: Molded button sewn onto glove. F: Flexion sensor lined up with finger. G,H: Hot air gun used to immobilize sensor after contacts have been soldered.

Healthy Limb Adaptor

In order to allow non-impaired volunteers to wear and test the mirrored teleoperation of the system, a healthy limb adapter was created incorporating an Otto Bock QuickConnect ring molded onto the end of a 5" diameter PVC pipe using thermoplastic (InstaMorph ™). Power and data wires were routed to the outside of the healthy limb adapter through a drilled hole, and a handhold was installed inside.

Circuit boards necessary to terminate the CAN cable and provide power, batteries, and a Kvaser Leaf ™ USB to CAN adapter were affixed to the healthy limb adapter using Velcro along with a Raspberry Pi ™ embedded computer, which interprets the signals from the Arduino Microcontroller to generate the CAN messages driving the RoboLimb. A 6' long USB cable connects the tracking glove to the Raspberry Pi device on the healthy limb adapter.

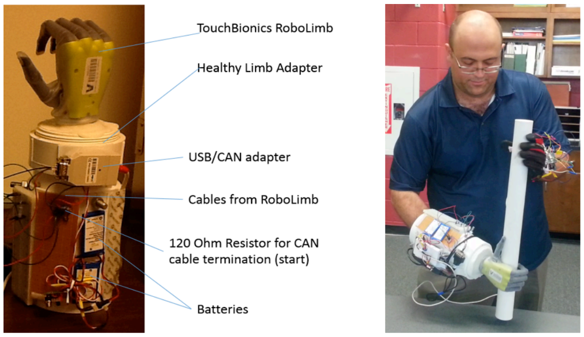

Figure 3: Left: Healthy Limb Adapter. Right: Subject using adapter to perform a bi-manual task

Software

The software configuration of our system relies on three components: 1) The Arduino microcontroller 2) The standard UNIX BASH shell 3) Code running on the Raspberry Pi device ("handControl") which can open and close individual digits via the command line.

The system operates as follows: 1) Code running on the microcontroller board reads the flexion values for each digit and maps them to a value between 0 (open) and 100 (100% closed). 2) Microcontroller software composes the necessary UNIX command to set the position of each digit and sends it over the USB cable to the Raspberry Pi. 3) The Raspberry Pi pipes the command received from the serial port to the BASH command interpreter, invoking the handControl software with the necessary arguments 4) The handControl software issues the command to a) stop any movement that might be happening on the prosthetic device b) issue the command to each digit to go to the required position.

Testing

Three non-impaired volunteers performed the following tasks, using the left (non-dominant) hand as the control input and the right (dominant) hand to operate the RoboLimb attached to the healthy limb adapter: 1) Picking up a large object requiring the use of both hands 2) Picking up a small pen using a pinch grip 3) Picking up a water bottle and drinking from it. Furthermore, a modified Box and Blocks test [4] was performed by one volunteer using a cubic block 6 cm on each side in an area 53.7 cm x 25.4 cm with a 16 cm high divider in the middle. The Box and Blocks test [5] is a standard measure of manual dexterity in which a user typically tries to move as many blocks from one side of a box to another. We have modified the test to incorporate a larger single block (6cm on each side) instead of a large number of blocks which are 2.5 cm on each side.

3 Results

Each user was able to perform the qualitative tests outlined above. The performance on the modified Box and Blocks test was 9 ± 1 blocks per minute (n=3) with the prosthetic device, compared to 39.3 ± 4.6 blocks per minute with the unimpaired hand.

Our testing also included characterization of the sensors in order to make sure that they can reproducibly drive the device. Figure 4 shows the output of flexion sensors on repeated hand openings and closings.

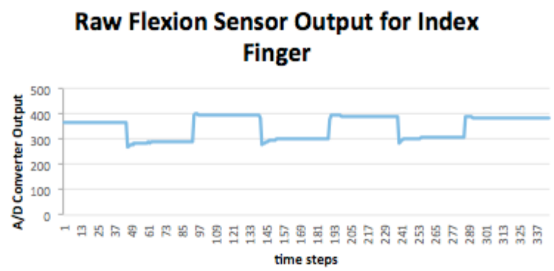

Figure 4: Raw data from flexion sensors on one finger on repeated opening and closing of the hand

4 Interpretation

Our preliminary results indicate that the tracked glove mechanism can provide a fast way of exploiting all the degrees of freedom available in modern powered prosthetic devices. Work is under way to enable the user to lock the mirrored pose on the prosthetic device when desired and record gesture sequences that can be played back under EMG control. We are also investigating the use of the prosthetic device as a teleoperated end-effector for non-prosthetic uses.

Acknowledgement

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References

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