

Gesture-based Interactions in Video Games with the Leap Motion Controller

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Abstract. This paper explores the Leap Motion controller as gesture-controlled input device for computer games. We integrate gesture-based interactions into two different game setups to explore the suitability of this input device for interactive entertainment with focus on usability, user engagement, and personal motion control sensitivity, and compare it with traditional keyboard controls. In a first user study with 15 participants we evaluate the experience with the Leap Motion controller in the two different game setups. We also investigate differences between gamers and non-gamers. The results indicate the potential in terms of user engagement and training efforts for short-time experiences. However, the study results also indicate usability issues. The experiences with gesture-based controls are rated as exhausting after about 20 minutes. While the suitability for traditional video games is thus described as limited, users see potential in gesture-based controls as training and rehabilitation tools.

Keywords: game input, input devices, hand tracking, natural input

1 Introduction

The concept of gamification is of increasing interest for the international research community due to the fact that games involve cognitive strategies that developed evolutionary over millions of years [11]. This form of *play* has potential to immerse and engage users in different contexts including non-gaming fields [8, 15]. An essential part of every game is the human-game interaction and in recent years, the range of input and interaction devices has advanced with various technologies to control computer-based systems. Whilst previously the focus was on device based interaction [10], recently more innovative and promising ways to interact with computers are provided by controllers with free-hand inputs. While previous research has focused on gesture-based interactions with Microsoft Kinect devices, which captures interactions of the entire body, only a few studies have covered the interaction with the Leap Motion controller,

which allows control with hand and finger gestures. Such free-hand interactions controllers show promising potential in entertainment, medical applications, rehabilitation, training, and education [12, 13, 16]. However, many of these devices were designed for tech enthusiasts and often fail to support the practicability of the technologies for everyday users. In this paper, we want to evaluate the Leap Motion controller as promising free-hand technology [4, 21] with focus on investigating differences in the usability and perception between experienced users and non-experienced users. In the study we concentrate on the interactions in the context of video gaming.

In a first study we evaluated the technology of gesture-based interaction with the Leap Motion controller for video games. We integrated gesture controls in two different game setups: (1) a platform game and (2) a local two-player shooter game. We recruited 15 participants to play the two games and assessed the experience based on usability, engagement, personal motion control sensitivity, and compared it with standard keyboard/mouse controls. Both, gamers and non-gamers are represented almost equally among the participant group. First results indicate the potential in terms of engagement and training effect of such devices for short-time experiences, however, they also reveal issues in terms of usability and comfort. Participants would use this control method for short-term experiences (e.g. training), but tend to prefer the keyboard for long-term experiences. They also tend to use different setups for gesture controls, sensitivity behavior and dead zones for different application scenarios. This data could be used to automatically identify gesture types, and allow dynamic and automatic settings and mappings to optimize setups.

With this work we aim to discuss the potential and issues of the Leap Motion controller as gesture-based input device for video games and other application scenarios through the following major contributions:

1. Integration of gesture-based controls in two different video games (a platform game and a local two-player shooter)
2. A user study with 15 participants (gamers and non-gamers) evaluating the two gaming experiences with focus on engagement, usability, and discussion of different application scenarios

The following section addresses background and related work on the Leap Motion controller in different application scenarios. After that we describe the two games used for the study. In section 4 the user study is presented and discussed.

2 Background and Related Work

Introduced in 2013, the Leap Motion is a small device that is meant to be placed facing upwards next to your keyboard or laptop. It features two infrared cameras that capture up to 200 frames per second [2]. Compared to Microsoft's Kinect [3] it has a higher motion resolution, but a smaller observation area, which covers roughly one meter in a hemispherical shape. The controller is primarily

marketed as a productivity device and was integrated into laptops, and other devices by HP and other manufacturers. In 2016 the company behind the Leap Motion expanded their strategy and released a new version of the software, named Orion, which focuses exclusively on VR. For this mode, the Leap Motion is mounted onto an Oculus Rift and enhances the virtual world with accurate motion detection [17]. The controller is connected to the PC via USB and requires the installation of a software suite, which contains different playground apps and mini games with simple interactions, such as picking flower leaves and positioning cubes.

There are numerous apps on the store that either integrate the Leap Motion controller into conventional programs, or new software tailored to the motion controls. The Leap Motion has also been used during surgeries as a means to control live medical imaging data. This has been found to reduce the risk of infections in operating rooms, while being very cost-efficient and practical[13]. All those studies show the potential of motion control technology, where the Leap Motion might not be its glorious final iteration, but a necessary and useful playground for generating ideas. As with all motion control systems, the added strain of keeping your hands in the air seems to make the Leap Motion more suitable for shorter infrequent gestures than heavy usage and a full keyboard and mouse replacement.

Several authors have used this device for evaluating various application areas, which require hand-based communication. In [20], the authors present an implementation to use the Leap Motion controller as a tool to recognize characters and words written in the air by hand. One promising research area and possible use case for the controller is sign language recognition. In [16] the authors present a first implementation of using the Leap Motion controller to recognize Australian sign language. While the authors describe the potential of the device for recognizing finger movements, they also describe issues with accuracy in their current implementation. They found that the Leap Motion is capable of recognizing basic signs, however, it fails to accurately detect most movements where the fingers are aligned perpendicular to the cameras. Moreover, complex signs that require simultaneous facial expressions were found to not work at all. The average accuracy of the device has been measured in a 2013 study as 0.7mm[21], which according to the authors trumps the Kinect and other competitors in this price range. A point which is even more valid today, since the Leap Motion's price dropped to 60\$. However, in another study [9] with focus on measuring precision and reliability of the sensors, the authors show limited sensor space and inconsistent sampling frequency, which limits its use as a professional tracking system.

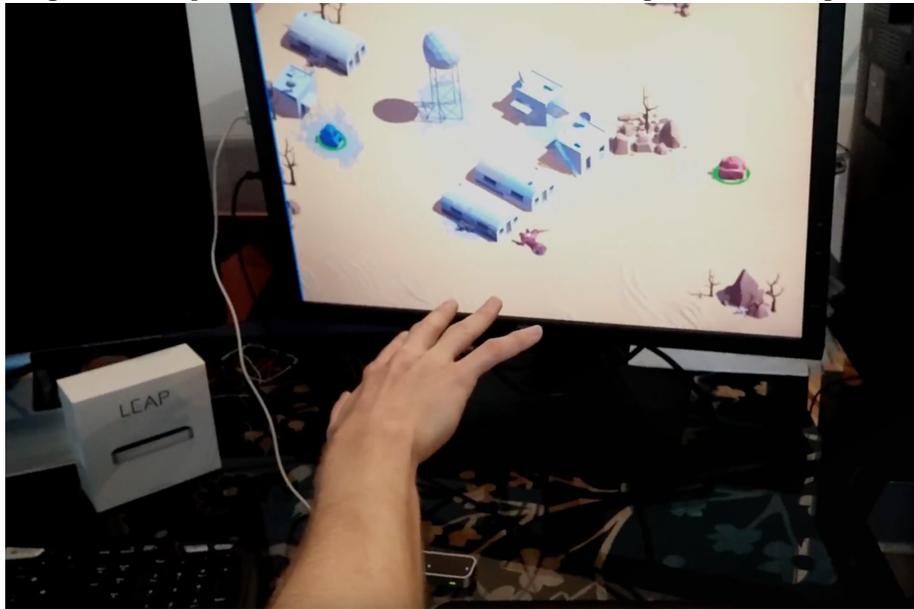
While several evaluations show the potential of the Leap Motion controller for various application scenarios in the fields of communication or recognition tools, there are only a few studies on the potential of the Leap Motion controller as a tool for video gaming. There is an increasing interest in new and innovative input devices to control games and virtual reality experiences, to create more immersive and engaging gaming experiences, and to overcome the limitations of

keyboard and mouse input with more natural interactions[19, 6]. In the following section we introduce two video games, which are used as a design basis to create and evaluate gaming experience using the Leap Motion controller as interaction device.

3 Leap Motion Game Design

The goal of the first prototype is to evaluate the thesis, that motion controls are more suited for infrequent edge gestures, than for using them as a primary input method. Therefore we aimed to incorporate the controller into conventional games that demand higher reaction speeds and a generally increased rate of interactions. To focus more on the integration than actual game development, we chose to expand open well-designed games. Another important point was that the games' mechanics had to be easy enough for non-gamers to get into, in order to compare their motion control impressions with people who play regularly. Figure 1 illustrated the use of the Leap Motion controller as input device. The controller is placed on the bottom of the monitor.

Fig. 1. The Leap Motion controller is used to control the game with hand gestures



3.1 Alien Invasion

Unity's Alien Invasion [1] is a simple 2D platform game where one has to defend a city from aliens (see Figure 2). The player controls a character that is able to fire a rocket launcher to clear the environment from the enemies. Moreover, players can collect bombs, which can be placed strategically. Building on that we added a shockwave that is emitted by the character and bounces enemies back to give the player additional tools to escape tense situations. The Leap Motion controller was added to the Unity project. We decided to always display a visual representation of the hands to enable the visualization of the tracking. After several iterations, the controls were configured in the following way:

- Left/right movement by rolling the left hand; the direction of the back of the hand determines the direction the character moves
- Jumping by swiping the left hand upwards
- Firing missiles by making a fist with the right hand
- Laying bombs by swiping the right hand upwards or downwards, or any vertical movement with higher velocity
- Emitting a shockwave by swiping the right hand left and right, or any horizontal movement with higher velocity

The gestures are detected by observing the hand models the Leap software maintains and tracks over time. This enables the differentiation between the left and the right hand. However, there is only a very limited amount of gestures detected by the controller natively. In effect, it identifies a circle movement, a swipe as well as forward and downward taps. For the implementation, only the pre-built swipe-gesture was used. Other movements were determined by the angle of the hand, with a dead zone to allow the player to stand still. The fist gesture is detected by calculating the sum of the angles of the finger joints. If they are curved over a threshold, a fist is detected. A pause menu with included sensitivity sliders was added to allow players to adjust the size of the roll dead zone and the fist sensitivity according to their preferences. Furthermore, features to export the chosen settings in order to statistically evaluate them were added. Tailored towards use as a demonstrator, the game now includes a "Leap Primary" mode that pauses the game automatically once no hands are detected, to enable changing the sensitivities without a keyboard (see Figure 3).

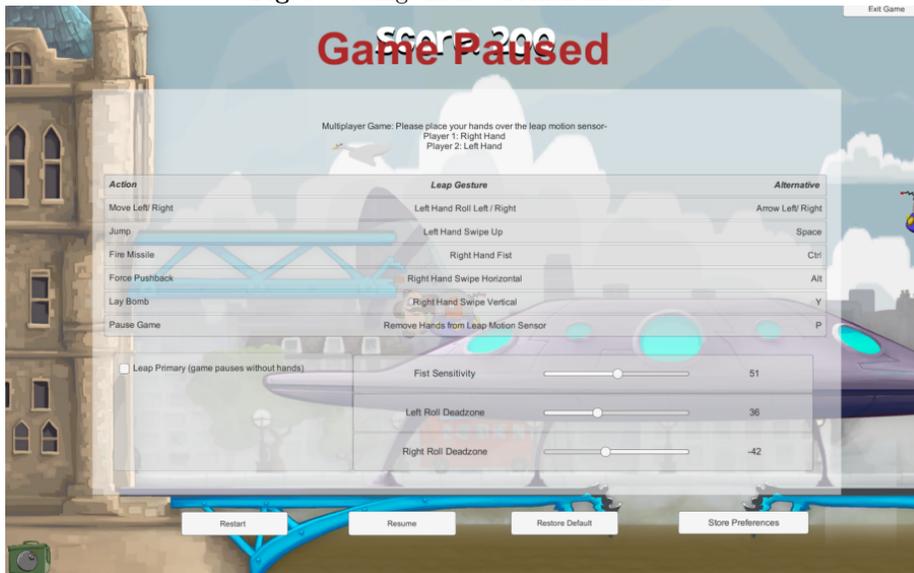
3.2 Tanks!

Aiming to test the controller in a 3D environment the Unity Tanks! multi-player demo [5] was used and extended. The game is a multi-player game, hence the Leap Motion controller as a multi-player input method can be evaluated. The goal of the game is to defeat the enemy tank (see Figure 4). Therefore, the player can move forwards and backwards, as well as turn left and right. The cannon of the tank is the only weapon and can be charged up to change the distance of the shot. Since the Leap Motion can only distinguish and assign two hands over time, separating the left and right hand, all functionality had to be controlled via

Fig. 2. Gameplay of Alien Invasion using the Leap Motion controller and visualizing the current position of the hands (at the bottom).



Fig. 3. Settings menu of Alien Invasion.



gestures of one hand. This means the player who uses the left hand, controls the blue tank, and the player using the right hand controls the red tank. Controlling the game works as follows:

- Left/right turning by rolling the hand; the direction of the back of the hand determines the direction the character moves
- Forwards/backwards movement by pitching the hand; the direction of the back of the hand determines the direction the character moves
- Firing the cannon by making a fist, the shot is charged for as long the hand is closed and the shot discharged once the fist is released

As before, the gestures are detected by observing the hand models. The pitch is detected the same way as the roll movement, just by analyzing a different axis. Due to the higher load of simultaneous gestures per hand, the dead zone is increased in comparison to the first game, Alien Invasion. Since it is difficult to keep the hand angled correctly while loading the shot, there are two additional settings to lock both movement and turning while charging the shot. Resulting from its 3D environment, the difficulty and emphasis of eye-hand coordination is enhanced. Thus a Simple Input mode is also available, whereby a player can only move or turn, effectively only applying the stronger motion vector - a setting aimed at inexperienced players. In addition to the Leap Primary mode of the previous game, there are colored indicators on the sides of the screen that light up in the color of the player when the Leap Motion loses track of the player's hand (see Figure 5).

Fig. 4. Gameplay of Tanks! using the Leap Motion controller - different colors represent the two different player hands.



Fig. 5. Settings menu of Tanks!.



In our research, these two games provide the frame conditions for our research to evaluate user interaction and experience of gamers and non-gamers with the different game formats.

4 Evaluation

In a first study, we focus on identifying variance in user preferences regarding the motion control settings, usability issues, and engagement and try to compare the experience to the keyboard input. Comparing the Leap Motion input with traditional keyboard interactions input is difficult as they offer a more habitual form of computer interaction. Participants were asked to play both game setups with keyboard and Leap Motion controls. Because of the strong differences in experience with the input device, a detailed analysis does not generate significant results, however, it gives a first impression of the potential of gesture-based devices and discusses application scenarios, which are mentioned by participants as interesting future experiences for this kind of input.

4.1 Material and Setup

For the experiment the two pilot game setup prototypes based on existing games as described above in detail were used: (1) a 2D platform game, Unitys Alien Invasion, which requires the player to control the character (left/right movement,

jumping), collect and fire rockets and bombs. (2) an extension of Unity's Tanks! demo, a multi-player game, which requires the user to control a tank (left/right turning, forwards/backwards movement, and firing the cannon). The controls were provided by (a) keyboard and (b) by the described gestures for the Leap Motion controller such as hand rolling, hand movement, or making a fist with the left or right hand. Both chosen games were designed as conventional games that demand higher reaction speeds and a generally increased rate of interactions but are also suitable for users with little gaming experiences.

4.2 Participants

We recruited 15 participants (5 females) between 21 and 67 (AVG=29.8; SD=10.58) from various disciplines and various skills in the use of computers with an arithmetic mean of 3.6 (SD=1.18) on a Likert scale between 1 (fully disagree) and 5 (fully agree). Both gamers and non-gamers are represented almost equally. Their experience with video games was very mixed (AM=2.4; SD=1.35). 10 mentioned they like playing video games. A correlation between being a gamer, and being an expert with computers exists. Because of that, as far as the following results are concerned, both terms are interchangeable and yield similar characteristics. 5 had heard of the Leap Motion controller before. Almost all noted to have almost no experience with gesture-based controllers (AM=1.73; SD=1.03).

4.3 Methodology and Procedure

In order to rule out the influence of the order in which the different input devices are tried, A/B testing was performed. The testers were put into two groups where group A started with the Leap Motion, and group B started with the keyboard version of the game. Additionally, if there is a difference in perception, this setup aims to reveal it. The survey is performed using LimeSurvey. After filling out a small demographic questionnaire, the participants have to rate both their experience using computers, and their exposure to and skill with motion controls. Following that they play Alien Invasion and are asked to provide written feedback of their experience. Next a SUS - System Usability Scale - is used to rate their subjective experience of the system. This scale developed by Brooke is a tool to quickly assign a global scale to that perspective and has been widely adopted over the years [7]. After playing the game with the other controls, the test moves on to "Tanks!". This survey is shorter than the Alien Invasion part. The participants are asked to play the game at their own pace with both control methods. At the end of the test, they have to select with which device they had more fun, what they would choose for longer gaming sessions, and which mode they prefer overall. Lastly they select gestures that were easy to perform for them, as well as the duration they could possibly play with motion controls.

5 Results

Next, the key elements of the post-questionnaires are discussed and framed with participants' quotes. Summarizing, users experienced the gesture-based controls as more interesting and engaging because of the novelty of the experience. Also the game itself was noted as more interesting with the novel input method, compared to traditional keyboard controls. The multi-player mode was experienced as more challenging, because of the two hands interfering with each other. The gesture-based controls were noted as valuable pedagogical and training tool to e.g. help people - especially children - with gross motor skills/fine motor skills to train in a playful way. However, the experience was also mentioned to be more stressful and less user-friendly compared to keyboard input. Overall, only 3 users would prefer controls with Leap Motion, but 10 rated this form of user input also as the funnier experience. 11 would rather use the keyboard when playing for a longer time.

SUS of keyboard controls is on average 20 points higher than of Leap Motion controls On average the SUS of keyboard controls is 75 compared to the SUS of 55 with the Leap Motion controls, which is quite a significant difference. According to the SUS rating methodology, the average score is 68, which means the Leap Motion provided a below average experience. Most testers claimed accuracy issues and stated that they could not trust the device to detect the intended gesture. Especially non-gamers tended to stress out and resort to hasty waving in hectic situations: *"It was challenging to get used to the controls. It felt stressful."*; *"The game controls much easier with the keyboard. The controls behave more exact in comparison to the fluid controls the other version provides."* *"The control was definitely easier on the keyboard - this is most likely also because of the own experience/practice."*

Gamers and experts rate both methods of input higher than inexperienced persons This result is not really unexpected, since regular gamers are more familiar with both types of games. Therefore they are not as overwhelmed with the game itself, and can concentrate more on mastering the motion controls. However, gamers sometimes picked at the simplicity of the game, especially when using the keyboard.

There is a higher increase in the score of the keyboard, if it was played after the Leap Motion version It seems that players value the increased accuracy of keyboard controls more after playing with motion controls first. With that subset, the keyboard controls even achieved a score of 83. The increase is more pronounced with gamers. This shows that A/B testing is important to limit the influence of the order on a testing result.

There is a higher spread of score difference of gamers between the two control modes Having developed a higher standard towards the feel and accuracy of controls, gamers seem to be put off more by the drawbacks of motion controls than non-gamers. On the other hand, this could also mean that having a lot of experience with conventional control schemes reduces the acceptance of new input methods. More investigation into that topic could prove insightful.

Generally people chose a larger left than right dead zone When tasked with holding their hands straight in front of them, most persons naturally seem to keep their hands slightly curved away from their thumbs. This means that the perceived neutral position of the left hand is slightly rotated counterclockwise in the coordinate system of the leap motion. Another result of this fact is that when both hands are required to perform rolling movements, it is important to provide separate settings for both hands. Otherwise fitting one hand worsens the recognition sensitivities of the other one.

Higher dead zones chosen for "Tanks!" Another attribute of the data set is that the same persons tend to choose higher dead zones for this game. This seems to be a result of having more gestures mapped to one hand. The increased allocation leads to more motion bleeding, whereupon performing a gesture inadvertently influences another gesture. In this particular case, users found it very difficult to perform a fist gesture without altering the angle of their hand in a way that also led to a direction change. Nearly every person locked their movement while channeling a shot. More non-gamers elected to also use the lock of turning motion than their gamer counterparts. This expresses the impulse of gamers to perform minor last minute adjustments. Taken even further, this finding concurs with the thesis that motion controls are unsuitable for fast paced games which require exact timing. By our very nature it is likely to overdo a movement, which can cause mis-detections. More importantly, mixing continuous tracking with concrete gestures is error prone. In our case, we use the angle of the hand in multiple directions as an input parameter. Therefore we cannot use this hand in conjunction with most other gestures, because they alter the directions of the hand. When asked for the maximum amount of gestures that should be loaded onto one hand, the average answer is 3.4 gestures.

Motion controls are experienced as exhausting Most participants give verbal feedback that they find the Leap Motion controls quite exhausting. On average the duration they could comfortably use it was rated at 23 minutes. They even stated that this tiring effect would stop them from trying to get familiar with the new control scheme. In that sense, the strenuous nature is counterproductive to the learning motivation. *"A bit tiring for the hands"; "The concept is pretty good, but might be a bit exhaustive after a while. This works for short sessions, but I wouldn't play it for much longer."*

Leap Motion mode is rated more fun to use For 66% of users the motion controls were more interesting and fun than the conventional scheme. However, when asked whether they would prefer this mode overall or for longer playing sessions, the majority chose the keyboard. Further research is needed on how long that feeling lasts, and how it fares with more complex games: *"Harder to control but strangely more fun. But I think that fun is going to wear off soon."*; *"[I liked it] very much. interesting."*

Application scenarios for Leap Motion controls Users listed mainly short party and sports games as entertaining application scenarios for the gesture-based controller. Additionally, the device was discussed as potential tool to enhance pedagogical and training scenarios such as training of gross motor skills/fine motor skills in a playful way, or hands-free interactions as necessary in surgeries.

6 Discussion and Conclusion

Conducting the study has provided some valuable insight into the perception of motion controls. While the engagement was high and the experience with the Leap Motion controller was noted as interesting and innovative, in many cases keyboard and mouse are still rated as preferred interaction device for games. There are niche cases where they perform exceptionally well, but on average they lack usability mostly because of the aforementioned accuracy issues. Especially accuracy issues like the limited tracking area and visual overlap need to be resolved. None of the participants felt more confident with the motion controls. Playing a game for more than 20 minutes was rated as exhausting and not a good use case for this input. However, participants noted several application fields where they see promising use cases for the device. This definitely includes gamified training tasks (e.g. therapeutical tasks, rehabilitation). Limitations in our study are given due to the small number of participants and the setup of the A/B study. The results indicate the potential of gesture-based controls to boost the users' engagement and interest in the experience, and show the potential for training and short-time entertainment experiences. We found several issues but also potential in this form of user input. Despite limitations based on accuracy and usability, the Leap Motion controller has been shown as interesting and engaging tool to offer basic hand input for small and short games and applications, which do not require a high accuracy.

For future work, an important step is to research how to enhance usability. One way to enhance usability and learnability of such devices could be the use of machine learning methods. Users tend to play differently and can be automatically categorized into different player types based on their interaction with the game [14]. In this study, it was shown that users often tend to use very different setups for gesture controls regarding sensitivity behavior and dead zones. In a large-scale study, data could be collected and used to automatically identify player types based on their gesture interaction behavior, and allow dynamic

and automatic settings and mappings to optimize setups. This would allow the generation and mapping of gesture-based user types to speed up learning of interaction with the device easier. For future work we will also focus on additional engagement elements, such as immersion, which becomes more and more important to create interesting playful entertainment experiences [18]. Thus, the value of the Leap Motion as a VR peripheral needs to be determined in further studies.

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