FINGER POINTING ACCURACY ON LEAP MOTION SENSOR

ABSTRACT

In this short paper we present a performance analysis of the Leap Motion depth sensor solely used as a single finger pointing device. Based on the evaluation of Fitts’ Law, we have examined the sensor capabilities with two groups of participants – 10 moderately aged computer affine technicians and 10 elderly people with no explicit experience in handling technical devices. Results have been compared to the currently most efficient pointing device, the mouse, and show clearly, that the gap between young and old, professional and unskilled users has to be considered by HCI designers in order to create a similar and consistent good user experience.

KEYWORDS

leap motion, pointing device, fitts’ law

1. INTRODUCTION

More than 50 years after Douglas Engelbart has invented the computer mouse (Engelbart 2014), 3D user interfaces are on the rise and research in gesture recognition domain is evolving rapidly (Ibraheem 2012). Comparisons with traditional input interfaces indicate though, that we are not yet prepared to use all these new natural interfaces in the same way, with the same efficiency as mouse or keyboard (Sambrooks, Wilkinson 2012). Human gestures require a lot of muscular interaction and energy. Figure 1 shows the regions in the primary motor cortex and the corresponding body parts they are in control of. Large areas, like for the hand and fingers indicate, that we can control them with a minimum of energy, not yet physical energy, but also mental energy for eye-hand coordination (Frick 1987).

Motion patterns involving the fingers are stored like computer programs and can run as unsupervised background tasks, whereas moving and precisely directing limbs, e.g. the forearm is ways more laborious for the cortex. Therefore our intention is to explore possibilities to control a computer with a minimum of energy, but a maximum degree of freedom. So instead of using gestures, we deal with pointing actions of the index finger and a click event triggered by the other hand. This workflow is inspired from results of Schwaller et al. using a Kinect V1 depth sensor for two-handed computer interaction, (Schwaller et al. 2013).

Weichert has investigated the accuracy and robustness of the Leap Motion depth sensor using an industrial robot (Weichert et al. 2013). According to his results, the sensor has a deviation from reference positions lower than 0.2 mm in a static setup and 1.2 mm if the target is moving around.

Figure 1. Mapping of body parts on the primary motor cortex. Source: (Penfield 1950)
2. FITTS’ LAW

Fitt’s law describes the relation between time to complete an acquisition task e.g. a pointing action, the distance between target and starting point and the size of the acquisition target. It has been developed in 1954 by Paul Fitts and is a fundamental basis for testing the performance of pointing devices (Fitts 1954). Later on it found its way into the ISO 9241-9 standard (currently revised by ISO 9241-400 and -410) for evaluating the efficiency and usability of such devices. MacKenzie and Buxton made further improvements and extended it to the 2\textsuperscript{nd} dimension (MacKenzie, Buxton 1992). With Shannon’s formulation it denotes to

$$MT = a + b \log_2 \left( \frac{A}{W} + 1 \right)$$  \hspace{1cm} (1)

The time to move a pointing marker into a target area depends on the distance (amplitude A) between start point and target, and the size W of the target area. Term

$$\log_2 \left( \frac{A}{W} + 1 \right)$$  \hspace{1cm} (2)

is the so-called Index of Difficulty (ID). A task gets more difficult, if the target is located farther away and smaller in size. This fits well with the common perception and the time it takes to perform such a task is linearly correlated with its ID (a is start time, b the speed).

3. EXPERIMENTAL SETUP AND EVALUATION

Performance measurement has been done on a laptop with a 4 core CPU, 4GB of video RAM, 16 GB of RAM, USB 3.0 controller and a 1TB SSD under Windows 8.1. Display resolution was full HD (1920 x 1080) and screen size 434 mm in diagonal. Additional to the Leap Motion sensor, a Kinect V2 (alpha) sensor has been capturing depth data synchronously at 30 fps during the whole experiment. This data will be evaluated later on. Software version for Leap Motion was 1.1.3-9188, device has been configured to interaction height of 7.0 cm (the lowest possible value), Automatic Interaction Height has been turned off. Tracking priority has been set to Precision (prioritise accuracy over speed). Low Resource Mode has been deactivated and Auto-orient Tracking been turned off. To provide a relaxed finger pointing environment, the hands have been placed on a 22.5 mm high pedestal, and the Leap Motion sensor has been rotated by 23.5° away from the hand with a 9 mm gap between sensor and pedestal.

For the initial setup we wanted to provide a well-defined setup, where the pointing hand would have been fixed with a tape on the pedestal, to assure reproducible results, but since this requirement would have turned our interface into a UI with a handcuff, we decided to allow position changes within a range of 20 mm, which turned out to be a useful requirement especially for second group of older participants.

Each test participant had to put his hand on the pedestal and just to move one finger for pointing action. One pass was defined to click 10 targets of a certain size within shortest possible time. After each pass, the distances A became larger, and the size W of the clickable targets smaller. The whole test covered 5 passes with ID values shown in table 1.

<table>
<thead>
<tr>
<th>A</th>
<th>W</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>150</td>
<td>1.22</td>
</tr>
<tr>
<td>300</td>
<td>100</td>
<td>2.00</td>
</tr>
<tr>
<td>400</td>
<td>50</td>
<td>3.17</td>
</tr>
<tr>
<td>450</td>
<td>25</td>
<td>4.25</td>
</tr>
<tr>
<td>500</td>
<td>15</td>
<td>5.10</td>
</tr>
</tbody>
</table>
Click pattern has been chosen similar to the suggested multidirectional tapping task by Soukoreff and MacKenzie with increased ID (Soukoreff, MacKenzie 2004), but with 10 targets per pass and starting position at the right side (East). As stated above, the click has been triggered by the other hand using a hot key.

After the five tests runs, the participants did the same test with the computer mouse as input device. For evaluation, click and pointer movement data of both test runs have been captured and saved into a local file. In a post processing step, the data has been imported to an adjusted version of the JavaScript based evaluation web page created by Simon Wallner, Otilia Danet, Trine Eilersen, and Jesper Tved (Wallner et al. 2012). Its source code is available under MIT license at github (see https://github.com/SimonWallner/uit-fitts-law). The results have then been exported to CSV.

The 20 test participants were organised into two groups: one group consisted of 10 technicians, 5 male, 5 female, aged between 35 and 55 (mean 43.7). All persons were highly skilled to use the computer; all of them except one were right-handed, 5 of them used glasses or lenses, but with proper vision correction. None of them was colourblind. All of them except one person choose the index finger as pointing device, one used the middle finger.

The other group consisted of 10 older persons (also half male and female) aged from 64 to 85 (mean 72.4). None of them worked with a personal computer; 8 where right-handed, all of them used glasses or lenses, with proper vision correction. None of them were colourblind. All used the index finger to control the cursor.

The result of the test is gathered as a scatter plot of time over effective ID. The effective Index of Difficulty is computed as follows:

$$ID_e = \log_2 \left( \frac{D_e}{W_e} + 1 \right)$$

where $D_e$ is the mean distance from start to end point and the effective width $W_e$ is defined as:

$$W_e = 4.133\sigma$$

where $\sigma$ is the standard deviation of the hit locations on the target. $\sigma$ is computed in the target direction and perpendicular to it, and then chosen using the ‘smaller-of’ heuristic (Soukoreff, MacKenzie 2004), (MacKenzie, Buxton 1992).
4. CONCLUSION

We have done a performance analysis of the Leap Motion depth sensor solely used as a single finger pointing device. Based on the evaluation of Fitts’ Law, the results have shown that currently, settings with a higher ID than 3.0 are hardly manageable by well-trained computer experts. At the same time, the group of elderly people performed well up to an ID of 2.0. All levels above 2.0 were not manageable. HCI designers should take that into account, when creating finger pointing UIs. It is also remarkable, that the difference between finger pointing and mouse pointing were much higher in the group of experts, than in the group of elderly people. This can be interpreted in a way that the experts have learned to deal with the mouse, but need some more time to train their motor skills for finger pointing activities as well.

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REFERENCES


