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FORUMS

CREATING USER INTERFACES WITH ELECTRICAL MUSCLE STIMULATION

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Muscle movement is central to virtually everything we do, be it walking, writing, drawing, smiling, or singing. Even while we're standing still, our muscles are active, ensuring that we keep our balance. In a recent forum [1] we showed how electrical signals on the skin that reflect muscle activity can be measured. Here, we look at the reverse direction. We explain how muscles can be activated and how movements can be controlled with electrical signals.

Insights

- Electrical muscle stimulation (EMS) is straightforward but must be practiced with care.
- There is an open-source toolkit available to make the usage of EMS easier.
- Once muscles become a user interface, new challenges arise that need to be tackled in future research.

The basic approach of electrical muscle stimulation (EMS) is to first attach electrodes to the skin above a muscle, then deliver an electrical signal via an electrode through the skin to the muscle. This signal imitates muscle activation similar to a nerve signal, which in turn results in an observable body movement. The muscle or muscle group to be activated is selected by the placement of the electrode. The signal (strength, duration, pattern) determines the activation level. In this article we explain the basics, show some examples of recent work, and provide links to hardware and software to experiment with this technology for new interfaces. This article is only a starting point—before you start experimenting, educate yourself properly on human physiology (see the Warning sidebar).

EMS is a technology that is well studied in medicine, biology, biomechanics, psychology, and art. A first encounter for many in the ubicomp and HCI research community was the dinner talk by the artist known as STELARC (http://stelarc.org/) at HUC2k, the second ubicomp conference in 2000. *Ping Body* was an installation in which ping commands could be sent to his muscles [2]. In the past decade, the human-computer interaction (HCI) community has discovered EMS, with more and more researchers considering its potential for novel user interfaces.

Activating Muscles

EMS stimulates muscles by using weak electrical signals that mimic the body's own electrical signals. These signals are applied via two electrodes attached to the user's body. The signal is transmitted transcutaneously (through the skin) via the electrodes to the nerve and muscle fibers. When placing electrodes on top of a muscle, users perceive a

tactile sensation (i.e., a slight tickling) at the electrode's position. Since the motor nerves are stimulated, the targeted muscle contracts. The type of nerves stimulated by the signal depend on the signal's current and impulse width. In general, a current of 20–40 mA with a pulse width from 50–300 ms and a pulse frequency in the range of 1–150 Hz is capable of stimulating the motor nerve fibers. The threshold at which the muscle starts contracting also depends on several factors, such as the exact location of the electrode, the resistance of the skin, and the condition of the muscle. Slightly moving the electrodes, for example, can result in substantially changing the way the signal affects the body, thus changing the effect from tickling to contracting.

Several properties of EMS are unique compared with other types of haptic feedback. First and foremost, the user perceives EMS feedback via various senses. The user perceives the tickling phenomenon via their tactile sense and the actuated movement via their somatic sense. Furthermore, the results of the movement (e.g., lifting a finger or changing the direction of a walk) can also be perceived by various other senses. Second, the amount of energy consumed by EMS is much lower than in other types of haptic feedback,