Deplau: Movement and Interaction in Virtual Reality

Harizb.Mohamed Mustafa, Quek Albert

Abstract: ***Since appearing on the consumer market two years ago, Virtual Reality (VR) games for the HTC Vive have begun to standardize their control schemes. The conventional control schemes for VR games consists of either teleportation or artificial locomotion via the Vive trackpads as a method of movement. These methods are not physically taxing to the players, but teleportation breaks immersion while artificial locomotion can induce motion sickness. Gestures that mimic natural human movement can prevent breaking the user's immersion and reduce motion sickness. Here, we have developed and released a commercial VR game using gestures that mimic natural human movement titled "Deplau" on Steam; a digital distribution platform. Deplau uses body movement, hand gestures and the included HTC Vive controllers for the users to move and interact in the virtual world. A set of gestures taking into consideration the movement of the human body are used as controls for the game. A total number of 30 users were selected, age between 10 to 20 years old as the target interest group. Through qualitative user evaluation on the target interest group during play testing, the majority of the users gave positive reception towards the movement and spell controls. For the overall game experience, all participants rated 4 and 5 out of 5 scores.***

Keywords: Gesture-based game; Gesture mechanics; HTC Vive; Intuitive gesture; Movement mechanics; Virtual Reality

I. INTRODUCTION

With the computational power available on consumer level hardware, Virtual Reality (VR) games with high frame rates and increased visual fidelity are now possible. While graphics and frame rate play a part in increasing the players experience of being in the virtual world, the method of navigation and levels of interaction in the virtual world are what completes the players' immersion. This level of immersion is also known as "presence" [1].Virtual Reality (VR) provides increased immersion and dynamic interaction to the player and by implementing gestures that mimic natural human body movement, a high feeling of presence can be achieved by the player [6]. The HTC Vive supports 360° movement via two stationary Lighthouse sensors that emit non-visible light. The Vive headset and controllers are covered with photo sensors that detect the light emitting out of the Lighthouses. The photo sensors determine the rotation and location of the headset and controllers by interpolating the photo sensors location and when the light hits the photosensors [12]. The optimal maximum area the Lighthouses are able to cover wirelessly is 5x5 meters. By using the included sync cables the area covered can be extended to 9x9 meters.

Revised Manuscript Received on April 15, 2019.
Harizb.Mohamed Mustafa, Zirasoft, Malaysia
Quek Albert, Multimedia University, Malaysia

This enables the Vive player to physically move around in the real world and have their movements interpreted into the virtual environment. Moving around in the real world while tethered to the HTC Vive is limited by the amount of space available physically. This presents a problem for games that require the player to navigate and explore levels larger than the physical space available to the player.

By using teleportation or artificial locomotion [9], game developers are able to solve this problem but at a cost of immersion to the player and risk of inducing motion sickness towards the player [2]. The Vive controllers are able to give haptic feedback [12], increasing the sense of presence for the player [4]. Even without haptic feedback, players feel more immersed when performing gestures and body movements compared to using traditional gaming peripherals [11]. There are also other examples of motion sensor device such as leap-motion that is used together with a head-mounted display for a better VR experience [15]. However a heightened sense of presence can only be achieved by combining intuitive and natural gestures, physical movement and haptic feedback for movement and interaction. In this paper, we discuss the mechanics of a commercial gesture-based HTC Vive VR game titled "Deplau" that implements the features needed for a heightened sense of presence. Deplau was made for the HTC Vive and has not been tested on the Oculus Rift CV1. By using intuitive gestures that mimic the human body's natural movement, players can explore and interact within the multitude of levels available in Deplau. Deplau also implements 3D Audio to complete the VR user experience. The remainder of the paper are organized as follows. Section 2 introduces the game concept of Deplau, user interface and current levels. Section 3 describes the set of gestures and its implementation in the proposed system. Finally, section 4 presents the result of user evaluation on the proposed system while section 5 concludes the paper.

II. GAME DESIGN

Game concept

Deplau is a gesture-based virtual reality (VR) action/adventure game where the player is a sorcerer trying to reclaim stolen magic. The player has to navigate the levels of Deplau, evade traps, solve puzzles and fight various monsters to reclaim their magic. Movement and interaction within the world of Deplau is done via body and hand gestures. The player can also pickup and destroy objects. The player is required to wear the HTC Vive head-mounted display (HMD) and the included two motion controllers. By using the HTC Vive's lighthouses the player is also able to move around in the virtual world via walking in the physical world.

Each level encountered by the player has different objectives that the player must complete to advance towards the next level.

User interface

Fig. 1a In-game hand model (front)

Fig. 1b In-game hand model (back)

Figure 1 refers to the in-game visual where the player views their motion controllers as hands in virtual reality (Figure 1a). The left hand contains information about the player such as remaining health and level objectives. When the menu button is pressed on the Vive controller, an in-game menu will appear on the right hand (Figure 1b). The player can use both hands to navigate and interact with the menu. Targeting lasers will appear to help the player navigate the menu. Pressing the trackpad of any controller will select the player's menu choice. Small haptic feedback and an audio cue will notify the player that the button has been pressed.

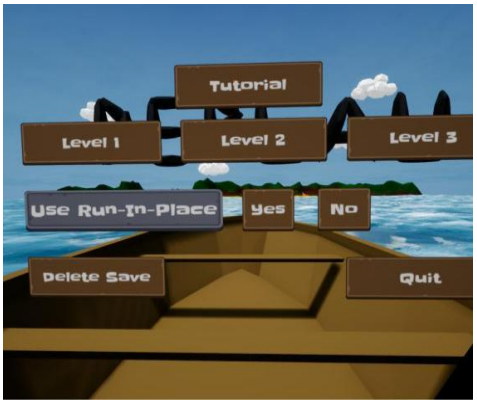

Fig. 2: Main menu

Figure 2 refers to the in-game visual that the player encounters when launching Deplau or when they quit to the main menu from in-game. The main menu is 3D and rendered in world-space to give the player a sense of scale and immersion [3].

Game levels

Deplau currently features an opening level, tutorial level and three game levels. More levels will be added in later stages.

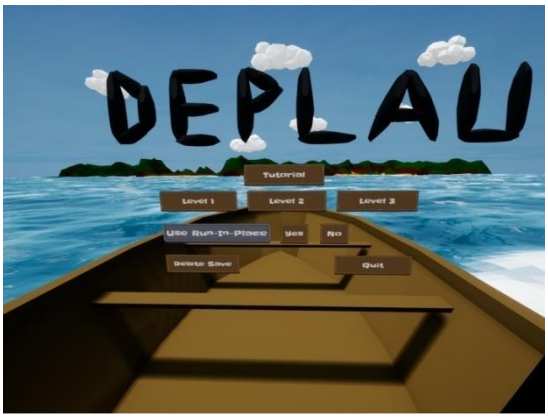

Fig. 3 Opening level

The opening level acts as a starting point for the player and a visual anchor to Deplau's plot. The player can continue from their last played level or delete their current save file to start fresh. Unlocked levels can also be selected via the opening level.

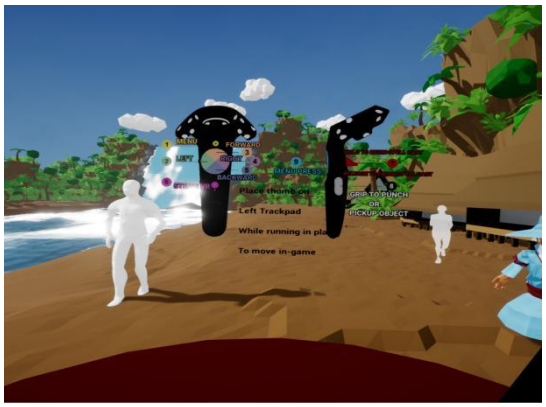

Fig. 4 Tutorial level

The tutorial guides new players on the basic controls and gestures which include movement and spell casting. Players will be guided with both audio and visual cues. The spell casting gestures will be represented by in-game representations of the Vive controller and a 3D mannequin representing the players' body. Players will have to complete each segment of the tutorial to move on to the next segment.

Fig. 5 Game level

The game levels require the player to move from starting point to the end of the level. All three current levels of Deplau feature different secondary objectives and mechanics. Main gameplay elements appearing in all three levels are exploration, puzzle solving and combat. Players may encounter multiple puzzles and secrets scattered around the level while fending off hostile artificial intelligence (AI).

III. GAME IMPLEMENTATIONS

Hardware and software

The hardware and software being adopted and implemented in this project are as below:

- Head-mounted display (HTC Vive)
- HTC Vive controllers
- HTC Vive lighthouses
- Steam VR API
- Desktop PC
- Unreal Engine 4 game engine

Deplau is developed using the Unreal Engine 4 game engine and executed on a Windows desktop PC. The game screen is mirrored to Windows via a function implemented in Unreal Engine 4. In order to access the hardware features of the HTC Vive, SteamVR [13] is used as a plugin for Unreal Engine 4. SteamVR, developed by Valve Corporation is the software that implements the OpenVR API and acts as the interface between software and VR devices. Examples of VR devices are the HTC Vive headset, controllers and lighthouses. Software features of SteamVR include VR boundaries to prevent the player bumping into walls in the real world. The HTC Vive lighthouses are placed opposite each other to generate the best overlapping play area [13] (Figure 6).

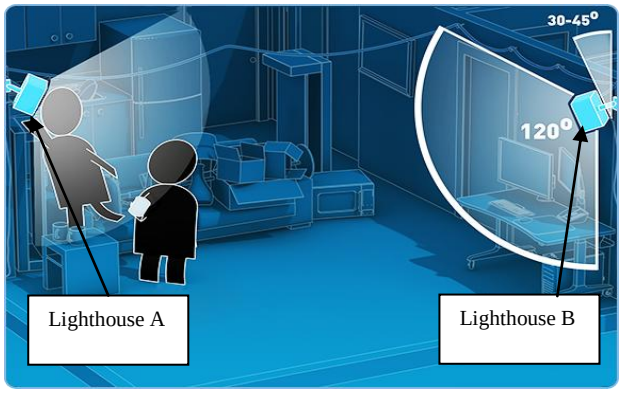

Fig. 6: Simple positioning of HTC Vive lighthouses

After positioning the lighthouses at the correct angles and facing each other, the HTC Vive is connected to the desktop PC via USB 3.0 and HDMI to pass audio and visual data from the desktop to the HTC Vive HMD. A separate cable attached to a power source is used to power the HMD (Figure 7).

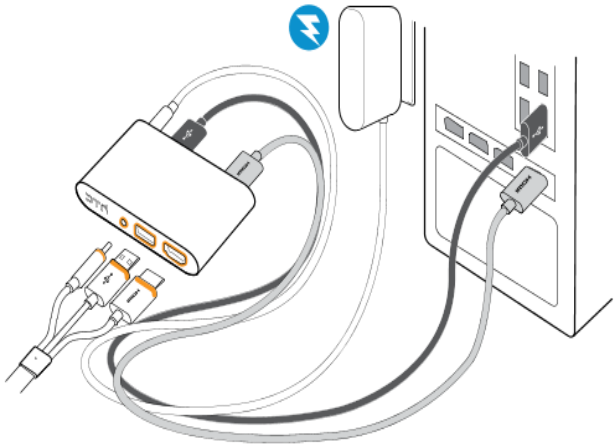

Fig. 7 HDMI and USB 3.0 connection between Vive and desktop

Gestures

The core mechanics of gesture control in the game comprise of the following:

- Movement Control – To move player forward, backward, left and right.
- Hand Interaction Control – To fight enemies in hand to hand combat and pick-up and throw objects in-game.
- Spell Control – To cast spells such as fire, ice or shield.

Movement control

Movement control allows player to move forward, backward, left and right in the game. The player can only use the movement control if their thumb is placed on the left trackpad of the Vive controller and they are jogging in place (Figure 9).The placement of the thumb on the left trackpad prevents unnecessary movement when the Vive HMD is moving [9]. The HTC Vive controller trackpad consists of four different regions that can be mapped to forward, backward, left and right direction (Figure 8).

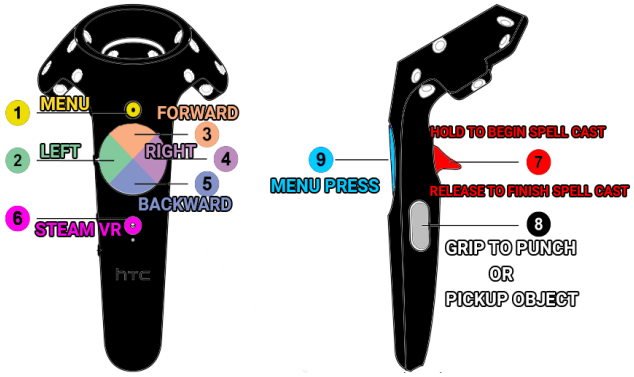

Fig. 8 HTC Vive controller scheme for Deplau

The player can look independent of body direction and movement. Eg: Look left and move forward. Player head direction and body direction are separated to emulate real-life conditions. Associating movement direction with head direction can induce motion sickness on some players [8]. Deplau detects the player jogging in place without the presence of additional photosensors located on the feet of players. This is done by tracking the players height via the Vive HMD location upon launching the game. The player's height is compared every frame. When the game detects abnormal fluctuation in height between the current frame and the previous frame, it associates the height change with player movement. This enables a smooth transition from stationary position to movement state. By triggering in-game movement with a gesture the brain associates with movement there is no motion sickness [5]. If the player jogs in place at a faster pace the game will automatically increase the in-game speed. Physical limitations prevent the player from running around the level at unrealistic speeds. Implementing this movement scheme enables the player to engage in light cardio exercise while playing [10]. An input simulator is used to simulate key presses such as key "W" and "S" in moving the character in the game. The thumb's position on the left trackpad determines the player direction. In the following, the pseudocode for movement control is stated.

```
IF Player Height Current Frame not equal to Player Height Previous Frame
AND Left Trackpad touched
    Check Left Trackpad touch location
IF Left Trackpad touch location is Forward THEN
    Press button "W"
    Move forward
ELSE
    Release button "W"
ENDIF
IF Left Trackpad touch location is Backward THEN
    Press button "S"
    Move backward
ELSE
Release button "S"
ENDIF
IF Left Trackpad touch location is Left THEN
    Press button "A"
    Move left
ELSE
Release button "A"
ENDIF
IF Left Trackpad touch location is Right THEN
    Press button "D"
    Move right
ELSE
Release button "D"
ENDIF
ENDIF
```

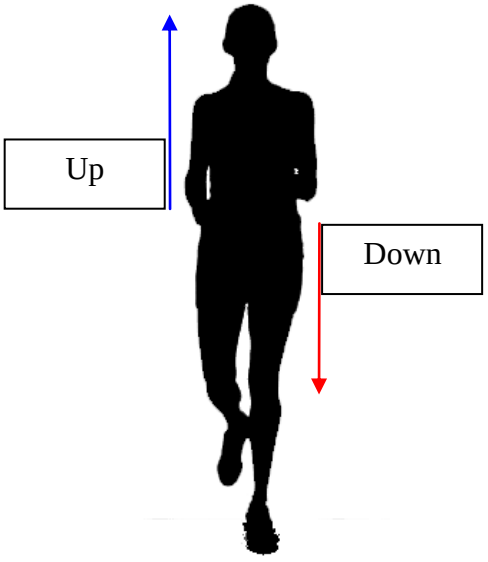

Fig. 9 Jog in place movement for movement control

Hand interaction control

Hand interaction control allows the player to punch enemies, pick-up or throw objects and it can only be activated if the Vive controllers are gripped. The player's hands have simulated physics in virtual reality so real word swinging of the controllers will affect the in-game hands velocity and momentum. Swinging the controllers faster will result in a more damaging punch. Players are free to use any style of punching if the grip buttons are pressed. Whenever the Vive controllers are gripped, the hand animation will change to mimic a closed fist and the controllers will give haptic feedback. When punching an enemy or picking up an object the controller will also give haptic feedback. Haptic feedback intensity increases with a higher velocity. A simple collision check occurs to detect the object type is an enemy or pickup item. The punches will deal damage if the hands collides with an enemy (Figure 10). If an object is a pickup item, the grabbing hand will pick-up the item without damaging it and give a light haptic feedback to indicate the presence of touch. The player can let go of the pickup object by releasing the grip button. To throw a pickup object, the player has to make a throwing gesture and then release the grip button (Figure 11). Picking up objects in virtual reality greatly increases the sense of presence for the player and provides an intuitive way of interacting with the puzzles in Deplau. By gripping the Vive controllers the player can also punch through destructible walls and objects to discover hidden passages and disable barriers. In the following, the pseudocode for hand interaction control is stated.

```
IF Hand is grabbing THEN
    Perform simple collision check between hand and object
IF currentTarget is type Enemy or Destructible THEN
    Apply melee damage * velocity to currentTarget
```

```
5    ENDIF
6    IF currentTarget is type PickupObject THEN
7       Attach currentTarget to Hand
8    ENDIF
9    IF Hand is not grabbing THEN
10     Release currentTarget * velocity
11   ENDIF
12   ENDIF
```

Fig. 10 Punching gesture

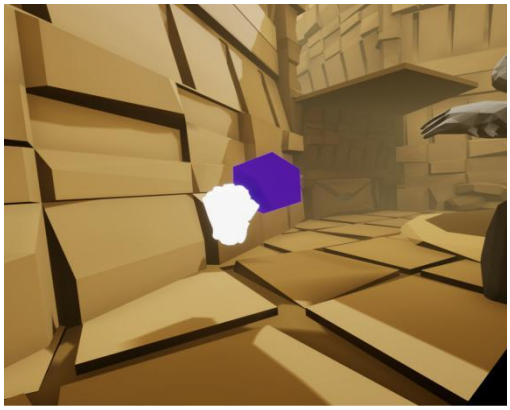

Fig. 11 Picking up an object and throwing an object

Spell control

Spell control allows the player to summon different spells by doing gestures with the Vive controllers. Pushing arm forward to summon “Fireballs”, swiping arm towards chest to summon “Shield”and swinging arms in a downward arcto summon “Freeze” (Figure 11). Gestures are prerecorded in Unreal Engine 4 and assigned an ID. When the player draws a gesture in-game it is compared to the original gesture. If the player’s gesture matches the prerecorded gesture within a tolerable range a spell is summoned. Tolerance range for spell comparison can be adjusted within the Unreal Engine 4 editor. Deplau uses a 0.5 tolerance scale where the maximum value is 1.0. A higher tolerance value is more accurate for gesture recognition but has a higher chance for failure to detect players’ gesture. Slower gesture recognition also occurs when using high tolerance value, eg: 0.8. This disrupts the gameplay flow of Deplau and slows down combat. Because of these reasons a value of 0.5 is chosen. The player can summon spells using either hand and can summon different spells at the same time. If player has successfully committed a gesture, the current spell will switch to the newly summonedspell, else nothing happens. A successful spell summoning gives the player a strong haptic feedback while a failed summoning gives a weak haptic feedback and an audio cue to indicate failure. Spell gestures try to mimic gestures seen in superhero films as players have a familiarity with those gestures [7].

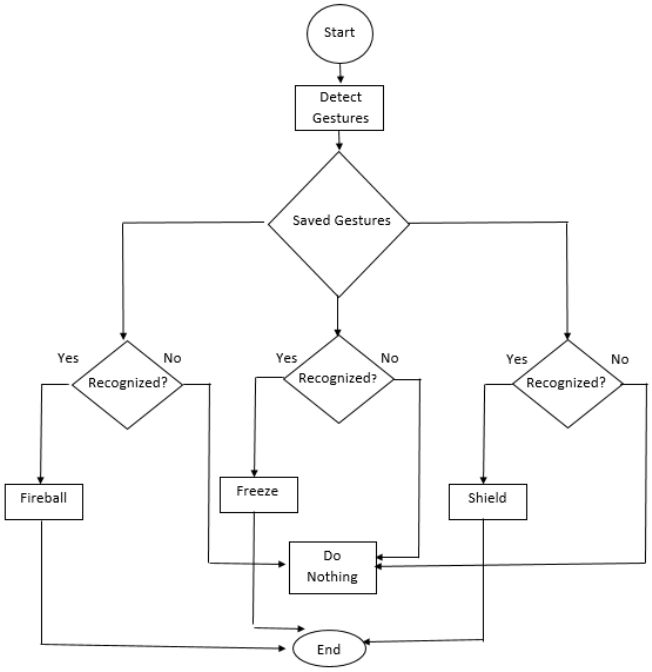

Fig. 11 Flowchart for spell control

Fireball spell

Fireball allows player to summon threeglowing flames that can cause damage to enemies. The fireballs spread over distance like shotgun pellets and self-destruct after five seconds. It can be summoned by holding the trigger button in (Figure 8); indicated in red and then pushing either left or right arm in a forward motion (Figure 12). To finish gesture recognition for fireball the player has to release the trigger button. For maximum damage the player can summon fireballs from both hands simultaneously. In the following, the pseudocode for fireball spell is stated.

```
1    IF LeftController trigger held down
2    Compare CurrentGesture to SavedGestures
3    ENDIF
4    IF LeftController trigger held down AND CurrentGesture within tolerance of FireballGesture
5    FireballGesture selected
6    ENDIF
```

```
IF LeftController trigger released AND Fireball-Gesture selected
 Cast Fireball
IF RightController trigger held down
Compare CurrentGesture to SavedGestures
ENDIF
IF RightController trigger held down AND Cur-rentGesture within tolerance of FireballGesture
FireballGesture selected
ENDIF
IF RightController trigger released AND Fireball-Gesture selected
 Cast Fireball
```

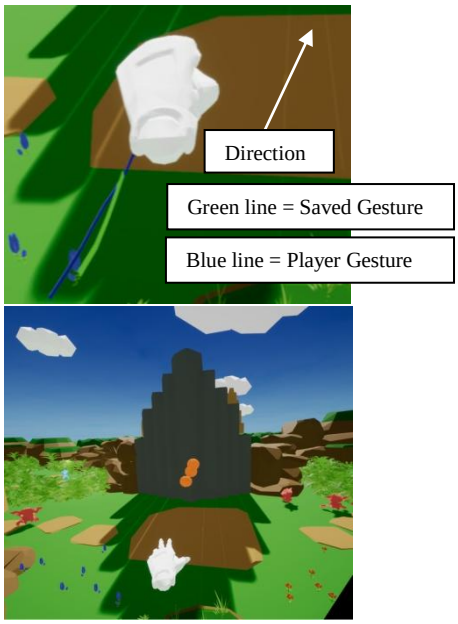

Fig. 12 Fireball gesture

Freeze spell

Freeze spell allows player to launch a bouncing block of ice that goes through enemies and freezes them for five seconds. It can be summoned by holding the trigger button in (Figure 8); indicated in red and then swinging either left or right arm in a downward motion (Figure 13). To finish gesture recognition for freeze the player has to release the trigger button. The player can also summon freeze from both hands simultaneously to freeze multiple enemies. In the following, the pseudocode for freeze spell is stated.

```
IF LeftController trigger held down
Compare CurrentGesture to SavedGestures
ENDIF
IF LeftController trigger held down AND Cur-rentGesture within tolerance of FreezeGesture
FreezeGesture selected
ENDIF
IF LeftController trigger released AND FreezeGesture selected
 Cast Freeze
IF RightController trigger held down
Compare CurrentGesture to SavedGestures
ENDIF
IF RightController trigger held down AND Cur-rentGesture within tolerance of FreezeGesture
FreezeGesture selected
ENDIF
IF RightController trigger released AND FreezeGesture selected
 Cast Freeze
```

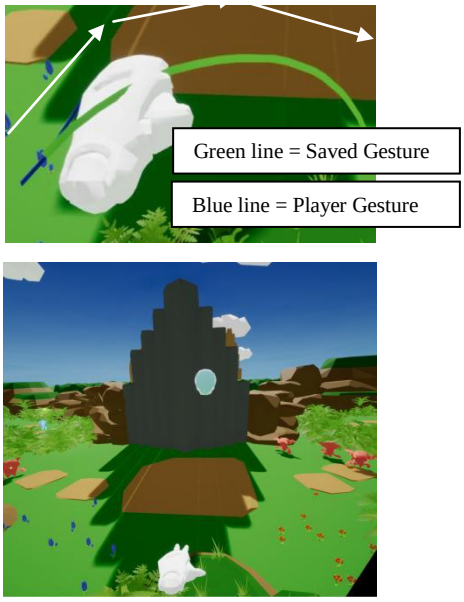

Fig. 13 Freeze gesture

Shield spell

Shield spell allows player to summon a magical shield that absorbs damage and pushes back enemies. The shield self-destructs in three seconds. It can be summoned by holding the trigger button in (Figure 8); indicated in red and then swiping either left or right arm towards the chest (Figure 14). To finish gesture recognition for shield the player has to release the trigger button. In the following, the pseudocode for shield spell is stated.

```
IF LeftController trigger held down
Compare CurrentGesture to SavedGestures
ENDIF
IF LeftController trigger held down AND Cur-rentGesture within tolerance of ShieldGesture
ShieldGesture selected
ENDIF
IF LeftController trigger released AND ShieldGesture selected
 Cast Shield
IF RightController trigger held down
Compare CurrentGesture to SavedGestures
ENDIF
IF RightController trigger held down AND Cur-rentGesture within tolerance of ShieldGesture
ShieldGesture selected
ENDIF
IF RightController trigger released AND ShieldGesture selected
 Cast Shield
```

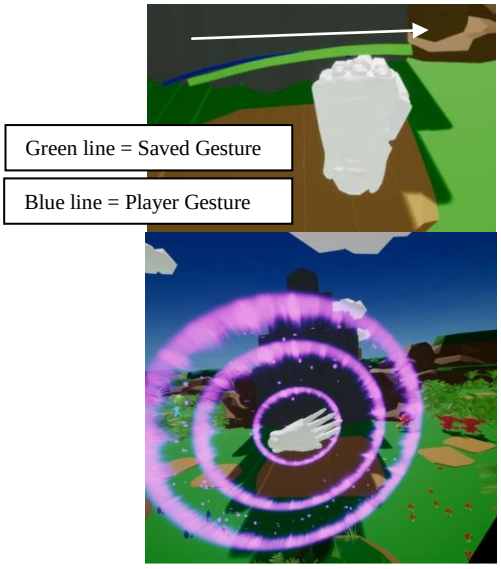

Fig. 14 Shield gesture

IV. USER EVALUATIONS

The Deplau game was created to introduce movement (locomotion), hand interaction and spell control in a HTC Vive gesture-based action/adventure game. Hence, the target audience were primarily people who have a strong interest in VR action/adventure games. The game was tested with 30 participants ranging from 10 to 20 years old. All participants were given only 20 minutes to play with an option to extend playing time. After the testing we provide the participants a total of 10 questions related to gameplay mechanics on gestures and movements to answer. Throughour qualitative survey and interviews, we found that 90% ofthe participants expressed a strong liking towards our control design especially the movement and spell controls. On average, the participants requested an additional 15 minutes of time extension as they felt immersed with the movement and spell controls in the game. All gestures were thoroughly tested, and we observed that all participants were able to complete the game with minimal or no assistance. However according to our observation, users with age between 10 – 13 years old were able to master the controls faster compares to other users in different age group.

The game was also showcased in the Kuala Lumpur Engineering Science Fair 2017 (KLESF 2017) [14] held at MINES International Exhibition and Convention Centre (MIECC), Kuala Lumpur. The feedbacks received were mostly positive as walk-in participants were able to perform movement, hand interaction and spell controls correctly. Overall the participants were satisfied with the VR game play experience without experiencing motion sickness. All of the users rated 4 and 5 out of 5 scores in gameplay experience and immersion.

Fig. 15 Screenshots from Deplau game depicting various gestures and gameplay. All gestures are captured by Vive Controller. Top row from left: Blasting an enemy with fireball; Casting freeze onto enemy; Grabbing gesture to grab puzzle object; Taking damage from enemies

V. CONCLUSION

In conclusion, we have proposed a different movement, hand interaction and spell control in Deplau, a gesture-based VR action/adventure game. The movement control proposed is different from the conventional VR game such as teleportation or artificial locomotion via the Vive trackpads. Our movement control requires user to move their head up and down to mimic jogging movement in real life.

Therefore, user can have a better immersion of the VR game where user is actually performed jogging in the virtual environment. With the combination of hand interaction and spell controls, it provides user with freedom to perform actions such as grabbing virtual objects and casting spells resulting a better gameplay experience and immersion.

REFERENCES

1. Lorenz M, Busch M, Rentzos L, Tscheligi L, KlimantP &Fröhlich P, "I'm There! The influence of virtual reality and mixed reality environments combined with two different navigation methods on presence," *Proceedings of 2015 IEEE Virtual Reality (VR)*, (2015), pp:223-224, http://dx.doi.org/10.1109/VR.2015.7223376
2. Treleaven J, Battershill J, Cole D, Fadelli C, Freestone S, Lang K, &Sarig-Bahat H,"Simulator sickness incidence and susceptibility during neck motion-controlled virtual reality tasks.", Virtual Reality, VOL.19, NO.3-4, (2015), pp:267-275, available online:https://link.springer.com/article/10.1007/s10055-015-0266-4, last visit:26.08.2018
3. Riecke BE, LaViola Jr JJ &Kruijff E."3D user interfaces for virtual reality and games: 3D selection, manipulation, and spatial navigation."*Proceedings of ACM SIGGRAPH 2018 Courses*, (2018), pp:13, http://dx.doi.org/10.1145/3214834.3214869
4. Ryge A, Thomsen L, Berthelsen T, Hvass JS, Koreska L, Vollmers C, Nilsson NC, Nordahl R, Serafin S, "Effect on high versus low fidelity haptic feedback in a virtual reality baseball simulation," *Proceedings on2017 IEEE Virtual Reality (VR)*, (2017), pp:365-366, http://dx.doi.org/10.1109/VR.2017.7892328
5. Pfeil K, Taranta II EM, Kulshreshth A, Wisniewski P, &LaViola Jr JJ,"A comparison of eye-head coordination between virtual and physical realities."*Proceedings of the 15th ACM Symposium on Applied Perception"*, (2018), pp:18, http//:dx.doi.org/10.1145/3225153.3225157
6. Tham J, Duin AH, Gee L, Ernst N, Abdelqader B &McGrath M, "Understanding Virtual Reality: Presence, Embodiment, and Professional Practice,"IEEE Transactions on Professional Communication, Vol.61, No.2, (2018), pp.178-195, available online:https://ieeexplore.ieee.org/abstract/document/8316900, last visit: 22.09.2018
7. Quek A & See J, "The invoker: Intuitive gesture mechanics for motion-based shooter RPG". *Proceedings of theGame Physics and Mechanics International Conference*, (2015), pp:6–10, http://dx.doi.org/10.1109/GAMEPEC.2015.7331847
8. Quinlivan B, Butler JS, Beiser I, Williams L, McGovern E, O'Riordan S, Hutchinson M, Reilly RB, "Application of virtual reality head mounted display for investigation of movement: a novel effect of orientation of attention." Journal of neural engineering, Vol.13, No.5, (2016), available online: http://iopscience.iop.org/article/10.1088/1741-2560/13/5/056006/meta, last visit: 20.09.2018
9. Martel E, Su F, Gerroir J, Hassan A, Girouard A, &MuldnerK, "Diving Head-First into Virtual Reality: Evaluating HMD Control Schemes for VR Games."*Proceedings of the Foundations of Digital Games*, (2015)
10. Farrow M, Lutteroth C, Rouse P, &Bilzon J, "Virtual-reality exergaming can increase enjoyment and performance during high-intensity interval training."*Abstract from 23rd Annual Congress of the European College of Sport Science*, (2018)
11. Amir MH, Quek A, Sulaiman NR and See J, "Duke: Enhancing virtual reality based FPS game with full-body interactions." *Proceedings of the 13th International Conference on Advances in Computer Entertainment Technology*, (2016), pp:35-41, http://dx.doi.org/10.1145/3001773.3001804
12. HTC Corporation and Valve Corporation (2018), HTC Vive. https://www.vive.com/us/product/vive-virtual-reality-system/
13. Valve Corporation (2018), Steam Digital Distribution Platform. https://store.steampowered.com
14. Kuala Lumpur Engineering and Science Festival (2017), KLESF2017, https://www.klesf.net
15. Chou KW, Quek A, Yew HH, "Onmyouji: Gesture-based virtual reality game", International Journal Of Engineering & Technology Vol.7, No.2.14, (2018), , available online: https://www.sciencepubco.com/index.php/ijet/article/view/11465/0, last visit:28.08.2018