Multi-Modal Haptic Feedback Device for Upper-Limb Prostheses

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***Abstract*— Sensory feedback provides the necessary means to interact with the surrounding environment. Despite significant advancements in prosthetic technologies in recent years, the transfer of sensory feedback capabilities to users of bionic limbs has yet to reach a satisfactory level. This work proposes a multi-modal haptic feedback device to evaluate how effectively a subject can perceive information from two different types of sensory stimuli. Indeed, the device is designed to provide both i) proprioceptive feedback through skin-stretch, achieved by expanding a silicone sheet, and ii) first contact information feedback through bone conduction, using vibration motors.**

I. Introduction

The loss of an arm is a traumatic event that precludes the accomplishment of daily life tasks. While artificial limbs aim to restore part of the missing functionalities, most of the commercially-available prostheses are unable to provide haptic feedback. Amputees frequently express the desire to perform daily tasks without solely relying on visual attention, highlighting the crucial role of haptic feedback. Among the different feedback modalities, providing proprioceptive information through skin stretch [1] and bone conduction [2] has shown promising results in terms of stimuli perception. The goal of our work is first to develop a multi-modal haptic device able to provide two different types of feedback, then to evaluate if the participants (with and without limb loss) can easily perceive and discriminate them. We will also explore how the integration of multiple haptic feedback information can improve the sense of ownership.

II. Methods

This section provides an overview of the devices (Fig. 1) developed for the evaluation of the two feedback modalities: **Proprioceptive feedback system:** The proposed device, named SENSE (Silicon-basEd skiN-Stretch dEvice), is composed of a main frame, a silicone sheet, a slider and a servo motor (FEETECH FS90R). The silicone sheet is attached to the frame with the help of embedded polyestester fabric, and connected to the slider using screws. A string is tied onto the central part of the slider, and connects it to a servo motor. The routing is guided using a pulley. Velcro bands are used to secure SENSE to the user's arm, providing a comfortable fit. The frame is designed with a 1.6 ° slope, to ensure that the silicone sheet is always in contact with the skin and applies pressure to it at all times, allowing the stretching sensation. The silicone extension is used to give proprioceptive feedback to the user regarding the prosthetic hand level of closure. We designed silicone sheets with different sizes and patterns (Fig. 1), that will be experimentally tested to compare their capability to provide sufficient stimuli.

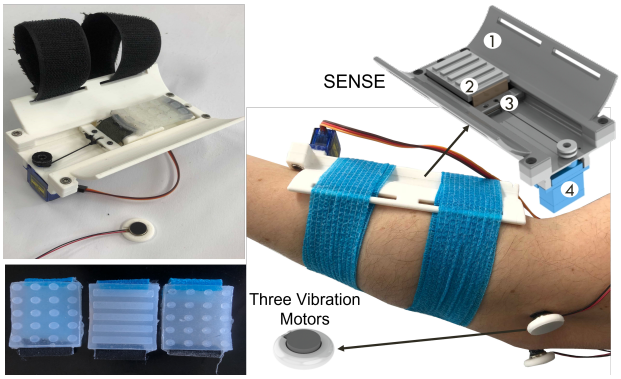

Fig. 1. Multi-modal haptic feedback device (top-left), silicone sheet patterns (bottom-left) and device worn by a user (right) with CAD models to highlight the main components. Note that: (1) frame, (2) silicone with fabric, (3) slider and string, (4) motor group with pulley.

First contact information feedback system: Three vibration motors (TRU COMPONENTS TC-9193500) are placed at the Ulnar Olecranon, the Epicondylus Medialis and the Epicondylus Lateralis, based on [2]. When the thumb, the index and/or the middle finger of the artificial hand enter in contact with a surface, the corresponding motors vibrate.

III. Conclusions

In this work, we presented the design of a non-invasive multi-modal haptic feedback device. The system will be tested with participants (with and without limb loss) to optimize its performance and evaluated with different silicone patterns and sizes. Finally, we will assess the effectiveness and intuitiveness of providing multi-modal sensory information simultaneously. We believe that providing both proprioceptive and first contact information feedback has the potential to enhance the perception and ownership of the prosthesis.

References

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