Properties of Shadow-Cursor for Calibrating Screen Coordinates of Tabletop Displays

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Abstract. This manuscript introduces the basic idea of a shadow-cursor for calibrating the screen coordinates of tabletop displays. The shadow-cursor is an invisible mouse cursor. We explain how the shadow-cursor works to calibrate the screen coordinates and discuss its properties of accuracy, and then show that the shadow-cursor has the potential to align the screen coordinates.

Keywords: shadow-cursor, screen calibration, pointing interfaces, tabletop displays.

1 Introduction

Human computer interaction or HCI becomes more important in helping people interact with computers more intuitively and implicitly. In the field of HCI, tabletop displays have been studied recently and become one of interesting challenges for application and interaction style. A tabletop display is a horizontal display which multiple users sit down around and use together. A tabletop display is most likely equipped with a touch screen so that the users can click on and drag contents on the screen in an interactive way. The contents could be water surface, a pool table, a satellite map etc.

Nowadays tabletop displays are often used for collaborative work such as brainstorming and meetings where multiple people work together around a single tabletop display. This trend leads to a strong demand for a large screen space.

A pointing interface is a system that locates the spot on a computer screen, which the user wants to focus on. One of key issues around a tabletop display is how to make the pointing interface if the tabletop display has a large screen so that the user cannot reach the contents by his/her own hands. In research, the trend is that the pointing interface functions by capturing the quadrilateral of the screen with a handheld camera and locating the center of the camera as a graphical cursor. Nintendo Wii takes this approach for pointing. Infrared LEDs are attached on a TV screen, which represent the quadrilateral of the screen. The Wii remote captures the LEDs and locates the graphical cursor in real time. This way works well as far as the camera captures the quadrilateral of the screen.

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One of solutions to this is to use Gray-code. Gray-code is a way to encode values 0 up to 2^n-1 into n bits binary sequences with the property that only one bit changes between any two consecutive sequences. A gray-code binary pattern is a visual representation of the binary sequences at a specific bit. In our previous work [1], we used black and white gray-code binary patterns. They appear on the screen in order then the temporal pattern captured by a handheld camera at a position of the screen uniquely represents its own position. Thus it is not necessary that the handheld camera captures the entire screen but one position. In an environment of projection, Lee, J. et al. [2] proposed a method for making the visible gray-code binary patterns imperceptible by transmitting the gray-code binary patterns through frequency-shift keying or FSK modulation. They later made a prototype of a projection system that is capable of emitting both infrared and visible rays simultaneously. This way is applicable to tabletop displays if their screens are projection.

Our pointing interface uses a common mouse so that it relies on neither the projection of infrared rays nor the quadrilateral of the screen. One of major problems with the use of a common mouse for pointing on a tabletop display is that the coordinates of the screen (hereafter the screen coordinates) are not always aligned with the coordinates of the mouse control space (hereafter the mouse control coordinates). Wigdor, D. et al. [3] showed that the correlation between display positions and mouse control orientations would have a significant impact on performance.

In our first attempt to align the screen coordinates with the mouse control coordinates [4], we used a reflex in eye-hand coordination. The reflex in eye-hand coordination is a natural response to inconsistency between kinetic information of a mouse and visual feedback of the mouse cursor. We showed that the reflex depends on the angular distance between the screen coordinates and mouse control coordinates, and the reflex is also viable to align the screen coordinates with the mouse control coordinates. It however takes 4 seconds to complete the alignment.

To improve the performance, we take another approach with the basic idea of a shadow-cursor in this manuscript. When we use a mouse, we track the mouse cursor at the same time to make sure that the mouse cursor is placed where we want. If we

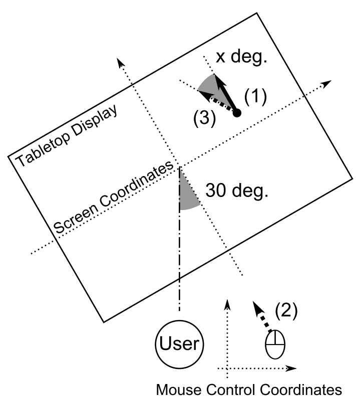

Fig. 1. Screen coordinates calibration with shadow-cursor

do not see the mouse cursor while moving the mouse, how accurately can we move the mouse cursor? Moving the mouse cursor accurately without seeing it plays an import role in aligning the screen coordinates with the mouse control coordinates. Here we call this invisible mouse cursor a shadow-cursor. We describe how it works in a later section. The aim of this manuscript is to conduct an experiment on accuracy of the movement of shadow-cursor and show that the shadow-cursor has the potential to align the screen coordinates.

Section 2 introduces the basic idea of a shadow-cursor and describes how the shadow-cursor aligns the screen coordinates with the mouse control coordinates. Section 3 conducts an experiment on accuracy of the movement of shadow-cursor and discusses its results, and then shows that the shadow-cursor has the potential to align the screen coordinates. Section4 gives the concluding remarks.

2 Shadow-Cursor

A shadow-cursor is an invisible mouse cursor. Figure 1 shows how the shadow-cursor works to obtain the angular distance between the screen coordinates and mouse control coordinates. In the figure, there is an angular distance of 30 degrees counterclockwise between these two coordinates. (1) An arrow appears on the screen and (2) the user moves the mouse in the direction indicated by the arrow and then (3) the mouse cursor will move at an angle of x degrees. In this case, x equals 30. Note that the mouse cursor is hopefully set invisible because it will move in the direction that the user doesn't expect. In order to obtain the correct angular distance, it is necessary for the user to manipulate the mouse in the same direction as the arrow without seeing any other visual feedbacks. We call this a shadow-cursor.

In the next section, we conduct an experiment on some properties of the shadow-cursor and give an answer to how accurately we can move the shadow-cursor.

3 Experiment

This section conducts an experiment on accuracy of the movement of shadow-cursor and shows that the shadow-cursor has the potential to align the screen coordinates.

3.1 Design

We conduct an experiment on how accurately we can move the mouse without seeing any visual feedbacks. Figure 2 shows the design of the experiment. The rectangle represents a laptop screen of Dell XPS M1210, which is 261mm wide and 164mm high (1280x800 pixels in resolution). The laptop has a processor of 1.73GHz. It is also equipped with a graphics card of nVidia GeForce Go 7400. The subject sees the laptop screen right in front.

A radial arrow appears in the center at each angle of -150 to 180 at 30 degrees intervals and the subject is asked to move the mouse in that direction, and then the system records the movement of shadow-cursor. There were 16 subjects between the ages of 21 and 23. All were right-handed, had an experience working with a mouse. Each subject had 10 trials at each angle, resulting in 120 trials.

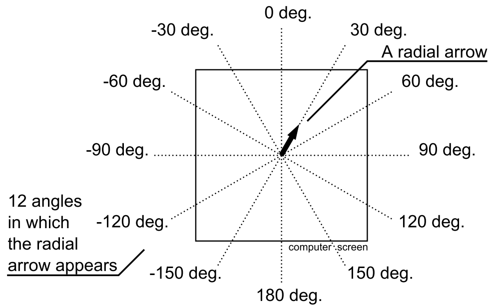

Fig. 2. Design of an experiment on accuracy of the movement of shadow-cursor

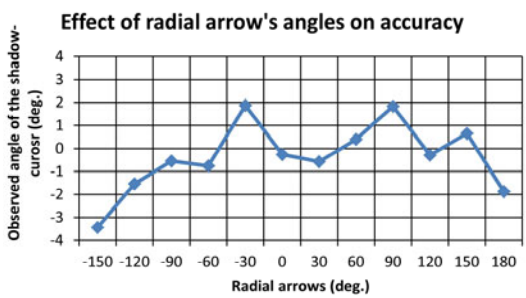

Fig. 3. Effect of radial arrow's angles on accuracy

16 subjects ×12 angles of radial arrow ×10 trials = 1920 total trials

To avoid learning effects, the sequence of trials is in a random order but it is the same between subjects.

3.2 Effect of Radial Arrow's Angles on Aaccuracy

Figure 3 shows the effect of radial arrow's angles on accuracy. The horizontal axis shows the radial arrow's angles and the vertical one shows the subtraction of the observed angle from the target one at each angle across all the subjects. From the figure, there seems to be a certain relation between the radial arrow's angles and accuracy. There are two increases around +/- 30 to 60 degrees, one subtle decrease in the center, and two drastic decreases at both sides. Analysis of variance shows that there is a significant impact of the radial arrow's angles on accuracy [F(11,1908)=4.54074 at p=0.001]. The accuracy is however kept within +/- 4 degrees.

3.3 Effect of Individuals on Accuracy

Figure 4 shows the effect of individuals on accuracy. The horizontal axis shows all the subjects and the vertical one shows the subtraction of the observed angle from the target one at each subject across all the arrow's angles. From the figure, there seems to be a certain change in accuracy between individuals. The 11th and 12th subjects

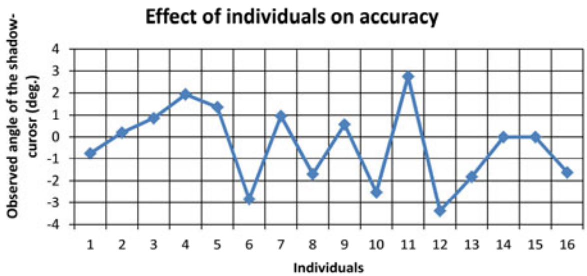

Fig. 4. Effect of individuals on accuracy

had worse accuracy than the others. Analysis of variance shows that there is a significant impact of individuals on accuracy [F(15,1904)=4.906141 at p=0.001]. The accuracy is however kept within +/- 4 degrees.

4 Conclusions

This manuscript introduced the basic idea of a shadow-cursor for calibrating the screen coordinates of tabletop displays and discussed its properties of accuracy, and then showed that the shadow-cursor had the potential to align the screen coordinates with the mouse control coordinates. In our future work, we are going to implement a prototype of our pointing interface and evaluate its performance.

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