Usability study on a new assembly of 3D interactive gestures for human–computer interaction

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Abstract

- In 3D gesture interaction, people engage in contactless interaction with computers through arm and palm movements. The aim of this study was to develop and verify a reasonable evaluation scheme for 3D gesture usability through empirical methods and finally form an efficient, natural, and standard gesture library for 3D interaction. Two experiments were performed. In the first experiment, an evaluation scheme for 3D gestures with different weighted indexes of usability was developed, and then the ratings of the usability dimensions of 30 gestures within 10 operations in the 3D interaction were compared with one another. The purpose of this comparison was to summarize a set of 3D gestures with the highest usability. In the second experiment, the validity of the gesture set acquired in the first experiment was verified by comparing the usability differences between the high- and low-rated 3D gestures. An optimal set of 3D gestures was obtained by comparing the usability ratings of the different gestures and then verifying the superiority of the operation performance and users' satisfaction of this 3D gesture set in a real operation task.

Introduction

- 3D gesture interaction, refers to a new way in which people engage in contactless interactions with computers through arm and palm movements (Pallotta, Bruegger, and Hirsbrunner 2007). In comparison with the 2D interactive mode, the current 3D gesture interaction mode is more adaptable and enables a more natural form of interaction with a machine. It can also reduce people's cognitive load because it is not limited to the form of hardware (Pantic et al. 2006).
- The aim of this study was to develop and verify a reasonable evaluation scheme for 3D gesture usability through empirical methods and finally form an efficient, natural, and standard gesture library for 3D interaction. Two experiments were performed. In the first experiment, an evaluation scheme for 3D gestures with different weighted indexes of usability was developed, and 30 college students with minimal experience in using 3D interactive devices were recruited to rate the usability of 30 gestures within 10 operations by comparing with one another. The purpose of this comparison was to summarize a set of 3D gestures with the highest usability. In the second experiment, another 60 novices were recruited, and the validity of the gesture set acquired in the first experiment was verified by comparing the usability differences between the high- and low-rated 3D gestures. An optimal set of gestures was obtained by comparing the usability ratings of the different gestures and then verifying the superiority of the operation performance and users' satisfaction of this 3D gesture set in a real operation task.

Experiment & Method

Experiment 1

The aim of this experiment was to develop an optimal 3D gesture combination. The usability of 30 alternative gesture motions corresponding to 10 operations were compared with one another.

Participants

- A total of 30 Chinese undergraduates (mean age = 22.4 years, SD = 1.2 years) participated in this study, who have minimal experience in using 3D interactive devices, such as Leap Motion or Xbox.

Experiment design

- A within-subject design with one independent variable was conducted. The independent variable was the gesture motion for various operations, and each operation included three corresponding gesture motions. The dependent variable was the usability evaluation of gestures, which included four aspects, namely, learnability, metaphor, memorability, and comfort. We presented the experimental materials randomly to avoid the order effect that may influence learning, evaluation, and recall of different gestures.

Experiment 2

The aim of this experiment was to verify the effectiveness and subjective satisfaction of gesture combinations developed in Experiment 1 in different operation tasks. The gesture combinations were compared with one another.

Participants

- A total of 60 Chinese undergraduates (mean age = 22.1 years, SD = 1.4 years) participated in this study, who have minimal experience in using 3D interactive devices, such as Leap Motion or Xbox.

Experiment design

- A between-subject design with one independent variable was conducted. The independent variable is the grade of gesture combination: high- and low-rated groups. The high-rated gesture combination was developed by the 10 optimal gesture motions that had been verified in Experiment 1. The low-rated gesture combination was composited by 10 gesture motions that were randomly selected from one of the other two gesture motions of each operation.

Results

***Table 1**. Gesture illustration and schematic of 10 optimal 3D gestures.*

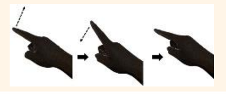
Task	Action description	Schematic
Left click	Open your palm, click downward with your index finger lightly	
Right click	Open your palm and turn it; bend your index finger, and then reverse it slowly	
Page up/down	Spread out your fingers, point upward to turn pages up, and point downward to turn pages down	
Page left/right	Slide your five fingers left and right	
Zoom	Extend five fingers to the screen (zoom in); shrink out five fingers off the screen (zoom out)	
Max/min	Open hand up /create a fist	
Switch	Turn the palm up and move upward	
Volume control	Point to the sound equipment, summon the menu, and move up or down to adjust	
Double click	Click twice with a single finger	
Pause/start	Supinate	

***Table 2**. Operating performance and subjective satisfaction of high- and low-grade gestures.*

	Operating performance			Subjective satisfaction score		
Task	High grade group	Low grade group	t	High grade group	High grade group	t
1	20.28±4.48	21.11±4.90	2.291*	4.46±1.04	3.81±0.92	2.541*
2	26.50±4.96	27.82±4.70	2.615*	4.07±0.96	3.13±0.92	3.831***
3	20.55±4.97	22.16±4.45	2.912**	4.15±0.93	4.09±0.95	0.241
4	32.95±6.42	35.54±7.31	2.536*	3.59±0.78	3.11±0.70	2.435*
5	25.85±5.92	27.99±5.65	2.723**	3.93±0.71	3.27±0.80	3.307**

*Note: t, t value of t-test; *p < .05; **p < .01; ***p < .001.*

Analysis method

- Considering that the data of memorability was enumerative, we performed chi-square tests to test the differences in memorability among the three schemes, one-way ANOVA to compare the three schemes with respect to learnability, comfort, and metaphor for each gesture task and t-test to compare the differences between the high and low groups.

Results (Table 1)

- The analysis of the three gestures of Page up/down, Zoom, Max/min, Switch, Volume control, Double click, Pause/start showed significant differences in memorability, but no difference in memorability was observed among the three gestures of Left click, Right click and Page left/right ($p_s > 0.05$).
- The three gestures of each operation all presented significant differences in learnability ($p_s < 0.05$), comfort ($p_s < 0.001$), and metaphor ($p_s < 0.01$) except Max/min, Right click in learnability ($p_s > 0.05$), Switch in comfort ($p > 0.05$) and Page up/down in metaphor ($p > 0.05$).
- Table 1 shows 10 optimal gesture designing schemes (the highest overall score of the three gestures of each operation).

Results (continue...)

Results (Table 2)

- The high-rated group performed significantly better than the low-rated group among all five operation tasks: Task 1, $t(58) = 2.291$, $p < 0.05$; Task 2, $t(58) = 2.615$, $p < 0.05$; Task 3, $t(58) = 2.912$, $p < 0.01$; Task 4, $t(58) = 2.536$, $p < 0.05$; and Task 5, $t(58) = 2.723$, $p < 0.01$.
- For the subjective satisfaction, the high-rated group performed significantly better than the low-rated group in the four tasks (Task 1, $t(58) = 2.541$, $p < 0.05$; Task 2, $t(58) = 3.831$, $p < 0.001$; Task 4, $t(58) = 2.435$, $p < 0.05$; and Task 5, $t(58) = 3.307$, $p < 0.01$), except Task 3 ($t(58) = 0.241$, $p = 0.810$).
- These results suggest that the optimal gesture combinations that were developed in Experiment 1 indeed show operational advantage to cope with simulated operation scenarios.

Discussion

- Basing on previous studies and questionnaire surveys, we presented a comprehensive evaluation system, which included learnability, metaphor, comfort, and memorability as indicators with different weights for the 3D gesture design. In accordance with this comprehensive evaluation system, we conducted an optimal set of 3D gestures by comparing the usability of the different gestures and then verified the superiority of the operation performance and users' satisfaction of this 3D gesture set via a simulated operation task.
- This study partially solves the lack of existing 3D gesture design proposed by (Norman, 2010). First, the 3D gesture motions suggested by our study is natural and can be easily learned and memorized and also with a high level of availability. Second, high-rated gesture combinations suggested by our study had been proven to be effective in terms of usability and user satisfaction in complex operations.
- This study had the following limitations and prospects. The usability data of all gestures proposed in this experiment were collected from college students. Given that gesture movements are affected by physiological and psychological factors, people with different ages and cultures may have different attitudes toward each gesture. In the future, exploring the preference differences on 3D gesture interaction among different age and cultural groups is necessary. Previous studies have suggested that as a result of the deterioration of the mobility of the elderly or the lack of athletic ability of some disabled people, 3D gesture interaction without actual touching is suitable for these special groups (Kobayashi, et al., 2011; Leonardi, et al., 2010; Murata & Iwase, 2005). Moreover, using neurophysiological indicators, such as electroencephalogram or myoelectricity, may offer new insights into the design and usability test of 3D gestures.