Using Virtual Keypads With a Cyber-glove^{TM} : Effects of Hand Size

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Abstract
A study has been conducted to determine the effects of hand size on subject performance of a key entering task in a virtual environment. Eighteen subjects participated in the study and their hand lengths have been categorized into three groups (165 to 178 mm, 181 to 185 mm, and 186 to 191 mm). The task was implemented through a head-coupled virtual reality system comprising a VR4 head-mounted display, a Cyber-glove^{TM}, a Polhemus head and hand tracking system, and a Silicon Graphics Onyx workstation running dVISE software. Results showed that both the task completion time and the number of incorrect entries are not significantly affected by the hand size. A possible reason was the lack of finger movement during the key entering task. A second experiment with another eight subjects was conducted to study the same key entering task in a real physical environment. Results indicated that the task completion time in the virtual environment was about seven times of that obtained in a real environment.

Index words: Human-Computer Interaction, Simulation, and Virtual Reality

1. Introduction
Virtual reality systems can be used for training and simulation (So, 1997). Examples include assembly task training (e.g. Tung and Kak, 1995); Computer Numeric Control (CNC) machine training (e.g. Lin *et al.*, 1996); and behavioral training (e.g. Sun, 1995). In most of these applications, the operators use their hands to interact with the simulated virtual environment. This interaction is achieved using an instrumented glove (e.g. Cyber-glove^{TM} [1]), which measures the position and gesture of the hands. At present, such an instrumented glove is available only in one size. In order to determine whether more than one size of Cyber-glove^{TM} needs to be available, a study has been conducted to investigate the effects of hand size on the performance of the Cyber-glove^{TM}. Kozak *et al.* (1993) previously reported a study using an instrumented glove to perform a 'pick-and-place' task in a virtual environment. However, hand sizes of the subjects were not measured in that study.

2. Methodology
An interactive virtual environment was constructed using the dVISE graphics development tools. This environment contains a virtual keypad that was projected on a VR4 head-mounted display with a 48° by 36° field-of-view (horizontal x vertical). The graphic images were generated using a Silicon Graphics Onyx workstation and were continuously updated according to the subjects' head orientations (Figure 1). A Polhemus 3SPACE magnetic head tracker was used to measure the head

[1] Cyber-glove^{TM} is a trademark for Virtual Technologies, Inc.

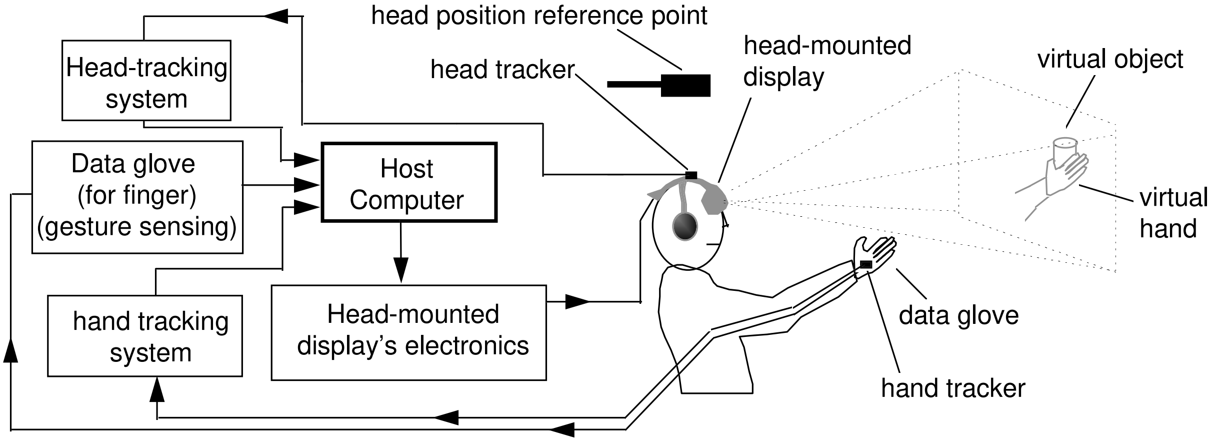

Figure 1 Block diagram illustration of the virtual reality system.

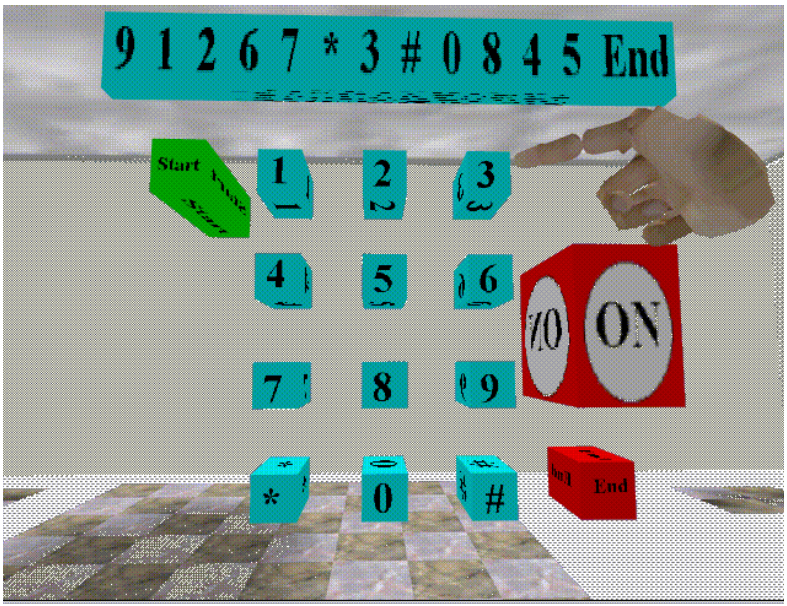

Figure 2 The virtual numeric key pad and the virtual hand

orientation. During the first experiment, the subjects were instructed to control a 'virtual hand' to press the keypad according to a pre-determined dialing sequence of 12 numbers (Figure 2). The position and orientation of this 'virtual hand' were controlled by a Cyber-glove^{TM}, which measured the position and orientation of the subjects' hands. Audio and visual feedback were given to the subjects as their 'virtual index fingers' made contact with the correct keys. The time of dialing the whole sequence and the number of incorrect key entries were recorded.

Eighteen right-hand-dominant subjects participated in the first experiment. They were university students and staff. Their right hand lengths were measured using an anthropmeter and the subjects were classified into three groups according to their hand lengths: (165 to 178 mm; 181 to 185 mm; and 186 to 191 mm). These three ranges of hand length correspond to the 33rd to 53rd percentile; 53rd to 73rd percentile; and 73rd to 93rd percentile of the Hong Kong Chinese population's hand size (Pheasant, 1986). The length of the Cyber-glove^{TM} was 183 mm. Before conducting the task, the sensors on the Cyber-glove^{TM} were calibrated to measure the subject's hand in both neutral posture and a pointing posture using the index finger. Each subject was given one minute to practice the virtual key entering task.

A second experiment was conducted to study the same key entering task in a real physical environment. A physical mock-up keypad was constructed and the subjects were instructed to press the physical keypad according to the same pre-determined dialing sequence. Eight subjects participated in this second experiment and they were different from the eighteen subjects who took part in the first experiment. Both the number of incorrect entries and the task completion times were recorded. The experiments were approved by the University's Committee on Research Practice.

3. Results and Discussion

The completion times of the virtual key entering task and the number of incorrect key entries with different hand lengths are shown in Figures 2 and 3. Inspection of the figures shows that the task times were similar among subjects of different hand lengths while the number of incorrect entries increased slightly with increasing hand lengths. Mann-Whitney U Wilcoxon Rank Sum W tests were conducted to compare the results between groups of different hand length and no significant difference was found for both task time ($p>0.8$) and number of incorrect entries ($p>0.1$). This is confirmed by the Spearman correlation test that showed no significant correlation between either task time and hand length ($p>0.8$) or number of incorrect entries and hand length ($p>0.1$). This suggests that hand length from 165 to 191 mm may not affect the use of a Cyber-glove™ during a key entering task with the index finger. A possible explanation is that the subjects did not change their hand and finger postures during the task: once the subjects formed a pointing hand posture (see Figure 2), they could move the hand from one key to another without changing the hand posture. In order to investigate the effects of hand size further, a task that involves more finger movements should be used (e.g. a 'pick-and-place' task).

Completion time of the same key entering task repeated in a real physical environment is also shown in Figure 2 (median of eight subjects). The time taken to complete the task in a real environment took about ten seconds while the same task took about seventy seconds in the virtual

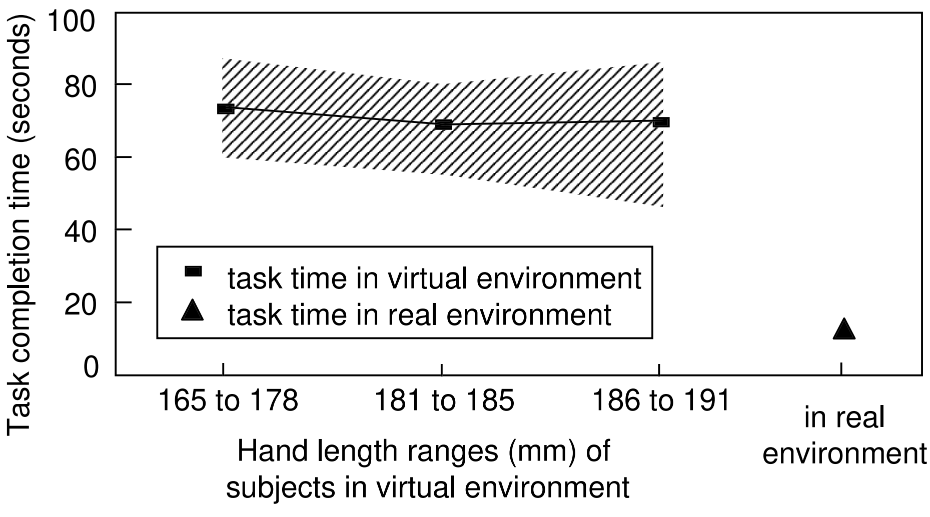

Figure 3 Task completion time (seconds) performed in the virtual environment with different hand lengths (medians and inter-quartiles of 6 subjects). The task time performed in a real environment is also shown (median of 8 subjects).

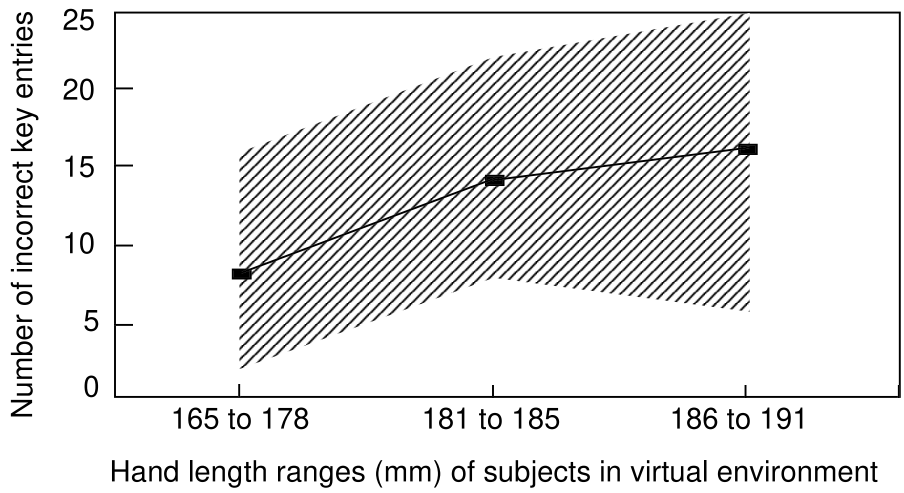

Figure 3 Number of incorrect key entries in the virtual environment with different hand lengths (medians and inter-quartiles of 6 subjects).

environment. This result agrees with the finding by Kozak *et al.* (1993) where the completion time of a 'pick-and-place' task performed in a real environment was one-tenth of that in a virtual environment. In the real environment, the number of incorrect entries was virtually zero.

4. Conclusions and Limitations

For a numeric key entering task using the Cyber-glove^{TM} in a virtual environment, variations in operator's hand length from 165 mm to 191 mm do not affect the task performance significantly. There is also no correlation between the task completion time and the operator's hand size. A possible explanation is the lack of finger movement during the key entering task, most subjects adopt a static hand posture with a pointing finger throughout the experiment. The range of hand length investigated (165 to 191 mm) represents 60% (33rd to 93rd percentile) of the Hong Kong Chinese population's hand length. In this study, subjects were given one minute of practice, which may not be enough. Further studies to investigate the effects of practice are desirable.

When the key entering task was repeated in a real physical environment, the task completion time was one-seventh of that measured in the simulated virtual environment. Studies to identify factors that degrade task performance in a virtual environment would benefit the application of virtual reality technology.

5. References

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