Elemphasize: Emphasizing Mechanical Tactile Sensation via Electrical Stimulation

Ryo Mizuhara
The University of Electro-Communications
Chofu, Tokyo, Japan
mizuhara@kaji-lab.jp

Akifumi Takahashi
The University of Electro-Communications
Chofu, Tokyo, Japan
a.takahashi@kaji-lab.jp

Hiroyuki Kajimoto
The University of Electro-Communications
Chofu, Tokyo, Japan
kajimoto@kaji-lab.jp

Figure 1 Electrical stimulation increases the intensity of physical stimulation. (a) Electrical stimulation while hitting the skin. (b) Gripper-type physical object with servomotor and an electrode attached at the tip. (c) VR scene of being bitten by a snake. (d) An electrode attached at the tip of a syringe. (e) Training to get used to injection.

ABSTRACT

In order to provide a tactile sensation that is appropriate for tense situations such as being slapped or slashed, it must be safe as well as strong and natural. Mechanical stimulation can present a natural sensation, but too much intensity can lead to injury. Electrical stimulation can present high intensity stimuli without mechanical damage, but the naturalness of tactile sensation is inferior due to its bizarre sensation. We proposed a method to combine mechanical stimulation and electrical stimulation to achieve strong sensation without losing natural sensation. An electrode is attached to the physical object and the subjective intensity of the mechanical stimulus is enhanced by the electrical stimulus when contact with the skin. We also present several scenarios such as application to a thrilling VR content and training to get used to fear of injection pain.

CCS CONCEPTS

• Human-centered computing~Haptic devices

KEYWORDS

Electrical stimulation, Mechanical stimulation, Tactile, Virtual Reality

1 INTRODUCTION

It is important to provide an appropriate tactile feedback in virtual-reality (VR) space to enhance immersion. Furthermore, when the VR experience is a form of entertainment, it is necessary to present not only a sense of grasping and tracing an object but also an appropriate tactile sense for tense situations; e.g., a sense of being slashed or slapped. In this case, the presented tactile sense must be strong and natural to maintain tension. Such a sensation must be safe so as not to damage the skin; otherwise, the sensation is not suitable for entertainment.

There are two main methods of presenting tactile stimulation; i.e., physical deformation of the skin through mechanical stimulation and direct excitation of nerves, such as through electrical stimulation. Tactile stimulus by mechanical stimulation can closely mirror a natural tactile presentation because it reproduces the natural mechanical interaction between the skin and object. However, intense stimulation may carry a risk of injury (e.g., PainStation [Reiff and Morawe 2001]).

During electrical stimulation, sensory nerves are stimulated by an electric current to the skin surface that produces a tactile sensation [Saunders 1983; Kaczmarek et al. 1994; Yem and Kajimoto 2017]. The applications to entertainment include a touch display that can apply tactile sensations to fingertips [Matoba et al. 2011] and the presentation of pain sensations [Kataoka et al. 2014]. The induction of a tactile sensation via electrical stimulation directly activates sensory nerves, and an intense tactile presentation is thus possible without mechanical damage to the skin. While electrical stimulation also carries certain risks, especially in terms of possible electrical current pathways, it is a sure way of eliciting a strong sensation without leaving marks on the skin. However, the degree to which the sensation is perceived as natural is lower than that when touching real objects. Indeed, many existing entertainment applications using electrical stimulation have been found to produce a ‘bizarre sensation’.

In summary, mechanical and electrical stimulation methods have advantages and disadvantages. A combination of the two strategies may therefore produce a natural yet strong sensation. Ideally, a

'natural' tactile feeling can be elicited by mechanical stimulation with sufficient tactile intensity achieved via electric stimulation. We propose a novel haptic presentation method Elemphasize which combines mechanical and electrical stimulation. In our previous work, We developed a haptic presentation method that combines electrical and mechanical stimulation to verify that subjective mechanical tactile intensity is enhanced via electrical stimulation [Mizuhara et al. 2019a]. We also found that mechanical stimulation reduced the bizarre sensation of electrical sensation, which contributes to naturalness of the sensation [Mizuhara et al. 2019b]. This work presents several use cases such as application to a VR content using relatively small physical object.

2 HARDWARE

Elemphasize consists of an electrical stimulation kit that we have developed (Figure 2) [Kajimoto 2012], physical object and electrodes. In order to apply electrical stimulus when mechanical stimulus is applied, one electrode is placed on the part of the physical object where it contacts the skin (Figure 3). The other electrode is attached to another contact area or skin. When the electrode on the physical object touches skin, a current flows and electrical stimulation is performed (Figure 1-a). The intensity of the electrical stimulus can be easily changed on the software, and its current limitation is 10 mA.

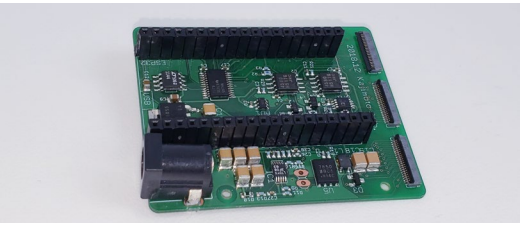

Figure 2: Electrical stimulation kit.

Figure 3: Physical object with an electrode.

3 APPLICATION

We propose two applications for Elemphasize.

3.1 Thrilling VR content

Elemphasize is suitable for thrilling VR content such as being attacked by animals because it can safely present natural and intense stimulation. In this content, the servo motor arm shown in Figure 1-b is used as a physical object. Electrical stimulus is applied when the arm catches user's skin. At the same time, the user is bitten by a snake in VR environment (Figure 1-c).

3.2 Getting used to injection

Not only children but also adults are afraid of pain of injection. Elemphasize can be served as a training kit for injection. Syringe-shaped object with an electrode at the tip (Figure 1-d) is used in this training. Users can get used to the pain and fear of the injection by manipulating pain intensity(it depends on amplitude of electrical stimulation) as their own (Figure 1-e).

ACKNOWLEDGMENTS

This work was supported by a JSPS KAKENHI Grant Number JP15H05923.

REFERENCES

KACZMAREK, K.A., TYLER, M.E., AND BACH-Y-RITA, P. 1994. Electrotactile haptic display on the fingertips: Preliminary results. *Proc. 16th Annu. Int. Conf. IEEE Eng. Med. Biol. Soc*, 940–941.

KAJIMOTO, H. 2012. Electrotactile display with real-time impedance feedback using pulse width modulation. *IEEE Transactions on Haptics 5*, 2, 184–188.

KATAOKA, Y., HASHIGUCHI, S., SHIBATA, F., AND KIMURA, A. 2014. Psychophysical influence on sense of pain by mixed reality visual stimulation. *7th Korea-Japan Workshop on Mixed Reality*.

MATOBA, Y., ETO, H., SATO, T., FUKUCHI, K., AND KOIKE, H. 2011. Biri-biri: Pressure-sensitive touch interface with electrical stimulation. *13th Virtual Reality International Conference*.

MIZUHARA, R., TAKAHASHI, A., AND KAJIMOTO, H. 2019a. Enhancement of subjective mechanical tactile intensity via electrical stimulation. *Proceedings of Augmented Human International Conference 2019 (AH2019)*.

MIZUHARA, R., TAKAHASHI, A., AND KAJIMOTO, H. 2019b. Combination of Mechanical and Electrical Stimulation for an Intense and Realistic Tactile Sensation. *The 17th International Conference on Virtual-Reality Continuum and Its Applications in Industry*, Association for Computing Machinery.

REIFF, T. AND MORAWE, V. 2001. PainStation. www.painstation.de/.

SAUNDERS, F.A. 1983. Information transmission across the skin: high-resolution tactile sensory aids for the deaf and the blind. *International journal of neuroscience 19*, 1–4, 21–28.

YEM, V. AND KAJIMOTO, H. 2017. Comparative Evaluation of Tactile Sensation by Electrical and Mechanical Stimulation. *IEEE Transactions on Haptics 10*, 1, 130–134.