DOI 10.34658/9788366741102.8

Hand gestures as a method of interaction in virtual reality HOPA games

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Abstract. *The main objective of the study was to implement the intuitive gesture set for movement and interaction in a virtual HOPA game. A review and analysis of existing solutions using the Leap Motion device to track gestures and hand movements was conducted. Two sets of movement modes were created and subjected to a series of tests to determine the best optimal movement and interaction technique. The tests were verified in terms of speed and accuracy of task performance.*
Keywords: *computer games, virtual reality, gestures*

1. Introduction

Although virtual reality has been around for a long time, in recent years it has undergone a renaissance in popularity. The combination of goggles with motion controllers allows users to immerse themselves in the VR environment and interact with virtual objects or other people in a natural way [1, 2, 3, 4, 5]. This has led to intensive development in the areas of hardware and applications supporting virtual reality. Players are demanding more and more realistic and modern gameplay solutions that produce stronger emotions. Developers are trying to come up with revolutionary solutions for controlling and interacting without restricting the users' freedom of movement by using gesture, eye or body movement recognition [6].

The aim of this work is to create and implement a set of gestures as an intuitive solution for movement and interaction in a virtual HOPA (Hidden Object Puzzle Adventure) game. Two sets of gestures have been tested using the Leap Motion device, which enables hand tracking. It will be determined which set is most optimal for movement and accurate when performing interactions. The game was developed using the Unreal Engine and Oculus Rift goggles.

2. Related Works

In order to create the most optimal ways to control using hand gestures articles presenting research on the use of Leap Motion in a virtual environment were studied.

In the paper [7], locomotion using LeapMotion, a game controller, and such based on gaze were compared. Users had to perform two locomotion tasks in virtual reality from a first-person perspective. The first test involved following a path in an open space, while the second involved finding a red vase in eight prepared houses. The speed of the task was evaluated, as well as the users' sense of comfort based on a questionnaire. The designed movement with Leap Motion consisted of a set of three gestures :

— Start - Opening both hands started the movement.

— Stop - Closing both hands ended the movement.

— Change of speed - The number of raised fingers indicated the speed.

— The tilt angle of the right hand was mapped to the rotation of the avatar.

The results presented showed that gesture-based controls performed better than gaze-based controls in terms of speed of task completion. Using Leap Motion, users had greater accuracy over their movement trajectory. It also didn't require them to hold a physical device, so they had more freedom of movement. However, moving with a controller performed best in terms of both speed and comfort.

Another article presenting the state of the art and ongoing research is [8]. It presents a gesture-based movement method using Leap Motion and compares it to game pad control. The tests involved a group of people who had no prior experience with the Oculus or Leap Motion, but who played first-person shooters using a mouse and keyboard. Users had to navigate two scenes using both modes of movement. The variable they evaluated was how long it took to move the avatar from the beginning to the end of the level. The solution that was presented for Leap Motion consisted of three types of gestures on the outstretched hand:

— Moving forward and backward - if the user wants to move their avatar forward he raises his hand in front of his face with the palm facing forward. To move backwards turn the direction of the hand towards the user.

— Step to the left and to the right - in this control, the user does not turn but makes a step to one side while facing forward. To do this you need to move to the left or right.

— Stop - in order to stand still, the user can keep his hand clenched or remove it from the Leap Motion view.

The results showed that the average time in seconds in hand gesture control was lower than when using the pad in the test scenes presented. Even when there were some hand detection instabilities caused by the device.

The article [9] was then analysed. It describes the creation of a set of gestures, which, thanks to Leap Motion, can be used to operate computer games in a first-person perspective. Pointing gestures were chosen for their simplicity. The set of gestures they presented consisted of three key movements:

— Front - user right hand with only index finger straight. Rotation view in the game is controlled by tilting your finger in the direction you want to turn.

— Backwards - the user may perform a backwards movement manoeuvre by clasping the hand and straightening only the thumb. It is not possible to turn while moving backwards.

— Stop - the gesture causing the user to stand still in the scene is a combination of the forward and backward gestures, which negates them.

The developers of this article claim that their gesture base can be expanded as needed to allow in-game jumping or shooting. This can be achieved by tracking the horizontal position of the hand and making a gesture to raise it higher.

3. Methodology

Based on the solutions outlined above and analysing the gestures in order to support movement in the game and to provide the functionality of collecting objects, it has been determined that the following gestures will need to be implemented:

— moving forwards,

— moving backwards,

— grip.

To reduce the likelihood of simulator sickness, the user will move through the game at a uniform speed with no possibility of acceleration or deceleration. The gameplay will take place in a room space, which by the rich placement of various types of objects will encourage him to stop and explore locally. In order to maintain precision and facilitate the user's orientation in space, movement will consist of smooth transitions.

In order to create optimal controls in the HOPA game, we implemented two sets of gestures for moving and picking up objects. Pointing is a natural and easy to understand gesture for humans. Therefore, the first set of gestures was based on controlling with the index finger of the right hand. Straightening it moves the user forward, and the angle of the finger corresponds to the rotation of the camera view [Figure 1]. Picking up objects in real life usually requires the hand to be stretched out. When the hand comes into contact with the desired object, it is instinctively clenched. This is the most intuitive gesture for humans to grasp. For this reason, clenching the hand is responsible for lifting objects in the virtual reality of the game.

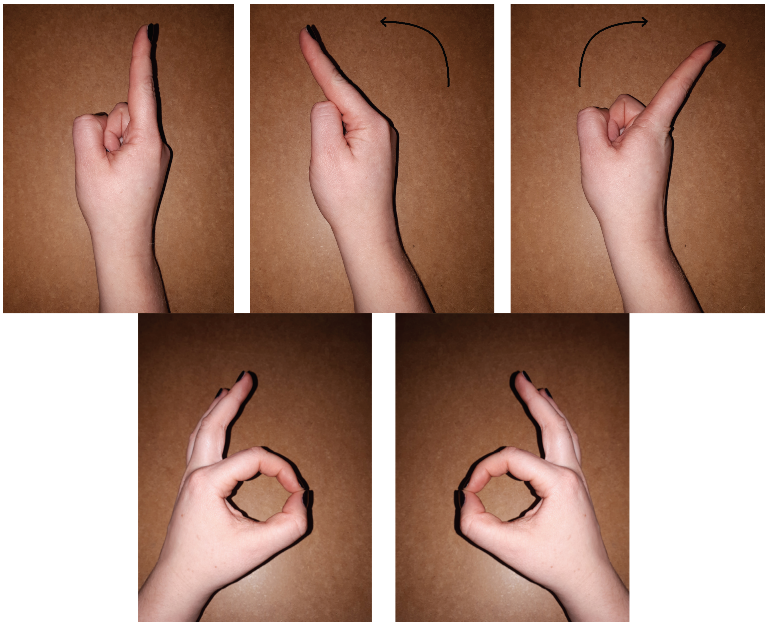

Figure 1. In the top row the first set of gestures. In the bottom row the second set of gestures.

The second designed set of gestures is based on using the basic gestures supported by the Leap Motion plug-in. A pinch gesture is used, which is very unlikely to be done by accident. As with the first set of gestures, to walk forward the user uses their right hand and moves in the direction they are looking. In contrast, use the pinch gesture of your left hand to walk backward [Figure 1]. In this set the approach to picking up objects has a more virtual character. The grab gesture is still used however a head pointing method is used to select the object the user wants to interact with [10]. Head pointing was implemented by drawing a small pointer in the centre of the field of view. The user places the cursor on the object of interest and signals the desire to interact with it.

4. Procedure

The tests were conducted on a group of 12 people, half of whom had previous experience with virtual reality and the Oculus Rift. Each subject tested both sets of gestures. For the analysis of the implemented movement gestures 4 test levels and one final level were created. All visible on Figure 2 and on Figure 3.

Test Level 1 was designed to get users accustomed to gesture-based movement. It consisted of a maze in which players had to go from a starting point to an end

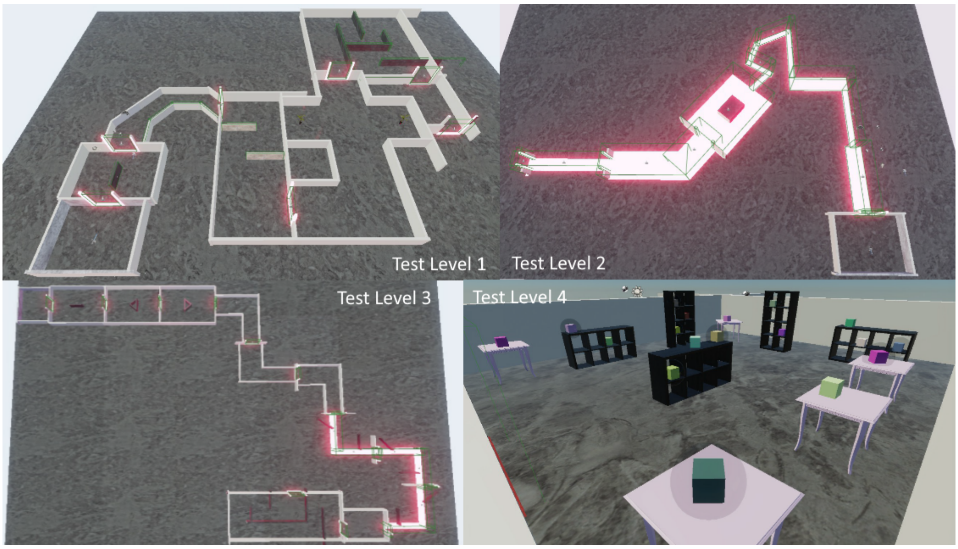

Figure 2. All test levels. Levels 1 to 3 - top view. Level 4 player's perspective view.

point. Each stage was followed by gates that counted the time taken to complete it. At the beginning of each test level there was a room where the user could put on the equipment and get used to using gestures. After passing through the first gate, the time counting began. In addition to the time, the number of touches on the walls was counted.

Test Level 2 was designed to test the accuracy of gestures. Users had to move on a specially created path. In addition to measuring the time taken to complete the level, the number of times players had to leave the path and the time taken off the path was also counted. At the final stage there were 3 gates of different sizes, on which the user was checked if he or she would pass through them without touching them.

Test Level 3 introduced three different speeds of movement. It consisted of 9 sections where the speed changes from the slowest to the the fastest and then from the fastest to the slowest. At the end of the level there was a room where users could stop and choose the most appropriate way of movement to go through the final maze. The designed level consisted of a series of turns, obstacles and paths presented in previous tests. The aim was to see which speed users thought was best for navigating the virtual scene.

To test the interaction gestures, a Test Level 4 was created in which 20 identical objects were placed. The users had to find and collect all possible objects. In this

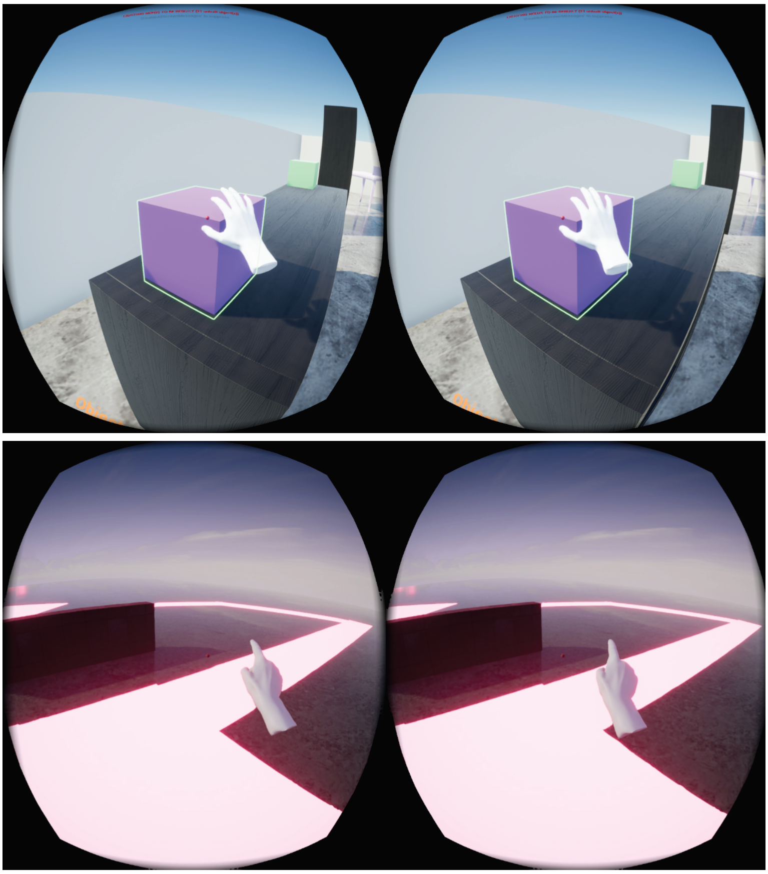

Figure 3. Screen shots from the Test Levels.

task, the time in seconds it took users to find all the objects and the number of grab gestures performed were counted.

In a HOPA game, a very important element is the environment and the objects hidden in it [Figure 4]. In the designed test fragment of the game there was a list of 9 objects that users have to find. To make the task easier, the list was displayed by looking downwards. In HOPA games, some objects are not immediately visible but are hidden in the scene.

Users must perform additional actions or solve puzzles to collect them. The level created was tested in terms of how quickly all items could be found. Because two sets of gestures were tested, two identical rooms were created with different arrangements of objects to interact with. As a result, users playing the game a second time had to search for the items anew.

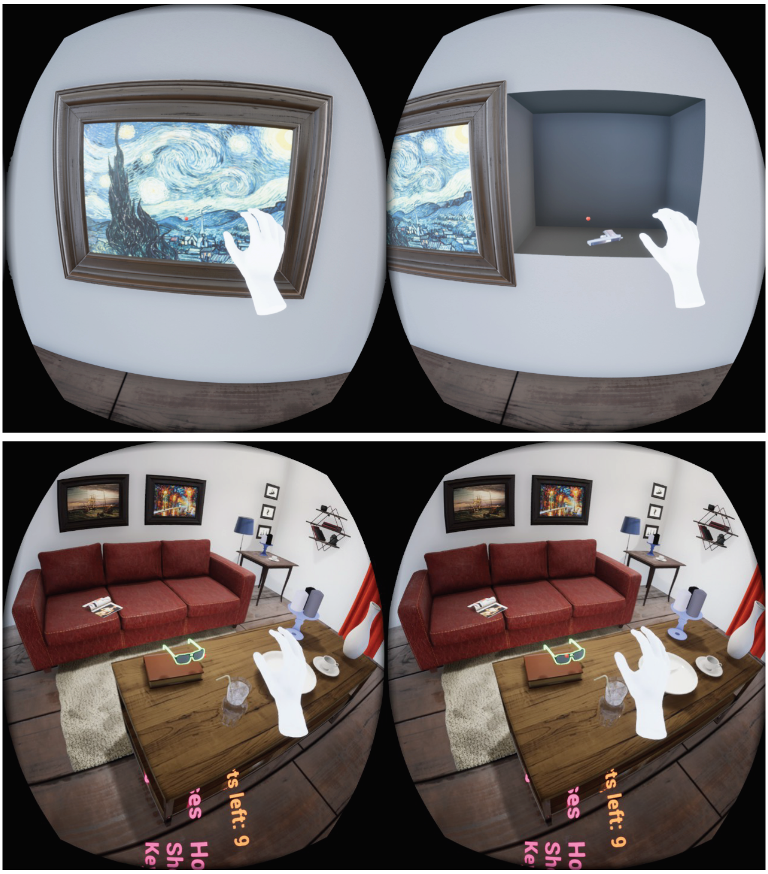

Figure 4. Screen shots from the designed final level.

5. Results

All results can be seen in the table [Figure 5].

In Test Level 1, the first set of gestures proved to be faster in terms of transition. However, the differences in average times were small - by 5.30 seconds. The biggest discrepancy can be observed in the slowest results, because the slowest user using the first gesture was 44.43 seconds faster than the slowest person using the second gesture. This could be due to Leap Motion having trouble recognising the pinch gesture for some people, while the finger pointing gesture was more intuitive for most users.

In Test Level 2, which involves accurately following a path, moving with the second set of gestures was faster. The difference in average values is as much as

15.94 seconds. While the number of deviations from the path was 0.75 higher when moving with pinch, users were quicker to return to the designated route.

In Test Level 3, it was faster to control using set 1. However, there was only a difference of 3.21 seconds.

In Test Level 4, when using the second way of interacting with objects, users on average completed the task 15.46 seconds faster with fewer gestures.

The average time to complete the Final Level of the game was better with finger gesture control. This is because the pinch gesture control was 45.77 seconds slower. This difference may be due to the addition of an item hidden in the desk drawer. It is interesting to note that in the game, those with previous exposure to VR technology performed worse with gesture one using movement behind the index finger.

	Test Level 1		Test Level 2		
	Mean time [s]	Average number of wall touches	Mean time [s]	Average number of off-route departures	Average time off-route
Gesture set 1	111,87	3,75	64,90	2,41	2,88
Gesture set 2	117,17	3,33	48,96	3,16	2,41

	Test Level 3	Test Level 4		Final Level
	Mean time [s]	Mean time [s]	Average number of gestures made	Mean time [s]
Gesture set 1	84,61	159,21	56,16	322,28
Gesture set 2	81,40	143,75	46,41	368,05

Figure 5. All averaged results collected during the study on Test Levels for both sets of gestures.

6. Discussion

In summary, second gesture set, commonly referred to as pinch movement, was faster and more accurate in most tests. Only in Test Level 1 and during gameplay of the demo game level gesture set 1 prove to be slightly faster. This may be due to the fact that users needed more time to get familiar with the pinch gesture and get used to positioning their hand in the right way to detect the sign. After the analysis of the study, the following conclusions can be drawn:

— Pinch gesture control proved to be faster but users in the survey said they were more likely to use finger pointing.

— Interacting with objects using first set of gestures by extending the hand towards the object was intuitive for users. They often extended their hand even in the 2nd set of gestures when it was not needed to function properly.

— Gathering items using the "look and collect" method proved to be faster and more precise. Users made fewer grab gestures with it.

— The complexity of finding objects at the HOPA level extends the gameplay and introduces variety.

— It turned out that people familiar with HOPA type games completed the task faster on the prepared game level demo than people unfamiliar with this genre of games. This could be due to the fact that most of them were people who had previous experience with virtual reality.

Due to Leap Motion's short cable, users were severely bothered by simulator sickness at the start of testing. They were not able to perform more than 180 degrees of body rotation in virtual reality, which they made up for by turning in the opposite direction on the chair. Particularly when turning at Test Levels 2 and 3 they were getting sick. This problem was significantly improved by purchase of a USB extension cable. After this, the test participants did not experience any disabling side effects.

7. Conclusions

The solutions proposed in the work and the technology used allowed us to create guidelines for HOPA games designed in VR. The research carried out allowed to define user requirements and their implementation in the test level. For further research, other characteristic elements of mechanics and ways of interaction in HOPA-type games should be introduced (mini-games, combining items, keeping event log, etc.). Gesture-based gameplay for HOPAs seems to be the most intuitive and engaging for users' hands, thus increasing immersion in the presented world. A limitation of the technology used in this work is that the hardware is equipped with wires that block the users' freedom of movement. With industrial development and the introduction of more wireless equipment on the market, the hindrance to users' movement capabilities will drastically decrease. The hand gestures presented can also be used to comfortably interact with the augmented reality environment.

Acknowledgment

This article has been completed while the second author was the Doctoral Candidate in the Interdisciplinary Doctoral School at the Lodz University of Technology, Poland.

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