論 文 内 容 の 要 旨

Text input methods are ubiquitous and vital when users attempt to enter text into digital devices for documentation and communication. Compared with typing on conventional user interfaces based on physical keyboards and mouses, typing performance varies when users typing on advanced user interfaces (e.g., smartphones, tablets, virtual reality, and mixed reality) due to their diverse limitations and characteristics. With the popularity of mobile devices (e.g., smartphones and tablets) and commercial Virtual Reality (VR) systems, there exists the need of efficient text input methods that are suitable designed for satisfying typing performance.

Keyboards are dominant and default input tools. On smartphones, keyboards are virtualized and customized (with various layouts) in the limited size on the touchscreen. For VR systems, keyboards are often shown virtually in the intangible space without essential haptic feedback. Although those keyboards could help users to finish the basic text input task, efficiency and satisfaction during the text input, however, cannot be guaranteed. The main reason is that the keyboard layout, definition of keys, and related operation patterns are inherited from the physical QWERTY keyboard, which already existed for decades with few adjustments based on various platforms and scenarios.

Generally, text input includes two main parts. The first part is text entry, which mainly focuses on generating text quickly into the computing system based on users' input. The second part is text revision, which is responsible for ensuring that the input text is both typo-free and proper to express the intended meaning of the typist. As far as we know (from the literature), most current text input methods and research focus on enhancing users' typing performance (e.g., faster typing speed). However, little attention was paid to improve text revision efficiency, which is essential to ensure the expression accuracy of the input text. It should be noted, again, that the main target of text input is for documentation (e.g., taking notes) and communication (e.g., discussion with friends via instant messaging or emails) rather than just entering some characters and show them on the screen.

Current text input methods can handle typos and grammar issues easily with auto-correction techniques. Whereas, for more general revision conditions (e.g., revising the word with right spelling but with improper meaning or adding missing words into the sentence), those methods cannot achieve the satisfying text revision experience, especially for smartphones and VR systems.

This dissertation mainly focuses on facilitating text revision on mobile devices and in VR applications, as two instances of advanced user interfaces. A systematic review was conducted first to summarize the text revision attempts applied in current smartphone and VR text input methods. With the review, we further analyze their commonalities and flaws. It revealed that, for typing with virtual keyboards, most text revision attempts still followed the operation process using the backspace and cursor control, which already existed for decades.

To improve the text revision efficiency on mobile devices, we revisited the existing text revision process and proposed Swap, a replacement-based text revision paradigm, to enhance the text revision performance by minimizing the use of backspace and cursor control. In detail, Swap regards all characters and words as replaceable and independent units. When observing the revision target, users can enter the revised content first and then use it to replace the target. To change the processes for various revision conditions (e.g., inserting, substituting, or deleting a word) into the unified replacement operation, Swap also visualizes some specific functions (e.g., deletion) and allows them to appear in the input string just as regular characters.

Based on the paradigm, we implemented a text revision technique (named Swap), and evaluated its feasibility on smartphones via conducting a comparative user study. Results showed that, compared

with the repetitive backspace pressing and imprecise cursor control, Swap simplifies the steps and the number of the potential mode switch process (i.e., from regular typing to revision or from revision to regular typing). Moreover, Swap enables users to keep their regular typing speed during the revision process on smartphones.

In the context of VR environments, a series of techniques have been designed and proposed to enhance the text input performance. However, few researchers put their eyes on the enhancement of text revision. To deeply understand the research status of current VR text entry, we first did a systematic review and revealed that there lacks the essential consideration on the problem of text revision. Even worse, most current proposed techniques did not include the tools and solutions to handle the need for text revision in VR. Then, we proposed a design space based on caret and backspace to explore the design solutions for enhancing text revision performance in VR applications. With the design space, we further implemented four text revision techniques and evaluated them using a comparative user study. Outcomes of the design space and proposed techniques not only provided a fundamental understanding of VR text revision solutions (with the backspace and caret) but also a comparable basis for evaluating future VR text revision techniques.

During the review of current VR text entry research, we also found that, during text entry, although characters are selected in sequence, there lacks smooth transition among every two selections, which (to some extent) influence the typing speed. Therefore, apart from text revision, an additional study was conducted to enhance the text input efficiency by proposing SewTyping, a novel technique which fully leverages the penetrable feature of the intangible interface and the daily-life sewing metaphor to achieve the fluid and successive text entry behavior just like sewing with a needle on the fabric. We got inspiring results that SewTyping not only improves the typing speed in VR applications but also changes the VR text input as engaging gameplay.

This dissertation shows contributions as follows:

First, the literature review reveals the insufficient attention of current text revision research when designing useful and efficient text input methods. For researchers who are interested in this field, this dissertation can also serve as a systematic overview of text revision.

Second, instead of the conventional text revision paradigm (based on backspace and cursor control), Swap shows an overturning perspective for designers to consider and design text revision techniques on mobile devices and in VR applications at both the process level and practice level.

Third, SewTyping provides a novel way to consider the penetrable feature of the intangible interface and convert it as an advantage when designing the fluid text input operation. Additionally, SewTyping also proposes a new interaction approach (sewing interaction), which sheds light on the novel interface design for VR applications.

Overall, methodologies and results reported in this dissertation will be beneficial for both researchers and practitioners when exploring and implementing text revision techniques to achieve the more satisfying typing performance on mobile devices and in VR applications.