Brief research directions for toes augmentation

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Abstract

we embarked on a study of foot augmentation in our master program. There are many different approaches in this area, but one of our idea relates to the toes. Although the toes cannot be moved independently, they have a great capacity to support standing and balance along with the other plantar parts of the foot. In this paper and the coming workshop, we would like to discuss the research directions for foot augmentation at first which can result in expanding the possibilities of the toes not only balance but also another potential of toes.

CCS Concepts

• **Human-centered computing → HCI design and evaluation methods**.

Keywords

Foot augmentation, Toes, Balance, Footprint

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1 Self introduction

The author received the B.S. degrees in Mathematical Engineering and Information Physics from the University of Tokyo in 2024. He is now in Graduate School of Information Science and Technology, the University of Tokyo. He belong to Information Somatics Laboratory, with supervisor Prof. Masahiko Inami. His research interests include vection, vestibular sensation, self-other distinction, and tele-existence.

One of the author's contribution is "I vs. Me" [2]. This work proposes an adversarial interaction with the past self. The player of this work fights with a virtual self who simply reproduces the movements that they experienced in just a previous round. Although the movements are those of their past self from a few dozen seconds ago, a lot of players of this work says they could not clearly remember the movements, and they had to respond immediately to the opponent's attacks, which are difficult to predict. This work can lead to find the psychological effects of interaction with a virtual self and to apply to individual training methods in interpersonal sports.

Based on the above experience, we remain interested in the cognitive aspects and potential effects of the body that are not yet known in detail and considerable. Although the field of foot augmentation is different from the above work, we plan to conduct researches in this area.

2 Introduction to our research

In this paper, we will mainly focus on toes augmentation. The chances to be conscious of toes is limited in daily life. Opportunities for being conscious of toes in daily life are limited. Toes were originally used in ancient times to grasp tree branches as were the fingers of the hands. The tendons and sheath had been bonded during the evolution process and eventually such fluency was lost. Toes became just a part of the sole of the feet, where we use as a unique body part contacting with ground when standing or walking. One study showed that the body image of toes are so indistinct that we misidentified index, middle, and ring toes [4]. Even though the role of toes have changed in human history, bipedalism, a prominent characteristic of Homo sapiens, requires us to stand and walk stably. The toes are mainly used for delicate balance control nowadays.

However, there is room for augmentation of toes ability, since we have still five toes in each foot of healthy individual, and each of them can move flexibly by external force. For instance, toes can percept of certain degree of accuracy [17], and can be used as an augmentation of the hand [11]. A variety of works on toes augmentation focuses on the geometric similarity between the toes and the fingers of the hand.

Hence, our challenge is to examine new ways to utilize the toes and conduct research that will lead to their effective use not limited to the alternatives to the fingers of the hand. Since this workshop is about foot augmentation, we will also discuss research directions that are applicable to the foot as a whole and but that may result in a focus on the toes in the process of investigation.

3 Consideration of toes utilization through some research plans

Here we will show some of the possible directions of the research for toes and foot augmentation.

3.1 Perception through drawing

If we are asked to draw a hand and a foot, it is not trivial how would we draw it. Some may draw inside out, right or left, upward or downward, perhaps the palm, or the instep in case of the foot. It seems that the result depends on the dominant hand, how to count with our fingers, and the direction we write or read the letters. Previous study showed that right-handed people and left-to-right

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readers and writers tend to draw the left side of faces rather than the right side [1, 6, 14]. The plausible explanation of this result is that the association of spatial processing with right cerebral hemisphere lead to great attention to the left side of space [16].

One of our work is to try a simple preliminary survey. Any tool to write would be fine, but frames are designated to be square paper, since frames in which the drawing is made can affect the drawn figures [3]. This survey can imply the cultural effect on the recognition of our hand or foot. Therefore, our first approach is to limit the subject to right-handed and left-to-right readers and writers. If there is any correlation between the drawn side of hand or foot, it might serve an implication for perceptual recognition of our limbs. In terms of the toes, the process of drawing is also noteworthy, as the subjects capture what features of each toe and in what order they draw them.

3.2 Potential of pinching

Involuntariness is one of the most critical characteristic of toes. Unlike fingers, we cannot move each of our toes independently in general. In order to utilize this nature, we try to apply for pinching with toes. It can be seen that toes have shape memory in that our toes keep the same posture unless an external stimulation is added, and even after once we change the posture we cannot keep our toes unnatural posture for a long time. Topologically, foot with toes is like a fork seat tag or book stopper, which are used as interfaces that makes use of the fact that it pinches more strongly when flexed. The shape and the involuntariness of our toes can enhance the force to keep something thin pinched when they are pulled vertically or horizontally.

To verify the force of toes, our first work is to investigate the type of posture that the toes are relatively stable in and identify several such ground states. Then we would measure how much we can empower to the pinching object with the toes transformation from the ground state. The example pinching object is string, as shown in Fig.1. In Japan, traditional sandals called Geta or Zori were common in old age, with which we pinch its strap with our foot thumb and index toe. Although these interfaces imply the possibilities of the pinching force of toes, few works have focused on this aspect. This work aims to design an interface to make use of such potential finally, but of course there is room for consideration as to where to apply it.

3.3 Tactile sensation remapping

In perspective of primary sensory cortex, the topographical size of a leg is as spread as that of a hand thumb. Humans have been tried to devise foot-controlled interfaces, such as the gas pedal and the brake of a car for acceleration and deceleration, the piano pedals for changing timbre, and so on. However, when it comes to using toes for control, the low sensitivity often leads to human error, and some cases are life-threatening such as controlling the delicate speed of a car.

A lot of research have been held to cope with this problem. In this context, we try to remap the tactile sensation of the foot to that of the leg. Since the cutaneous tactile sensation of the legs except for the sole is not usually used for this type of control in particular, there is room to explore applications when trying to control something with the foot. Previous study showed that we can re-associate our right thumb with the virtual left arm by visuo-motor synchronization, [8]. Therefore, the toes could also be feedbacked onto the leg, or could be amplified the sensation of the toes through a virtual mechanism.

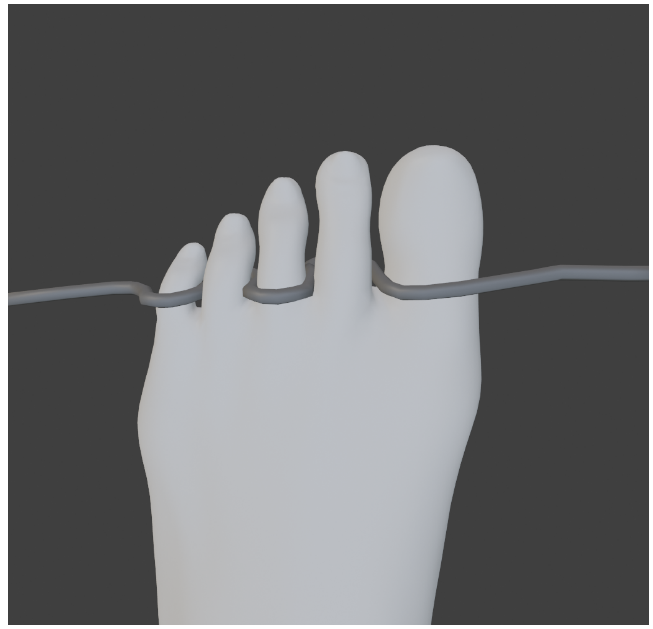

Figure 1: The image of the example usage of strings for pinching by toes.

The key point to be addressed is the ways to remap the five toes to the leg in this case. It is said that a horse has one toe and stands on the pad of that single toe. Like the correspondence between the horse's toes and the human sole seen there, we are considering a direction that naturally augments and enhances the function of the entire foot as a coordinated system. One important factor for evaluation is whether the remapping is intuitive and whether the virtual mechanism can increase the sensitivity of the control.

3.4 Spatial resolution measurement

From the viewpoint of human factor, just measuring the spatial resolution of each toe in detail can be a considerable study. The study which measured the spatial tactile resolution of the index finger showed that the tactile acuity from the finger end to the finger pad changes almost linearly with a steep decrease in tactile acuity at the finger side [13]. On the other hand, Although there have been several previous studies on the pressure distribution and general sensitivity of the sole of the foot during ground contact [10], there are not many detailed investigations. Moreover, the spatial characteristics of each toe are considered trivial and there are almost no previous studies on this subject.

Therefore, our approach is to devise a specialized measurement method for foot. Classically, previous studies which measures the spatial resolution on skin have used two point threshold [18], or two-point orientation discrimination [15]. However, it has not been considered whether such measurement is suitable for getting exact data. Looking ahead at applications, the method should be focus on the directional perception because the sole of the foot is specialized in sensing balance though the resolution of a foot is far lower than that of a hand.

Related to this, there is a concept called the footprint shown in Fig.2, which corresponds to the fingerprint on the finger of the hand and can identify an individual in the same way as a fingerprint [7, 9]. This means that the footprint can retain such a high amount of information. Few previous studies have investigated the tactile properties of footprints, but just as fingerprints play an role in serving friction for tactile perception [5, 12], the use of footprints may help us understand the spatial characteristics of the foot.

For designing new toe devices or interfaces, knowledge of the spatial resolution is crucial to sense or feedback tactile stimulus on foot precisely.

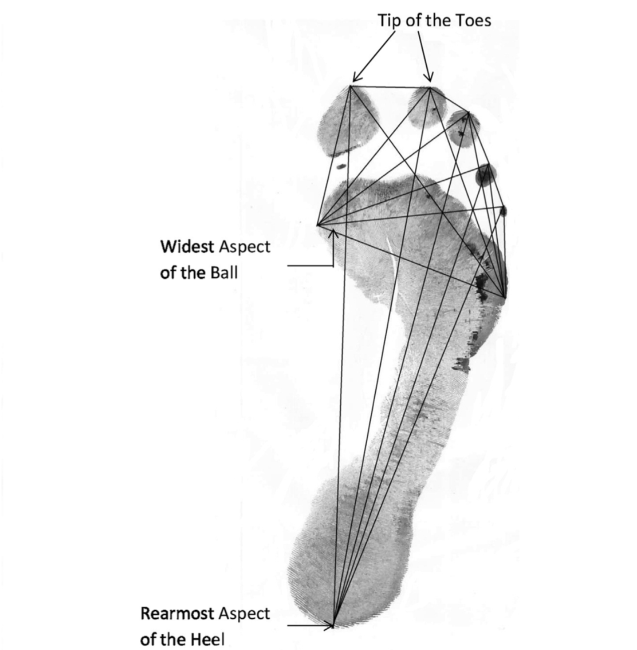

Figure 2: A footprint record, cited from [9]

4 Conclusion

In this paper, we explore the possibility of toes through introducing some research plans. Toes have high degree of freedom but does not have distinct body image and cannot moves independently, and often use for balance control. The first work can give a implication of our feet perception compared to hands. The second work is applicable for novel interface in which toes can exert their potential. The third and the last work could contribute to the better accuracy for foot control and feedback from different perspective.

We are in the process of conducting the research that will lead to toe and foot augmentations, including these research directions. Our future work is to implement these plans to examine how applicable for foot augmentation.

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