Gaze Typing Through Foot-Operated Wearable Device

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ABSTRACT

Gaze Typing, a gaze-assisted text entry method, allows individuals with motor (arm, spine) impairments to enter text on a computer using a virtual keyboard and their gaze. Though gaze typing is widely accepted, this method is limited by its lower typing speed, higher error rate, and the resulting visual fatigue, since dwell-based key selection is used. In this research, we present a gaze-assisted, wearable-supplemented, foot interaction framework for dwell-free gaze typing. The framework consists of a custom-built virtual keyboard, an eye tracker, and a wearable device attached to the user's foot. To enter a character, the user looks at the character and selects it by pressing the pressure pad, attached to the wearable device, with the foot.

Results from a preliminary user study involving two participants with motor impairments show that the participants achieved a mean gaze typing speed of 6.23 Words Per Minute (WPM). In addition, the mean value of Key Strokes Per Character (KPSC) was 1.07 (ideal 1.0), and the mean value of Rate of Backspace Activation (RBA) was 0.07 (ideal 0.0). Furthermore, we present our findings from multiple usability studies and design iterations, through which we created appropriate affordances and experience design of our gaze typing system.

Keywords

Gaze typing; Wearable devices; Foot-operated devices

1. INTRODUCTION

Text entry by gaze serves as the primary means of communication for individuals who have encountered a serious injury resulting in the loss of speech and motor functions [4]. Among the various gaze-assisted text entry methods, "Gaze Typing" has received most of the focus since it is a direct text entry method. Using gaze typing to enter a character, the user dwells on the specific key on a virtual keyboard for the duration of the dwell time. The existing gaze typing systems use a specific duration of dwell time (150-200 ms); this works well for typing short and simple phrases. However, working on these systems for longer durations leads to visual fatigue, and consequently results in lower typing speeds and higher error rates. In our solution, we intended to eliminate the dwell time based approach, and support direct, instantaneous activation of the target key. Our system incorporates a virtual keyboard, where the frequently occurring keys have larger dimensions than less frequent keys (Figure 2). Dwell time is eliminated by using a wearable device, attached to the user's foot, using which the user activates the target key. In addition, the wearable device approach allows for customizations, since it can be 3D printed to support various interaction paradigms (foot, hand, etc.). We developed foot interaction because for users with arm or hand impairment, foot interaction is an appropriate modality. For users with other impairments like spine, low back, etc., which affect postural functions, foot interaction enables a hands-free approach. Hence, based on the kind of impairment alternative interactions can be made available through the same wearable-device paradigm.

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2. PRIOR WORK

Research in gaze-assisted text entry dates back to more than 20 years [4]. Existing research in "Gaze Typing" focuses on three design considerations: 1) The mode of continuous feedback indicating the key of the user's focus on the virtual keyboard, 2) The method of key activation, and 3) The arrangement of keys on the virtual keyboard [4]. Hansen et al. [1], presented "GazeTalk," a gaze typing system that integrates both word and letter prediction features. Its character prediction feature dynamically changes the characters presented to a user based on the characters already entered. Rajanna et al. [5], presented "GAWSCHI," a gaze and foot input framework that enables accurate and quick mouse-based interactions on a computer. The authors found that gaze-driven interaction using GAWSCHI is as good (time and precision) as mouse-based interaction in the majority of tasks. GAWSCHI, however, is not optimized for gaze typing.

3. SYSTEM DESIGN

The gaze typing system consists of three modules: 1) Virtual Keyboard (VKB), 2) Gaze Interaction Server, and 3) Foot-Operated Wearable Device. A pictorial depiction of the system is shown in Figure 1.

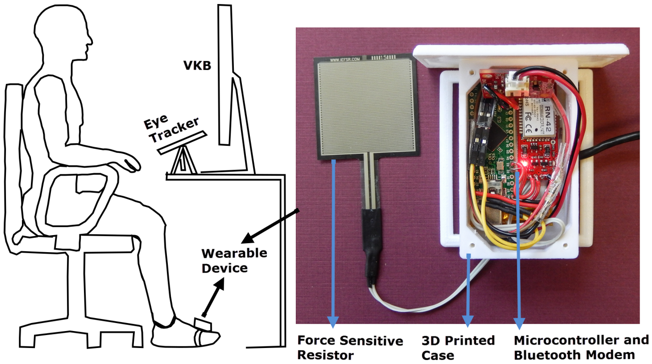

Figure 1: Gaze Typing System with an Eye Tracker and Foot Operated Wearable Device

Virtual Keyboard: The system incorporates a refined version of the open-source VKB "OptiKey[1]." Through design iterations, we customized the VKB by moving the infrequently used keys to the secondary screen, adding numeric keys to the primary screen, emphasizing frequently used keys with larger dimensions, and making some of the functional keys (space, enter, backspace) prominent (Figure 2).

Figure 2: Customized Virtual Keyboard - High Frequency Alphabets and Functional Keys are Larger

Through an eye tracker (Tobii EyeX), the VKB receives the user's gaze positions on the screen as a pair of (X,Y) values. As the user searches for the target key, the border of each key that the user is looking at is highlighted in red. When a key is selected, the background of the key is highlighted in blue, and the key is printed in the writing space.

Gaze Interaction Server: It runs on the computer and connects to the wearable device over Bluetooth. It converts the user's inputs, encoded as single byte characters, into the appropriate commands (mouse and keyboard events) for the VKB. The VKB constantly listens to inputs from the Gaze Interaction Server to confirm selection of the target key.

Wearable Device: The user selects the target key on the virtual keyboard using the wearable device. To select the target key, the user first looks at the key and then presses the pressure pad, attached to the device, with the foot. The device communicates with the Gaze Interaction Server over Bluetooth, and sends user commands encoded as single byte characters. We 3D print the housing for the wearable device; hence, it can be printed in various form factors customized for each user (Figure 1).

[1]github.com/OptiKey

4. EXPERIMENTS AND RESULTS

We conducted a formative evaluation during the system development by involving four non-disabled participants (4 male, aged 21 to 29). Each participant typed 25 phrases, chosen from the standard phrases sets for evaluating text entry techniques [2]. Feedback from these evaluations helped us to improve the design of VKB, the wearable device, and the overall user experience. Specifically, we found that just increasing the dimensions of the keyboard does not improve the performance, but causes strain, as the user needs to constantly tilt the head for whole keyboard reachability. We also found that keeping the size of the keyboard optimum (minimal to no head tilting), while increasing the dimensions of high frequency keys does improve the performance.

Furthermore, we conducted a preliminary summative evaluation by involving two participants with motor impairments (1 female, aged 49; 1 male, aged 28). The two participants used a wheelchair and had limited motor functions. The study with each participant lasted for one hour; it comprised of a training and an experiment phase. During the experiment phase, each participant typed a set of phrases chosen from the standard phrases set [2]. The time taken to type each sentence was captured by the system, and the participants were allowed to break for a few seconds after completing a sentence. Results show that the participants achieved a mean gaze typing speed of 6.23 Words Per Minute; a mean KPSC of 1.07 (ideal 1.0), and a mean RBA of 0.07 (ideal 0.0). The gaze typing speed from our study (6.23 WPM) is comparable to the typical gaze typing speed (6.97 WPM) achieved with participants having no impairments [3]. Prior studies, like ours, involving participants with impairments do not report a mean gaze typing speed since the speed significantly varies based on the severity of the impairment. In future, we will be comparing our method against other gaze typing systems by involving a large group of participants with motor impairments.

5. REFERENCES

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