Ringteraction: Coordinated Thumb-index Interaction Using a Ring

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Abstract
The thumb has the unique property of being opposable to the other fingers and is thus used to perform specific tasks such as grasping objects, which cannot be done otherwise. In this paper we present an interactive ring that takes advantage of this biomechanical advantage, by enabling thumb-index interaction. We propose a set of gestures involving the coordinated movement of the thumb against the proximal phalanx of the index finger that we call bi-digit interaction. Further, we present several scenarios where performing bi-digit interaction is quick, easy and advantageous for users.

Author Keywords
Joint interaction; Smartphone; Ring; Wearable Computing; Bi-digit interaction; Mobile computing.

ACM Classification Keywords
H.5.2 [User Interfaces]: Input devices and strategies, Interaction styles.

Introduction
The thumb is the only digit that is opposable to the other four fingers in a human hand and has two phalanges rather than three. Such unique properties make the thumb naturally useful for various forms of physical interaction. However, coordinated thumb-index interaction does not happen frequently on mobile devices, and is usually restricted to simple pinching gestures (zoom in and out).

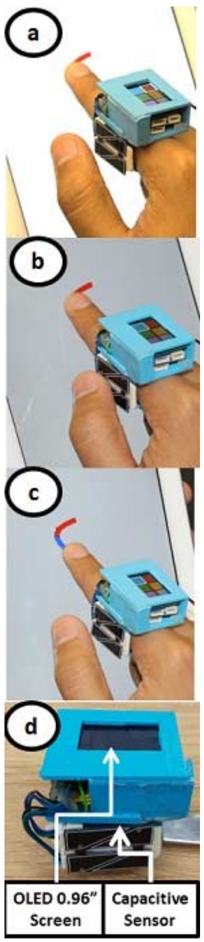

Figure 1. Workflow of Ringteraction. (a) The user is drawing in red; (b) by tapping on the capacitive sensor of the ring with their thumb, they change the color to blue and (c) start drawing in blue. (d) Hardware details of our prototype.

In this paper we propose a new technique of utilizing thumb based gestures for digital interaction. Ringteraction (Figure 1) introduces an interactive ring worn on the index finger of the dominant hand and coupled with a mobile device. We use capacitive sensing on a side of the ring, to recognize thumb gestures performed against the index finger. This arrangement enables coordinated thumb-index interaction (referred to as bi-digit interaction in the rest of the paper) and demonstrates its unique advantages.

We envision that an interactive ring can function both as a standalone device and as a companion to a larger device such as the mobile phone, a tablet, or a laptop. Ringteraction explores possible interaction scenarios in these two modes. In standalone mode, the ring acts as a wearable device that is always available and extremely easy to access. In companion mode, we leverage the unique localization of the ring on the index finger to propose one-handed parallel inputting capabilities: the thumb interacting on the ring and the index finger interacting on the mobile device.

The contribution of this paper is threefold:

1. We systematically investigated the set of the interaction possibilities between the thumb and index finger with an interactive ring and/or a touch-based mobile device.
2. We designed and developed a custom interactive ring with display, processing power, touchpads, etc.
3. We demonstrated the usage of Ringteraction in various practical applications we implemented.

Related Work

In review of the previous work we consider the large amount of work done chiefly in the fields of Dual Device interactions, Ring-based and Finger-based systems.

Interactive Rings

Rings as wearable devices have been considered for research since 1997 [6], but gained more attention in the last few years [1,8–10,12].

In many cases, the ring is used as a convenient tracking device for hand or finger motion [6,12]. This is usually achieved using accelerometers [6,16], gyroscopes [12] or magnetometers [4]. This kind of interaction proposes simple and eyes-free interaction but may lead to fatigue as it involves mid-air gestures of varying amplitudes.

Other projects consider the ring as a proper input device. Nenya [1] and iRing [10] introduced a novel method of interacting by rotating the ring around the finger wearing it. A ring can also be used to transform the hand into an immaterial mouse, e.g. LightRing [8], or into a trackpad [7].

None of the proposed solutions take advantage of the unique properties of the thumb and do not investigate parallel input on both the ring and a mobile device.

Dual-Device Interaction

Many previous works investigated dual-device interaction. Works such as Duet [5] investigate the potential of multi-touch and multi-devices gestures with a mobile device and a smartwatch. Thaddeus [13] also proposes multi-devices interaction between a smartphone and a tablet.

Finger interaction

FingerPad [3] uses a small hall sensor grid, fixed at the back of the index finger tip, to track the movements of the thumb, against the index finger's tip. Although this serves as a discrete method of controlling mobile devices remotely, it needs augmentation of both the index finger and the thumb. Moreover it cannot be used if the index finger is utilized in some other forms of interactions, such as pressing a switch or touching a mobile phone.

NailDisplay [11] provides a secondary display on top of the nails to fight the problem of mobile screen occlusion. However this solution might not be always easily visible and might hamper normal usage of the finger, because of augmentation of the finger-tip region.

NanoStylus [14] is a very small stylus mounted on the user's finger that enables extremely precise pointing on small wearable devices such as a watch. Magic Finger [15] uses a micro-camera, turning any surface to a touch screen.

None of these works actually considered the simultaneous use of a ring and a mobile device, such as a smartphone or a tablet. With Ringteraction, we propose a new interaction paradigm leveraging the capabilities of the thumb to interact with other fingers.

Ring Prototype

To realize Ringteraction, we created an interactive ring, and developed a software platform for the ring to interact with a tablet or a slate.

Hardware

We 3D printed a ring using PLA. The upper part of the ring contains dual layered PCBs within $35 \times 28 \times 16$ mm. The lower part of the prototype is shaped as a ring.

The system is controlled by a PIC32MX470 microcontroller. A small 0.96" OLED color display (SSD1331, 96 × 64 pixels) provides visual feedback. The fast computational capabilities of the core are advantageous for the touch sensing (using mtouch touch panels) and smooth animation display. The microcontroller is also interfaced to a Bluetooth low energy module (BLE 4.0) to communicate with the mobile device wirelessly.

For thumb-based input we used two linear (1D) capacitive touch sensors (23 × 7 mm) attached side by side0. Each linear sensor can reliably distinguish up to 100 different positions along the X axis. Limited 2D support can be achieved, with each sensor providing a different position on the Y axis. On The 2 sensors are fixed on the left side of the ring which is currently suitable for right handed users. The prototype is powered by two 3.7V 2000 mAh batteries. An additional universal asynchronous receiver/transmitter (UART) port is also provided for debugging purposes.

Software

The microcontroller is programmed using embedded C, utilizing various commonly available libraries for display driver control, UART control, etc. The ring is connected using a serial Bluetooth connection to Windows 8.1 laptop with a 2.4 GHz Intel Core 2 Quad with 4 GB of RAM. This computer runs the experimental server written in Java that handles both serial connection and

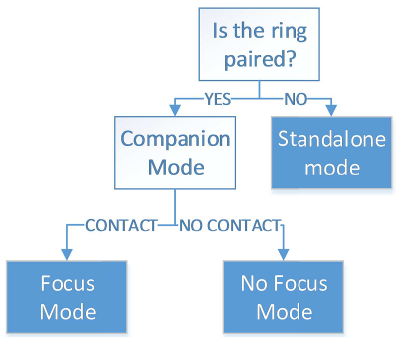

Figure 2. Flowchart of the three interaction modes of the device. If the device is not paired, it goes to standalone mode. Else, if the user is not interacting with the mobile device, the mode switches to No Focus, otherwise to Focus.

TCP connections. From this server, several mobile devices can connect at the same time. Each important event from the ring is broadcasted to the mobile devices and vice-versa. We developed numerous applications for Ringteraction, on Android tablet (Samsung ref tablet), smartphone (Xiaomi Mi3) running Android 4.3. We also developed apps for a Samsung Windows Slate tablet running Windows 7.

Interaction Modes with the ring

By default, Ringteraction supports three modes of interaction, which are directly linked with the level of engagement of the user with the mobile device(s):

1. Standalone mode
2. No Focus mode
3. Focus mode

Figure 2 summarizes how each of these three modes can be activated.

Standalone mode

This mode is the minimal interaction mode, if the ring is not paired with any device. In this mode, the user can simply check the current time, take a picture using the ring if it contains an integrated camera or play simple games. Upon pairing with a device, the ring leaves this mode and switches to "No Focus" mode.

No Focus mode

In the *no focus* mode, the ring is paired with a mobile device but the user is not actively interacting with the mobile device. In this mode, the ring acts more as a simple remote controller for the mobile device. This is similar to controlling the music player of a smartphone using a button on the earphones. Users may be on the go and may not be able to actively interact with a mobile device. The ring thus provides simple, punctual and discrete microinteractions [2]. The advantage of the ring for microinteractions is its direct accessibility; the user does not need to extract the mobile device from a pocket or a bag. Typical tasks in this mode would be changing songs on a music player, switching the phone to silent mode, rejecting a phone call or sending a predefined message to a contact. If the user gets more engaged with the mobile device, the ring will switch to focus mode.

Focus mode

As soon as the user gets engaged with the mobile device (touches it) with the ring already paired, the ring will switch to *focus* mode. In this mode, both the input and output capabilities can be used to their fullest. In terms of input, the user can perform precise continuous control, (zooming, vertical scrolling). The screen of the ring can also be used to display contextual menus. The screen allows to comfortably display a contextual menu with three to five simple commands.

This interaction mode is the richest. In a painting app, the ring can be used to change colors or tools without the need to release the finger to go and select a tool from a toolbar. This limits disruption from the main task. If the user stops interacting with a touchscreen for a specific time, the ring will automatically switch back to *no focus* mode. If the pairing is lost, the ring will go back to standalone mode.

Input Vocabulary

The ring prototype allows us to detect simple gestures. Currently, our prototype can detect the four following gestures:

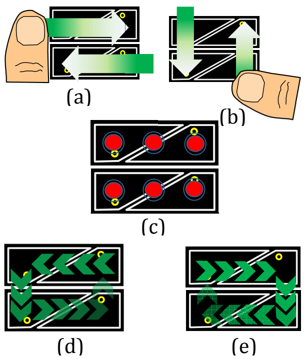

Figure 3. (a) Horizontal swipes. (b) Vertical flicks. (c) Discrete taps. (d, e) Rotational gestures.

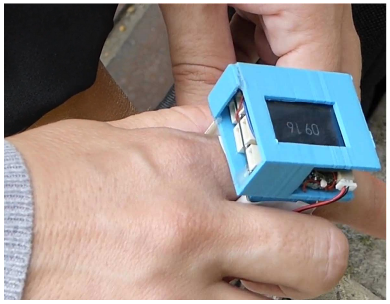

Figure 4. Ring displaying the time in standalone mode.

- Horizontal Slide/Swipe along the finger individually on the two sensors or capacitive panels.
- Single Taps on three different locations of each panel
- Vertical swipe at both ends for panel1 and panel2
- Clockwise/Counter-clockwise rotation- The thumb slides up on panel1, goes down vertically to panel2, slides down on panel 2 and so on. The initial position of the thumb can be anywhere on either panel.

This input vocabulary, presented in Figure 3 , is suitable both for discrete command selection, using single taps or swipe but also continuous control with swipes and rotations.

Bi-Digit Applications

To demonstrate the potential of Ringteraction, we developed a series of examples and applications for each mode of interaction presented below. The applications we have already implemented are indicated with a * in their title

Standalone mode

This mode is a bit limited in terms of applications the user may want to use, but the device should still be able to offer some interaction if the ring is not paired.

WATCH*

Throughout the day, users may need to check the current time. In this respect, they can take advantage of the immediate availability of the ring to check the time (Figure 4). No need to grab the phone or even roll up their sleeves. In addition, detection of the user moving the screen closer to the eyes could be done using IMU or gyroscopes [12].

TAKING PICTURES

While our initial design does not include a camera, we see a camera as a strong addition to a smart ring. Contrary to a smartphone, aiming with the camera would be as simple as pointing with the finger. The screen could also help for aiming/displaying a preview

No Focus mode

In Focus mode, the ring is used as a remote controller for the mobile device.

SYSTEM COMMANDS

The ring on the index finger provides quick remote access to the commonly used system commands, when the phone is not in use. A set of discrete commands can thus be invoked by tapping or swiping on the ring, e.g. declining a call, switching to silent mode, turning Wi-Fi on/off, etc.

NOTIFICATIONS

In many situations such as travelling in a bus, the phone may not always be within reach. In such cases, the always available display on the ring can provide information-rich notifications like several lines of text, images and animations.

MUSIC CONTROL

With the availability of the input space at the tip of the thumb, gestures like slide up and down can be utilized to browse through songs, while a rotation gesture can be used to control the volume. Taps can be used to play and pause.

UNLOCKING PHONE

An added layer of security can be used for unlocking of phone. Usually personal patterns or gestures are

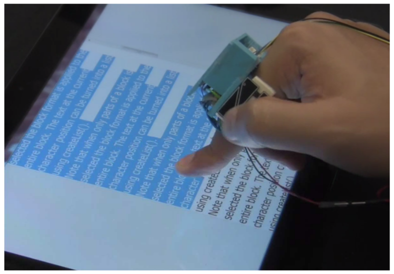

Figure 5. Select+Scroll- Index finger used for selecting and the thumb controls the scrolling.

utilized for this purpose. However with a ring, the phone will only get unlocked when the user performs the specific pattern while keeping the thumb pressed on the ring.

Focus Mode

In focus mode, the ring can especially be used for parallel task completion, with the main task being performed on the mobile device and the secondary one on the ring.

PARALLEL TASK COMPLETION

Color and tool switching in a paint application.* In focus mode, the user is likely to be focusing on one specific task and does not want to be interrupted, even to select a command or change some parameters. We implemented a paint application that allows the user to change color while drawing (Figure 1), without lifting the finger. This allows the user to continue from the same exact point but with a different color. We divided each capacitive sensor into three different tap-regions. The screen of the ring is used to display the colors, thus the user only needs to focus on his index finger to change colors. When the user lifts their finger from the screen the color menu changes to a tool menus with also 6 options.

Select+scroll.* Selecting long chunks of text in a document spanning across several pages can be tedious. With bi-digit interaction, the user simply initiates selection with the index finger and then can perform flicking gestures with the thumb (Figure 5). Selection can also be adjusted in real time by moving the index finger.

Zoom+Pan.* In applications like maps, users use the index finger to point at a specific location. They can then pan using the same index finger, while they zoom using the thumb, allowing them to precisely control the focal point. Zooming is either performed using clockwise/counterclockwise rotation or by swiping along one of the capacitive panel.

FOCUS+CONTEXT

While the mobile device can provide the overall view of a map (context) the ring displays a zoomed image of the map at the location where the index finger occludes the screen. The proximity of both the displays prevents the division of attention as well.

SEAMLESS DATA SHARING*

The ring can act as a bridge between two applications. Users select some text or content, and then perform the copy command by simply dragging the data "into" the finger (swipe up). In a similar way, the data can be dropped into a selected application by dragging data out of the finger (with a swipe down). Data can be transferred between mobile devices through the ring.

Conclusion and Future Work

We presented Ringteraction, a bi-digit (thumb+index) interaction using an interactive ring. This new type of interaction enables fast microinteractions and also instant mode switching without the need to rely on long taps or multi-touch gestures which occlude the screen. We presented a classification of modes of interaction.

In future, we would conduct a systematic study of the affordances of bi-digit interaction. We also wish to further understand the effects of using a ring added on to regular mobile usage.

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