OctaRing: Examining Pressure-Sensitive Multi-Touch Input on a Finger Ring Device

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ABSTRACT
In this paper, we introduce OctaRing, an octagon-shaped finger ring device that facilitates pressure-sensitive multi-touch gestures. To explore the feasibility of its prototype, we conducted an experiment and investigated users' sensorimotor skills in exerting different levels of pressure on the ring with more than one finger. The results of the experiment indicate that users are comfortable with the two-finger touch configuration with two levels of pressure. Based on this result, future work will explore novel gestures involving a finger ring device.

Author Keywords
Ring; pressure-sensitive; multi-touch; wearable;

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Recently, researchers in human–computer interaction have been exploring an array of finger ring devices for input control as a paired input device with personal computers [2]. In addition to pointing and gesturing, touching a ring device is a common input action. However, even though users can simultaneously manipulate a ring device with more than one finger, the application of touch techniques has been limited to simpler actions, such as binary signals (e.g., clicking) [2].

To address this issue, we explore multi-finger touch techniques with a finger ring device for more diverse touch inputs. We employ *finger pressure* as an additional input source, which can fine-tune multi-touch gestures made on a ring device.

In this paper, we present OctaRing, an octagon-shaped finger ring device that facilitates pressure-sensitive multi-touch gestures. With the prototype, we conducted an experiment to study how many fingers users can be used, and how many pressure levels can be distinguished. Inspired by Rendl et al. [1], we examined users' sensorimotor skills in controlling pressure levels when manipulating the ring without any feedback. Our results show that users felt comfortable using two-finger pressure-sensitive touch input with two levels of pressure. We see our work as an early effort in designing better pressure-sensitive multi-touch techniques for ring devices.

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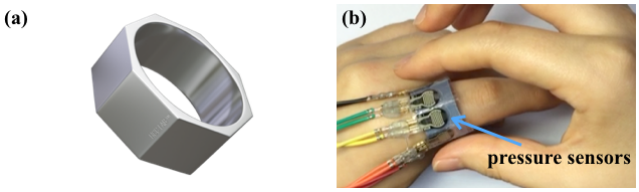

Figure 1. OctaRing: (a) the concept design and (b) the prototype.

OCTARING

In designing a pressure-sensitive multi-touch interface with a finger ring device, we considered the design issues of ring shape and touch configuration. A pilot study was used to experientially determine our design space (two males and two females, aged between 26 and 31 years). Based on participants' input, we developed an octagon-shaped ring prototype and identified multi-touch gesture types.

Ring Shape

To provide a natural tactile feedback for multi-touch gestures such as sliding and pinching, we designed a polygon-shaped ring device, as opposed to a circular one. Participants were asked to wear three types of polygon-shaped rings (hexagon, octagon, and decagon) on their index fingers, and they then performed multi-touch gestures, such as pinching. After the session, we asked them to describe their experiences with each ring type.

The study revealed that the octagon-shaped ring was most suitable for participants to naturally perform multi-touch gestures. Participants reported that the size of each side of the ring mattered. They found it difficult to grab the sides of the hexagon-shaped ring with more than three fingers. On the other hand, the sides of the decagon-shaped ring were too small for a participant to gesture on. We therefore decided to use the octagon-shaped ring, called OctaRing, to investigate multi-touch input techniques on a finger ring device.

Touch Configuration

In the pilot study, we were able to observe many ways in which users can interact with polygon-shaped ring devices (Figure 2).

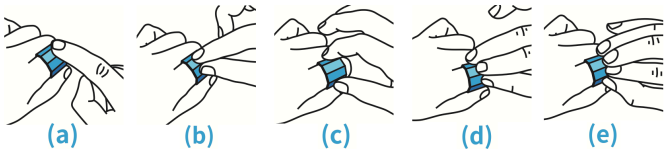

Figure 2. Five touch configurations: (a) one finger, (b) two finger (together), (c) two finger (apart), (d) three finger, and (e) four finger.

Implementation

An OctaRing prototype was implemented using pressure sensors to detect pressure-sensitive multi-touch. As shown in Figure 1(b), a force sensor resistor (Interlink FSR-400) is attached to each side of the ring. The sensor can recognize 0.2-20N, and its outputs were sampled at 100 Hz using an 8-bit analog-digital Arduino convertor.

EXPERIMENT

We performed a user study to investigate the feasibility of our ring design. To evaluate the effectiveness of interaction with the pressure-sensitive ring device, we measured interaction accuracy and user rating for varying pressure levels and touch configurations.

Procedures: We used a 2 × 5 within-subjects factorial design with different pressure levels (*2-level* with light-strong pressure, and *3-level* with light-medium-strong pressure), five touch configurations, and three repetitions. We had nine participants (four females, aged 24–32), and thus a total of 270 (30 × 9) trial data were collected.

As shown in Rendl et al. [1], measuring the accuracy of gestures with pressure-sensitive devices cannot use a single-pressure threshold value because pressure perception is user dependent and finger dependent. To calculate accuracy, we used different thresholds for each participant's fingers. After each session, we manually judged the accuracy of the applied pressure level of the given gestures by observing the explicit differences between pressure levels. In addition, we asked the participants to rate the difficulty of each condition according to a 5-point Likert scale.

Results: Table 1 shows the accuracy and user rating results. Participants performed interactions more accurately with the 2-level pressure than the 3-level pressure ($F_{1,8}$ = 11.83, p = .008). We also found a significant two-way interaction between pressure levels and touch configurations ($F_{4,32}$ = 10.72, p < .001), indicating that touch configuration affects accuracy differently at each pressure level. With 3-level pressure, participants achieved low accuracy when interacting with more than three fingers.

User ratings showed noticeable differences in both pressure levels ($F_{1,8}$ = 25.29, p = .001) and touch configurations ($F_{4,32}$ = 119.5, p < .001). Post hoc analysis shows that one-finger touch as well as two-finger (apart) touch (Figure 2(c)) was relatively easier than three- and four-finger touch (p < .001). The result also shows that controlling 3-level pressure was more difficult than the other. From among the 10 experiment conditions, all participants chose 2-level, two-finger (apart) touch (Figure 2(c)) as the easiest.

Type		Five Touch Configurations				
		(a)	(b)	(c)	(d)	(e)
Accuracy	2L	100 (0.00)	100 (0.00)	96.3 (0.11)	96.3 (0.11)	85.2 (0.24)
	3L	85.2 (0.24)	85.2 (0.18)	96.3 (0.11)	63.0 (0.35)	44.4 (0.37)
User Rating	2L	1.13 (0.35)	2.63 (0.52)	1 (0.00)	3.63 (0.92)	4.50 (0.76)
	3L	2.13 (0.83)	3.63 (0.92)	2.00 (0.76)	4.63 (0.74)	5.00 (0.00)

Table 1. Summary of results: the accuracy rates (%) and user ratings (SD in parentheses; 1 = easiest, 5 = most difficult) on each of the five touch configurations at 2L (2-level) and 3L (3-level).

DISCUSSION AND CONCLUSION

Overall the octagon-shaped ring, OctaRing, could facilitate pressure-sensitive multi-finger touch techniques for a diverse array of gestures. This suggests that polygon-shaped rings could help 1) give distinct tactile feedback naturally when users perform multi-touch gestures such as pinching, and 2) accurately detect how many fingers are being touched on the sides of the ring. In particular, an octagon-shaped finger ring is optimal for matching users' finger sizes.

We found that users performed well when using two fingers with 2-level pressure. Despite the subjective difficulties in controlling 3-level pressure, we observed that 3-level pressure-sensitive touch input has potential when using one and two fingers. In addition, when using two fingers to perform pressure-sensitive input, we found that the distance between two fingers is important. Even though users achieved high control accuracy with the two fingers, they performed slightly better and felt more comfortable when their two fingers were apart rather than together. We believe that the gesture of holding the ring with their fingers facing each other should be considered first in the design of pressure-sensitive ring interfaces.

In this research, we focused on low-level gestures. Further research is required to apply the proposed gestures to high-level interactions with paired devices in diverse contexts. We hope this research can inform the design of interactions with finger ring devices.

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