Design and Evaluation of a Dwell-free Eye Typing Technique

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Abstract

Dwelling, activated through gaze fixation for a prolonged time, is an essential task to be performed to select keys from on-screen keyboard present in the eye typing interface. Normally fixation on a key takes sufficient time which slows down eye typing rate. To get rid of it, researchers focused on minimizing or diminishing dwell time toward building a dwell-free interface. In this paper, we present an efficient dwell-free eye typing mechanism and compare it with a previous work with respect to text entry rate, learning rate and usability. The user experiment results reveal that newly proposed method performed slightly better than the other.

Author Keywords

Eye typing; dwell-free eye typing; text entry

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation: User Interfaces – evaluation/methodology;

Introduction

In recent times, gaze based interaction has been evolved as a strong alternate to support faster and accurate text entry in digital devices [5]. This mechanism holds moderate similarity with traditional text entry methods; the only difference in interaction is instead of hand, the controlling human organ is eye.

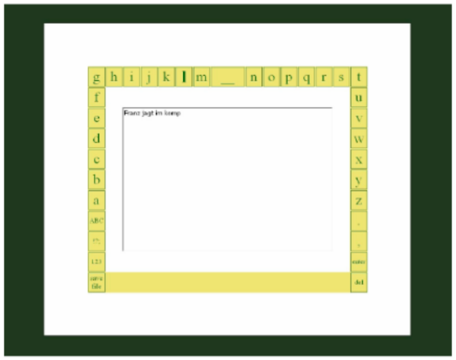

Figure 1: Squared keyboard (Urbina and Huckoff, 2007)

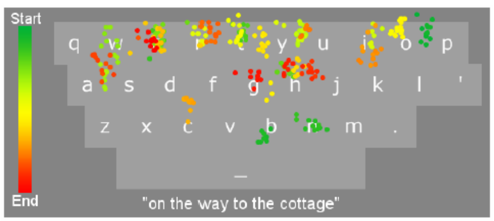

Figure 2: QWERTY keyboard (Kristensson and Vertanen, 2012)

Figure 3: Scrollable keyboard (Špakov and Majaranta, 2008)

Many applications support text entry through eye gaze [8, 9]. Presently, the text entry rate of gaze-based systems is still low than the other text input modalities [5, 3].

Text entry through eye gaze, *Eye typing*, is accomplished by direct pointing at the desired character in interface [5]. Eye typing process execution requires an on-screen keyboard and an eye tracking device. Key selection is performed by hovering on the key for a slightly prolonged duration, named as *Dwell time*. Despite significant progress, even the best eye typing systems possess slow text entry rates ranging from 7-20 wpm [5]. The major cause behind the slowness is dwell time. Also, speed-accuracy trade-off exists where a long dwell time leads to slow eye typing rate while shorter dwell time enhances the chance of *Midas Touch* problem [2]. So, it is not obvious that better text entry indicates less dwell time incurred. Majaranta et al. [5] developed an interface which dynamically adjusted dwell time during experiment depending on the user's comfort.

Urbina and Huckoff (Fig. 1) [9], Morimoto and Amir [6], Kristensson and Vertanen (Fig. 2) [3] proposed eye-typing principles which are potentially much faster as well as dwell-free. Urbina and Huckoff proposed two kinds of interfaces; (1) a pie-menu based circular interface and (2) a square-shaped interface where characters are getting selected by gazing toward the outer frame of the interface. The developed interfaces support controlled eye movements, by following a path, to select the character keys. Morimoto and Amir [6] introduced *Context Switch*, a new dwell-free mechanism, suitable for gaze controlled interfaces. In this mechanism, user focused the intended key within one of the contexts and saccade to the other context to select that key. Kristensson and Vertanen [3] implemented an eye typing methodology which selects a key in presence of eye gaze in nearest proximity.

In this paper, we have developed a dwell-free eye typing method better than our previous method (*EyeK* interface [8]) due to presence of more controlled way to select a key by *Continuous Eye Writing* through gaze. Both mechanisms are intuitive, fast and less error prone. We compare these with respect to user comfort, learnability and eye typing rate.

Methodology

We develop a dwell-free eye typing mechanism as well as consider previously designed methodology [8] supporting non-stationary eye movement and less fixation tendency of users. In our approach, hovering over every key creates an overlay area over the actual key area of the keyboard. The two methods are stated below.

Method 1: Dwell-free method in EyeK interface

The interaction selects a character while user moves the eye pointer through the key areas in inside-outside-inside fashion, described in *EyeK* eye typing interface [8]. A pictorial example (see Fig. 4) clarifies the scenario further. Suppose, user wants to select character 'C'. While hovering on the character, key and outside areas are visible. User starts moving the eye pointer from the key area, goes to outside area and again comes back to key area to complete the interaction phase (Fig. 4(a), enlarged portion). After coming back to the key, character selection gets activated (Fig. 4(b)). After selecting a character, visual feedback is given by changing its font color to red

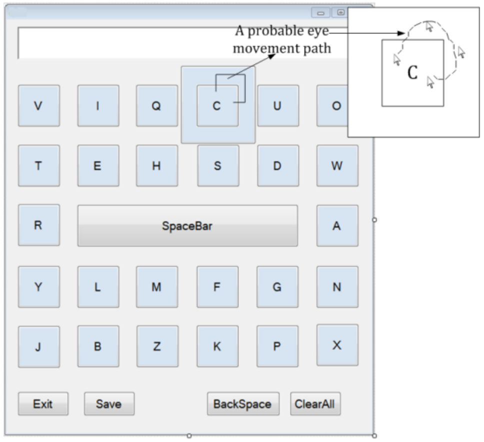

Figure 4(a): Eye movement on a key

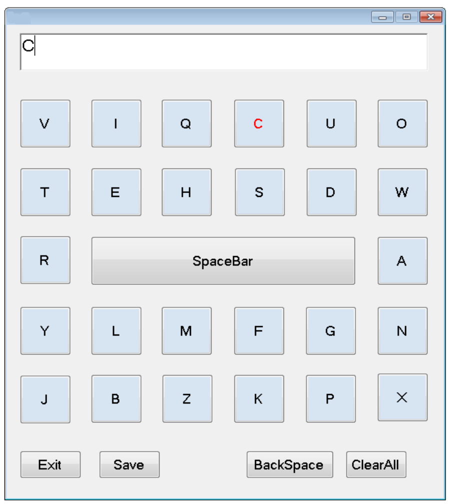

Figure 4(b): The key gets selected

Figure 4: Dwell time free eye typing through Method 1 in *EyeBoard* layout

which remains up to next character selection. If users need to enter same characters twice, they have to get out of the character initially and enter it again in similar manner. A facility provided by the mechanism is that the "going out" and "coming back" sides of a button not necessarily be the same and fixed. With this oriented movement, keys will be selected automatically. This interaction takes minimum effort and time compared to dwell time.

Method 2: Proposed eye typing mechanism

The interaction pattern for this method is different from Method 1. It supports more controlled eye movement for key selection. In the outer key area (activated after hovering), a black circular disc appears at upper side of the key. After hovering on the intended key, user requires to "go out" from the inner key, reach to that prominent point and after looking, "come back" inside the inner key area (Fig. 5(a)). Feedback system, same as Method 1, is applied providing selection confirmation to the user (Fig. 5(b)). Suppose, at an instance, user needs to select character 'C'. Then, on hovering 'C', the outer layer becomes visible and user "goes out" from the upper side, sees the point and "comes back" into the inner key from the same side. For double selection of a single key, same procedure as Method 1 is to be followed.

Experimental setup

The description of setup prepared for the experiment to compare the effectiveness of two aforementioned methods is given below.

Apparatus

Low cost setup with a computer, modified Sony PlayStation Eye webcam, original lens was replaced by manual focus and Infrared (IR) filter removed lens, IR Lamp, consisting a matrix of 25 IR LED, along with open source ITU GazeTracker software [1], were used. Controlled light conditions and positioning of the setup were ensured.

Participants

15 participants (11 male, 4 female) participated in eye typing experiments. Participants ranged from 23 to 31 years (mean = 26.9). All were regular computer users, access on an average 4 hours per day and have prior experience in composing text using eye typing techniques. The participants also have profound experience in typing text through on-screen keyboards used for the experiments. 14 participants were right-eye dominant and 1 was left-eye dominant, as determined using an eye dominance test [10].

Designs

Three on-screen keyboard layouts were selected to test efficiency of the aforementioned mechanisms namely, compact screen space optimized full *scrollable keyboard* layout proposed by Špakov et al. [5] (Fig. 3), Panwar et al.'s key size and space optimized *EyeBoard* [7] layout, incorporated in *EyeK* interface [8] and QWERTY layout. The size and space between key buttons were maintained same as specified in first two keyboards whereas for QWERTY, these were modified as 1.6 cm for both height and width and 0.6 cm for distance between two keys, respectively. For experiments, texts were considered from MacKenzie and Soukoreff's phrase set [4].

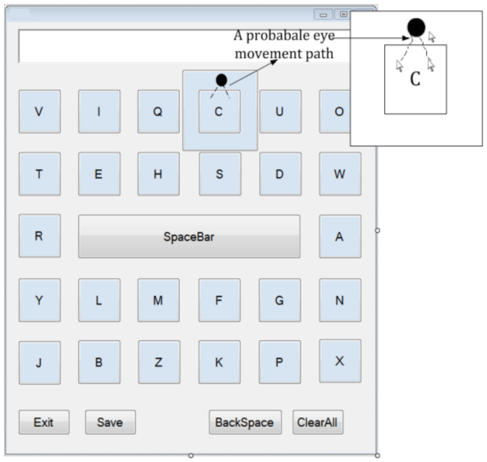

Figure 5(a): Eye movement on a key

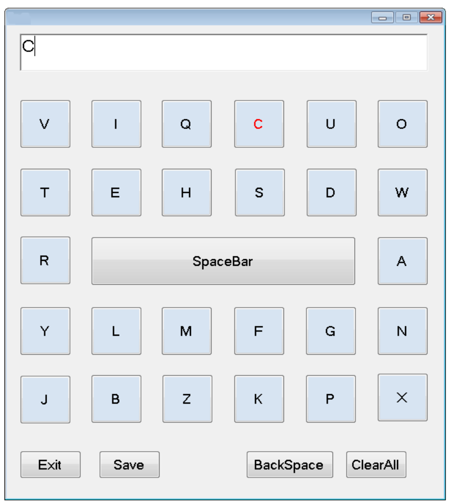

Figure 5(b): The key gets selected

Figure 5: Dwell time free eye typing through Method 2 in *EyeBoard* layout

Procedure

To perform user evaluation, users first performed Calibration [5] followed by performing eye typing task with gaze controlled movement. During these typing sessions, one restriction was that users were unable to move their eyes beyond the visibility range of screen. Overcoming that, participants first wrote the phrase using pen and paper or listened while instructor prompting it. The objective was to type the phrases as fast as possible allowing few errors. Correcting errors occurred due to wrong key selection was possible only by erasing it using backspace and then retyping it.

Before the experiments, participants spent first few sessions as training where they were briefed about the experiment and completed a short demographic questionnaire. They also got familiarized with eye tracking hardware (camera and Infrared lamp positions) and the on-screen keyboard interfaces (Fig. 6). The total time for this interaction was about 10 minutes. After practicing 4 phrases from standard phrase set [4] on paper, participants composed these phrases for each of the 3 keyboards each executing 2 methods of dwell-free eye typing. After practicing, we collected participants' feedbacks where they agreed about strong familiarity with the keyboards and eye typing methods. After getting confirmation from all the participants, we started the testing sessions keeping log for each.

Hypothesis

Hypothesis was Method 1 of dwell-free eye typing would be suited well in the short term, but in longer term, Method 2 would perform better.

Experimental Results

Within subject eye typing experiments were performed with 3 keyboards each having two dwell-free methods measuring eye typing rate and *overhead time* [3]. Subjective evaluations were also performed by users to qualify measures like user friendliness, usability etc. Collected results of participants were averaged for each session to form single measures per participant per session on a variety of metrics, including entry rate in wpm as ((|T|-1)*60)/(5*s) where |T| is the length of the transcribed string and s is the time taken to transcribe the text in seconds, including backspaces [11]. Each Participant completed a total of 24 trials (4 trials X 3 designs X 2 methods). With 15 participants, the entire study comprised of 360 trials. Also, during testing, keyboards' order was counterbalanced across participants. 3 sessions were performed per day by each participant. The whole study lasted for approximately 3 months. Each trial consists of 10 phrases taken randomly from aforementioned phrase set [4].

The overall average eye typing rate achieved by participants with 2 dwell-free methods applied on 3 different keyboards was ranged from 6.4 to 8.1 wpm (Fig. 7). Using Method 1, *Scrollable* keyboard, QWERTY and *EyeBoard* layout earned the eye typing rate ranging from 5.6 wpm to 7.8 wpm (mean = 6.4), 6.1 to 7.9 wpm (mean = 6.8) and 5.8 to 8.1 wpm (mean = 7.1), respectively. With Method 2, irrespective of users, 3 keyboards achieved 6.1 wpm to 7.9 wpm (mean = 6.9), 6.5 wpm to 8.2 (mean = 7.4) and 6.9 wpm to 8.8 wpm (mean = 8.1), respectively. With both the methods, it was observed that participants' eye typing rates got improved in the first few sessions and then reached to saturation.

Figure 6: Participant performing

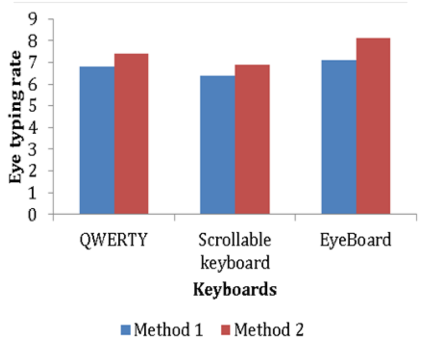

Figure 7: Comparison among different

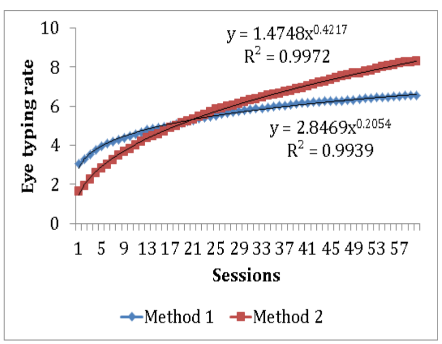

Figure 8: Learning curve

Kristensson and Vertanen [3] stated the task completion time, apart from the dwelling, as overhead time. In our case, as key selection time for large number of character entry took moderate time, key selection plus error correction time became overhead time. Throughout the sessions, we captured both key selection and error correction time and stored into log file. The average overhead time for Method 1 and 2, irrespective of keyboards and participants, were measured as 600 ms and 530 ms, respectively.

We collected the subjective ratings from the participants with the nonparametric *Wilcoxon Matched Pairs Signed Ranks Test*. We consulted with the participants asking them about their eye fatigue, ease of use and eye typing speed in 1 to 7 Likert-scale (1 = Strongly Disagree, 7 = Strongly Agree). The result revealed that users liked dwell-free eye typing methods for ease of use and less fatiguing. Further, after spending initial sessions, participants chose Method 2 augmented interface yielding faster eye typing rate. However, users agreed that concentration was needed initially for eye typing through both the mechanisms, but they could improve their eye typing skill with practice easily. Learning in less time with Method 2 produced faster key selection for most of the participants. Regarding the interaction of go out, see point and then come back in Method 2, users faced problems in performing them during starting sessions. Soon, it was overcome.

Longitudinal Study

We performed longitudinal study with two methods augmented QWERTY layout. 5 participants having familiarity with QWERTY based text entry but unfamiliarity with eye tracking methods performed the eye typing sessions with aforementioned testing phrases. For each session, 5 phrases have been typed by each user with each keyboard and method. The average user result is depicted in Fig. 8. It indicates that Method 2 needs more initial effort to learn compared to existing Method 1, however, after 20 sessions, Method 1 outperforms other. We derived standard regression models in the form of the power curve fitting as it follows Power law of learning. The longitudinal study lasted for 60 sessions. The learning curve inevitably reflects the increasing efficiency of users after performing several sessions. The highest eye typing achieved through Method 1 and 2 are 6.56 and 8.27 wpm, respectively.

Discussion

Through user experiment, two dwell-free eye typing methods were compared in terms of performance measures and subjective usability criteria. The results could not reflect any firm conclusion regarding eye typing rate superiority of any method, but Method 2 performed slightly better. The interface with on-screen keyboard implementing Method 2 was learnt quickly because of a fixed pattern based selection for every key. As reached to the learning plateau is quick for Method 2, users picked up the speed after few eye typing sessions and felt comfortable afterwards.

Conclusion and Future Work

In this work, we present a new dwell-free controlled movement based eye typing mechanism and compare its previously proposed ancestor with respect to eye typing rate, user friendliness, eye fatigue etc. User experiment result concludes the suitability of Method 2 with respect to user's eye typing behavior. The learning rate as well as text entry rate of the chosen method augmented on-screen keyboard based interface are moderately higher. This result undoubtedly supports the superiority of Method 2 than other technique in terms of eye typing rate. Also, due to its more controlled nature, Method 2, can accurately be performed once become familiarized. Experiment with more number of users and usability criteria need to be conducted next for strong validation of the hypothesis taken. This work can further be continued by combining two presented methods into an adaptive interface which, depending on user's eye typing behavior, will provide dwell-freeness through either of these two.

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