Design of a Haptic Force Feedback System for Pinch

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***Abstract*— Brain-machine interface (BMI) systems hold promise in promoting rehabilitation after brain injury by driving functional neural plasticity. Here, we have designed a force-feedback system to provide haptic sensory feedback during BMI therapy. The system utilizes dual linear actuators and feedback from embedded load cells to control pinch force. Custom electronics and software were created to operate the system in coordination with ECoG or EEG signals produced by the user.**

I. INTRODUCTION

Restoring intuitive control of the hand, particularly grasp and pinch, could greatly improve quality of life for people with traumatic brain injury (TBI). Brain-machine interfaces (BMIs) hold promise in promoting rehabilitation by driving neural plasticity [1]. Adding haptic feedback to BMIs could enhance current therapy techniques by coordinating motor cortical activity with sensory feedback to promote a type of Hebbian learning.

Here, we developed a mechatronic system to enable BMI control of pinch force with haptic feedback. The system both measures and generates pinch force for the index finger and thumb. Haptic sensation can be generated in accordance with BMI signals provided by the user.

II. METHODS

For the haptic actuator, the index finger and thumb are positioned within the device such that their palmar surfaces contact 1 DOF load cells (FC20-10kg, Forsentek, Shenzen, China). These load cells are fixed in the center of the structure (Fig. 1a). Total pinch force, both voluntary and applied, can be measured independently for each digit. Two linear actuators (pq12 linear actuators, Acutonix, Victoria, Canada) are able to provide desired force to the dorsal surface of the index fingertip and thumb tip to provide sensation of pinch. Subjectively, providing force to the dorsal side while the palmar side contacted a fixed surface provided a more natural sensation of pinch. A short stroke length could be used for the linear actuators as preliminary testing revealed that 2mm of finger displacement resulted in almost 50 N of pinch force.

Load cells between the actuators and the digits measure applied force, distinct from the total force recorded by the other load cells. Thus, active force created by the user can be computed. All 4 load cells and both motors sit in the acrylic housing, supported by two posts which rotate about the center to allow for different wrist angles (Fig. 1a). Custom housings for the load cells were 3D printed (Fig. 1b). Acrylic and paramagnetic materials were used in the base to minimize potential interference with cortical signals.

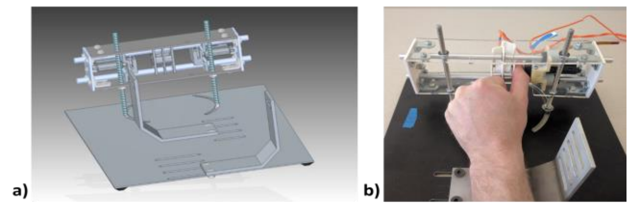

Fig. 1: Design of the haptic actuator a) SolidWorks model. Main enclosure with actuators and load cells is free to rotate about the center, arm mounts are adjustable for varying arm size. b) Thumb being compressed in prototype system, from center to right: two load cells measuring pinch force, one load cell measuring force exerted, linear actuator providing specified forces.

Custom circuitry was created to amplify and filter signals from the load cells, power the actuators, and isolate the system and patient from data acquisition boards and computers. The custom electronics are powered using LiPo batteries.

Custom Labview software communicates with the data acquisition hardware and drives the linear actuators through linear actuator control boards (National Instruments, Austin, TX).

III. RESULTS

To date, we have used this system in 7 subjects with TBI to record isometric thumb flexion force. The subjects performed a 1-D force-matching task. Signals were recorded cleanly from all subjects.

IV. CONCLUSION

We describe the design and implementation of a haptic force controller that can be controlled by a BMI. We are proceeding to test this system.

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REFERENCES

[1] S. R. Soekadar, N. Birbaumer, M. W. Slutzky, and L. G. Cohen, "Brain-machine interfaces in neurorehabilitation of stroke," *Neurobiol Dis,* vol. 83, pp. 172-9, Nov 2015.