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Target Acquisition with Leap Motion: Evaluation

1 Introduction

In this report, a leap motion interaction technique “hand rotation” (HR) is evaluated. This technique uses single hand movement to control the cursor coordinate on a screen, and uses a 45 degree clockwise hand rotation to trigger a click event.

In the experiment, I compared the speed and accuracy of HR with the traditional move and tap with one finger[1] Trackpad interaction technique with standard 2-dimensional Fitts’ law tasks [1].

Participants are asked to do 12 Fitts’ law tasks in total and are then interviewed on their feedbacks about the techniques. Both quantitative and qualitative data are recorded. Results show that using Trackpad is more accurate and faster than HR. Interacting with Leap Motion is also significantly more effort-taking after using it for about 15 minutes. However users did report that interacting with Leap Motion is more fun and feels more engaged and “real”.

2 Evaluation

2.1 Method

2.1.1 Subjects

5 subjects are recruited for the experiment: 4 males and 1 female. They are all students with an average age of 25.4. All subjects are Mac users who use Trackpad on a daily basis. 2 of them have some limited experience with Leap Motion. One has played with it before. The other one has tried the prototype for less than 20 minutes in the past week. None of them used Leap Motion on a daily basis.

2.1.2 Apparatus

The study was conducted on a 13-inch MacBook Pro, which has a screen width of 12.78 inches and a height of 8.94 inches[2]. It has a retina display of 1280 by 800 pixels. The

[1] “Use Multi-Touch gestures on your Mac”. https://support.apple.com/en-us/HT204895

[2] “13-inch MacBook Pro”. http://www.apple.com/macbook-pro/specs/

Leap Motion is a model No. LM-010 and can detect hands in a roughly 1 meter hemi-spherical area[3].

The experiment software was developed in HTML, CSS and JavaScript. The experiment was done in full-screen mode under Google Chrome Version 48.0. Data including time for each click, hit or miss (accuracy), length of each movement and distance from the click to the target are logged to the browser console. All clicks are also recorded on the web UI indicated by red circles. Figure 1 shows a sample screenshot of the software. Note that more data are logged to a separate browser console. The data on web UI are just feedbacks for users.

In addition, several videos of the participants completing tasks are also taken by an iPhone 6 for the later more detailed observations.

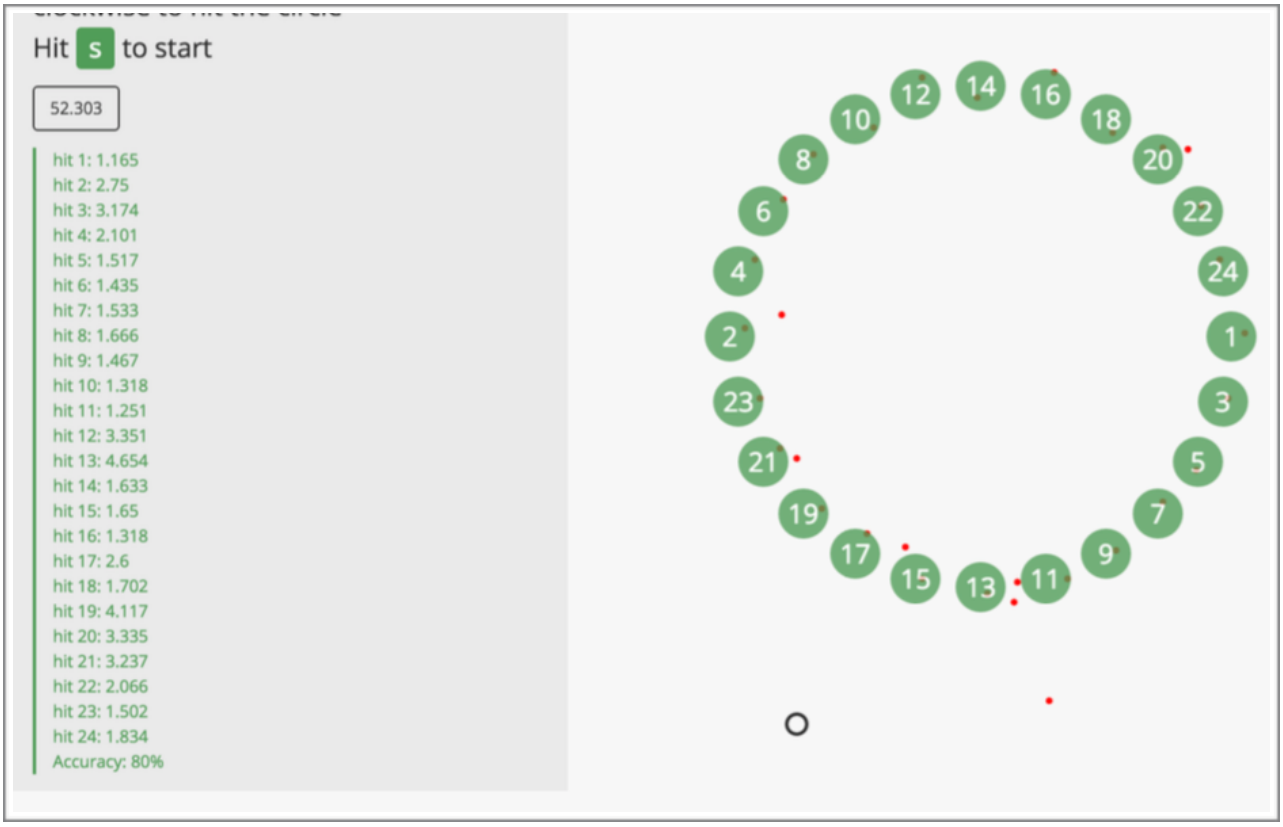


FIGURE 1. A SAMPLE SCREENSHOT OF THE EXPERIMENT SOFTWARE.

2.1.3 Procedure

The experiment consisted of 6 different Fitts' law tasks for each user. 2-dimensional Fitts' law tasks are used here, with 2 different A (target amplitude) values and 3 different

[3] "Analysis of the Accuracy and Robustness of the Leap Motion Controller". PubMed Central. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3690061/

W (width) values. The A values are 300 pixels and 400 pixels and W values are 30 pixels, 40 pixels and 50 pixels. Each task required the user to complete 24 clicks.

The experiment applies a within-subject design. For each task users have to complete it with both HR and Trackpad, so for each user there are 12 tasks required in total. Each task received a total of 24 trials and each interaction technique received a total of 144 trials. The tasks are assigned in random order for different users.

In the beginning of each study, I briefly described the coordinate system of Leap Motion and the way to interact with it. I also explained that the participants should click the circles in the order of the number label and the circle will turn green if it is correctly hit. I then asked the participants to play with the prototype and try 3 trials. This is because they have to go through 12 tasks (288 clicks) later and they might become too tired if they have done too many trials already in the beginning. All participants reported that they felt comfortable with HR after the 3 trials.

They were then asked to complete the tasks with either HR or traditional Trackpad as fast and accurate as possible. In order to start a trial, they should tap the “s” key on keyboard themselves whenever they felt ready. I don’t want the starting action be a factor to the results, so I simply used the keyboard here. The cursor was initially placed on the No.2 circle (See Figure 1 for the circle layout).

In the end of 24 tasks, a brief interview was conducted. Questions include:

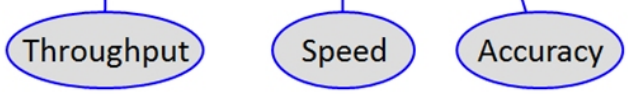
- What do you like and dislike about HR?
- Did you encounter any difficulty using it?
- How do you think HR can be improved?

2.2 Results and analysis

2.2.1 Throughput and accuracy

The throughput (TP) is calculated by the following equation [1]:

$$TP = \frac{\log_2\left(\frac{A_e}{4.133 \times SD_x} + 1\right)}{MT}$$



For each task with different W or A, A_e and MT values are the mean number of the corresponding values of the 24 trials and SD_x value is the standard deviation of the d_x values of the 24 trials. More calculation details are specified in [1]. Detailed results are shown in Figure 2 (left). HR achieved an average throughput of 1.229 (SD=0.100) while the number for Trackpad is 1.959 (SD=0.125). Trackpad is about 59% better than HR.

For both techniques accuracy is also recorded, as is shown in Figure 2 (right). HR has an average accuracy of 85.06% and Trackpad has an average of 98.72%, which is 16% better than HR. We can see that for each task, out of the 24 clicks interacting with Trackpad only made 1 or 2 errors, while with HR there are usually around 5 errors.

2.2.2 Target acquisition time and standard deviation (SD)

The average SD and speed values for each task with HR and Trackpad are shown in Figure 3 (SD on the left, speed on the right). We can tell that using Trackpad is significantly faster, and more stable. For the speed there is a peak in the W=30, A=400 task, since this task has the smallest target size and largest target distance. For this task HR also has a significantly high SD, while Trackpad doesn't. The speed with Trackpad seems to be not so easy to be affected by different W and A values compared to HR.

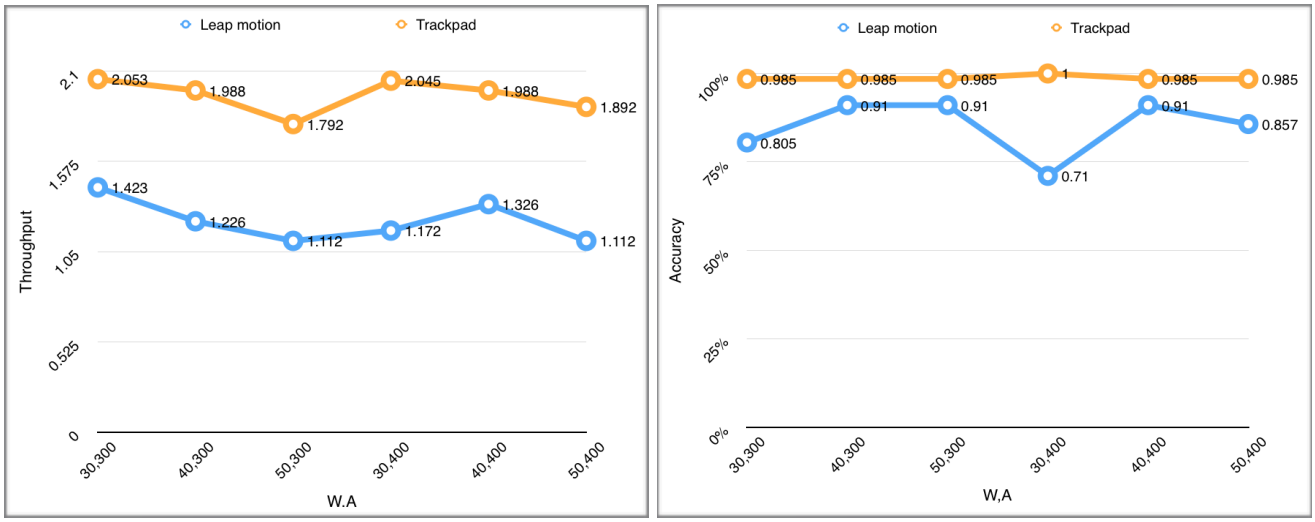


FIGURE 2. THROUGHPUT (LEFT) AND ACCURACY (RIGHT) FOR THE TWO INTERACTION TECHNIQUES.

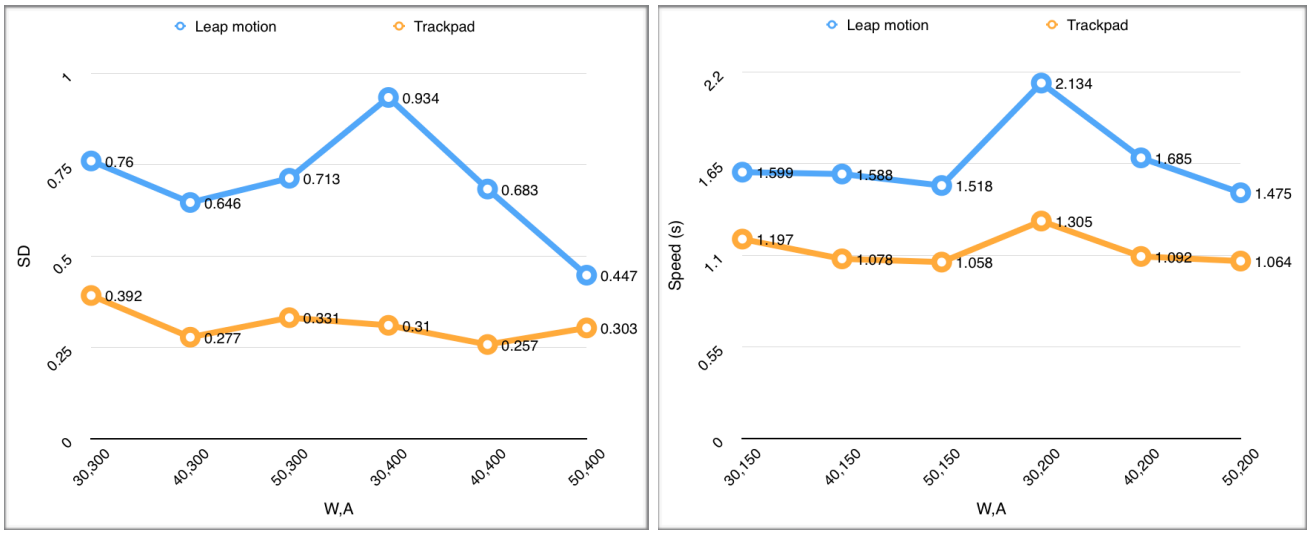


FIGURE 3. STANDARD DEVIATION (LEFT) AND TARGET ACQUISITION SPEED (RIGHT) FOR THE TWO INTERACTION TECHNIQUES.

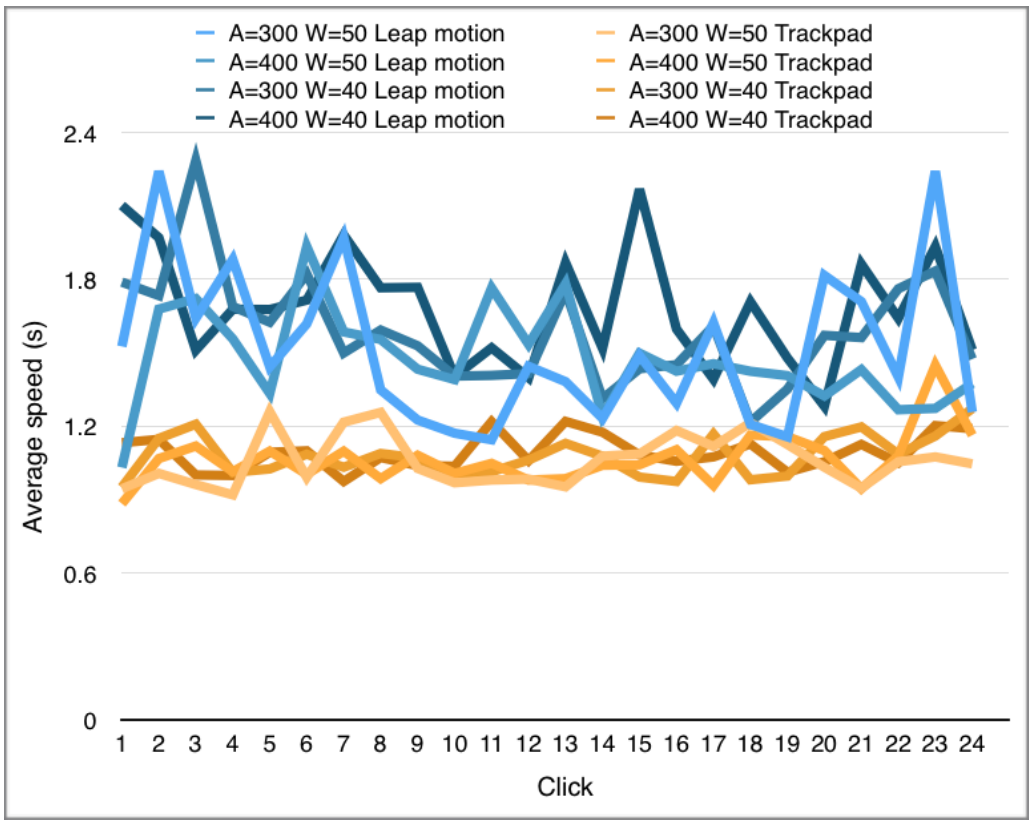


FIGURE 4. AVERAGE SPEED FOR EACH CLICK DURING EACH TASK.

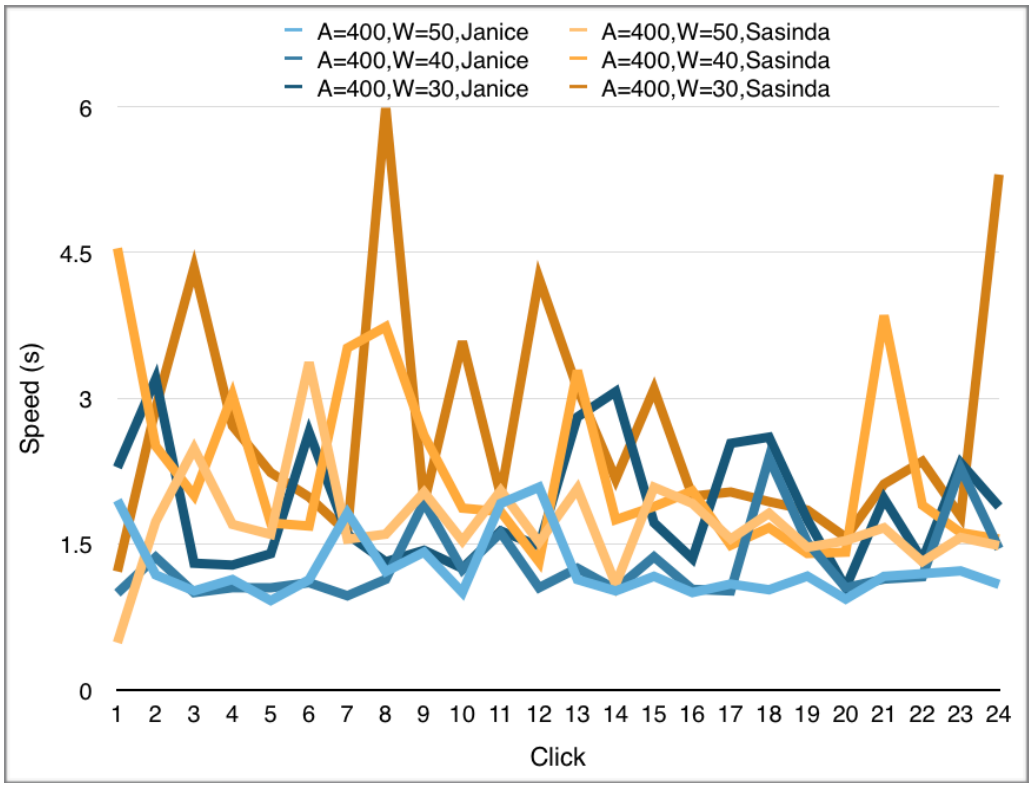


FIGURE 5. AVERAGE TARGET ACQUISITION SPEED WITH LEAP MOTION FOR EACH CLICK FOR EACH USER.

2.2.3 Discussion

Some other interesting observations from the data are the difference between targets in the task and the difference between users.

Figure 4 shows the average speed of users completing each of the 24 target acquisition tasks. From the graph, we can see that for HR, there is a peak in acquisition time for the 2nd, 15th and 23rd clicks. From some of the videos I found that users' hand block their sight when trying to move hand to the 2nd, 15th and 23rd targets. They either moved their head to find the target, or just kept trying clicking near the target, which leads to both lower speed and accuracy. On the other hand, the speed of Trackpad remains stable, since users' hand never blocks their sight in front of the screen.

After the studies I tried to solve this problem by placing the Leap Motion next to the laptop instead of in the front. However, after a few extra experiments I found that users naturally tended to point their hand to the screen. If putting Leap Motion on the side, there is a distortion of the x-y plane, which causes frustration to users when they couldn't get the cursor to where they wanted.

Figure 5 shows the performance data with Leap Motion HR from two users Janice and Sasinda, who have different Leap Motion experience levels. Janice has tried this prototype a week before, and has played with it for some time before the study, while Sasinda is completely new to the technology. As is shown in the graph, Janice completed the task in a significant shorter time, with a more stable speed. The difference becomes more obvious as the task becomes harder (W from 50 pixels to 30 pixels).

According to the interviews, Sasinda said he got very frustrated when keep failing clicking the target, and found the technique very hard to control. However Janice said the technique is very easy to use and she could always execute the correct action she wanted. This shows that even when the user reported they feel comfortable with the HR technique after several trials, practicing can still improve the results a lot. More experienced users generally have a better control of the technique.

3 Further discussion

From the experiment data, it seems obvious that the traditional Trackpad interaction technique is the winner. It has a higher throughput and also a higher accuracy. For each of the 6 tasks its target acquisition speed is significantly higher (lower moving time), and is more stable (lower SD). It is also less strenuous.

However, according to the interviews, users found there are also lots of advantages about the Leap Motion HR interaction technique. Thomas said he had a nice "sense of control" when using the Leap Motion. Xingxing said that he felt it is more "real" since it is a more natural mapping of the cursor position, and that he was also more physically involved in the interaction.

The studies took longer than expected. Each study took around 30 minutes. Participants often reported that they felt tired after the 12 tasks. Though I already counterbalanced

the experiment with a random task order, to better address this fatigue problem, for future studies I can possibly split the experiments into different sessions.

To conclude, the traditional Trackpad interaction is faster and more accurate, while Leap Motion hand rotating interaction is more fun and more engaging. These should be taken into consideration for different scenarios and they can both be very useful and effective interaction techniques.

References

[1] MacKenzie, I. S. (2015). Fitts' throughput and the remarkable case of touch-based target selection. Proceedings of the 16th International Conference on Human-Computer Interaction - HCII 2015 (LNCS 9170), pp. 238-249. Switzerland: Springer. doi: 10.1007/978-3-319-20916-6_23