Distance Effect: Where You Stand Determines How Promptly You Interact with Game

Xiaolong Lou, Andol Xiangdong Li, and Ren Peng

Dept. of Digital Media, College of Computer Science, Zhejiang University, Hangzhou, China
{dragondlx68,axli,pengren}@zju.edu.cn

Abstract. Interaction efficiency is an important concern in game playing, due to that it reflects the degree of how promptly users respond and dominates user experience. To understand the relationships between interaction efficiency and distance in motion-sensing games, this paper conducted empirical studies to assess user performance (mostly hand gesture movements) at various interaction distances. The results identify the existence of 'low point' at which users responded less efficiently, the range of 'low point' values was much smaller than that of usual distances as we selected though. Beyond that, interaction efficiency recovered quickly to a steadily high level with distance increase. The results implied the distance's direct influence on interaction efficiency in motion-sensing game playing, and it also shows new avenues to address the interaction efficiency in game playing according to standing distances. Furthermore, guidelines were provided to assist game developers to fully consider the role of distance.

Keywords: Interaction efficiency, game interface, hand track, distance effect, game balance.

1 Introduction

Motion sensing technology such as hand gesture detection provides new opportunities for human-computer interaction with more natural interfaces. In the domain of game playing, it transforms traditional interaction ways into novel ones by introducing 'motion-sensing game'. To date such interaction has been gradually acquainted by game players, to whom the interaction efficiency is constantly concerned at the first place. Since interaction efficiency has overwhelmed influence on game user experience, research in how to respond promptly and precisely with the new motion-sensing technology has gained increasing interests.

This paper is aimed at investigating the relationships between interaction efficiency and the distance in motion-sensing game playing. In order to understand how the distance at which the users stand influences the general interaction efficiency in game playing, empirical studies were carried out to observe and compare users' game performances. On the basis of that, the roles of distance were analyzed and the influence was summarized. More importantly, further implications were discussed thus to provide guidelines for future motion-sensing game development, and that also provided new perspectives for considering the distance in motion-sensing interaction design.

M. Kurosu (Ed.): Human-Computer Interaction, Part III, HCII 2014, LNCS 8512, pp. 614–621, 2014.

2 Related Works

2.1 Interaction Efficiency in Motion-Sensing Game Playing

Motion sensing technologies, especially hand gesture recognition are increasingly applied in interactive video games since 3D depth cameras such as the Microsoft Kinect sensor arose [1]. As a natural and intuitive interaction measure, the gesture begins to role as one of the most primary and expressive forms of operation mode [2]. Be regarded as a mechanism for interaction [3], interaction efficiency of gesture recognition affects user's manipulation experience in motion sensing games. According to Murthy and Jadon, for making a highly effective gesture recognition system, four principles are required: Robustness, Computational efficiency, User's tolerance and Scalability. To this end a superior interactive system with high interaction efficiency for game playing are also supposed to possess such principles appropriately.

As mentioned in other studies, gesture interaction concerns complex factors, including computer vision and graphics, image processing, learning mechanism, bioinformatics and human-related psychology [3]. The interaction efficiency can be affected by any of these factors. From hand gesture recognition algorithms' perspectives, there are well developed techniques to enable accurate gesture recognition for both experimental and commercial purpose. However, research in interaction factors (such as the distance) and responding behaviors is little. Therefore, in this paper robust algorithms were adopted to investigate the relationships between interaction efficiency and the distance. Such algorithms had three main tasks, including detection, tracking and recognition, which reflected the accuracy, efficiency and robustness of motion-sensing interaction respectively [4-7].

2.2 Distance-Related Optimization in Gestural Interaction

Despite the large amount of optimization algorithms regarding to the improvement of hand gesture recognition, factors concerning interaction behaviors, such as the distance between hands and display are still implicit in the specific domain. The fact is, as a complementary influential element, distance was focused in other traditional fields.

In research work of Lee, the relationships between distance and ambient conditions (such as the display size and illumination) was evaluated, and it revealed user's tendency (preference) of distance (in TV watching) according to various sizes and illumination intensity [8]. Another research by Shieh and Lee explored the satisfied distance by user under different conditions (light sources, ambient illuminations, and character sizes) in E-reading [9]. In other studies, the distance was assessed to reflect the accuracy of Kinect depth data in [10] and thus found the random error of depth measurement increases with distance increase, which lowered the recognition accuracy. However, these studies considered distance more as an ergonomic factor, from interaction efficiency perspectives the understanding is still preliminary.

The importance of distance in previous studies is claimed as an additional and inessential factor to algorithm effectiveness. As a result, the emphasis on the role of distance in motion-sensing interaction was insufficient. To date the progress of gesture recognition techniques have made the distance not only an ergonomic factor but also (only more importantly) a factor that dominates overall user experience. The increasing popularity of virtual competition -based game is a good example of that. As Jaffe et al. discussed in their work [11], the balance amongst game factors determines the depth, fairness and engagement of game playing. When it comes to motion-sensing game, such balance has not been well gained. So via comparisons of game playing at various distances, this paper raises the awareness of the relationships between interaction efficiency and distance.

3 Method of Study

An empirical study was conducted via observing and comparing interactions at multiple distances. The laboratory-based study evaluated the differences in terms of hand gesture movement. To highlight the distance as the solo variable, the study was carried out in forms of within-subject experiment.

3.1 Independent Variable and Dependent Variable

Independent Variable. The only independent variable in our study is determined by how far the subject stood away from the interactive object, namely the distance from hand to the display, which was captured by 3D depth camera in our study. As the hand moving freely during the experiment, the depth value is changing accordingly. Thus, the depth data captured for each test per subject is floating, and average values were calculated in data analysis.

Dependent Variable. Dependent variables in the study include the cursor moving speed. By hand tracking program, subjects' hand moving was tracked and drove the mouse cursor on interface. Thus, cursor's speed was the substitution of subjects' hand moving speed. As a result, a higher moving speed means accessing targets more quickly and interacting more promptly.

3.2 Subjects

There were 27 subjects (17 male and 10 female) recruited in the study with an average age of 25. All subjects were undergraduate students and Ph.D candidates from local universities and were recruited through campus BBS. All subjects had heard about motion sensing games before, but only 3 of them had experience with motion sensing interaction. They received $5 for their participation.

3.3 Apparatus

The experiment was conducted in a lab equipped with a wall-sized large display (70 inches: 1587mm × 975mm, resolution ratio: 1920 × 1280). A motion-sensing camera (ASUS Xtion PRO LIVE) was set underneath the display. The program drove the camera to track the subjects' hand gestures and make the mouse cursor to be bounded to move on the interface with hand moving synchronously. The program was also devised to record the depth data of hand constantly and the coordinate values of moving cursor per 30 mili-seconds.

3.4 Task

Searching 9 Targets in a Geographic Map. Given many other elements might affect users' performance (i.e., pervious researches proved that immersion affects gamer performance differently), the tasks were designed without any gaming mechanism to test the merely variable: distance. We prepared a geographic visualization contained 9 targets (Figure 1) to imitate the interaction. The 9 targets were visually noticable. Subjects in the study were instructed to retrieve these 9 targets and checked them by moving the cursor over these one by one.

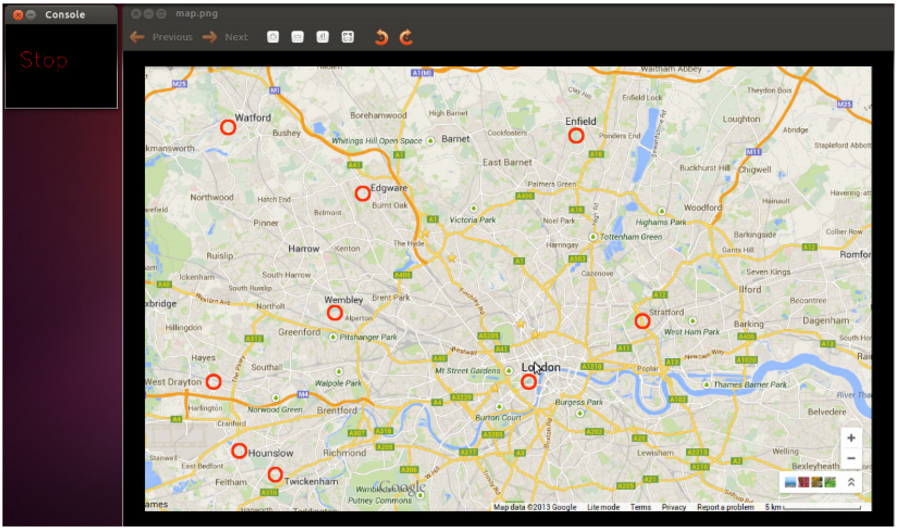

Fig. 1. Map contains 9 targets

3.5 Procedure

Subjects were asked to have a practice session after a briefly introduction of this study. Then, they were required to complete the experimental tasks. Each subject repeated the tasks three times at three distances respectively. Standing distances were limited from 800 millimeter to 2500 millimeter. Subjects were required to move the cursor to 9 targets orderly. The 9 targets were listed on the margin of the display to make subjects execute tasks more smoothly. For each subject, three standing positions were selected by themselves. Figure 2 shows a scenario of study. The study captured the hand depth and the coordinate values and saved these data to a TXT file. Our experiment collected totally 81 (27 × 3) data files. At last, 72 files were saved.

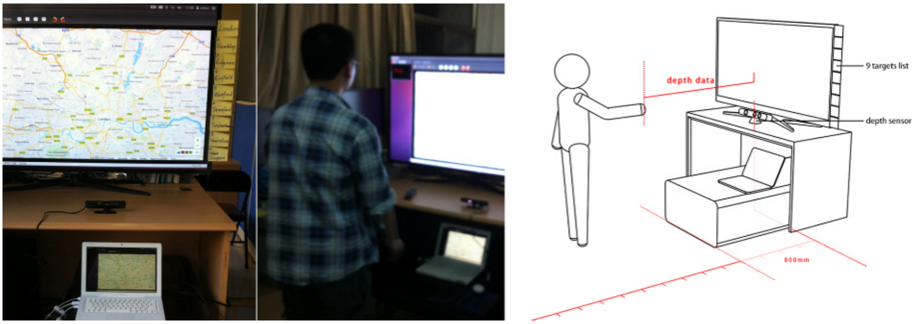

Fig. 2. Experiment scenario (the distance captured in this study is shown as 'depth data' above)

4 Results

Except 9 data files were captured or recorded incorrectly, other 72 data files from 27 subjects were maintained for analysis (Table 1). By SPSS, we calculated the distance (depth) and moving speed for each subject. For distance, it was calculated by averaging for each data file. For moving speed, the fastest forty percentage of movements were selected in the analysis, due to that this part of data directly reflected subjects' gestural moving.

As shown in Table 1, subjects performed differently at various distances, but some really tendentious implications were extracted: subjects tended to have lower interaction efficiency (slower movement) at a specific distance. The else distances corresponded to higher interaction efficiency. Statistical data from 23 subjects confirmed this implication (except for 4 subjects' data shown with gray bar chart in Table 1). As the green bars shown in the table, subjects (numbered as 03, 04, 05, 10, 16, 19, 22, 23) had relatively lower efficiency at the median distances. While other subjects (numbered as 06, 13, 20, 21, 25, 26, 27) got positive change in efficiency with distances increasing.

As shown in Figure 3, we draw a scatter diagram to visualize the statistical results. The black trend line validated the implications drawn from Table 1, there exists "low point" of distance where subjects interacted less efficiently. The "low point" lay near the value of 1000 millimeter, which is far less than distance users select in common use. This explains the difference between the subjects who were relatively less efficient under a median distance while the others got improving efficiency with increasing distances.

Besides, the distance element affected subjects' interaction efficiency differently. As shown in Figure 4, we selected 4 subjects' data randomly and calculated their trend lines. The trend lines revealed the differences among individuals. Comparing the participants numbered as 05 and 10, subjects numbered as 16, 22 performed more sensitively with distance changing.

Table 1. Distance (depth) and moving speed for each subject

Participant (Serial : Sex)	Distances (mm)	Mean Moving Speed (Pixels / Second)
01	1191.7	259.2
	1526.9	321
02	1220.9	287.5
	1481.2	215.5
03	676.9	286.4
	987.9	164.6
	1770.3	217.3
04	777.2	282.1
	1092.1	174.4
	1745	210
05	919.3	246.8
	1237.6	185.6
	1624.7	259.6
06	1156.5	191.2
	1595.2	238.2
	2180.5	279.5
07	1103	178.6
	1363.2	406.2
	1739.2	222.1
08	763.6	281.2
	1277.8	243
09	1438.5	244.8
	2003.1	605.4
10	994.5	367.9
	1334.5	324.3
	1810.3	357.4
11	1278.1	328.5
12	1108.5	205.7
	1312.4	326.1
	1704	261.7
13	1229.3	232.6
	1717.1	242.8
	2155.4	284.9
14	1139	410.3
	1531.8	319.4
	2034.5	286.1

Participant (Serial : Sex)	Distances (mm)	Mean Moving Speed (Pixels / Second)
15	1661.9	222.1
	1780.3	318.1
16	974.3	212.7
	1020.5	163.3
	1577.5	239.6
17	1369.1	288.7
	1986.6	672.7
18	1039.1	232.1
	1540.7	455.1
	2045	400.4
19	846.6	383.1
	1450.3	333.2
	1889	407
20	1061.5	278.4
	1312.2	282.7
	1528.7	345.3
21	1062.3	283.1
	1378.2	403.7
	1627.9	394.3
22	992.6	354.8
	1295.2	251.6
	1775.4	408.9
23	924.7	288.8
	1190	275.4
	1634.9	325.2
24	1247.4	209.2
	1584.9	325
	1947.5	186.7
25	656.3	381.9
	1178.6	451.2
	2286.6	560.8
26	985.9	218.3
	1590.9	230.5
	2025.6	262.8
27	910.9	195.8
	1304.8	255.2
	1642.8	307.5

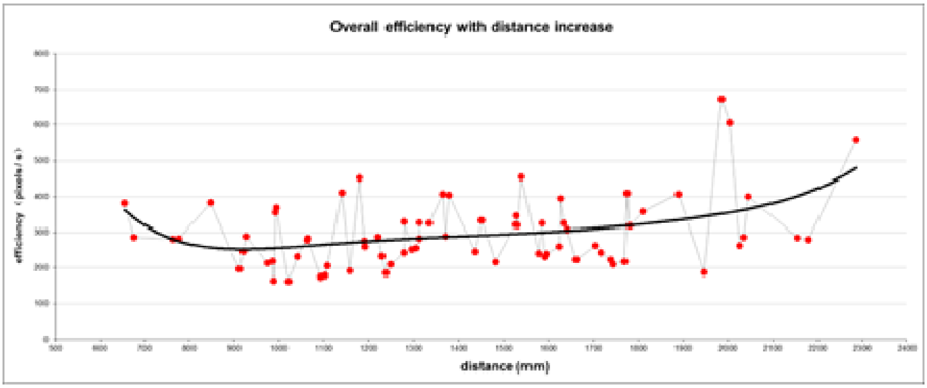

Fig. 3. Overall efficiency with distance increase

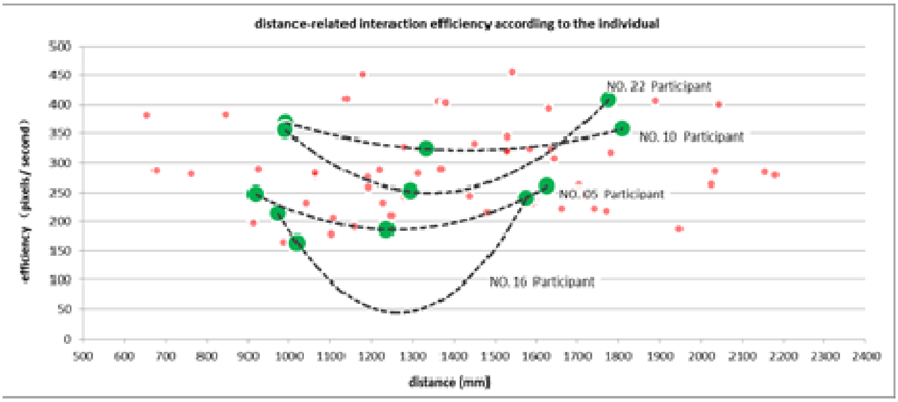

Fig. 4. Distance-related interaction efficiency according to individual subjects

Beyond the "low point", interaction efficiency improved with distances increase. This finding revealed that the distance affects interaction efficiency, greater distance helps subjects respond more promptly. This can be applied to optimize game player's interactions or to adjust the game balance when the players interact at different distances (see Figure 5). Two suggestions are provided for making equity between players or for optimizing operation agility merely.

1. A distance-adapted gestural detection algorithm can be developed to balance the distance gap. Different levels of optimization can be applied on user interface according to distance. The key of this algorithm is to connect the efficiency change mechanism with distance increase. But as Figure 4 reflects, individuals respond to distance changing with differences. Thus, the personalization determines how the distance affects interaction efficiency individually and the efficiency change mechanism should be carried out according to different users. This method balances games precisely, but individual-related optimization algorithms make the tracking program more complex. Since "personalization" exists in distance-efficiency connection, pre-test of efficiency under various distances is needed.
2. Another alternative suggestion is to supply a distance guide for game players. For instance, reminder can be presented on interface to guide players to stand at larger distance. Since the distance is changing dynamically for users may move during interaction, this method can not balance the distance factor between game players. But it can really be utilized to guide players to get better user experience by suggesting standing at a farther distance.

To sum up, these two suggestions suit for different conditions. The first offers precise balance for competitors, which is based on complex optimization algorithm recording to the individual. This will satisfy competitive game players with gestural interaction, in which there are strict requirements for game balance. As rough it is, the second suggestion can be applied to optimize interaction efficiency among the general public rather than to supply game balance, especially when game players get inferior achievements, user interface can guide them to enhance their operation agility by recommending standing farther.

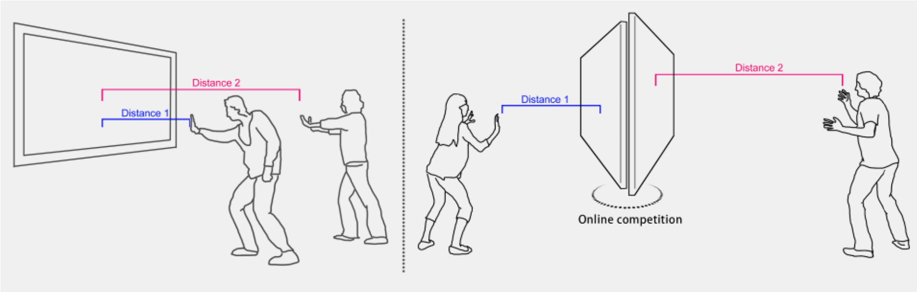

Fig. 5. Gamers compete at different distance (Distance 2 > Distance 1)

5 Conclusion

The study has explored user performance on interaction at various distances. The finding showed that the distance can be utilized to adjust game players' performances. From this root, suggestions are given to game designers that the players standing at a relatively greater distance can interact more promptly, which can be utilized to optimize players' operation agility and to supply a precise game balance mechanism for competition participants.

References

1. Zhengyou, Z.: Microsoft Kinect Sensor and Its Effect. IEEE MultiMedia 19, 4–10 (2012)
2. Wachs, J.P., Kölsch, M., Stern, H., Edan, Y.: Vision-based hand-gesture applications. Commun. ACM 54, 60–71 (2011)
3. Murthy, G., Jadon, R.: A review of vision based hand gestures recognition. International Journal of Information Technology and Knowledge Management 2, 405–410 (2009)
4. Rautaray, S., Agrawal, A.: Vision based hand gesture recognition for human computer interaction: a survey. Artificial Intelligence Review, 1–54 (2012)
5. Vo, N., Tran, Q., Dinh, T.B., Dinh, T.B., Nguyen, Q.M.: An efficient human-computer interaction framework using skin color tracking and gesture recognition. In: 2010 IEEE RIVF International Conference on Computing and Communication Technologies, Research, Innovation, and Vision for the Future (RIVF), pp. 1–6 (2010)
6. Zhu, Y., Xu, G., Kriegman, D.J.: A real-time approach to the spotting, representation, and recognition of hand gestures for human–computer interaction. Computer Vision and Image Understanding 85, 189–208 (2002)
7. Ren, Z., Yuan, J., Zhang, Z.: Robust hand gesture recognition based on finger-earth mover's distance with a commodity depth camera. In: Proceedings of the 19th ACM International Conference on Multimedia, pp. 1093–1096 (2011)
8. Lee, D.S.: Preferred viewing distance of liquid crystal high-definition television. Applied Ergonomics 43, 151–156 (2012)
9. Shieh, K.K., Lee, D.-S.: Preferred viewing distance and screen angle of electronic paper displays. Applied Ergonomics 38, 601–608 (2007)
10. Khoshelham, K.: Accuracy analysis of kinect depth data. In: ISPRS Workshop Laser Scanning, p. 1 (2011)
11. Jaffe, A., Miller, A., Andersen, E., Liu, Y.E., Karlin, A., Popovic, Z.: Evaluating Competitive Game Balance with Restricted Play. In: Proceedings 8th Artificial Intelligence and Interactive Digital Entertainment Conference, pp. 26–31 (2012)