Applying “Out of the Body” Funneling and Saltation to Interaction with Virtual and Augmented Objects

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ABSTRACT
Funneling and saltation are two major illusory tactile feedback techniques. Recently, these techniques have been found to be applicable to eliciting “out of the body” experiences as well (e.g. through user-held external objects). We discuss the possibility of applying this phenomenon to build a less cumbersome feedback device with a reduced number of vibrators, and interact with virtual and augmented objects.

Keywords: Phantom sensation, Illusory feedback, Funneling, Saltation, Vibro-tactile feedback.

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Interaction styles;

1 INTRODUCTION
Tactile feedback is one inexpensive and effective way to enhance the interaction experience. Well known illusory feedback techniques associated with tactility are the funneling and saltation [1, 2]. Illusory feedback refers to the phenomenon that user's perception of feedback that does not match the stimulus' physical characteristics. Funneling refers to stimulating the skin at two different locations simultaneously with different amplitudes and eliciting phantom sensations in the space between. On the other hand, in saltation, the skin is stimulated at two locations with proper time intervals (also known as inter-stimulus interval or ISI), and the phantom sensation is felt in between. By varying the amplitudes (funneling) or time interval (saltation) between the two adjoining actuators, we can adjust the position of the phantom sensation between the fingers. These two techniques have often been applied to reduce the number of tactile actuators on the body [3, 4].

Recently, Miyazaki has discovered that saltation could be extended to body-worn objects and to create phantom sensations from “out of the body” (see Figure 1) [5]. This means phantom tactile sensations can be felt as if coming from an external object. In [6], the authors have experimentally the possibility of the “out of the body” experience using funneling and saltation for interacting with “virtual” objects without any physical medium (see Figure 2). Our motivation lied in realizing more flexible and inexpensive and less mechanically complicated tactile/haptic feedback for interfaces for tangible interfaces for virtual and augmented objects. Conventional tangible interfaces employ physical props for the sense of tangibility and physicality, but being passive and fixed in shape, cannot effectively and realistically represent all different shapes or dynamic interactions. In this exposition, we discuss the practical ways to of applying this phenomenon to interact with virtual and augmented objects.

![Figure 1: The concept of “out of the body” tactile experience (saltation) from a hand-held object (the figure is a reproduced version from [5]). When vibrations are given to the fingertips with proper delay values, phantom tactile sensations are felt as if occurring in the middle of the hand-held ruler (a). No such sensations are felt without the physical medium (b).](image1)

2 PHANTOM SENSATIONS FROM “OUT OF THE BODY”
In [6] we have conducted usability experiments for effects of funneling and saltation from out of the body in an augmented reality setting. In this experiment, the two fingertips were tracked using small markers by a head mounted camera and an augmented reality video imagery was presented to the user as visual feedback in which a virtual ruler was overlaid (to look as if being) on between the two fingers (see Figure 2). We have newly verified for the first time that funneling and saltation, the two main perceptual tactile illusions exist also on virtual objects without any physical medium.

![Figure 2: The experimental set up to create phantom sensations from out of the body [6].](image2)

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† This paper is based on a longer paper [6] to be presented at the ACM SIGCHI 2012 but an emphasis on the application of the proposed techniques.
Our experiment showed that it was quite possible to modulate the locations of the phantom sensations with the funneling technique quite accurately. Out of the body saltation, on the other hand, while shown to be existent even for virtual objects, only showed relatively low precision/resolution (only one or two phantom sensations created within 10 cm span). In addition, saltation exhibited more dependence on personal differences. However, the experiment was carried out with minimal associated visual feedback (i.e. only the virtual ruler). For example, in Figure 4, the dynamic object is also shown rendered. We expect that by strengthening saltation or funneling with additional modal feedback the overall experience can be enhanced in actual usage scenarios.

3 APPLICATION SCENARIOS

Figure 3 shows four possible application scenarios for using the "out of the body" phantom sensation to interact with physical, virtual and augmented objects.

![Figure 3](image-url)

Figure 3. Four application scenarios of applying funneling or saltation to interacting with (a) physical, (b) virtual/direct, (c) virtual/indirect, and (d) augmented objects.

Figure 3(a) shows a case of using a physical medium, such as a mobile device with a visual display. The users can feel the dynamics of the visually rendered object in the display with tactile stimulations on the grasping hands/fingers. Figure 3(d) shows a similar case of using a physical medium but for a marker or tangible prop in an augmented reality situation (as was the case in the experiment). While the user holds prop, the dynamics of the augmentation object can be felt through the two tactically stimulated hands/fingers. We hope to be able to simulate various indirect dynamic effects (e.g. holding a virtual bottle and feeling for the moving objects in it) using only minimal number of vibrators. Note that it is not necessary to use "two" hands, but to use two fingers instead.

Figure 3(b) illustrates the case of interacting directly with a virtual object (e.g. stereoscopically rendered object) without any physical medium. Finally, Figure 3(c) shows the case of using a physical prop but interacting with a virtual object indirectly (e.g. an object rendered in a separate display, unlike the case of Figure 3(a)).

We implemented a simple application representing the case of Figure 3(d) to interact with augmented objects (Figure 4). A very preliminary pilot study has shown that for funneling the perceived intensity of the dynamic (e.g. moving/bouncing) objects (the ball and rabbit in Figure 4) on the virtual ruler was rather weak despite the simultaneous visual rending of the dynamic object, while relatively stronger for the case of saltation. This is contrary to the results in the previous experiment which showed the advantage to the funneling over saltation in terms of the accuracy or richness of the feedback experience. However, this can be due to the simple linear (rather than logarithmic as suggested by [1]) stimulation interpolation function we used. A formal experiment is still ongoing.

![Figure 4](image-url)

Figure 4. A simple application of funneling or saltation to interacting with augmented objects.

4 CONCLUSION

In this paper, we have introduced an experiment of verifying the "out of the body" funneling and saltation effect for interacting with virtual objects and discussed several application scenarios for actual usage. We hope that the suggested technique can be one way to provide richer interaction experience without complex and cumbersome machinery, thus improving the overall usability at the same time.

In the future, we plan to further validate the phantom sensations for virtual objects through brain imaging [7] and continue to develop practical interaction techniques and applications based on it. Another avenue for future work is to investigate the multimodal effect, e.g. the extent to which the multimodal feedback affects funneling or saltation.

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REFERENCES