Suitability of 3D-Input Devices for the use in 2D Application

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Abstract. The use of non-intuitive 2D input devices for manipulations in 3D applications causes non-fully ability expression. This paper aims to judge the suitability of utilizing an isotonic 3D input device, the Leap Motion, and an elastic 3D input device, the 3D mouse, for common 2D applications. Suitability is investigated by means of a Fitts' task and results are compared to performance achieved by using a standard PC mouse. Findings of our experiment reveal that size of manipulated objects, manipulation distances, sensitivity settings of the device, and direction of manipulation, significantly affect task performance. Based on our findings we set up suggestions for using and designing applications for these devices.

Keywords. Input device, Leap Motion, Human-Computer Interaction, Performance, 3D mouse, Fitts' task

1. Introduction

1.1 Background

Human-computer interaction (HCI) is an important topic and constantly renewed in our daily life. Multi-dimension applications, such as PC games, SolidWorks, Virtual reality applications may require 2D and 3D manipulation interfaces. It is an annoying method if users are required to use different input devices (IND) for merely one task in the application. There are two common solutions to avoid the use of multiple interfaces. First, combine the functions of keyboard and mouse (2D) in order to implement 3D operations. However, efficient use of such a method requires a lot of practice, as for example, may be experienced in playing first person shooter (FPS) games. Second, combine translations of the mouse with some mouse input buttons, such as the mouse wheel, in order to enable 3D operations. Such a method is used, for example, in the SolidWorks application. There is actually a lack of intuitive methods to operate 3 dimensional (3D) objects by means of 2D INDs. However, we may ask whether 3D IND may be used to efficiently control 2D applications. In particular, we then may consider how factors such as type of 3D device, device settings, size and distance of manipulated objects affect performance when manipulating in 2D.

1.2 Movement time and index of performance

Fitts (Fitts 1954) publish a descriptive model of human movement enabling to investigate performance in a manipulation task. According to Fitts, the total movement time (MT) for pointing a target of size W at a distance D, can be predicted by the following equation:

$$MT = a + b\log_2(1 + \frac{D}{W}) \quad (1)$$

Where $\log_2(1+D/W)$ represents the index of difficulty (ID) and a and b are constants. Equation 1 is the most frequently formulation proposed by Scott MacKenzie to modify the definition of ID made by Fitts (MacKenzie 1992). This well-known method is one of the most robust laws for motor control. As reported in the literature (Card et al. 1978), the equation fits well to express MT in task consisting out of controlling a cursor on a computer screen. Pioneering studies on fast and accurate pointing tasks have shown that movement speed decreases when accuracy level is enhanced (Woodworth 1899).

1.3 3D input devices

According to Zhai (1995) IND may be grouped into three classes, namely, isotonic (ex. mouse), isometric (ex. TrackPoint), and elastic (Joystick) IND. To test the suitability of 3D INDs, we choose Leap Motion (LM) as the 3D isotonic representative and Space Navigator as the 3D elastic representative. LM is a new IND produced by Leap Motion Inc. and began selling in July, 2013. Space Navigator, alias 3D mouse (3DM), is produced by 3Dconnexion. There is no similar classical commercial production for isometric class. Both, mouse and LM are position control input devices (PCIND), and 3DM is a speed control input device (SCIND).

2. Method

2.1 Pre-experiment

In our study, we compare manipulation performance when using a PC mouse (Logitech, 800 dpi) and the two 3D manipulation devices mentioned above. In all three devices, sensitivity, i. e. the gain by means of which manipulation input is transformed into translation of the cursor, may be adjusted to fit the user's preferences. By means of a pre-experiment, we investigated the effect of sensitivity setting on performance in a manipulation task. Results of the pre-study will indicate whether sensitivity settings should be considered in the main experiment as a relevant factor affecting performance.

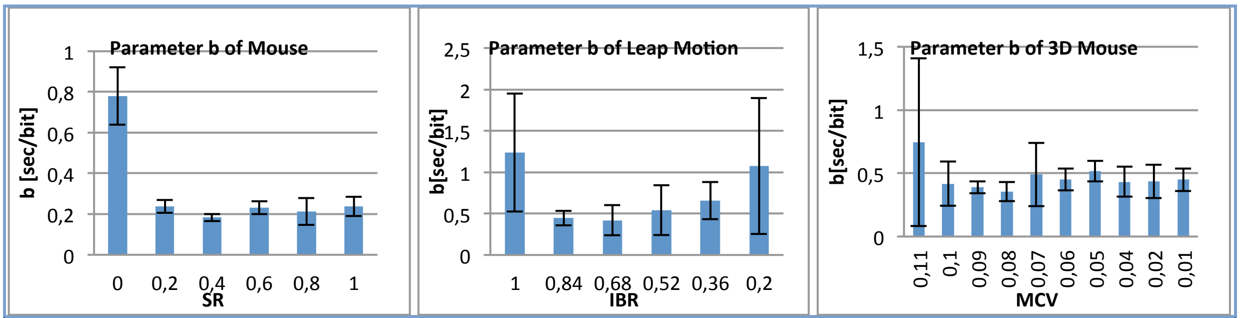
Three subjects (26 y, 40 y and 56 y) took part in the pre-experiment. In the pre-experiment, a Fitts' task was presented on a Samsung SyncMaster 930BF-LCD 19" monitor (resolution: 1280*1024). The task started by placing the cursor in a starting field presented on the monitor. After a short time was elapsed, a target appeared at a random location on the monitor. Subjects were asked to place the cursor as fast and accurate as possible in the target and to immediately confirm the end position of the cursor by pressing a key of a keyboard. Distance, size and orientation of the target were varied randomly from trial to trial. A total of 60 trials were performed in one session.

Subjects were comfortably seated at a viewing distance between 0.7 m to 1.0 m in front of the monitor. They were asked to perform the task, starting with the PC mouse using the lowest sensitivity settings. Three sessions were recorded. Data of the three sessions were fitted separately using Fitts' equation (1) in order to compute the parameter. The average of the values of the parameter b was then used for further processing. After three sessions were recorded, sensitivity settings were varied according to below listed table 1. After having tested all sensitivity parameters in one device, subjects repeated the measurements with the next device. In all subjects the sequence of tested devices remained the same: PC mouse, Leap Motion and 3D mouse. The total duration of the pre-experiment was 2.5 h per subject.

Table 1. *Definition of speed ratio (SR = speed ratio setting in the PC mouse; IBR = interaction box ration in the Leap Motion; MCV = maximum cursor velocity in the 3D mouse).*

Sensitive property	SR		IBR		MCV	
	ratio	dpi	ratio	dpi	ratio	Pixels / s
Relationship of values and speed	0	25	1	12.7	0.11	2392.5
	0.2	200	0.84	15.1	0.1	2175.0
	0.4	600	0.68	18.7	0.09	1957.5
	0.6	1200	0.52	24.4	0.08	1740.0
	0.8	2000	0.36	35.2	0.07	1522.5
	1	2800	0.2	63.5	0.06	1305.0
					0.05	1087.5
					0.04	870.0
					0.03	652.5
					0.02	435.0
					0.01	217.5

Figure 1 shows the average of averages of parameter b across the three subjects. The left hand graph reports averages assessed using the PC mouse at various sensitivities. Analog results for the Leap Motion and for the 3D mouse are reported in the middle and right hand graph respectively. The results indicate that an optimal performance is achieved for sensitivity settings of SR=0.5, IBR=0.8 and MCV=0.06. Optimal sensitivity settings were used in the main experiment. Keeping sensitivity settings constant, helps reducing the duration of the experiment (see below).



(a) (b) (c)

Figure 1. *Performance comparison by the parameter b of Fitts' analysis for each device (a)b-SR diagram for mouse, (b) b-IBR diagram for LM, (c) b-MCV diagram for 3DM*

2.2 Main experiment

2.2.1 Participants

Nineteen right-hand participants (12 f, 7 m, mean age 28.7 y, standard deviation 8.35 y). None of the subjects had upper extremity musculoskeletal disorders and all reported normal or corrected to normal vision.

2.2.2 Task

Except for the variation of sensitivity settings of tested devices, the task and other experimental settings in the main experiment were the same as in the pre-experiment. For each device tested, the optimal sensitivity setting was used as was found by means of the pre-experiment. Several measures were taken to establish a certain degree of compatibility in manipulation of the three devices. All participants tested the devices in the same order, which was mouse, LM and 3DM. Before testing a device, participants were given some time to train using the device. Participants required about 35 minutes in average to complete the main experiment.

3. Results

A repeated measure analysis of variance (ANOVA) for parameter b of Fitts' equation was run in which device and session were considered as three level within subject factors and gender, age and participant were considered as between subject factors. The analysis revealed no significant effect of gender, age, and session. In contrast, a significant effect on parameter b was found for the factors device and subjects. From results plotted in fig. 2 we may conclude that both 3D INDs are similar. When using the 3D INDs, the speed of information processing (parameter b) during the manipulation task is about 2.5 slower as is the case when using the PC mouse.

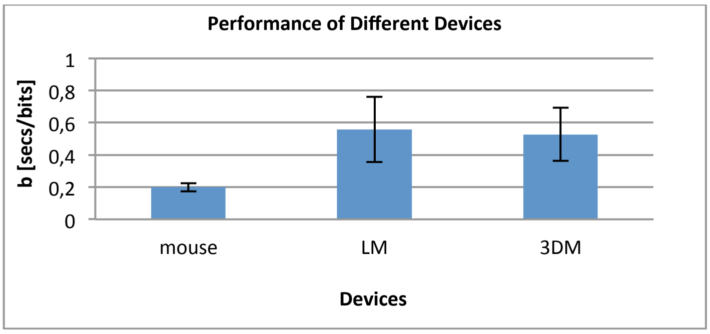
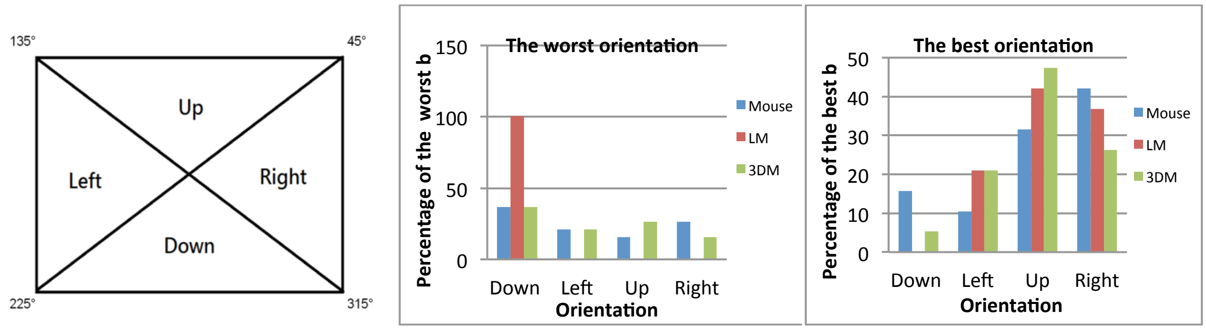


Figure 2. *Average and standard deviation of performance using the three devices. 19 participants.*

By means of a post-hoc analysis the effect of orientation of the target on manipulation performance was investigated. Orientations of presented target may be grouped into 4 parts as shown in fig. 3 (a). Fig. 3(b) shows a low performance for down. According to -reports of participants the uncomfortable gesture (shaped as z or 7) and error detecting the gesture in the LM caused the bad performance.



(a) (b) (c)

Figure 3. *Orientation analysis (a) Orientation definition, (b) The worst orientation, (c) The best orientation*

Result not reported here also show that the performance when using a PC mouse depends on the distance (two groups: short and long) and on the diameter (two groups: small and big) of the target. The results of the worst performance for these 4 conditions are 60% for 3DM in short-small condition, 73% for 3DM in short-big condition, 60% for LM in long-small condition, and 46.8% for 3DM and LM in long-big condition.

4. Discussion

Following reports of the literature, the logistic relationship between screen and IND permits for more rapid, more harmonic movement without loss of precision for all levels of the task difficulty (Fernandez & Bootsma 2008). According to Burgess et al. (2013) high-order system with high-order controlling devices (velocity, acceleration control), and low-order system with low-order controlling devices (position control) had high performance. On the other hand, miss matching the orders lead to low performance. PCIND is more logistic in common applications, such as MSOffice as less effort is required for converting coordinate between isotonic INDs and 2D applications. SCIND cause excessive cognitive load due to required transformation of the input. According to the figure 1, it seems that there are optimal settings in PCINDs but none in SCIND.

The controlling musculatures of hands and fingers allow for more precise manipulation than those for upper arms. Freedom of movement without support of the wrist (Leap Motion) causes excessive effort in the user for keeping the hand at the same location in the interaction box. Tremor decreases the ability of precise controlling. According to the result of the pre-study, the dpi setting of LM should be much lower than the setting of the PC mouse. According to our findings, SCIND is not convenient for performing short distance movements and LM is not convenient for performing long distance movement, especially when manipulating small targets.

5. Conclusion

There is no perfect input device to be used in applications varying in the dimension of manipulation. The freedom of LM can decrease the postural load caused by frequently using the same muscles; however, decreasing constraints also enhance the complexity of manipulation. The following table lists pros, cons and the suggestions to improve tested devices.

Table 3. *Effect of various factors (upper table) in performance, pros (+), cons (-) and suggestion (lower table) for the tested devices (Mouse LM and 3DM).*

	Device		
Factor	**Mouse**	**LM**	**3DM**
Stability	+	-	+
Supporting at wrist	+	-	+
Freedom of movement	+	+	-
Position control	+	+	-
Controlled similarity of holding a pen (precise)	?	+	-
Friction effect	-	+	+
Non-intuitive in 3D	-	+	+

Suggested Improvement	**LM**	1. Set the original center point of LM as the bottom's center of applications. 2. Set a transparent plate between hand and LM. It can give some support while surf in 2D and keep intuitive manipulating in 3D. 3. Set the size of button as big as possible.
	3DM	1. Set it as PCIND. Set a constant speed for every orientation. 2. Set the distance of buttons as longer as possible

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