Interactive Systems based on Electrical Muscle Stimulation

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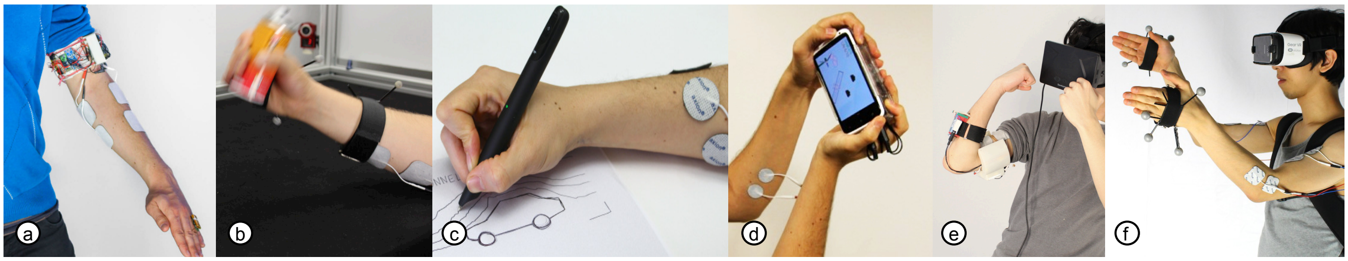

Figure 1: Six examples of interactive systems based on electrical muscle stimulation (EMS). Note how EMS-based devices borrow "components" from the user, in particular the mechanics already contained in the human body. This makes EMS systems comparably small and even allows them to be worn invisibly under the user's clothes.

ABSTRACT

We provide attendees with a hands-on demonstration of several our interactive systems based on electrical muscle stimulation. These wearable devices allow attendees, for example, to transform their arms in interactive plotters, physically learn how to manipulate objects they never seen before, feel walls and forces in virtual reality, and so forth.

CCS CONCEPTS

•**Human-centered computing** → **Haptic devices; Mobile devices;** Gestural input; •**Hardware** → *Emerging technologies;*

KEYWORDS

Electrical Muscle Stimulation, wearable, haptics, body, cyborg

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1 INTRODUCTION

Electrical muscle stimulation (EMS) systems employ a signal generator and electrodes attached to the user's skin in order to send electrical impulses that involuntarily contract the user's muscles. While EMS devices have been used to regenerate lost motor functions in rehabilitation medicine since the '60s [Moe and Post 1962], it has only been a few years since researchers started to explore EMS as a means for creating interactive systems. These more recent projects explore EMS as a means for teaching users new motor skills (e.g., PossessedHand [Tamaki et al. 2011]), increasing immersion in virtual experiences [Farbiz et al. 2007], and allowing users to access information located inside a computer system [Lopes et al. 2015b].

2 INTERACTIVE SYSTEMS BASED ON EMS

We demonstrate our six interactive systems based on EMS. These prototypes focus on two particular benefits of EMS: (1) eyes-free input and output by leveraging the user's muscles and proprioception, which enables information access in mobile scenarios; and, (2) increasing immersion of virtual experiences by allowing users to feel strong forces, yet without sacrificing a wearable form-factor.

2.1 Information access via proprioception

Firstly, we demonstrate how interactive systems based on EMS effectively create displays smaller than those in conventional wearable devices (e.g., smart watches). These "displays" are haptic since the user receives information by feeling their muscles, by means of proprioception,[1] as they are actuated by the EMS device. The following three projects depict how interactive systems based on EMS enable users to access information:

Proprioceptive Interaction (illustrated in Figure 2a) transforms the user's wrist into an interactive device by means of poses as input (sensed by an accelerometer) and poses as output (i.e., using EMS) [Lopes et al. 2015b].

Affordance++ (illustrated in Figure 2b) allows objects to communicate their use by means of actuating the user's muscles with EMS (e.g., a spray can, by itself, show the user that shaking is mandatory before spraying) [Lopes et al. 2015c].

Muscle-Plotter (illustrated in Figure 2c) combines an *Anoto* pen with EMS to transform the user's wrist into a plotter. The user

[1]The human proprioceptive system includes sensory receptors, located inside our muscles and tendons, that allow us to understand how our limbs are oriented in space without requiring any visual processing.

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inputs via sketches (textual commands and drawings) and the system responds via sketches (by controlling the user's wrist as to plot). This allows the system to display, for example, an interactive wind simulation onto regular paper [Lopes et al. 2016].

The core concept that ties these projects together is the idea of interacting through the user's proprioceptive system. Hence, we named this concept "Proprioceptive Interaction" (Figure 2). One of the strengths of proprioceptive interaction is that it allows for eyes-free use — a quality that gains in relevance as more and more wearable devices, such as smart watches and fitness trackers, compete for the user's visual attention. While many wearable devices allow notifying users using vibration, EMS is substantially more expressive, allowing a single EMS actuator pair to communicate a continuously changing parameter to their user.

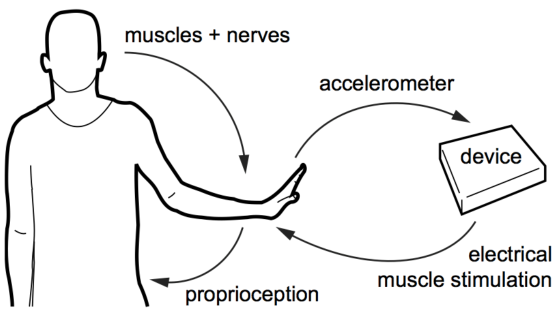

Figure 2: EMS-based devices allow implementing the concept of proprioceptive interaction [Lopes et al. 2015b]

2.2 Increasing immersion

Secondly, we investigated the potential of EMS to simulate physical properties in virtual experiences, such as forces that arise when the user interacts with objects in Virtual Reality (VR). The following three projects demonstrate how EMS successfully recreates physical forces, yet keeps the hardware considerably small and wearable:

Muscle Propelled Force Feedback (illustrated in Figure 2d) brings back force feedback sensations to a mobile phone experience by electrically actuating the user's muscles with opposing forces to their voluntary contractions [Lopes and Baudisch 2013].

Impacto (illustrated in Figure 2e) combines EMS with a solenoid to realistically render the sensation of impact in VR [Lopes et al. 2015a].

VR Walls (illustrated in Figure 2f) utilizes EMS to render walls and other heavy objects in real-walking VR (e.g., the weight of a cube or the spring of a button) [Lopes et al. 2017].

Here, the core concept that ties these projects together is that EMS-based actuation can create counter forces against the user's voluntary motion. The interaction between these forces, as depicted in Figure 3, is perceived by the user as force feedback.

3 CONCLUSIONS

We demonstrate two core benefits of EMS: (1) it miniaturizes well because rather than adding mechanical components to the user's body, EMS-based devices borrow components from the user — making EMS systems comparably small and even allowing them to be worn invisibly under the user's clothes. (2) EMS-based devices effectively overlap with the user's body and this allows them to maintain a continuous bidirectional channel with the user's muscles. The result is a closed loop of input and output between user and device that users can perform eyes-free — a desirable quality especially for mobile devices.

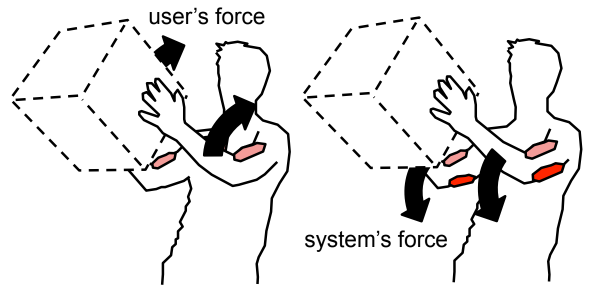

Figure 3: EMS creates force feedback by inducing an involuntary motion that counters the user's own motion. For example, we simulate a cube's weight by actuating the user's triceps as the user pulls the biceps.

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