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Study on Wiping Operation to Accelerate Human Activities on Hidden Object Game

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Abstract

An aesthetical image composition and mysterious stories are the main components of a hidden object game (HOG) to make it enjoyable. In an HOG, players find objects hidden in an image and inquired by a list. As far as we know, there have been insufficient studies to explore game elements such as the efficiency of game effects on an HOG to accelerate human activities. In this paper, we propose "wiping operation" to accelerate human activities for an HOG. In an HOG that we developed, first, an original image is transformed into a triangulated image. Then, during game play, the quickness of the wiping action by a player makes the level of detail of the triangulation finer and rougher. We did an experiment to investigate the performance of the wiping operation. Each player in the experiment wore a brain activity sensor to obtain a brain activity value during game play and answered a questionnaire after game play. We show the experimental results by the questionnaire and brain activity value to verify the effectiveness of the wiping operation.

1. Introduction

Hidden object games (HOG) are a subgenre [1, 2] of casual gaming. In HOG, a player must find objects that are hidden within a scene by a given hint. The hint is often the names of the objects. The games have a repetitive play, predictable storylines, enjoyments, etc. Aesthetical image composition and mysterious stories are used to make an HOG enjoyable. Therefore, exploring the efficiency of game effects on HOG is required to make an enjoyable HOG.

Measuring game enjoyment is a complicated task in the game research field. Some researchers correlated brain activity data and questionnaire data [3, 4] to measure game enjoyment. Thus, using brain activity data by electroencephalographic(EEG) system proved to evaluate a game enjoyment. If player's brain is active, the game enjoyment is higher [3]. Then, if some human operation to accelerate brain activity is able to introduce on HOG, it's operation becomes effective operation to enjoy HOG.

In this paper, we propose a new wiping operation ~~t~~ on an HOG. The wiping operation is applied to a triangulated scene image in which a player finds objects. This operation activates human brain and gives a player great enjoyment. To verify the effectiveness of the wiping operation, a brain sensor is used to measure a player's brain activity.

2. Related works

A hidden object game is a puzzle genre game in which players find the objects from the list that are hidden within a picture. From the given English name of the list of objects, the player finds them. A hidden object game is usually used for learning a new language, such as English. Playing the game to memorize a new vocabulary gave a significant result in those researches [5, 6]. Therefore, acceleration of human activities is necessary, since more effectiveness of HOG is required.

In those games [1, 2], more minor effects are used to make their game enjoyable. For example, the silhouette of an object or randomly shuffled English words of an object make HOG more challenging. In another way, the whole of a scene becomes ~~black~~ dark, and only an area on which a player moves a mouse becomes bright and visible. The player has to find ~~the~~ objects while moving the mouse to see specific areas as if the player gives light to the areas the player wants to see.

Even though there are insufficient studies exploring game enjoyment in Hidden Object Games, Michael Sailer et al. [7] stated game design elements address psychological needs and motivation even in non-gaming applications. At the same time, the benefits of developing a game based on player experience were indicated [8]. Therefore, to evaluate the game efficiency of human activity objectively, the Game Experience questionnaire [9] to measure new action on HOG is useful.

New developments in Brain-Computer Interface (BCI) using wireless electroencephalographic (EEG) system provide recordings and access to neuronal activity, enabling the computer to analyze information from brain waves. EEG data could be correlated to other physiological data measured during the experiment [3]. Enjoyment has been shown to be associated with user's motivation and intentions for media use including various games [10]. Some suggested [11] app-based exercises are useful in impacting cognitive enhancements using the XB-01 brain activity sensor. Despite its low price and portability, it is useful and reliable because of its robustness and efficiency [11]. Then our research introduces XB-01 as the brain activity sensor.

An arbitrary image transformation's attractive appearance often entertains the player visually. In some games, an object image is divided into tiles which are rearranged irregularly [12]. Typically, a target object is blurred [13] or mosaicked [14], such as triangulation and quadrilateral division. Triangulation is one of the typical image mosaic techniques, one of the Non-Photorealistic (NPR) techniques. Jonathan [15] developed a system to triangulate an original image. In the digital artwork by Miguel Chevalier [16], triangulation is one of the typical mosaic effects with various polygonal pieces. Triangulation is a well-known geometric technique used for multiple purposes such as image processing, 2D/3D modeling, physical/mechanical simulation, and graphic design. However, to accelerate human activity, triangulation HOG is not sufficiently evaluated.

3. Proposed method

To realize the wiping operation, we develop an HOG using a triangulation algorithm [17, 18] on our game as follows:

1. An original image is first transformed into an initial triangulated image. As each triangle is large in the initial triangulated image, it is difficult for a player to distinguish each object clearly.
2. If a player moves hands over the triangulated image during gameplay, the triangulation is refined in real time. Then, it becomes easier to distinguish each object. We call this effect by moving hands *wiping operation*.
3. If the player stops moving hands, the triangulation returns to the initial state gradually.
4. After a certain period, the refined part returns to its initial state. Then, it becomes harder to distinguish each object again.
5. The above 2 and 3 are repeated by the player's hand movement everywhere on the triangulated image.

3.1 Wiping operation

The wiping operation accelerates human activity on HOG. This operation refines the level of detail of a triangulated image by moving hands over the image, that is, wiping the image as if to wipe a misted window to see an outside scene clearer through the window. The refinement is locally applied to only the image part, which a player wiped. If a player moves hands over the image, triangles increase. Then, increased triangles decrease after a certain time. The demonstration of the game process is shown in section 3.2. In the increasing and decreasing progresses, we use incremental and decremental triangulation algorithms that reconstruct triangulation locally in efficient ways.

Triangulation

We used triangulation because of the low-cost as compared with other methods such as the blur effect. In other words, when using a blur filter, scaling the area takes more time than the Delaunay triangulation algorithm.

After the game starts, a player first sees the initial triangulated image generated by a Delaunay triangulation algorithm. The positions and kinds of existing objects are not recognizable in the initial triangulated image. During the game play, triangles are increased and decreased in real-time. The color of each triangle of a triangulated image is given by averaging the colors of the positions of the three vertex points on the original image. In Figure 1, (a) represents an original image, (c) shows a triangulated image, and (b) shows the wireframe of the triangulated image.

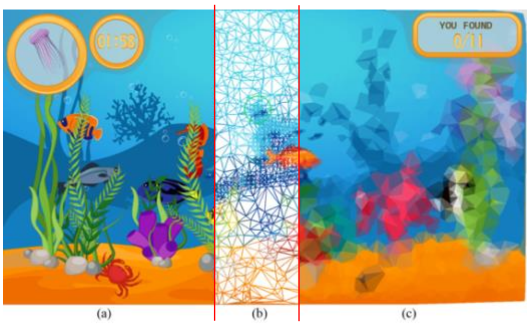

Figure 1:The triangulation of our game. (a) original image (b) wireframe of triangulation (c) triangulated image after filled triangles

The initial triangulated image is made using randomly generated *p=2000* points. In the image, the position where each object is located is unknown.

If a player moves a hand, basically, 20 points are added in a hand circle, whose center is the position of the hand, in each frame. For example, if the updating rate is 30 frames per second, 600 points will be added per second. If a new point *P(x,y)* is added to the triangulation, as shown in Figure 2(b), the triangulation is reconstructed locally, as shown in Figure 2(c). We used an incremental Delaunay triangulation algorithm in this process. Particularly, the simple stochastic walk algorithm [17] is used to obtain the location of the point in the triangulation. If the point already exists on the pixel coordinates *(x,y)* where a new point *P(x,y)* will be added, the new point is not added. In this case, less than 20 points are added. If all pixel coordinates in a hand circle are occupied by the existing points, any new points are not added.

The added points have lifetime during which they remain. The added points are deleted after *0.3* seconds from the time when the points were added. In the deletion process, the triangulation is reconstructed using the remaining points by the decremental Delaunay triangulation algorithm, which makes the triangulated image unrecognizable again. When the point *P(x,y)* is deleted, shown in Figure 2(c), from the triangulation, the triangulation is reconstructed using local points around the deleted point [18], as shown in Figure 2(a). The efficient local reconstruction in adding and deleting points makes our game lively in real-time.

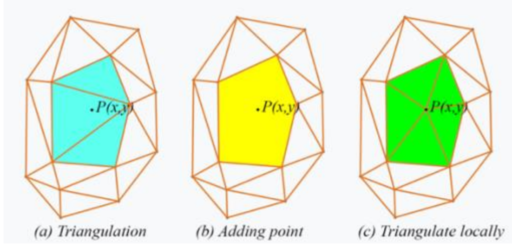

Figure 2: Local reconstruction of triangulation

More points are added if the player moves hands faster. As a result, the player sees a more recognizable triangulated image. In other words, the triangulated image works as an approximation of the original image. The detail of the original image gradually emerges by the player's hand motion, while the detail disappears after the lifetime of each point.

The triangulation is reconstructed repeatedly in real-time whenever points are added and deleted during the gameplay. The initial points are not deleted, which means that the initial triangulated image is recovered after adding no points for a longer time, as shown in Figure 4. An example of rough and fine triangulated images is shown in Figure 4. The wireframes of (c) and (d) are shown in (a) and (b), respectively.

3.2 Our game

Our game story is simple. The rule of this game is to find 11 randomly placed fishes from the tank in 2 minutes. As we demonstrated in section 3.1, a player first sees the rougher triangulated image where the positions and kinds of objects are unrecognizable. When the player refines the triangulated image, the player can see where and what objects exist. The finer and rougher changes in the level of detail of the triangulation are repeated by the wiping operation of the player during gameplay. Triangulation with fewer points looks rougher and makes objects more unrecognizable. Therefore, a player needs to move hands more quickly to find objects fast. As shown in Figure 3, a finer triangulated image (c) looks more recognizable than a rougher triangulated image (b).

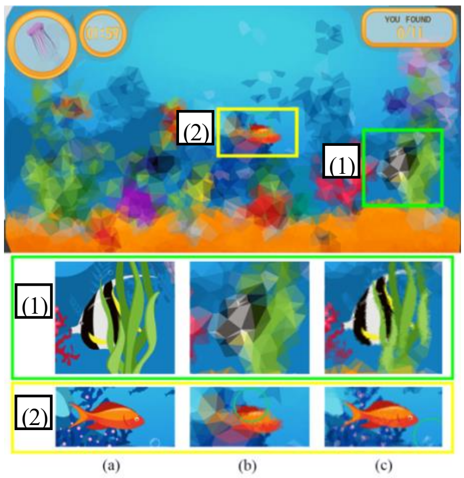

Figure 3: An example of rough and fine triangulated images. (a) An original image. (b) A rough triangulated image. (c) A fine triangulated image.

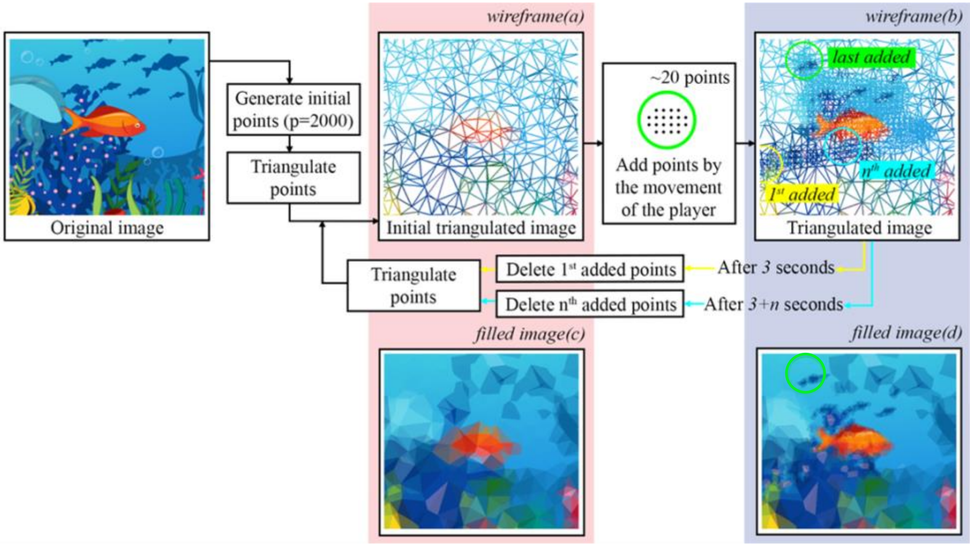

Figure 4: Triangulation process. (a) wireframe of a rough triangulated object (b) wireframe of a fine triangulated object (c) a rough triangulated object (d) a fine triangulated object.

4. Implementation

We developed our game in two environments: *hand-game* and *mouse-game*. In hand-game, an image is projected on a wall, and a player plays by moving hands in front of the wall. The player's body movement is captured by a Kinect sensor, as shown in Figure 5(a). In mouse-game, a player plays a game on a personal computer by holding a computer mouse, as shown in Figure 5(b).


(a) (b)

Figure 5: Game environments (a) Hand-game (b) Mouse-game

To measure brain activity, a player wears a headband with a brain sensor, XB-01 sensor, during game play, as shown in Figure 6. We will describe it and compare both games' results in section 5.2.

Figure 6: XB-01 brain sensor in a headband. A sensor must be placed in the upper area of the left eye.

4.1 Interfaces of our game

The main components of the interface of our game are shown in Figure 7. The components are the same in hand-game and mouse-game. They are as follows: (1) A current target object to find is queried by showing its original image. Even if there is more than one target object to find, the objects are queried one by one after each object has been found. (2) The time indicator shows the remaining time to find target objects. Limiting playtime excites the competitiveness of a player. The player is usually given a task to find more than one target object within a limited time. (3) The number of objects the player has found is indicated.

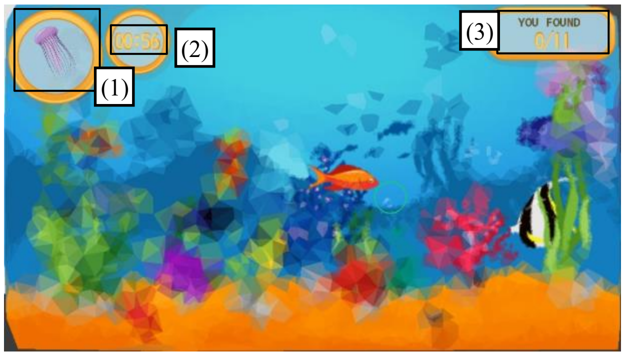

Figure 7: Interface of our game. (1) A target object to find. (2) Time indicator. (3) Counter of found objects.

4.2 Hand-game

The game screen is projected on the wall by a projector, as shown in Figure 5(a). A player interacts with a game to find each object, fish, by moving both hands in front of the projected game screen.

First, if a player wants to find an object, fish, the player has to refine the image to know where it exists. The player moves hands on a specific image area where the object to find seems to exist, which results in refining the triangulation of the area. The Kinect sensor captures the hands' motion, and approximately 20 points are added to each hand position as described in Section 3.1. In the game screen, the positions of the hands are represented by green circles, as shown in Figure 8. If the player wants to find an object, the player needs to move hands faster and not stop.

Second, if the player thinks that the object has been found on a certain position, the player grips a hand on the position as if to grab a real fish. The player can grip each hand.

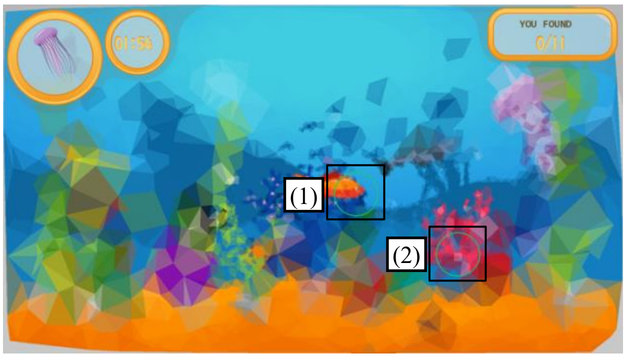

Figure 8: Interface of hand-game. Green circles (1) and (2) represent left and right hands respectively

4.3 Mouse-game

The game is playable by a mouse on a computer screen, as shown in Figure 5(b). The green circle represents a mouse position, as shown in Figure 9.

First, if a player cannot recognize the object to find, the player moves the green circle by moving the mouse over the image area in which the object seems to exist. While the player moves the green circle, approximately 20 points are added around the green circle.

Secondly, if the player thinks the object has been found on a certain position, the player clicks the left button of the mouse on the position. If the object does not exist in the position, 5 seconds are reduced from the remaining time.

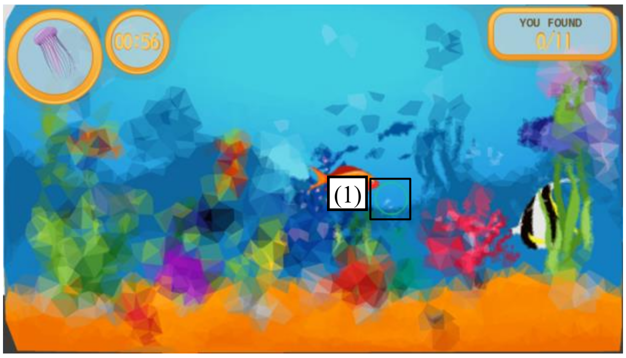

Figure 9: Interface of mouse-game. Green circle (1) represents a mouse position

4.4 Game without wiping operation

In order to evaluate wiping operation, we developed other two games for comparative experiments to the hand-game and mouse-game with wiping operation explained in sections 4.2 and 4.3. These games also use triangulated images generated from an original image and reconstruct the triangulation. However, the way of the reconstruction is completely different. In these games, the game screen has a refine button. If a player presses the button, the triangulation is refined globally by adding new points randomly over the whole image. After starting from an initial triangulated image, the player can press the button anytime in the playtime and several times. Every button press adds new points and the triangulation is refined gradually. One button press reduces 5 seconds from the remaining time. The local reconstruction of the triangulation by wiping operation is replaced with the global reconstruction by button press, and other game features are the same as the hand/mouse-games explained in sections 4.2 and 4.3. We call the games explained in sections 4.2 and 4.3 *hand/mouse-games with wiping operation*, and the games explained in this section *hand/mouse-games without wiping operation*.

5. Experiments

We did an experiment to investigate the performance of our new action, wiping operation, by showing how it accelerates human activities on our hidden object game.

We did a survey for 26 players after playing the game. Among them 16 players played the mouse-game while 10 players played the hand-game. 22 players were students aged between 16 and 25, and 4 players were aged between 25 and 36.

We asked the following questions to measure the player's gaming skills. Table 1 shows that 22 players answered they play games frequently: a month(7), a week(10), and daily(5). Approximately 84% of the players have game enjoyment in daily life.

Table 1. Result of the Question “How frequently do you play games?”

Frequency of playing game	Player
Daily	5
Several times a week	10
Several times a month	7
Several times a year	2
Not at all	2

Table 2 shows the players' desire for game playing. 21 players, that is, approximately 80% of the players like to play games. This result implied the players have a taste of game to measure its enjoyment.

Table 2. Result of the Question “Do you like to play video and/or computer games?”

	Very much	Somewhat	Not really	Not at all
Players	7	14	4	1

The last question was asked to measure the player’s experience in a hidden object game. Only 2 of the players had never tried this type of game before.

Overall, the above results showed 26 players had any experience in any type of game, which means they can value game enjoyment.

5.1 Questionnaire result

Enjoyment is a commonly stated reason why people play games and why people are active. Therefore, we did a survey using game experience questionnaire, GEQ [9], to measure the enjoyment.

Immediately after the game play, all players completed the GEQ. The questionnaire has 7 factors: *negative affect, tension/annoyance, competence, challenge, sensory and imaginative immersion, flow,* and *positive affect*. Each factor consists of 2 questions and there are totally 14 questions as we mentioned in Appendix. The questions measure the player's feeling statement by five-point scores ranging from 1 (not agreeing) to 5 (strongly agreeing).

Among 7 factors, "negative affect" and "tension/annoyance" are negative questions. That is, lower scores mean better evaluation. Other factors have positive questions, and higher scores mean better evaluation.

Figure 10 shows the questionnaire result of the mouse-game. Each player played both of the mouse-games with and without wiping operation. Then, the player filled in the questionnaire for each game. In Figure 10, for each factor, the scores of all questions of the factor for all players are averaged. As a whole, "negative affect" and "tension/annoyance" are given low scores, which means that the games are given good evaluation. Other factors are given high scores, which are higher than 3. This also means good evaluation. After this, we consider 5 factors other than "negative affect" and "tension/annoyance". The game with wiping operation is given higher scores than the game without wiping operation for all factors. Especially, "competence" has larger difference, which is approximately 0.66, than as comparing other factors. The scores of "competence", "sensory and imaginative immersion", "flow", and "positive effect" are more than 4.

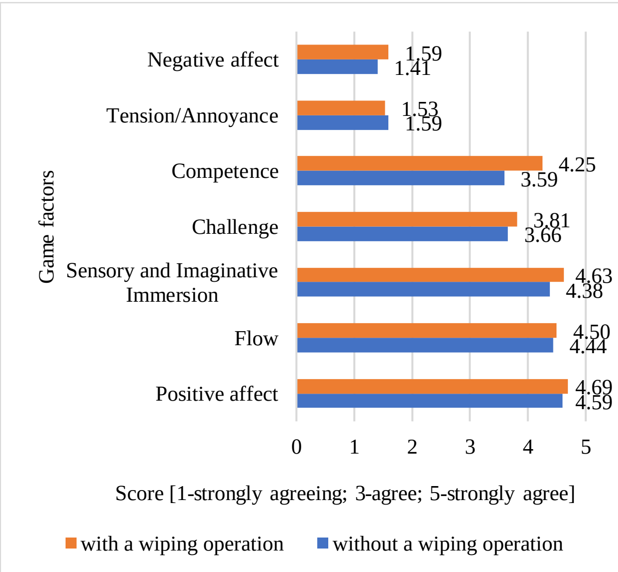

Figure 10: Questionnaire result of mouse-game

Figure 11 shows the questionnaire result of the hand-game. The questionnaire was filled in after the gameplay in the same way as the mouse-game. In the same way as the mouse-game, "negative affect" and "tension/annoyance" are given low scores and other factors are given high scores. This means that our games are given good evaluation. After this, we consider 5 factors other than "negative affect" and "tension/annoyance". The game with wiping operation is given higher scores than the game without wiping operation for all factors. Especially, "challenge" has larger difference, which is approximately 0.65, than other factors. In the hand-game, the player moves hands actively when moving their body parts. Thus, this play style might make the player improve the challenging spirit [19, 20]. The scores of "sensory and imaginative immersion", "flow", and "positive effect" are more than 4.

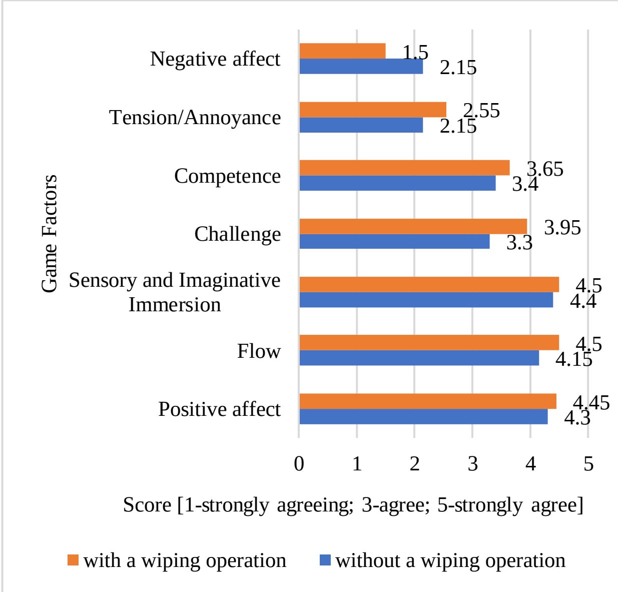

Figure 11: Questionnaire result of hand-game

Comparing Figure 10 with Figure 11, the score of "tension/annoyance" in the hand-game is much higher than that of the mouse-game. In the hand-game, players need to move not only hands but also other body parts. We consider that some players felt tense. Besides, the hand-game uses a Kinect sensor and it sometimes fails to capture a player's hand motion exactly. In such a case, we consider that the player felt annoyed. In addition, the score of "competence" of the mouse-game was much higher than that of the hand-game. The questions of "competence" ask the players whether they felt skillful and played the game successfully. Considering the play style of the hand-game by capturing the player's hand motion using a Kinect sensor, the hand-game must be difficult to play successfully than the mouse-game which is controlled easily by a mouse.

To examine the game factor differences between the game without wiping operation and with wiping operation, we conducted the Wilcoxon signed rank test, which is a non-parametric statistical hypothesis test. Test results are shown in Table 3. For the Wilcoxon test, a p-value is a test statistic probability that implies a difference in the data distribution. If the probability is below 0.05, it is indicated that there is a significant difference in data.

Table 3 reveals a significant difference between the game with wiping operation and without wiping operation, $p = 0.031$, for the mouse game. This means players were more likely to enjoy when they were playing a mouse-game with wiping operation. On the other hand, the p-value, $p = 0.156$, for the hand-game does not show a significant difference. When some players played the hand-game, the Kinect sensor was out of control when they went far from the play space. We consider that, in such a situation, the players must have been frustrated or irritable. Thus, we infer that the Kinect sensor's response problem was one serious reason for the high score of tension/annoyance factor and made p-value high.

Table 3. The probability result of questionnaire result

	Mouse-game	Hand-game
	p value	
Without wiping operation With wiping operation	0.031*	0.156

$p < .05$

5.2 Brain activity result

During the gameplay, the player wore a headband with a XB-01 brain sensor over the left eyebrow on the forehead. The sensor was connected to an iPhone using Bluetooth for data collection. XB-01 measures real-time brain activity, by blood flow volume during the exercise program. After the gameplay, the application of XB-01 gives us one brain activity value by the score from 0 to 100; 100 means brain activity is the highest while 0 is the lowest.

Figure 12 and Figure 13 show the brain activity result of the mouse-game and hand-game. The horizontal value represents the players' numbers while the vertical value represents their brain activity values. In Figure 12, the game without wiping operation has the maximum 53 and the minimum 18, and the game with wiping operation has the maximum 70 and the minimum 29. Among 16 players, 4 players have higher values for the game without wiping operation, 7 players have higher values for the game with wiping operation, and 2 players have the same values. Among 10 players with higher values for the game with wiping operation, the player 13 has the highest score, 70, in the game with wiping operation, and also has the largest difference, 36, between the games with and without wiping operation. The player 2 has the second highest score, 62, in the game with wiping operation, and has the second largest difference, 29, between the two games. Among 4 players with higher values for the game without wiping operation, the player 8 has the highest score, 52, in the game without wiping operation, and also has the largest difference, 10, between the two games. As a whole, large number of the players tend to have higher scores in the game with wiping operation, and some players have large differences between the two games.

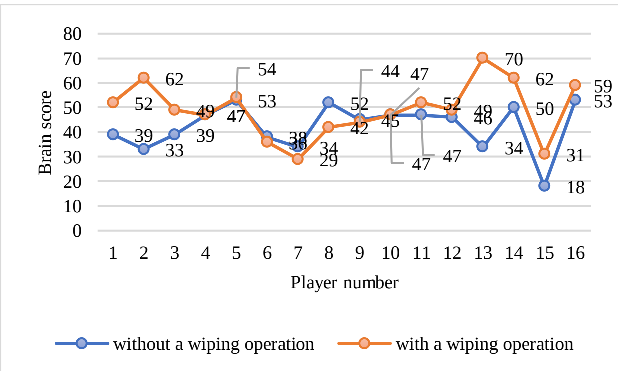

Figure 12: Brain activity result of mouse-game

In Figure 13, the game without wiping operation has the maximum 52 and the minimum 38. The game with wiping operation has the maximum 75, and the minimum 42. Among 10 players, 1 player has higher values for the game without wiping operation, 6 players have higher values for the game with wiping operation, and 1 player has the same values. Among 8 players with higher values for the game with wiping operation, the player 9 has the highest score, 75, in the game with wiping operation, and also has the largest difference, 30, between the games with and without wiping operation. The player 2 has the second highest score, 62, in the game with wiping operation, and has the second largest difference, 21, between the two games. The player 8 is the only player who has higher score, 52, in the game without wiping operation, and the difference between the two games is only 1. As a whole, most of the players tend to have higher scores in the game with wiping operation, and some players have large differences between the two games.

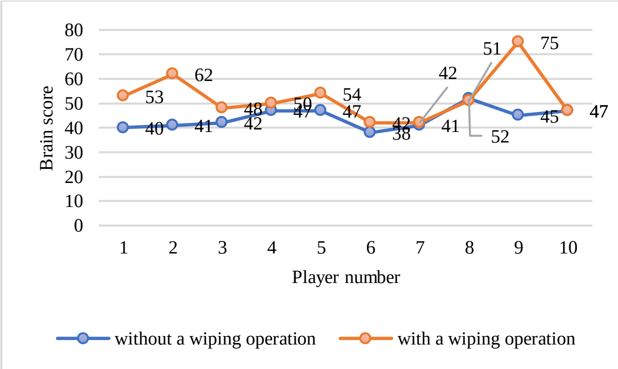

Figure 13: Brain activity result of hand-game

Table 4 provides the probability result of the Brain activity. The differences between the game without wiping operation and with wiping operation on both of the mouse-game, $p = 0.035$, and the hand-game, $p = 0.015$, are significant because the p-values are lesser than 0.05. As a result, the wiping operation gave more enjoyment to players while they were playing the game with it. From the questionnaire and brain activity results in the experiment, the wiping operation accelerates human activity and gives more enjoyment to players in hidden object games.

Table 4. The probability result of brain activity

	Mouse-game	Hand-game
	p-value	
Without wiping operation With wiping operation	0.035*	0.015*

$p < .05$

6. Conclusion

This paper presented the wiping operation, to accelerate human activity on a hidden object game. In the games to find objects in a triangulated image by mouse and hands, the wiping operation works well to activate human brain efficiently. By the Wilcoxon test analysis, the brain activity data showed significant differences between both of the mouse and hand games without and with wiping operation and the effectiveness of wiping operation. In addition, the questionnaire result of the mouse-game also showed the effectiveness of wiping operation. However, the questionnaire result of the hand-game was not an expective result mainly due to the limitation of the Kinect sensor's sensing range. Overall, the wiping operation is highly effective on HOG as we hypothesized. In the future, we need to investigate the effect of the wiping operation more. In addition, we are planning to apply the wiping operation to other types of games.

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Appendix

Game Experience Questionnaire

	Questions	**Game factors**
1	I was interested in the game's story	*Sensory and Imaginative Immersion*
2	I felt successful	*Competence*
3	I felt bored	*Negative affect*
4	I found it impressive	*Sensory and Imaginative Immersion*
5	I forgot everything around me	*Flow*
6	I felt frustrated	*Tension/Annoyance*
7	I found it tiresome	*Negative affect*
8	I felt irritable	*Tension/Annoyance*
9	I felt skillful	*Competence*
10	I was fully occupied with the game	*Flow*
11	I felt content	*Positive affect*
12	I felt challenged	*Challenge*
13	I had to put a lot of effort into it	*Challenge*
14	I felt good	*Positive affect*