Virtual Reality Maze: Multiplayer Game for Android Smartphone

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Abstract—**When thinking of Virtual Reality (VR), people often think of a realistic open scene virtual world where players can do anything their hearts desire. Unfortunately, not all people can afford to buy the best VR equipment such as HTC Vive, Oculus Rift and PlayStation VR. The cheaper option such as Android VR Box tends to give its user a very basic VR experience where there can only look around and have little or no interaction with the VR environment while the expensive option allows players to freely interact with objects in the game. The aim of this project is to develop a VR maze game that can provides a player with better user experience while playing game using a VR headset and a smartphone. This project's developments processes include study about VR and its implementation integrated with accelerometer and Bluetooth controller to make interactive and more immersive android VR maze game. User testing is also done to evaluate the player's playing experience on this game. The outcome from this project show that most of the respondents are able to understand how to move their character and interact with objects in the game developed without the needs of further explanation.**

Keywords—**Virtual reality, android, maze game, VR box**

I. INTRODUCTION

In the span of twenty years, we can see how much technologies have improved our entertainment experiences. In the past, it seems like technologies such as Virtual Reality (VR) will never be achieved in a few decades. VR can support practically all human activities, and it is becoming more widespread in walkthrough and entertainment applications [1]. This is true as VR equipment in the present days can be bought by people easily via in-store or online purchase. There is less need for people to go out and only try demos to experience the VR world.

Not only the hardware has improved, but the software also plays an important part in VR development unlike Augmented reality (AR) that only needs the minimum hardware requirements [2, 3]. As stated by [4], this is because it is easy to anticipate how changes in hardware or software may affect system performances. The VR community's development over the last two decades has been founded on [5]. It enables developers to construct a more open technology than the visual simulation community, resulting in the rapid growth of the number of people working in three-dimensional (3D) graphics. More developers are eager to learn and implement their knowledge about VR also an effecting index of the increasing number of VR software in the market.

Although VR headsets and VR applications are always readily available, it is still not a common household item due to its price being unaffordable in general. Our current market for some of the famous brand VR headsets ranging from few hundreds to thousands which is considered unnecessary and expensive by most people. This usually does not include the cost of software such as VR games that people have to buy to experience VR on their VR headset.

Fortunately, there are cheaper alternatives to this high-end VR equipment and a lot of people agree as the sale for VR headset for smartphones is higher than the ones for computer. On the downside, VR headset for smartphones does not have the ability to allow player to fully control their movement because of the smartphone limitations. The games for smartphones also are not the best as it tends to become a walking simulator where player have little until no interaction while playing.

Thus, the purpose of this project is to develop a VR game where player can move around according to their body movement using the combination of accelerometer and

Bluetooth controller. A player should be able to navigate through the game area with lease limitations while enjoying the VR experience. The maze premise is to provide the players a reason to explore and experience VR environment while also reach their goal by finding all required keys to exit the maze. Therefore, this project is basing on the maze theme game development to expand the users' VR experience.

II. LITERATURE REVIEW

VR was discovered during the 19th century when the concept of stereoscope appeared. Research showed that human brain is capable of combining two images from both eyes so that the image seems to have a sense of depth and space. In 1838, Sir Charles Wheatstone constructed the first stereoscope what used two mirrors that had been set at a 45-degree angle. This angle reflected images set opposite to each other and create a spatial image [6].

The term VR came from two words which is virtual and real. The former means "almost" or "conceptually," implying a technologically enhanced experience that is close to reality [7]. We understand and interact with our surrounding by feeling and touching objects with our physical form. However, virtual reality requires devices such as goggles, headphones controllers.

A. VR Application Concept

VR headsets works by using splitting the screen in two and change the flat screen into a stereoscopic 3D image. With split screen, each eye is able to have an individual view which create a 3D perspective. VR screens also utilize lenses between the screen and the eyes to help distort image into something lifelike [8].

Players should be able to move their head in several different directions for the VR to work properly. VR uses head tracking system to help measure their head movements which called six degrees of freedom (6DoF) that monitor the player's head position along X, Y and Z axis [9].

B. Types of VR

There are three (3) types of Virtual Reality. They are non-immersive VR, semi-immersive VR and immersive VR.

Non immersive Virtual Reality: The common definition of VR includes full immersion which require player to wear a head-mounted displays and have freedom in movement. However, there are alternate form of VR that had been explored. In several research labs, an alternative form of VR is being investigated. Non immersive VR also locate the user in a 3D environment that can be directly manipulated, but it does so by using a monitor, keyboard, and mouse in a traditional graphics workstation [10].

Semi immersive Virtual Reality: Semi-immersive is the combination of non-immersive and immersive VR. Semi-immersive environments also known as hybrid systems are virtual environment that employed in the training and education industries. It uses graphical computing and large

projector system [11]. A study on the semi-immersive VR environment was implemented by combining and extending the use of 3D depth sensing camera, a middleware, and a high-performance real-time 3D engine. It was to allow participant to display their postures to be displayed as a 3D virtual representation of themselves on a screen placed in front of them [12].

Immersive Virtual Reality: Immersive VR as the name suggest, give player the full immersion into the virtual world during playtime. Immersive environments foster a sense of "being-in-the-world" [13]. This means that players know that they are still in the real world, watching a virtual world from a display but they can feel themselves inside of the virtual world.

Based on the above clarification, research directions nowadays are moved towards immersive VR due to its better users' experiences. Immersive VR simulation provides the most realistic experience imaginable, hence it is the much more costly. Head-Mount Display (HMD), tracking devices, data gloves, and other components are included [11] while high-resolution content with a broad field of view is provided by the VR headsets for immersive VR environment.

C. Head-mounted Display (HMD)

HMD is largely needed for the full immersive experience. HMD is a type of binocular stereo displaying equipment and a micro display device. It may be utilized with computers, MP4 player and mobile phones as a portable and mobile large-screen display. HMD model which called Telesphere Mask was invented in the year 1960. This device uses miniaturized projection lamps to transmit stereoscopic television images [6].

D. Bluetooth

Bluetooth is a low-cost, low-power, short-range radio technology that was developed in the 1994. It was created to link devices like as mobile phones without the use of cables, handsets, headsets, and laptop computers are all examples of mobile devices [14]. Bluetooth has created the concept of a Personal Area Network (PAN), a type of near range wireless network that seems destined to revolutionize individuals interact with the information technology landscape around them. L. M. Ericsson of Sweden invented Bluetooth in 1994 [15]. Harald Blåtand "Bluetooth" II, king of Denmark from 940 to 981 A.D., is honored with the standard. He also stated that Ericsson, IBM, Intel, Nokia, and Toshiba formed the Bluetooth Special Interest Group (SIG) in February 1998 to produce an open specification for short-range wireless connection.

E. 3-Axis Accelerometer on Android

Accelerometers were originally built in the smartphones to support advance game play and allow the automatic screen rotation but does not limit these functions. Accelerometer can be seen to also monitor user's activity to generate periodic

reports. Fitness applications uses data from these reports to calculate amount of user's exercises and calories count [16].

These accelerometers are capable of detecting the device orientation along X, Y and Z-axis. The coordinate system origin it on the lower-left corner of the smartphone where X-axis is horizontal pointing right, Y-axis pointing up and Z-axis pointing outside from the front face of the screen [17-19]. Fig. 1 shows the accelerometer coordinate system for an Android smartphone.

Fig. 1.
Fig. 2. Android accelerometer coordinate system [15]

III. METHODOLOGY

Fig. 2 shows the development process for this project. The tasks were separated into four different phases which start from researching until the evaluation process finish.
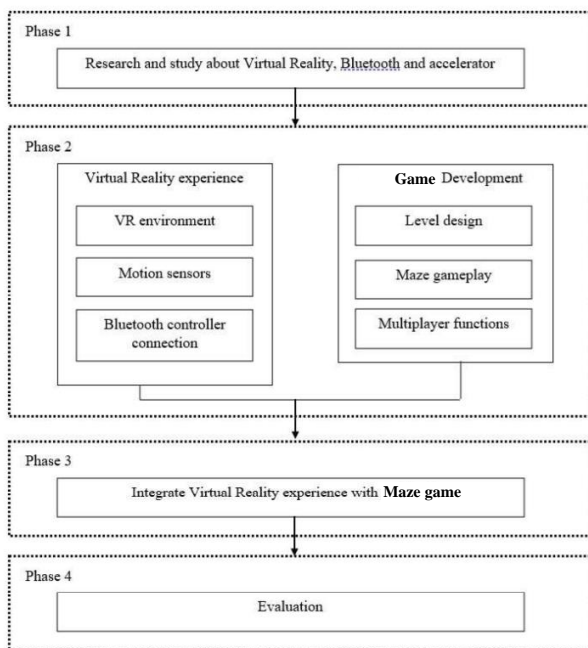

Fig. 3. Project methodology

A. Phase 1 : Study about VR, Bluetooth and Accelerometer.

Phase 1 is related to study on topics such as VR and its concepts and implementation, Bluetooth, and accelerometer in gaming industry. This study introduces the students the fundamental and important details of each topic. This phase is important as it allows students to determine how they would implement each component to their project. Aside from that, the study also includes searching for existing projects throughout the internet. Existing projects can serve as a guideline to determine what should be include in this project.

B. Phase 2 : Game Development.

Phase 2 contains the development process for the game. It consists of designing level, playable character and programming for the game to function. There will be a maze for the players (multi-player game with 2 players allowed in a time) to run around in search for three (3) key fragments. Each key is only appeared once at a time where each key is leading the player to three (3) different minigames. Once a key has been collected, it is disappeared and another key appears. Only one player needs to collide with the key in order to teleport both players into a minigame in multi-player environment. Most of the functions used in the minigames are collision detection and ray casting.

The three (3) minigames included can only be solve by two players who cooperate with each other during multi-player environment. Upon finishing the level and basic character functions such as walking, turn around, animation and collision boxes, enemy is placed inside the maze to chase players. The enemy is spawn at a fixed spawn location and disappear once it collides with the players. After the cooldown timer hits zero it is spawn again. Players are force to enter and play a minigame every time 2 players or either one collides with the enemy.

The game mechanism is happened within VR environment assisted with accelerometer and Bluetooth controller as the user input.

C. Phase 3 : Integrate VR game and its components.

The project is proceeded to phase 3 after the main game, VR game world and user input are functioning well. Integration is then been done to ensure the user inputs and VR game environment are interactable. This can be achieved by giving the players option to choose between accelerometer mode or controller mode. This option appears every time players open the game on their smartphone.

VR is used build the immersive game environment for user to look around the game area with VR headset or any VR hardware while Bluetooth controller is used to move their character around along X-axis or Z-axis using the joystick. Accelerometer on the other hand is used to sense the speed of player's movement to emulate jog or running in the game. The return values from the accelerometer indicate the intensity of the smartphone's movement. These values' differences is then be used to move the game character forward.

D. Phase 4 : Evaluation.

Phase 4 is focusing on project evaluation to evaluate the game functions and interaction based on a group of participants after they tried the game. Before the test, users needed to complete a survey based on their VR experience. Users and then played the game and indicate its performance.

Their feedback will be gathered for analysis purpose. Instructions and the game details are provided at the start of the game and users could try the game several times and needed to answer another survey regarding their playing experience afterwards.

IV. IMPLEMENTATION

A. Google VR Software Development Kit (SDK).

Google VR Software Development Kit (SDK) is available for download in Google Developers website for free. Their website also contains a guide to help new developers set up Google VR with Unity. In order for VR to work in Android smartphones, some Google VR scripts need to be added to the scene in Unity.

Each script has its own function. The commonly used Google VR scripts such as emulate player's head movement in unity editor, replacing the current event system to Google VR event system and enable reticle pointer to game and use ray casting. Fig. 3 shows the comparison where in (a), the reticle remains as a pink dot when it does not detect anything while in (b) the reticle expands into a circle when it detect the button.
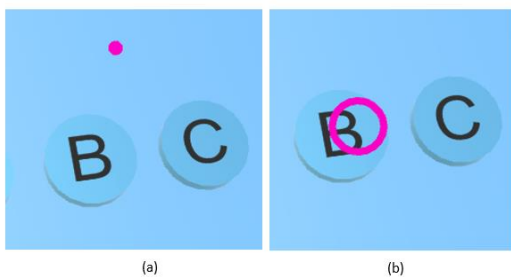

Fig. 4. Use one of Google VR script to enable ray casting. Reticle (a) no detection, (b) detect a button

B. Bluetooth Controller

Unity allows developers to add different kind of inputs from input manager. The default settings are keyboard and mouse inputs. In order for game controllers to work, new input needs to be added to the input list. The input type was changed to joystick axis in order for the game to detect joystick inputs. Input axis is set X axis to the horizontal joystick input and Y axis to vertical joystick input. Fig. 4 shows the input manager inside Unity where developer can set up the inputs for their project.

C. Accelerometer Input

The accelerometer input is assigned into a vector 3 variable where it only takes the x and z positions of the accelerometer. The code then filters the input using **if** method where if the x and z positions are detected less than a certain values, the player characters (1 for single player mode and 2 players for multi-players mode) will move forward. This input option only allow player/s to move forward and they need to

turn around in order to move the other way as the character/s will always move according to where the camera is pointing.
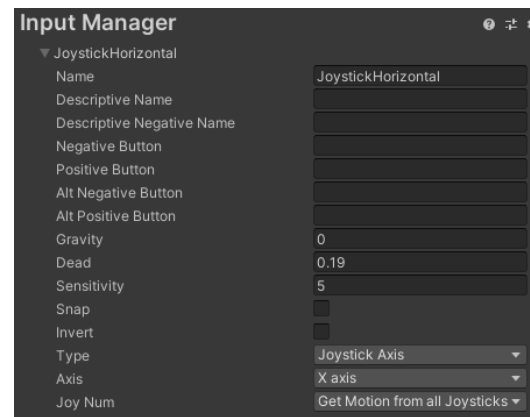

Fig. 5. Joystick horizontal input setting in input manager

D. Photon Unity Network

The multiplayer session is made possible by using the free version of Photon Unity Network 2. It was used to allow player to create room, join room, view another player in the room and send data between players. PUN need to be imported from Unity Asset Store into the current project in order for it to work. PUN also require developers to sign into their Photon engine website and create their Photon cloud application there. Upon creating the cloud application, photon is giving an application id for the project.

Photon connection is determined in the create or join script. At the start of the game, the script tries to connect with Photon server. Once players are connected, they can join or create a room using a Photon network function. After players has entered their desired password, they need to click on button **join** or **create** which trigger Photon functions that require their password as parameters. It is also required to use Photon load level function in order to change scene.

There are two majorly used photon scripts that are being used in the project. They are Photon View and Photon Transform View. Photon View is able to identify object across network and control the client updates. Photon Transform View used to synchronize the object's transform and rotation across the network. The other photon script that had been used in the project is Photon Animator view that synchronize the players' animations.

E. Enemy Artificial Intelligence.

In order to make the enemy chases player/s around, Nav Mesh Agent component need to be attached to the enemy. A script also was added to the enemy object so developer can control on which object the enemy will follow.

Nav Mesh Agent require NavMesh to operate. NavMesh is the navigation system which allow the object with Nav Mesh Agent component to move around in the game. The process is automatic once developer click on bake in the navigation tab.

When baking, it collects render meshes and terrain of all the game object that is marked as Navigation Static.

V. EVALUATION

A. Experiment Setup.

The setup begins with connecting a Bluetooth controller to an Android smartphone. This option is optional for the players who wants to play the game using a game controller instead of accelerometer input. Once the pairing is success, a participant has to launch the game and insert the smartphone into a VR headset for smartphones. Fig. 5 shows a Bluetooth controller asking permission to pair to the Android smartphone.
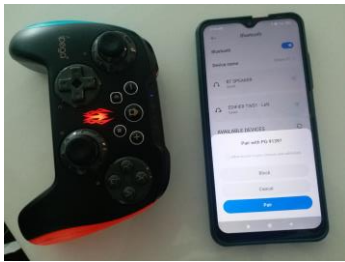

Fig. 6. Pair Blutooth controller with Android smartphone

A participant and then can wears the VR headset and adjust its strap to make it comfortable to wear. Lenses in the VR headset also need to be adjusted in order for participant to view through the screen clearly. Lastly, a player can look around the VR environment by turn around his/her head to explore the game environment. Fig. 6 shows a player had wear the VR headset and handling the Bluetooth controller.

Fig. 7. Player using VR headset and Bluetooth controller.

B. Pre-experiment questionnaire.

From the pre-experiment questionnaire, it shows that a total of ten (10) respondents had taken part to test the game. The number of respondents are enough based on the preliminary test sample requirements [20, 21]. Half of the respondents are males and the other half are females. Their age is between 16 to 26 years old. All respondents have experience Virtual Reality before testing session. Most of the respondents have a

general knowledge about VR based on the bar chart as shown in Fig. 7.
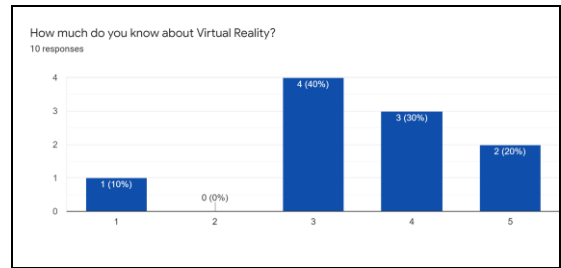

Fig. 8. Respondent's knowledge about Virtual Reality

C. Post-experiment questionnaire.

The post-experiment contains 18 questions. All of the data can be summarized as per below :

All of the respondents choose Bluetooth controller as their input during the testing. The test sessions are done in pair. So 50% of the respondents play as player 1 and the other half play as player 2.

All of the respondents agreed that the main menu is easy to understand. 70% of the respondents like how the main menu is presented while 30% of the respondents are mixed feeling about the main menu. None of the respondent dislike the main menu.

60% of the respondents voted that the player movement in game is not challenging while 40% of the respondents thinks it s challenging when moving around in game. All of the respondents agreed that it is enjoyable to move around in the game.

The first minigame, Enemy Encounter, is considered enjoyable by 70% of the respondents while the other 30% have mixed feelings. 90% of the respondents think that the minigame is easy to undestand while 10% does not understand the minigame.

The second minigame, Let's Paint, is considered enjoyable by 80% of the respondents while 20% has mixed feelings. All of the respondents agree that the minigame is easy to understand. Most of the respondents have neutral feeling about the difficulty of the minigame as shown in Fig. 8.
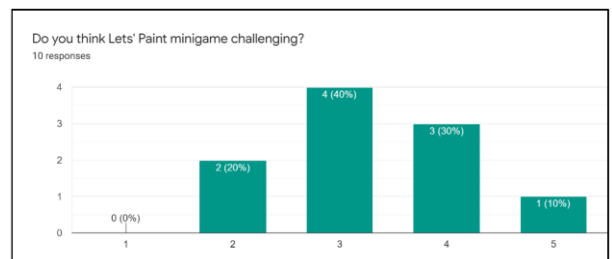

Fig. 9. Challenge scale for Let's Paint minigame.

The third minigame is Food Drop where 70% of the respondents find the minigame enjoyable, 20% does not enjoy the minigame and 10% has a mixed feeling about it. 90% of the

respondents agree that this minigame is easy to understand while the other 10% does not find it easy to understand. Most of the respondents find it slightly challenging as shown in Fig. 9.
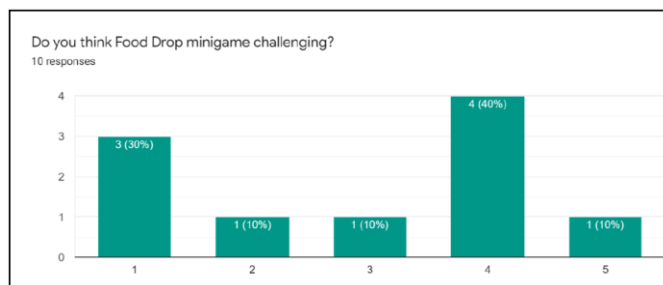

Fig. 10. Challenge scale for Food Drop minigame.

The last minigame, Decipher Text, is considered enjoyable by 90% by the respondents while 10% of the respondents have a mixed feeling about it. All of the respondents are able to understand this minigame easily. Most of the respondents have a neutral felling about the minigame's difficulty as shown in Fig. 10.
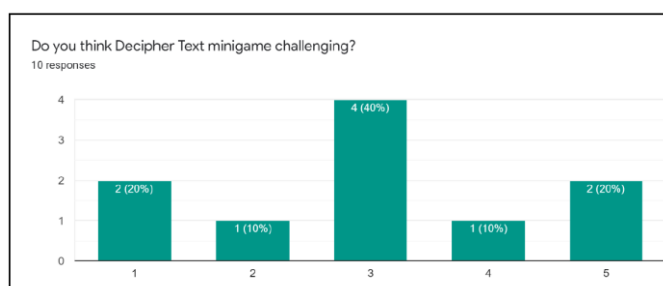

Fig. 11. Challenge scale for Decipher Text minigame

D. User Acceptance Testing

The user acceptance testing is done by observing the respondents during their testing session. This test is in purpose to observe if respondents are able to understand and interact with this application before getting any instructions.

Since half of the respondents are player one and the other half is player two, not all of the actions can be observed. Only player one can trigger enemy, play enemy relevant minigames and trigger keys. Decipher text minigame also have different actions for player one and two. The test sessions are done in pair where odd number respondents become player one and even number respondents become player two.

The symbol "✓" indicates that respondent's result is done as expected while symbol "x" indicates that respondents fail to achieve expected result. The empty cells are ones that the action does not imply to the player. The data are shown in Table I.

From Table I, it can be observed that respondents are still able to experience VR by using cheaper alternative device and setting. They are able to look around, gaze to select the buttons and move around their characters using a controller while also playing the minigames without much problem.

Table I also shows that all of the respondents are able to understand the user interface to create or join the game. For the maze and minigames that collided with enemy are fully dependent on player one. Thus, the result for player two are empty during these scenarios. In Lets' Paint minigame, both players are able to push the paintball to the target location. All of the players get confused in Food Drop as they try to catch any falling objects that they see instead of only catching food object and avoid catching the enemies. As for the last minigame, Decipher Text, both players are able to understand each role and worked together to decipher the symbols shown.

TABLE I.   USER ACCEPTANCE TESTING

No	Action	Expected Result	Actual Result									
			1	2	3	4	5	6	7	8	9	10
1	Choose controller	Gaze at the controller or motion button	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Create/Join room	Gaze at the create or join button	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Create Password	Gaze at a shape four times	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	Meet enemy	Collide with enemy	✓		✓		✓		✓		✓	
5	Avoid enemy	Look left or right	✓		✓		✓		✓		✓	
6	Interact with key	Collide with key	✓		✓		✓		✓		✓	
7	Submit paintballs	Push the balls to the submit point	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8	Catch food	Use basket to catch food	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9	Avoid enemy	Don't let enemy fall to the basket	x	x	x	x	x	x	x	x	x	x
10	Decipher text (Player 1)	Look at board in game and describe to player 2	✓		✓		✓		✓		✓	
11	Decipher text (Player 2)	Look at board in game and give result to player 1		✓		✓		✓		✓		✓
12	Finish game	Collide with exit door	✓		✓		✓		✓		✓	

VI. CONCLUSION AND SUGGESTION

In conclusion, the respondents are still able to experience VR even when using a cheaper alternative setup. Most of the respondents can understand the basics movements and able to interact with the objects inside the VR game created.

There are a lot of comments and suggestions from respondents after the testing phase. The most important part is to show instructions to the players for each minigame before they start the game. This is to help players to understand what to do in order to win instead of taking few seconds being clueless at the start of each minigame. The next one is to make a bigger and detailed map as the current one is quite barren where there is no actual scenery for the player to look at. A good suggestion from one of the respondents which is to randomize the wording is also a good idea to implement in the future. The last one is to create a better gameplay for player two as the current game is focused on player one most of the time.

ACKNOWLEDGMENT

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