論文の内容の要旨

論文題目：

Providing an Experimental Platform for Interfaces that Apply Electricity to the Human Body

（身体に電気入力を行うインタフェースの実験基盤の提供）

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The border of computer technology and human beings have become ambiguous, where they are integrated and merged with each other. The human body is being modified and even artificial components are implanted *inside* the body. However, we may often face fear or anxiety in such approaches, due to the unclearness of safety and threat of social acceptance. Therefore, there are still limitations and issues that we must overcome to develop and deploy such techniques.

As an alternative approach, there has been an interest in using surface electrodes and electricity to modify the body without direct implants to the body. I consider this approach to be positioned between wearables and implants, where artificial electrical signals are applied *inside* the body from the *outside* surface. Researchers are making use of the unique electrical characteristics of the human body, and many interactive applications are considered. In this thesis, I call this approach "*Electrical Body Hacks*." This thesis aims to bridge the gap between wearables and cyborgs (implants), by practice through electrical body hacks, and to increase the acceptance of such attempts by providing an experimental platform for both developers and users.

Usage of electrical signals and applying them to the human body (*electrical body hacks*) may have several benefits over other technical methods, when building interactive systems. In general, the approach has a great benefit from the aspect of mobility. Furthermore, in cases for some applications, the method also has a high scalability and/or wearability. The body is a convenient place that has many functions manipulated by electrical signals. We can utilize such features and make use of the body as a part of an electric circuit. In addition, the input signal and medium can be controlled from various parameters. We can even attach systems to a body part in a distance,

and to avoid disturbing the body part that is in interest. Resulting from such benefits, many systems and products have been deployed for social and personal use cases.

However, electricity is not completely safe for the human body. The knowledge required for such consideration is spread throughout a large number of research fields, which makes it difficult for developers and users to collect the required knowledge and to work with electrical body hacks. Therefore, I start by reviewing previous research pertaining to HCI in which users come into contact with electricity, as well as providing safety consideration and guidelines.

As a practice of my approach, we present a multi-channel electrical muscle stimulation (EMS) toolkit, in order to ease the access of users for electrical body hacks. We organized a workshop and found that multi-channel EMS has a significant demand for human augmentation purposes.

To consider and address the acceptance of electrical body hacks, we attempted to apply EMS on an unacceptable body part and explored the cognitive understandings of it. We present studies of EMS applied to a human face for this attempt. EMS may stimulate the face to express emotions through the facial muscle actuation, which may work better for negative emotions. Furthermore, a user study was performed to explore the effect of our approaches with combinations with virtual reality (VR) contents, which was found effective to enhance and improve the experience from both emotional and tactile aspects.

Finally, we present an approach which allows a human body to activate low-power electronic devices by touching them, and to present application domains that overlap with wearable and cyborg approaches. Signals are applied to the human body that allows electrical current to pass through the body safely that are imperceptible.

Consideration for the acceptability of such systems are key issues, and discussions are required. Therefore, I present a careful discussion to address this issue, and to help increase the acceptability of the research area and future work.

This thesis provides an experimental platform constructed with my practices and discussions, which includes a design guideline, a prototyping tookit, and example applications. Through this experimental platform, I envision future development and research of body modification to be more safe and acceptable for human augmentation.