Muscle-Wire Glove: Pressure-Based Haptic Interface

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ABSTRACT

This work follows a novel approach to information presentation through haptics using muscle-wire. The muscle-wire is extremely lightweight, silent and does not require complex circuitry. Its property to shrink in length when an electric current is applied, can have many interesting applications, some of which we present as a proof of concept of our vision. In this paper, we describe our initial prototype and a first series of user tests that demonstrates the possibility of representing discrete and continuous informations.

CCS CONCEPTS

• Human-centered computing → Haptic devices; **• Computer systems organization → Sensors and actuators**;

KEYWORDS

Haptic interface; Soft actuators.

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Figure 1: We investigated different parameters to emulate a haptic feedback on user's hand (depicted right). Our target audience at this stage is researchers and experimenters interested in cognition and perception. In this setup, our objective was to evaluate how can the participants perform cognitive tasks, such as getting informations from daily life objects. The early prototype is depicted on the left.

1 INTRODUCTION

The concept of cognitive load, developed by John Sweller in the late 1980s, may have never been as meaningful as today, as we are overwhelmed with visual and auditory stimuli. The average mobile user consumes hours of data queries without even noticing, whether it is checking the social network status, bank account informations or train timetable. After a prolonged exposure of audio-visual sensory interactions, chronic fatigue, a widespread medical condition, can occur. Research suggests that cognitive overload can be linked as a cause, even among healthy individuals [3]. The purpose of this experimental setup is to test the viability of haptic cues in daily life scenarios performing at the level of visual cues for simple tasks. Not satisfied with the current solutions provided by the current standards in haptic interfaces, requiring the use of either cumbersome servomotors or noisy vibration motors, we developed a lightweight, soft and silent actuator based on muscle-wires. This setup presents the advantage of being mounted directly on the user's finger, so that any physical object can turn into a source of information. In this paper, we will test the accuracy of this device in representing the information in different daily scenarios.

2 RELATED WORK

There is a vast amount of related work using other modalities than visual cues for status information [1, 4, 5]. Especially, haptic feedback is gaining popularity for augmented and virtual reality use cases. There is some related pioneer work by Minamizawa et al., requiring either motors or air tubes and pumping devices [1, 2]. However, so far we don't know any work using pressure haptic feedback with muscle-wire.

3 EXPERIMENTAL SETUP

For the actuator part, we developed a glove with 3 segments of muscle-wire BMF 150 (BioMetal Fiber, Diameter=0.15 mm, TOKI Corporation, Japan) wrapping each phalanx of the index finger in a ring-like fashion. Each of the segments is providing pressure by slightly shrinking and thus squeezing the finger, resulting in a haptic sensation. The prototype is actuated using 3 IRLML6344

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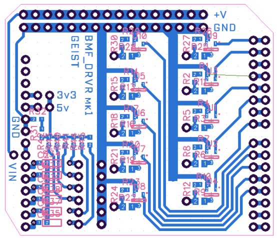

Figure 2: Actuator-driver PCB layout.

power MOSFETs, connected to a NUCLEO-F446RE STM32 board. We use 10 KHz PWM signal to drive the MOSFETs. The current through each segment is restricted to 350-500 mA range at 5V. For safety reasons each segment is isolated using silicon tubes and is firmly attached to the glove. Each contraction consists of two distinct events, thereafter named 'hold' and 'release'. The time at which the events occur can be easily and reliably controlled by varying the current using PWM or voltage regulation. However, we observed that the tensility property of BMF requires a non-compressible delay between its full 'hold' and 'release' states, of approximately 500ms.

4 APPLICATION CASES

We tested 3 different application scenarios with 8 users (Female: 4, Male: 4, Age: 19-27, AVG: 23.75, SD: 2.44). In each scenario we presented the user with some information 10 times and asked users to what information did they perceive. Users were wearing our muscle-wire enabled device during the whole testing session. 2 out of 8 participants had smaller palm size, so were not able to perceive some of the nuances, especially in the first test.

The first case is a "Bank Account Balance" test. We briefed the users on the device setup and the scale we were using, for instance one strong, long, 'hold', on on the proximal and intermedial phalanges, would be equal to 66% available from the credit allowance; a weak yet repetitive, short, 'hold', on all the phalanges, suggested instead that the account was empty. In total we used 4 possible conditions. Then the participants were given a credit card, as soon as the card was touched, a pulse signal was sent, contracting the rings; then the practitioner was asking what is the card balance. The test resulted in 81% accuracy. See Fig.3-A

The second session was a "Timing Reminder" test, each ring on the finger representing a train station on the Toyoko-line in Tokyo (main line to our campus): the station closest to campus, Hiyoshi, was represented as the destination on the distal phalanx; Motosumiyoshi, one station away from Hiyoshi station, on the intermedial phalanx; and MusashiKosugi, the furthest station, on the proximal phalanx. Then the users were asked to imagine a scenario where they are on a train bound to Hiyoshi, and that they will be given haptic feedback representing the next station on their way. Then they were presented with a haptic sensation corresponding to one of the stations and asked what is the next stop. Users were able to determine the station correctly in 97.5% cases. See Fig.3-B

The last session, we were trying to emulate a progress bar. It is

A

Actual \ Perceived	0	1	2	3
0	14	1	0	0
1	0	15	0	2
2	0	1	16	5
3	0	4	2	20

B

Actual \ Perceived	1	2	3
1	23	0	0
2	1	29	0
3	1	0	26

Figure 3: Confusion matrices for the experiment 1(A) and 2(B)

worth noting that we used only 3 rings on the index finger to represent values ranging from 1% to 100%. We modulate the value using the timing of "hold" and "release" events on each phalanx. The sequence representing 100% was the following: 0ms - proximal "hold", 250 ms - intermedial "hold", 500 ms - proximal "release" and distal "hold", 750 ms - intermedial "release", 1000 ms - distal "release". The sequence consists of 1000 ms in total. For lower percentages the sequence was stopped at the time corresponding to the percentage. E.g. at 53% percent progress the sequence was interrupted at 530ms. Participants had a short training session, where they were showed how would 100%, 75%, 50%, 25% and 15% feel like. After that they were asked to estimate the progress of 10 sequences of random length. The results show that the average error is 9.61%, SD: 8.28, SE: 0.93.

5 CONCLUSION

The most interesting finding of this work is the ability to provide a "data feel" for continuous progress using only discrete stimulations. Our motivation was, not only to test our hypothesis that we could achieve an accurate haptic representation of a dataset, but more importantly, we were keen to demonstrate that the usage of this lightweight haptic technology for a non audio-visual interface is worth investigating. Indeed, we found out that because muscle-wire is extremely light and compared to other mechanical devices feels very natural, so that the awareness of the device was declined, and the focus on the tactile experience is increased. We would be interested in the future to redesign the glove into an adjustable one-size-fits-all device and compare it with other conventional haptic devices (servomotors, linear resonant actuators).

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