Text Entry Method for Immersive Virtual Environments Using Curved Keyboard

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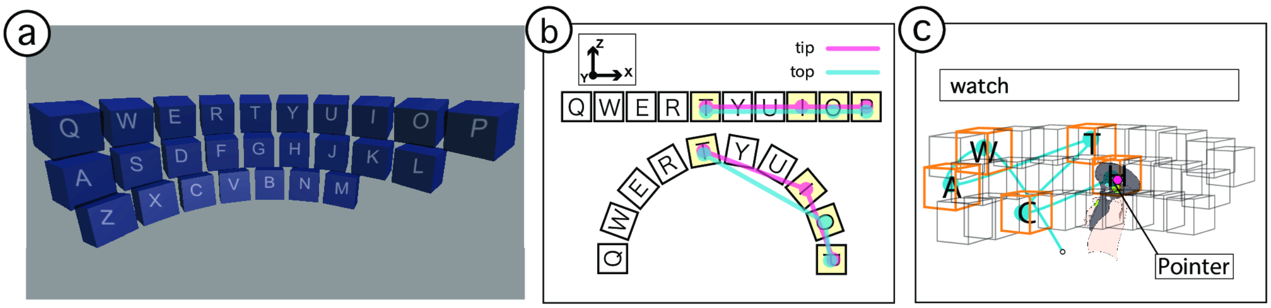

Figure 1: Our method. a) Appearance of the curved keyboard in IVEs. b) A difference of planar keyboard and the curved keyboard against trajectories of "tip" and "top". c) 3D word-gesture text entry. A user is entering the word "watch".

ABSTRACT

In this paper, we introduce a curved QWERTY keyboard, bent spherically in front of the user, to facilitate 3D word-gesture text entry in immersive virtual environments. Using the curved keyboard, the number of candidate words in the 3D word-gesture text entry is reduced compared with that using a planar keyboard. In the pilot study, the text entry performance of the first author was 21.0 WPM (SD = 5.06), with a total error rate of 26.0% (SD = 15.2).

CCS CONCEPTS

• **Human-centered computing → Virtual reality**; *Text input*; Gestural input.

KEYWORDS

Curved surface, spherical surface, virtual reality, WPM, text entry

ACM Reference Format:
Naoki Yanagihara, Buntarou Shizuki, and Shin Takahashi. 2019. Text Entry Method for Immersive Virtual Environments Using Curved Keyboard. In *25th ACM Symposium on Virtual Reality Software and Technology (VRST '19), November 12–15, 2019, Parramatta, NSW, Australia.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3359996.3365026

VRST '19, November 12–15, 2019, Parramatta, NSW, Australia

ACM ISBN 978-1-4503-7001-1/19/11…$15.00
https://doi.org/10.1145/3359996.3365026

1 INTRODUCTION

Text entry is widely performed in immersive virtual environments (IVEs) via a planar keyboard floating in mid-air, where the user selects a key on the keyboard using an imaginary "ray" emanating from a hand-held virtual reality (VR) controller (ray-casting); however, this method results in many key misselections and a large selection time due to minor changes in the position of the controller with pushing of the button, which is referred to as the Heisenberg effect [Bowman et al. 2002].

Compared with text entry methods based on ray-casting, the text entry method using direct touch, where the touches are regarded as "object hits" by a VR controller, shows great potential because direct touch is not influenced significantly by Heisenberg effect. However, this method imposes high arm fatigue because of mid-air interaction. To reduce the key selection time, [Gupta et al. 2019], [Chen et al. 2019], and [Markussen et al. 2014] adopted word-gesture text entry methods similar to SHARK^2 [Kristensson and Zhai 2004] for IVEs, each of which uses a planar keyboard. Yanagihara et al. [Yanagihara and Shizuki 2018] proposed a cubic keyboard, which adopted a 3D word-gesture text entry method for IVEs based on direct touch. However, use of the cubic keyboard is associated with difficulty in viewing the keys because many keys overlap from the user's point of view. Moreover, it can be difficult to memorize the layout of the cubic keyboard because the layout is unique.

In this paper, we show a curved QWERTY keyboard that is bent spherically in front of the user (Figure 1a) for optimal 3D word-gesture text entry in IVEs.

2 SYSTEM DESIGN

The curved keyboard has the following characteristics. 1) To reduce arm fatigue, the keyboard is bent spherically in front of the user,

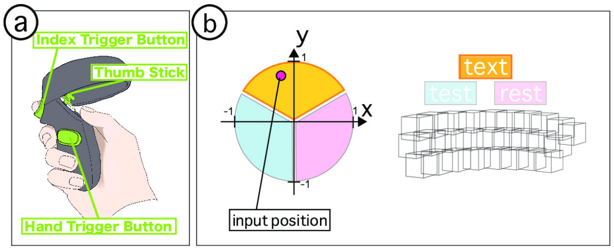

Figure 2: Controller and word key selection method. a) Side view of the controller used for the proposed method. b) Word keys appear above the curved keyboard. To select the word "text", the user moves the thumbstick to the area having the same color area as the word key.

such that the keyboard surface is curved for along with the user's hand position. To realize this advantage, calibration is necessary to center the spherical surface on the user's shoulder and adjust the radius to the length of the user's arm. 2) The keyboard uses a 3D word-gesture text entry method to reduce fine pointer movement and the number of candidate words required compared with 2D word-gesture text entry methods. As an example, while the 2D word-gestures for entering "tip" and "top" have the same trajectories (i.e., a straight segment from 'T' to 'P'), the 3D word-gestures are different, as shown in Figure 1b. 3) All keys are not overlapped from the user's point of view. 4) The user can easily memorize the layout because the layout is QWERTY.

We implemented the curved keyboard in IVEs using the Unity game engine (Figure 1a) with an Oculus Quest and an Oculus Touch controller. The keys are blue. When the pointer enters a key, the key turns red and the controller vibrates for 16 ms, to provide the user with visual and haptic feedback. A small spherical pointer is placed at the controller.

A user can enter a word using the curved keyboard via a 3D word-gesture (Figure 1c). While not pressing the index trigger button of the controller (Figure 2a), both the keyboard and the pointer follow the controller. Pressing the button anchors the keyboard at the current position, enabling the user to move the pointer to the surrounding keys. A user enters the letters of the intended word by hitting keys in sequence with the pointer. Releasing the button finishes the letter input phase and words are predicted based on the trajectory of the pointer movement. Up to three candidate words are presented as bricks (word keys) above the keyboard. A user can select a word key by moving the thumbstick (Figure 2a) to the area having the same color as the word key (Figure 2b). In addition, the first candidate word (blue word key) is automatically selected when the user starts to enter the next word. Thus, if the first candidate word is the intended word, the user can immediately proceed to enter the next word.

3 PILOT STUDY

We conducted a pilot study to investigate text entry performance using the curved keyboard.

The first author (male, 23 years old) was the participant in this study; he used his dominant hand for the task. The task involved transcribing short phrases. Error correction could be achieved by pressing the hand trigger button (Figure 2), which deletes the last word from a transcribed text. We used the phrase set of Mackenzie et al. [MacKenzie and Soukoreff 2003]; 30 phrases (20–28 characters in length) were extracted at random.

We used the metrics of words per minute (WPM) and total error rate (TER), among which the latter is defined as $TER = (INF + IF)/(C + INF + IF)$, where INF, IF, and C are the numbers of incorrect, corrected, and correct characters, respectively [Soukoreff and MacKenzie 2003]. The result showed that the average WPM and TER across all phrases were 21.0 WPM (SD = 5.06) and 26.0% (SD = 15.2), respectively.

4 CONCLUSION AND FUTURE WORK

In this paper, we introduced a curved keyboard to resolve the problems commonly associated with text entry in IVEs. The curved keyboard could potentially reduce arm fatigue, as the keyboard surface is curved along with the user's hand position. Moreover, 3D word-gesture text entry should reduce fine pointer movements, thus improving text entry performance and further reducing arm fatigue. In the future, we will conduct an experiment to evaluate arm fatigue during the use of the curved keyboard.

In the pilot study, we defined many parameters (e.g., the key size, the distance between two keys, and the curvature) heuristically. In future work, we plan to optimize these parameters for improved keyboard text entry performance. Moreover, we will conduct a long-term evaluation, and a comparative study with other keyboards, to further validate the usability and text entry performance of the curved keyboard.

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