CrowbarLimbs: A Fatigue-Reducing VR Typing System

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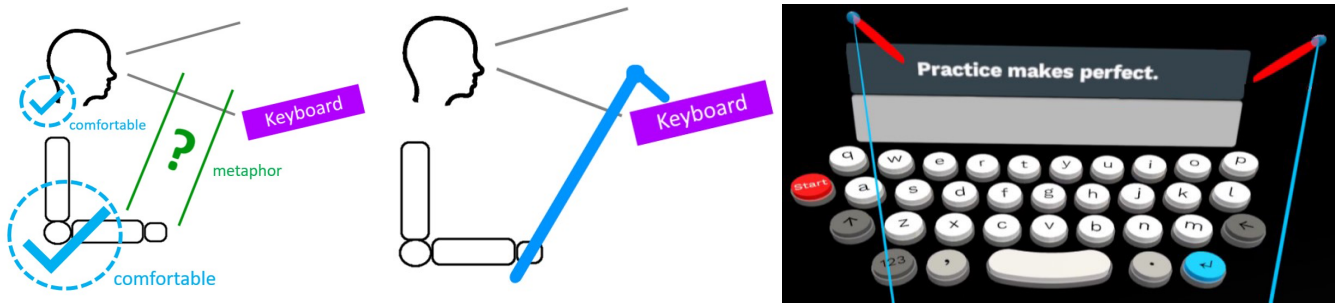


(a) (b) (c)

Figure 1: For text entry in VR environments, to keep user's arms and shoulders comfortable (a), we propose a new metaphor called "CrowbarLimbs" (b) whose curved end is approximately perpendicular to the virtual keyboard, such that the user's fatigue of arms and shoulders can be reduced after typing for a period of time. (c) A screen shot of our system.

ABSTRACT

We present "CrowbarLimbs", a new method with two deformable extending virtual limbs for text entry in virtual reality (VR) which relies on a crowbar-like metaphor. Text entry is the basis of many applications but remains challenging in VR environments, where some body parts of a user may quickly get fatigued by using previous selection-based methods [Speicher et al. 2018], such as the ray metaphor [Lee and Kim 2017] and "DrumStick" [Doronichev 2016]. By adding two deformable virtual limbs and placing the virtual keyboard at a user-preferred location, our method can help users to place their hands in a comfortable posture, thus reducing the physical fatigue of different body parts, such as arms and shoulders. To the best knowledge of ours, previous text entry papers have not yet discussed which metaphor is more suitable for reducing physical fatigue. We thus introduce "CrowbarLimbs" to allow less fatigue, good system usability, and comparable text entry speed/accuracy to previous methods.

CCS CONCEPTS

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

SIGGRAPH '20 Posters, August 17, 2020, Virtual Event, USA

ACM ISBN 978-1-4503-7973-1/20/08.
https://doi.org/10.1145/3388770.3407399

KEYWORDS

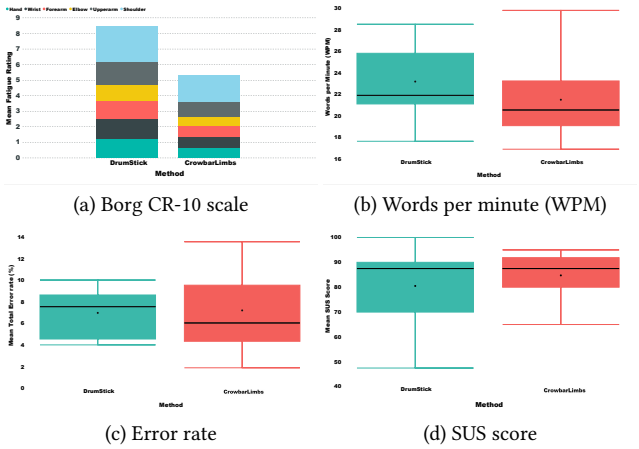
virtual keyboard, physical fatigue, text input, virtual reality

ACM Reference Format:
Muhammad Abu Bakar, Hao-Han Hsueh, Yu-Ting Tsai, and Elena Carolina Li. 2020. CrowbarLimbs: A Fatigue-Reducing VR Typing System. In *Special Interest Group on Computer Graphics and Interactive Techniques Conference Posters (SIGGRAPH '20 Posters), August 17, 2020.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3388770.3407399

1 INTRODUCTION

Text entry is a common operation in various VR applications, and modern related methods are often based on selections [Speicher et al. 2018] and non-selections (such as speeches [Pick et al. 2016]). Speech-based approaches have privacy issues and are not suitable for places where people need to keep quiet. Although many selection-based systems [Doronichev 2016; Lee and Kim 2017] have been shown to be user-friendly and effective, they are mostly suitable for short-term tasks, such as account/password typing. For mid- and long-term tasks, for example, document editing and email writing, some body parts of a user may quickly get fatigued (usually 10~15 minutes from our experience) due to frequent movements.

In this study, we propose "CrowbarLimbs", a new metaphor for selection-based VR text entry, to reduce the physical fatigue of a user over a medium or long period of time. The key idea is to employ two deformable virtual limbs like crowbars and place the virtual keyboard at a user-preferred location (Figure 1). In this way, the user can place his hands in a comfortable posture, thus reducing the fatigue of different body parts, especially arms and shoulders. In addition to fatigue reduction, our user study results further show that the proposed method also can achieve good system usability and comparable text entry speed/accuracy to previous approaches.



(a) Borg CR-10 scale (b) Words per minute (WPM)

(c) Error rate (d) SUS score

Figure 2: Comparisons of user study results between CrowbarLimbs and DrumStick.

2 METHOD

When a user types on a physical keyboard for a long period of time, he tends to place hands in a natural posture, for example, looking straight forward and keeping arms relaxed, in order to bear the least burden on his body. We assume that users have a similar tendency when using a virtual keyboard in VR environments. Moreover, according to RULA [McAtamney and Corlett 1993], which can evaluate the muscular effort associated with different postures of body parts, an effortless posture is to place hands in front of the body at the waist level, with elbows slightly bent, upper arms relaxed, and trunk straight, as shown in Figure 1(a).

We thus design the metaphor "CrowbarLimbs" to satisfy the effortless posture according to RULA. As shown in Figure 1(b), CrowbarLimbs are two deformable virtual limbs like crowbars, which extend the arms of a user to keep his body parts in a natural posture while typing over a period of time. The curved end of a virtual limb is approximately perpendicular to the virtual keyboard, such that the necessary movements of the hand, wrist, and arm can be substantially reduced. Our system also allows the user to lengthen or shorten the straight/curved end of a virtual limb and change the angle/orientation of the joint between the two ends according to his preference.

3 USER STUDY

Our user study evaluates two metaphors, including CrowbarLimbs and DrumStick [Doronichev 2016]. We recruited total 10 participants (4 females and 6 males) for the user study. All participants are familiar with the QWERTY keyboard, but seven of them are novices to VR, two have had a little experience, and one is a regular user. Before the user study, each participant was briefed on the experiment, trained on VR, instructed to move the virtual keyboard to his line of sight height and adjust CrowbarLimbs (or DrumStick) according to his preference, and finally asked to type 30 random phrases with usual speed. The participant then conducted two trials, one with CrowbarLimbs and other with DrumStick, each of which included typing an article with 134 words (total 672 key presses)

Table 1: Details of the one-way ANOVA on the fatigue ratings of six body parts.

Body Part	Hand	Wrist	Forearm	Elbow	Upper Arm	Shoulder
$F(1, 18)$	22.13	13.56	4.89	14.71	5.68	11.50
p	0.001	0.005	0.05	0.003	0.04	0.007

and took about 10 minutes on average, with a rest interval of 10 minutes. After each trial, the participant was asked to take off the HMD, rank the perceived fatigue of hands, wrists, forearms, elbows, upper arms, and shoulders based on the Borg CR-10 scale [Borg 1998], fill the questionnaire of SUS.

Figure 2(a) compares the mean fatigue ratings (in terms of the Borg CR-10 scale) of the six body parts between CrowbarLimbs and DrumStick, while details of the one-way ANOVA are listed in Table 1. On average, CrowbarLimbs can effectively reduce a fatigue rating of 3.22 over DrumStick. The fatigue of most body parts also shows significant differences, especially for hands, wrists, elbows, and shoulders.

Figure 2(b) compares the text entry rates of the two metaphors in term of words per minute (WPM) [Speicher et al. 2018], where a word is defined as five successive characters (including blank spaces). Participants were able to type 21.51 WPM ($SD = 5.73$) on average with CrowbarLimbs and 23.20 WPM ($SD = 6.08$) with DrumStick. Figure 2(c) further shows the box plot of error rates, as defined in [Speicher et al. 2018]. The error rate of CrowbarLimbs is 7.23% ($SD = 9.77$), and that of DrumStick is 7.00% ($SD = 9.47$). From the one-way ANOVA, there are no significant differences ($F(1, 18) = 0.07, p < 0.8$). As for the SUS result illustrated in Figure 3(c), CrowbarLimbs obtains a mean value of 84.75 ($SD = 8.69$), while the mean of DrumStick is 80.50 ($SD = 15.20$), which indicates good and similar usability scores for both CrowbarLimbs and DrumStick.

In addition to quantitative analysis, qualitative user feedback was also collected in an open questions session after the user study. Six out of the ten participants mentioned that the proposed method, CrowbarLimbs, is more intuitive and easy to press keys on the virtual keyboard. Five participants also mentioned that less movement of their arms was perceived while typing with CrowbarLimbs.

ACKNOWLEDGMENTS

This work was supported in part by the Ministry of Science and Technology of Taiwan under Grant Number MOST107-2221-E-155-051-MY2.

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