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Performance Evaluation of Gesture-based 2D and 3D Pointing Tasks

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Abstract. We present two studies to comparatively evaluate the performance of gesture-based 2D and 3D pointing tasks. In both of them, a Wiimote controller and a standard mouse were used by six participants. For the 3D experiments we introduce a configuration analogous to the ISO 9241-9 standard methodology. We examine the pointing devices' conformance to Fitts' law, and we measure some extra parameters that describe more accurately the cursor movement trajectory.

Keywords: Fitts' law, 3D pointing, Gesture User Interface, Wiimote,

1 Introduction

Nowadays, low-cost hand-held devices introduced along with wide spread game platforms/consoles can also be used as input devices in general purpose Personal Computers. Thus, the last years there is a growing research interest in the domain of device-based gesture user interaction. Nintendo's Wii Remote Control (known as Wiimote) represents a typical example of such devices. Most of them incorporate accelerometer sensors. Accelerometer-based recognition of dynamic gestures has been investigated in numerous studies [1-4]. Various methods and techniques have been developed for gesture recognition using the Wiimote [5-10]. SignWiiver is a gesture recognition system which lets the user perform gestures with a Wiimote, and uses a language built around the movement parameter of Natural Sign Languages [11].

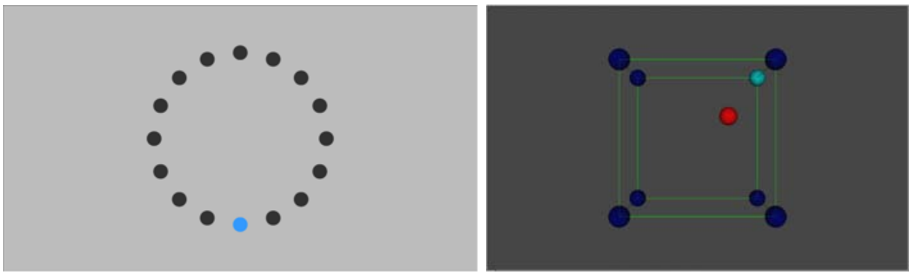
The point-and-click metaphor (usually referred to as *pointing*) constitutes a fundamental task for most two-dimensional (2D) and three-dimensional (3D) Graphical User Interfaces (GUI) in order users to perform an object selection operation. Moreover, typing, resizing, dragging, scrolling, as well as other GUI operations require pointing. In order to develop better pointing techniques we need to understand the human pointing behavior and motor control. Fitts' Law [12] can be used to: a) model the way users perform target selection, b) measure the user's performance and c) compare the user's performance amongst various input devices or the change of performance over time. Fitts' law has been applied to three-dimensional pointing tasks [13] as well as for the design of the gesture-based pointing interactions [14-15] including the Wiimote [16-17]. The most common evaluation measures of Fitts' law are speed, accuracy and throughput. In this paper we present two studies to comparatively evaluate the performance of gesture-based 2D and 3D pointing tasks. Beyond testing Fitts' law, we measure some extra parameters that describe more accurately the real cursor movement trajectory.

2 Methodology

According to Fitts [12], the Movement Time (MT) needed to hit a target must be linearly related to the Index of Difficulty (ID) of the task: $MT=a+b \cdot ID$, where $ID=\log_2(D/W+1)$, D and W are the target's distance and width respectively. In order to evaluate the Wiimote input device comformance to Fitts' law, we have designed and implemented a novel software application for our experiments, based on the ISO 9241-9 standard [20-21], that covers both 2D and 3D gesture-based user interaction.

For the 2D case, in each multi-directional test, 16 circular targets are arranged in an equidistance layout (Fig. 1a). The task begins with a click on the centre of the first target; then the participant must move the cursor directly to the opposite target and click on it, and so on clockwise. The next target is highlighted every time. Each test block ends when all targets have been selected (16 trials) and 5 blocks are run for all combinations of different target widths and different circle radii (with 5 different Indexes of Difficulty) giving a total of 80 trials for each user.

For the 3D case, 8 spherical targets are placed at the corners of a 3-dimensional cube (Fig. 1b). Each task begins with a click on the centre of a target. Then the participant must move the cursor directly to the target that is opposite to the center of the cube and click on it.. After a successful trial the cursor teleports to another non-highlighted target that will become the beginning of the next route. The next target is highlighted every time. Each test block ends when all the 8 equidistance routes that can be supported by the 8 targets are successfully done (8 trials), and 3 blocks are run for 5 different target circle radii (in total 5 different Indexes of Difficulty) giving a total of 40 trials for each user.



(a) (b)

Fig. 1. Screenshots of (a) the 2D and (b) 3D pointing tasks.

Our development is based on the theory proposed by MacKenzie et al. [18]. Specifically, we measure the following extra parameters of the real cursor movement trajectory monitored by our application: target re-entry (TRE), task axis crossing (TAC), movement direction change (MDC), orthogonal direction change (ODC), movement variability (MV), movement error (ME) and movement offset (MO). These extra parameters have been previously applied in a 2D setup for Brain Computer Interface Cursor Measures for Motion-impaired and Able-bodied Users [19].

The experimental application has been developed as a Virtual Instrument using the LabView (Laboratory Virtual Instrumentation Engineering Workbench) graphical programming environment by National Instruments [22]. We have tested Wiimote as a gesture input device getting data in real time from both its high-resolution IR camera (in combination with the IR LED array illuminator) and its 3-axis accelerometer. The Wiimote was treated as HID (Human Interface Device) compliant device when connected to a regular PC using Bluetooth communication. The computer was a Pentium Core 2 Duo 1.8 GHz laptop with 3 GB of RAM and a NVIDIA GTS250 graphics card, running MS-Windows 7 Professional and LabView 10.1. It was connected to an external 24” TFT monitor with 1280x800 pixels resolution.

Six male participants, volunteered for the study. Their age range was 22 to 35 years (mean 25.0, SD 4.9). All had normal or corrected vision and were right-handed. All of them reported an average of three hours per day using the mouse device. No one of these participants had any experience with the Wiimote.

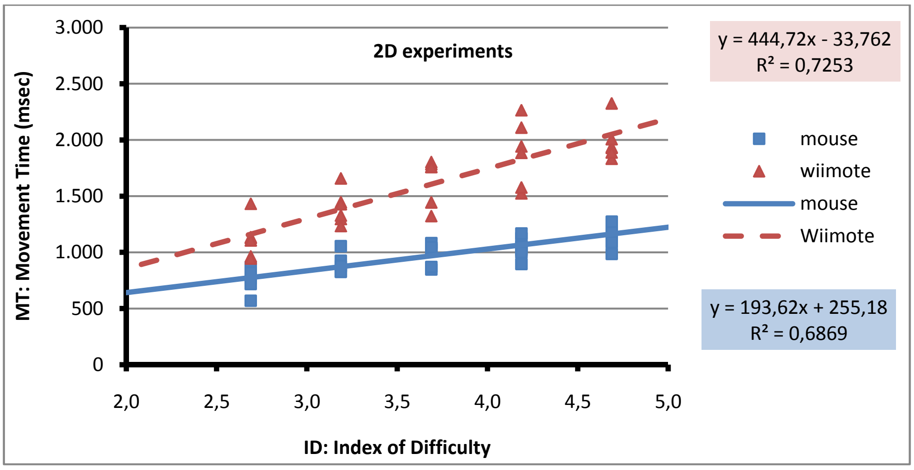
3 Results

Results of using the Wiimote for 2D and 3D pointing tasks by six participants are presented in Fig. 2 and Table 1. In both tests users were instructed not to stop on erroneous clicks and an audio feedback was given in that case. Visual and audio feedback is also given on successful clicks. Each task was explained and demonstrated to participants and a warm up block of trials was given. A 100 Hz sampling rate was used for cursor trajectory and click data acquisition.

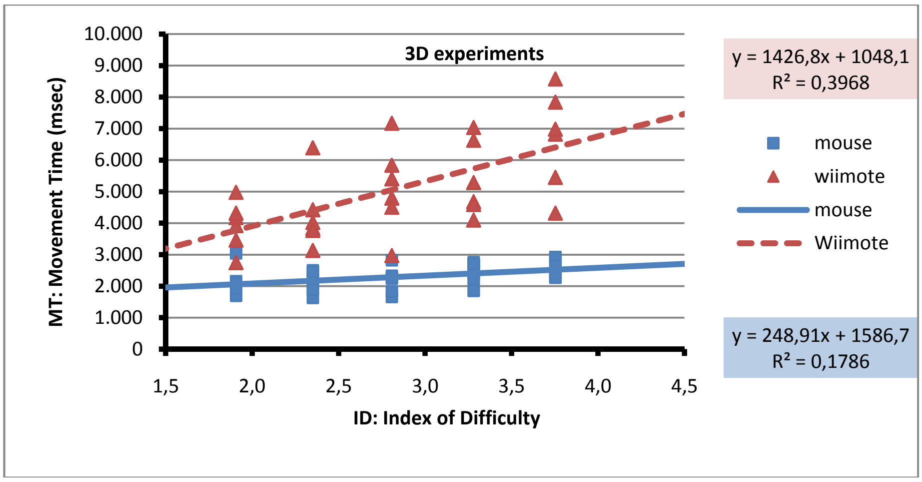
Measurements of movement time as a function of index of difficulty (mean values for all trials) for all the participants in 2D (a) and 3D (b) experiments using the Wiimote and the mouse are presented in Fig. 2. After the statistical analysis of all data from all users we present the results of the additional cursor movement parameters in Table 1.

4 Conclusions

We conclude that for the 2D tasks using Wiimote, throughput ($TP=ID_{avg}/MT_{avg}$) is 41,2% lower than using the mouse, target re-entry is almost the same and missed clicks count is three times higher. For the 3D tasks using Wiimote, throughput is 56,1% lower than using the mouse, target re-entry is almost 50% increased and missed clicks count is sixteen times higher. Furthermore, Fig. 2 shows that the fitting line correlation coefficient (R^2) which reflects the reliability of the linear relationship between MT an ID values, and therefore the compliance to Fitts’ law is generally slightly higher for the Wiimote controller than the mouse, and significantly lower for the 3D than the 2D Experiments.



(a)



(b)

Fig. 2. Measurements of movement time as a function of index of difficulty (mean values for all trials) for all the participants in 2D (a) and 3D (b) experiments using Wiimote and the mouse.

Table 1. Calculated pparameters of the cursor trajectory generated by the two gesture input devices in 2D and 3D experiments.

		TP	MCL	TRE	TAC	MDC	ODC	MV	ME	MO
		throughput	missed clicks	target re-entry	task axis crossing	movement direction change	orthogonal direction change	movement variability	movement error	movement offset
2D	mouse	5,05	0,05	0,12	1,48	6,04	0,91	0,32	0,39	0,04
	Wiimote	2,97	0,14	0,11	1,56	18,06	2,48	0,55	0,79	0,22
3D	mouse	1,71	0,06	0,10						
	Wiimote	0,75	0,96	1,46						

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