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DESIGN AND TESTING OF VIRTUAL REALITY CYCLING EXERGAME USING HANDHELD CONTROLLER

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ABSTRACT

Nowadays, people are busy with gadgets, social media and playing video games that tends their bodies to physically inactive. However, Virtual Reality (VR) exergaming in literature has proven to be one of the best solutions to encourage these sedentary people to live in a healthier lifestyle. Exergaming refers to a combination of video games with a physical exercise that rely on the technology that can track body movement. Hence, this project aims to develop a cycling exergame that integrate with HTC Vive hand controller in VR. There are four phases

have been carried out namely (i) problem investigation, (ii) designing the game structure, (iii) implementation of VR cycling exergame, and (iv) testing and evaluation. The usability testing results shows the users feedback on the development of VR Exergame for cycling in terms of the user interface design, player interaction, difficulty of the game and user satisfaction in understanding the game. The user acceptance testing results shows that this game works accordingly, however there are some suggestion and expectation from user that can be measured for improvement and enhancement in future works. Based on the result, this project is successfully produced a cycling exergame in VR and significantly improve the user experience in VR.

Keywords: Virtual Reality (VR), cycling, exergame, hand controller, usability, user acceptance.

INTRODUCTION

Exercising is important in our daily lives, but people rarely take it as their weekly routine. Keep active is crucial for staying and it's important to remember that bodies are created and have develop gradually to be consistently active. Bankoski et al. (2011) stated that sedentary behaviour is associated with a condition called metabolic syndrome. Metabolic syndrome causes people having a high risk for coronary artery disease such as type 2 diabetes, obesity, and high blood pressure. While Warren et al. stated that men tend to have a significantly high risk of dying from cardiovascular disease if they reported to have high levels of sedentary behaviour. In addition, from the research it shows that sedentary behaviour is related to someone overall physical activity level.

To encourage people to have active lifestyle, researchers and developers in Human Computer Interaction (HCI) have developed a lot of VR exergames (Alce et al., 2019; Born et al., 2019; Campbell & Fraser, 2019b, 2019a; Cao et al., 2020; Cho & Park, 2020; Ijaz et al., 2020; Kishishita et al., 2019; Kojic et al., 2019; Li et al., 2019; Liu et al., 2020; Michael & Lutteroth, 2020; Narejo et al., 2020; Perrin et al., 2019; Ščiglinskas et al., 2019; She et al., 2020; Varela-Aldás et al., 2020; Wirth et al., 2020b; Xu, Liang, et al., 2020; Xu, Ma, et al., 2020). Exergames is one of the ways to encourage people to exercise as the physical exercises was gamified with the game mechanics in VR systems (N. Nor et al., 2020a; N. N. Nor et al., 2020b). Cycling exergames is one of the physical outdoor exercises that allow people

to explore the new views by cycling in indoor. This exergame will allowed user to exercise indoor as they will be move/swing the movement hand controller while playing virtual reality video games. In VR exergames, people can have fun with the virtual environment but at the same time they will also be exercising. Interaction is a crucial key in virtual world (Basori et al., 2008; Ismail & Sunar, 2015; Yusof et al., 2016). So, when the players play through the VR exergame, they will focus more on the game world instead of their physical pain and exertion. As the game includes game mechanics likes challenger, it tends to make people spends more time playing this game. Besides, playing VR exergames will make the player immersed with the environment so they will experience the virtual world excitedly. The more the user spends their time playing the games, the more it helps in burning their calories. This will help people in having a healthy and active lifestyle. In order to achieve such lifestyle, three Research Objectives (RO) have been proposed as follows:

RO1 To design the cycling exergame in VR.
RO2 To integrate the VR cycling exergame with HTC Vive hand controller.
RO3 To implement and test the VR cycling exergame on the real users.

LITERATURE REVIEW

VR has beginnings that introduce the time that the concept was coined and formalized. In 1960s, the concept of VR was formulated, and the first commercial VR tools appeared in the late 1980s. For this reason, during the last 20 years, 100s of researchers explored the processes, effects, and applications of this technology. Besides, the application of computer-based technology towards sport become more intense interest. VR is one of the technologies that was applied in sport since 1990s. In sport, existence of exergames becoming popular as it helps in providing user with some exercises at the same also the entertainment stated by Neumann et al. (2018). Exergames is an integration of the sports interactive video game with various innovative exertion-based interfaces. There are various type of task activity in VR exergame studies, such as cycling (Michael & Lutteroth, 2020), rowing (Shoib et al., 2020), running (Perrin et al., 2019), fighting (Xu, Ma, et al., 2020), soccer (Wirth et al., 2020a), and many more. However, cycling seems to be the most popular VR exergame to be conducted in recent years (Neumann et al., 2018). The objective of exergames have been

stated by Neumann et al. (2018) which allow the players to utilize body movements to achieve the engaging experience of playing games and thus promote physical activity, fitness and gross motor skill development. Below shows the related and existing study that combine both technologies.

Virtual Reality Cycling Exergame

The game was implemented by using several devices. Oculus Rift VR headset is one of the devices that allow the user to display the virtual environment. Besides that, Trek FX bicycle that combine with a Kickr power trainer that provide the user ability to cycle while playing games. Microsoft Kinect camera help to give the data of user gesture. The function of Kickr power trainer is to detect the pedaling speed of the user at once also controls the virtual bike's speed. Kinect camera have been used to track the user's upper body. For instance, the detection of throwing newspaper by the user. Bolton et al. (2014a) presented a virtual reality cycling that combine with game refer with the arcade game Paperboy. It is because, the environment of the game is virtual suburban neighborhood. Player are allowed to ride a bike to start the game which they must complete a paper route around the neighborhood environment. In order to play the games, virtual reality headset (Oculus Rift) have to be mounted at player's head and the gesture will be detected by Microsoft Kinect when the player start to move their body as Kinect have mapped the joints to an in-game avatar (3D representation of a person online).

Figure 1

VR Cycling Exergame (Bolton et al., 2014b)

The game allows player to go through and see their arm and hand movements in virtual representation during the game. The game was rendered using a first-person perspective. From there, player is allowed to hit the mailboxes by throwing the newspaper with their own hands. Throwing gesture will be performed as the gesture started by the player. Player can start cycling naturally as the game give the player experience to pedal the real bicycle and immersed with the virtual environment. The speed of the pedaling are mapped with the virtual world. Hence, it helps to mitigate the motion sickness that always related with VR headsets. The immersion increasing by mapping the player's joints to the game and creating a sense of player's body in virtual world. The game help in encouraging exercise without feeling like cycling is an invention added input mechanism.

In this project implementation, Bolton et al. (2014a) use cycling hardware and gesture and skeleton detection. Wahoo Kick Power Trainer consists in the systems which attached to a Treck FX bicycle for cycling hardware. The kick power trainer sends speed and power to a companion iOS application over Bluetooth. The iOS app, in turn, sends the speed received from the trainer to their Unity based game via a UDP connection. Besides, Microsoft Kinect 3D camera will detect gestures. The user's upper body is tracked and associated skeleton data is mapped to the avatar within the game. The virtual representation of user body can be displayed and controlled using Kinect in order to increase the immersion towards virtual world. In addition, the gesture of throwing newspaper that performed by the user are being triggered the movement and tracked by using Kinect.

Indoor Cycling Exercises with Virtual Reality

In 2018, Kassim and Said (2018) have stated in their paper and presented a study development. The study entitled Interactive Indoor cycling exercise with virtual reality video games. This study integrated two features which are interactive video games and cycling in virtual reality. A prototype of exercises bicycle have been designed by Kassim and Said (2018) that allowed player to manage the VR game using smartphone power by Arduino Uno controller. They also collected and analysed users' data on the reading of heartbeat, the speed during cycling, the time taken to complete the game, the distance travelled along the game and the level of the player stamina. The connection of mobile and webpages is used in the system as followed the internet of

things concept. The bike simulator will be run from the phone. Player will get their paddling speed, handling value and balancing value by smartphone until the game finish.

Figure 2

Indoor Cycling Exercises Prototype (Kassim & Said, 2018)
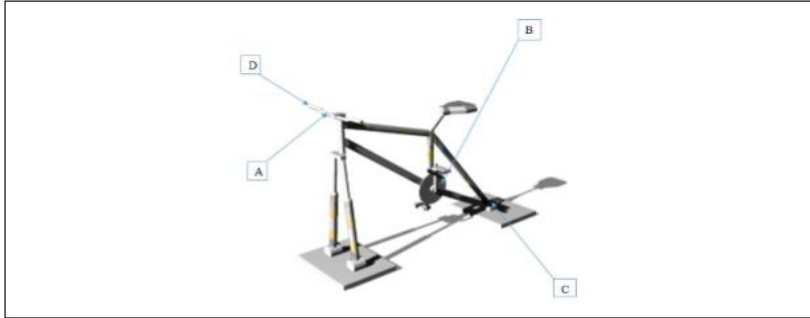
Arduino Uno will be handling the paddling systems which it will process all the sensor on the bike. Several sensors are attached and used in this study. For instances, potentiometer, heartbeat sensor, button sensor and DC motor are attached at the bicycle to allow the integration of the bicycle with the games. The database platform to store the user's data is using Fusionex cloud database and analytics. Several data that have been collected during the games are the game score of players, stamina level and health level. The User Interface (UI) of the study was designed and developed using Unity3D software.

Smart Exercises Bike Virtual Reality System

Katsigiannis et al. (2019) have designed and proposed a physical exercise system. The study entitled a smart exercise bike which combine with the base of VR. User can control the game during pedaling the stationary exercise bike. The transmission of the pedaling signals to the computers occurred when the user started to pedal the bicycle. In order to test the functionality of the study, a trial have been conducted by several users to check whether the system defined the quality setting. The test also to evaluate about the visual representation quality and motion sickness symptoms. Electrocardiography (ECG) and galvanic skin response (GSR) are physiological responses in terms of signals. The responses were recorded for the whole periods during

the experiments. It is because, to discover a better assess the effects of visual representation quality and motion sickness experiences based on the quality that get from the systems. The study allows to transmit the data from the bicycle to the computer in bike module components. The transmission process can be performed before the data received were converted to the actions that required for the functionality of VR application.

The attachment of Smart Exercise Bike and a custom micro-controller-based circuit is for triggered and detect the rotation of the exercise bike's pedals. There are also buttons that were provided for controlling the steering which will sends the information to the computer in real time. The bike module was designed as generic peripheral which it allows to combine with other exercise bike and connected the games to any USB enabled computer. During their studies, they conducted experimental evaluation which the participants were asked to use the smart exercise bike system while using a commercially available HMD.

Based on the Table 1, all the related study has similarity in using VR headset and integrate with the real bicycle. In order to integrate the study with the real bicycle, two of the study use a sensor detection for pedaling while the other one connects with a system that can track the movements of the pedaling. Other than that, only indoor cycling exercises with virtual reality video games study implement a sensor for the handlebars tracking while the other two study does not implement available HMD.

Table 1

Characteristics Comparison of Previous Study on Exergame

Characteristics	Virtual reality cycling exergame	Indoor cycling exercises with virtual reality video games	Smart exercise bike virtual reality system
Use Microsoft Kinect Camera for body movement	✓	✗	✗
Use VR headset	✓	✓	✓

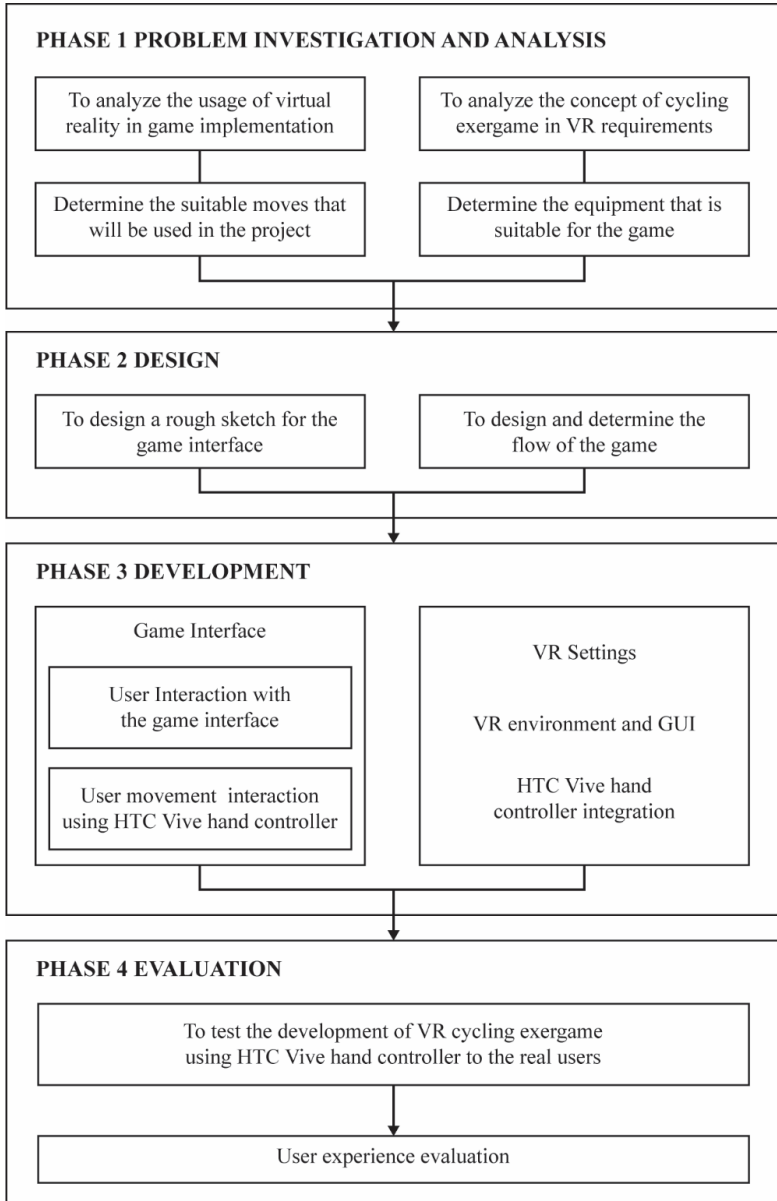| Characteristics	Virtual reality cycling exergame	Indoor cycling exercises with virtual reality video games	Smart exercise bike virtual reality system
Use sensor detection for pedaling	✗	✓	✓
Use system that track the movements of the pedaling	✓	✗	✗
Game mechanics	✓	✓	✗
Use sensor tracking handlebars	✗	✓	✗
Integrate with bicycle	✓	✓	✓

Based on the information that have been explored and gathered from the analysis of the related study, there are several ideas that are suitable with the development of cycling exergame in virtual reality study. Based on the studies of the related study, its help in getting the idea on how the virtual reality game are being integrated. The studies also help in defined the implementation of each study and the purposed of the study development. The game idea also has been decided based on the information gathered from the previous studies about the related and related study.

METHODOLOGY

The organizational process has four main phases that are equally essential in determining the progress of this study. Each phase has been performed the objective of the study to achieve good results. Figure 3 shows the overview of the study methodology which includes problem investigation and analysis, development of virtual reality cycling game, implementation of VR cycling game that has been integrated with the HTC Vive hand controller and lastly the evaluation phase.

Figure 3

Research Framework

PHASE 1 PROBLEM INVESTIGATION AND ANALYSIS

To analyze the usage of virtual reality in game implementation	To analyze the concept of cycling exergame in VR requirements
Determine the suitable moves that will be used in the project	Determine the equipment that is suitable for the game

PHASE 2 DESIGN

To design a rough sketch for the game interface	To design and determine the flow of the game

PHASE 3 DEVELOPMENT

Game Interface

User Interaction with the game interface

User movement interaction using HTC Vive hand controller

VR Settings

VR environment and GUI

HTC Vive hand controller integration

PHASE 4 EVALUATION

To test the development of VR cycling exergame using HTC Vive hand controller to the real users

User experience evaluation

Phase 1: Problem investigation and Analysis

This phase was to analyze the problem by focusing on the prior approaches of virtual reality cycling game including the technique to develop the virtual environment of the cycling game. Research analysis has been made on the virtual reality technology such as the display technology, interaction, implementation, and application to assist in better understanding of the technology before procced with a suitable game design. The analysis on the existing study also have been conducted to compare in terms of the functionality, requirements, and specifications of the study.

Phase 2: Designing the game structure

Based on the information explored and gathered in the previous phase, a low fidelity design of virtual reality cycling game has been sketched. The ideas of the game design have been decided based on the analysis made from the previous studies. Figure 4 shows the flowchart of the game design that has been implemented for this study.

Phase 2a: Designing the Gameplay and Concept

The concept of this game was challenging. The player had to finish the race within an allocated amount of time. The game begins when the player moved the HTC Vive Controller in y-axis until the finish line within the allocation time. The environment of the game was at the lake racetrack. There were three levels of the game with different difficulty. In this game, player had a mission that they needed to achieve in order to go to the next level. In each level, player need to collect several coins according to the requirements for each level. During the games, there were also some obstacles and beneficial elements. Those elements were very important for scoring purpose of the games.

Therefore, several obstacles have been placed in front of the road while playing the games. The score will be deducted if player failed to avoid the obstacles. As the score has been deducted during the games, there were also several elements that helped player to gain their points again. The elements that were mentioned before was the coins that player need to collect. The coins helped in gaining player points or score. In order to make the game more challenges, there were 3D turtle model elements which would reduce the allocation

time if player collided it. Fortunately, player also can increase their current time by pick up the clock timer elements.

During the time player moved the HTC Vive Controller while playing the games, they can view their score and the time keeper at the top of the game. Every level has different rules to win the race. For instance, in level one or easy level, player need to achieve only 60 scores and collected 7 coins to go to the next level. While in level two or medium level, player need to get 120 scores and collected 12 coins. If player successfully completed both levels, they able go to the last level or hard level. The objective of the hard level was to test the cycling agility of the player. Therefore, there were more obstacles, higher score requirements, higher amount of coins collected and limited time compared to the other level.

Lastly, the game over can be reached if player failed to complete the game within the allocated time. The game will be restarted if user also failed to achieve the requirements score and amounts of collected coins. At the end of the game, the score and time remaining will be displayed on the screen.

Phase 2b: Designing the Game Mechanics

Octalysis framework by Yu Kai Chou (Chou, 2021) has been used as game mechanics in this game study and has been listed down below in this subsection.

A.   Obstacles

In order to make the game more challenging and difficult, the obstacles have been added. The obstacles will be placed randomly along the routes of the games. The number of obstacles has been differently added for each level. The higher the level, the greater number of obstacles. The function of the obstacles was to deduct the score 10 points. Therefore, player need to avoid the obstacles to prevent the score being deducted. If the score of the player less than the expected score, the game will be over, and player need to restart the games in order to play the games.

B.   Time Increment and Decrement

Time management important in this game as the race must be completed within the allocated time. There were two elements that

help in making this game more interesting and challenging which were time increment and time decrement. Time decrement in this game has been presented by 3d turtle while time increment represents by alarm clock. The turtle will be given disadvantages to the ocation time will be reduced by five seconds if they pick the elements. While the time increment (clock timer) gave the players opportunity to increase their allocation time by adding ten seconds from the current time. Then, it made their time taken longer than the initial allocation time. Besides, player also able to view their time left to finish the race at the screen. The time keeper has been displayed at the top right corner of the display screen.

C. Coins

Collecting coins was the mission for every level in this game. The difference for each level was the rules and required amount of coins that has been collected. Coins was the special assets that have in this game which player need earn points by collecting the coins. The coins play a role to attract people to continue playing cycling exergame in virtual reality. In beginner level, several gold coins have been placed randomly in the games. While in moderate level, there were silver gold and skull design coins. The score of the coins were different based on the design. If player picked coin with design skull, they earned 10 points while for gold coins only earned 5 points. It was because, in expert level the minimum points that player must score were 180 points which was higher than the beginner level.

D. Scoring

Scoring for cycling exergame in virtual reality are based on the amounts of coins collected and obstacles avoidance. The score will be started counts when player collected the coins. One coins will gave player 10 points. Therefore, player need to collect the coins until they achieved the requirement score for the level. Several obstacles have been placed along the routes that will be deducted 10 points from different rules to complete the level. For instance, in beginner level, player need to score minimum 60 points before completed the routes. Next, in moderate level, the minimum score was 120 score that need to be achieved in order to go to the hard level. At the end of each level, a scoreboard will be displayed to allow player to view their scores.

E.   Level / Missions

Cycling exergame in virtual reality have three level and mission. Every level had same missions but different level of difficulty. Here are some of the rules for each level:

i.   Level 1
      Easy Level Easy level is the beginner level. Player did not have to get high score in this level as easy level is to help player to get used to this game.

ii.   Level 2
      Medium Level In this level, the difficulty will be increased as the player managed get used with the previous level.

iii.   Level 3
      Hard Level Hard level is the hardest level. In this level, the agility player in handling the handheld controller is needed. The period to complete the routes is the shortest among others. The requirements and rules also the highest and harder compare to easy and medium level. In this level, it will be allocated the player 1 minute to complete the missions and achieve the requirements within 1 minute.

Figure 4

Game Flowchart
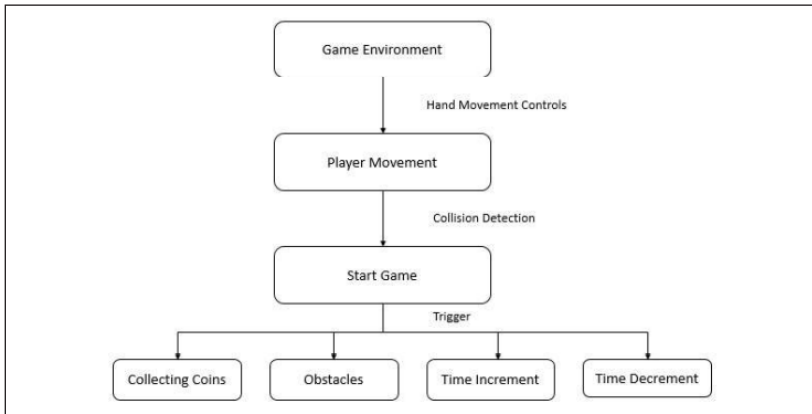
HTC Hand Controller will allowed user to move the player when the controller swing their hand in y-axis. The speed of the player movement depends on the higher the swing of the hand. The player

converts into handle of bicycle where the bicycle is placed with the box collider. All of the elements also located with collider, the game score and time will respond after the collision detection is entered. The output such as score and time will be affected by the trigger from collecting coins, obstacles, time increment and time decrement.

Phase 3: Implementation of VR cycling game

In the implementation phase, the step begins by setting up the User Interface (UI) so that it is easier to test the game. The virtual environment of the cycling game also has been decided to represent the virtual world. Next, the virtual reality cycling game has been integrated with the HTC Vive hand controller in order to give the full functionality of the virtual reality cycling exergame. The controller has been integrated to allow the movement of the player in the game. This phase will be discussed further in the next section.

Phase 4: Testing and Evaluation

In this phase, testing and evaluation has been made to test and evaluate the functionality of the game. 10 respondents have been evaluated in this study to analyze the improvements that can be made. The evaluation considers the VR technology, game development and the integration of real bicycle. Usability testing has been used for this study.

IMPLEMENTATION

This section consists some of the more critical part of this study. The core features of the study that has been implemented are included in the game interface, game mechanics and virtual reality implementation.

Game Interface

This cycling game was a first-person point of view as a single player. A bicycle's handle will represent the single player while grass road at the lake was the environment for this game. The login and registration interface have been developed out of the VR environment. So, the user will key in their details first before wearing the HTC headset and started the game. It will be given several times for the user to setup the HTC Vive devices after completed registration and login to the game (See Figure 5 and Figure 6).

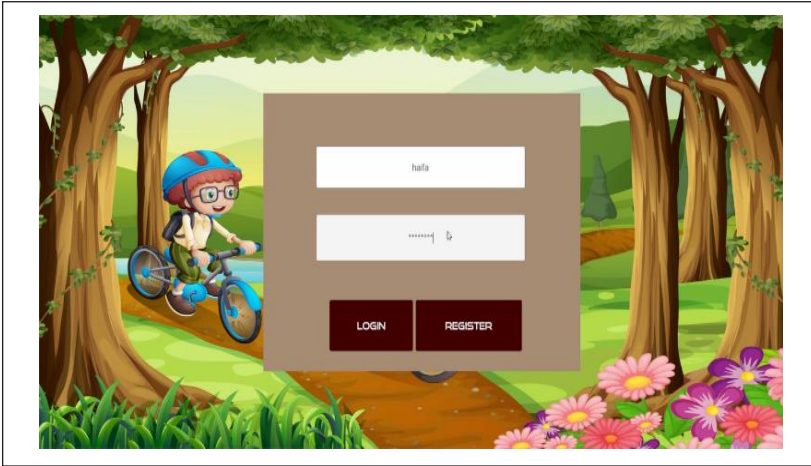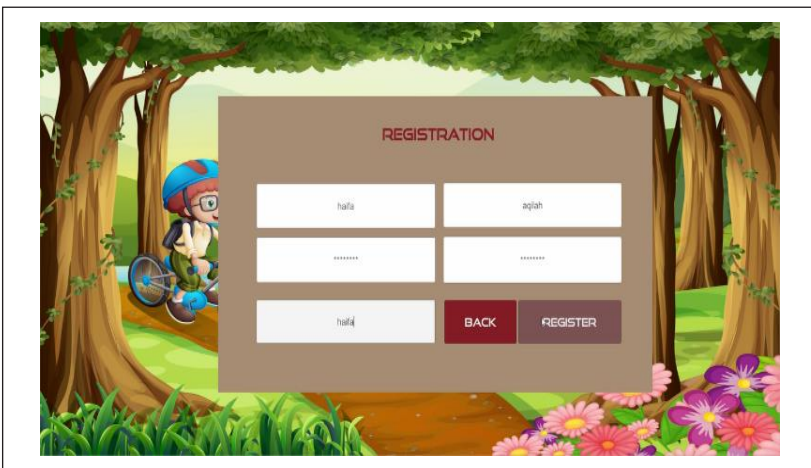**Figure 5**

User Login Interface

Figure 6

User Registration Interface

An instruction displayed as in Figure 7 when player completed login. Once the user finish read and followed the instruction, after a few seconds, an interface for *How to Play* will be displayed in VR environment (See Figure 8). UI is positioned at a comfortable reading distance and is designed to allow the user to understand the instruction before started the game.

Figure 7

User Instruction Interface

Figure 8

How To Play Interface

For this cycling game study, game score was the main components that will be decided either the player win or lose. For each level, there was a requirement score to win. In this game, it included three level start from easy, medium, and hard. Therefore, the higher the level the higher score needed to complete the level. The game elements that will be affected if the game score consists of gold coins, skull coins and jellyfish. 10 score will be added for gold coins, 30 coins for skull coins while 10 score be deducted for jellyfish.

Besides, game timer will start to countdown once the player started the game. Different level had different allocation time to finish the level. The allocated time become shorter as the level up. There are several elements included in this game that affected the time which are 3D turtle and clock timer elements. Both elements had different functionality where 3D turtle act as the time decrement (deduct 5 seconds) while clock timer helped in time increment (add 10 seconds). Figure 9 shows the game environment while playing.

Figure 9

Game Environment
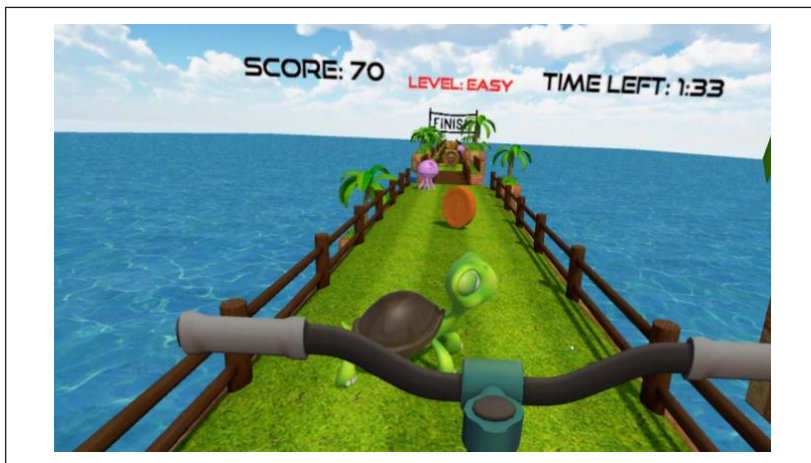
Virtual Reality Implementation

Virtual Environment

A virtual grass road at the lake environment has been chosen for this study environment. Firstly, the 3D environment has been created and arranged in making a straight long route. All the 3D component for the environment has been import from Unity Asset Store. After created the environment, the SimpleVR (SVR) packages has been imported into the study. SVR packages consists of SteamVR plugin that will launched the virtual reality environment.

Player Movement Controller

HTC hand controller was the controller that tracked the movement of the player. In this study, it required player to move/swing the HTC hand

controller to start or moved the player in the game. In SVR Plugin, for the hand controller, it only consists of some function likes teleportation, grab and throw. Therefore, a new function for player movement using hand controller need to be added. The implemented function will calculate the distance and momentum of the hand movement. After that, from the resultant momentum, need to implement the way to move a player by constantly changed the position of the player prefab in update function. Therefore, when player move/swing their hand in y-axis, the player will move according to the height of the hand. The higher the hand, the more speed occurred to the player movement.

EXPERIMENT PROCEDURE

In evaluation phase, experiment setup was the most important aspect that should be prepared properly. All hardware use for this project have been setting up at a suitable position and place as in Figure 10. The essential device needed to run the project is a high-performance laptop because the game only run on computer platform. The HTC Vive have been setup and connect to the laptop. HTC Vive Headset and Controller are integrated with the cycling exergame in the laptop, in order to experience a virtual reality environment.

Figure 10

Hardware Setup
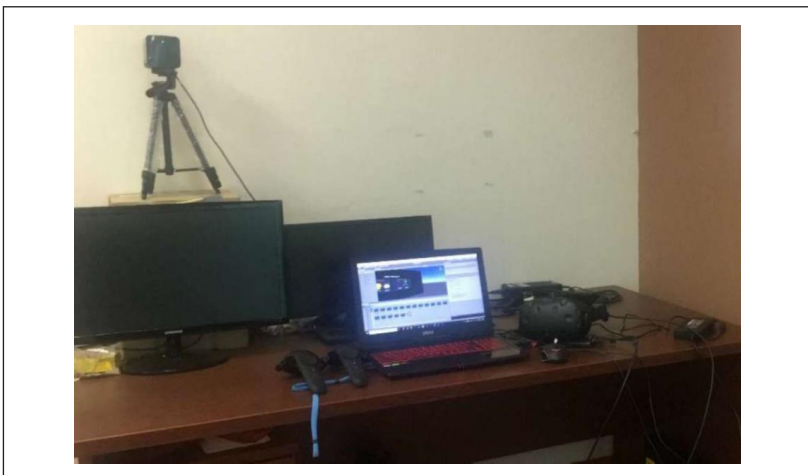
A supported laptop for VR is required to make sure this project run properly. In order to carry out the testing, it required a room with a free space to move around, pick a suitable spot to setup the base stations, and connected all the related cables include HTC Vive Headset to the laptop in order to view virtual environment in the application. All of the related HTC Vive devices have been setup properly and the controller need to be turned on when user start the testing (Figure 11).

Figure 11

Player Plays the VR Cycling

During testing this project, 10 students (6 females, 4 male) from School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia (UTM) has been chosen as participant for this project testing. Firstly, before the project testing started, all participants were given a pre-questionnaire to record data regarding their involvement with virtual reality environment and exergaming experiences. After that, the objective and instructions of the project were explained before they do black box testing. The average time use by the users to test this project is at least 5 minutes. Lastly, post-questionnaire was distributed to collect their feedback from the test in term of User Interface (UI) design, gameplay, and user satisfaction. Likert scale been used to measure the application.

USER ACCEPTANCE TESTING RESULTS

During evaluation phase, usability testing and black box testing (user acceptance testing) are the method used for this project testing and evaluation. A room with a free space to move around are required to carry out the evaluation. Therefore, the test was held in XR Lab at Faculty of Biomedical Engineering, UTM as the HTC Vive device been setup in the lab.

Pre-Questionnaire Result

Total of 10 participants have been chosen to test the study performance and functionality. Nine out of ten participant has knowledge about the VR. However, only eight of them have an experience with VR. Interestingly, six of them considered themselves as intermediate level with VR experience, while the remaining three as beginner.

The data of knowledge on exergame were also collected. Seven out of ten participant knew about exergame, while the remaining three were not familiar with exergame. Interestingly, six of them has experienced the exergame and the remaining four mentioned that this was their first time experiencing the exergame (also together with VR).

Post-Questionnaire Result

Figure 12 shows most of the respondent have no problem with this application as they find it easy to use. The Likert scale shows that 1 is for strongly disagree while 5 is strongly agree. Therefore, from the bar chart it shows that 4 respondents (40%) rate as the application is very easy to use and 5 respondents (50%) rate as easy while only 1 respondent find the application is in average.

Figure 12

Application Feedback on Ease of Use
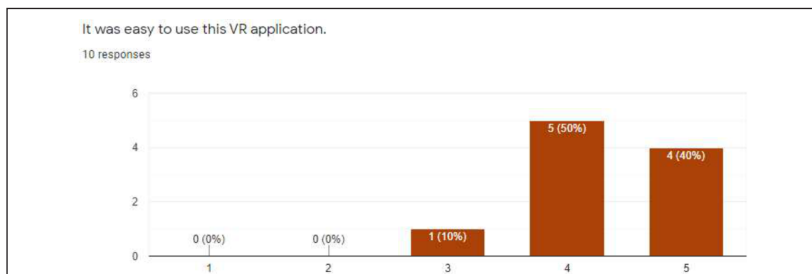
The bar chart in Figure 13 state on how easy respondents learn to use this Virtual Reality application. Half of the respondents strongly agree while the rest of the respondent agree that the application is easy to learn in using it. This shows that most of the respondents are familiar with the virtual reality game and comfortable with the integration of HTC handheld controller.

Figure 13
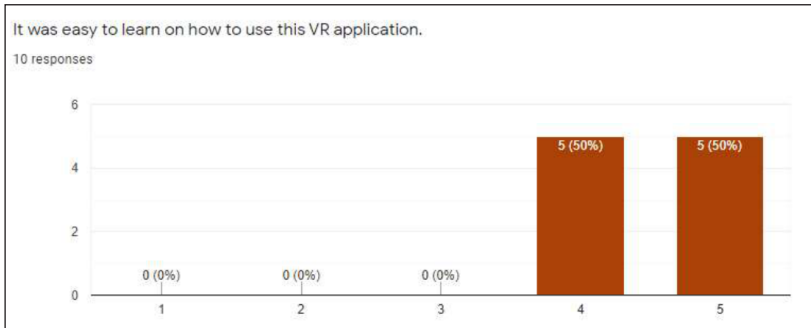
Application Feedback on Learning Difficulty

It was easy to learn on how to use this VR application.
10 responses

Figure 14 shows the result of the respondents in understanding the instruction of the application. As the result in the bar chart, it shows that 6 over 10 of the respondents strongly agree that the instructions provided in the application is easy to understand while the other 4 respondents slightly agree with it. Therefore, it shows that instruction in an application is one of the most important elements for user to understand the application.

Figure 14

Application Feedback on Learning the Instruction

The instruction in the VR application is easy to understand.
10 responses
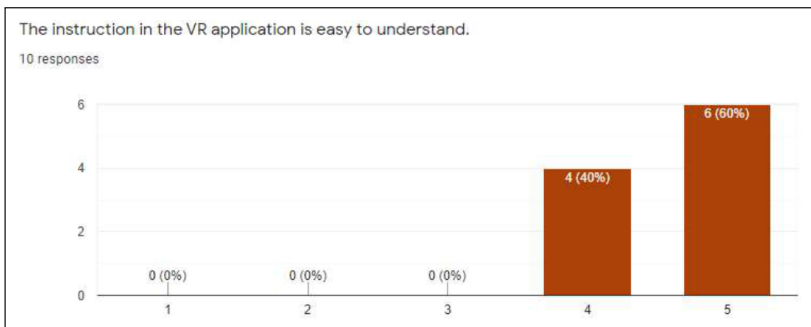
Based on Figure 15 below, the result of the bar chart shows that most of the respondents agree that they were able to complete the task in a short period of time. It is proving that the application is user friendly where user can complete the task without dragging time as the application not too hard for them.

Figure 15
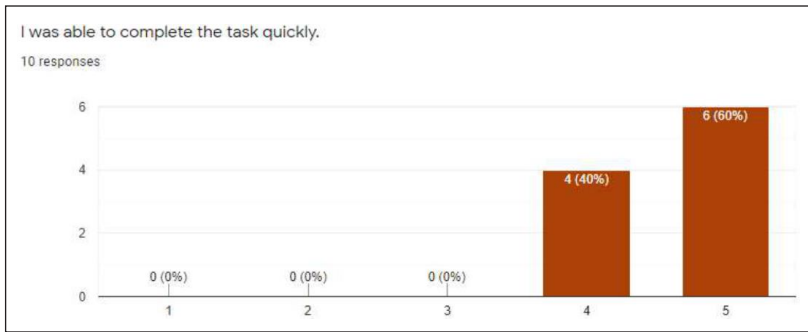
Application Feedback on Time Completion

Figure 16 state the result of satisfaction in understanding the User Interface (UI). The result shows that most of the respondents give high scale for satisfaction in understanding the UI. The UI should be properly design when designing and developing a project in order to make it more attractive and easier to understand.

Figure 16

Application Feedback on Understanding Interface
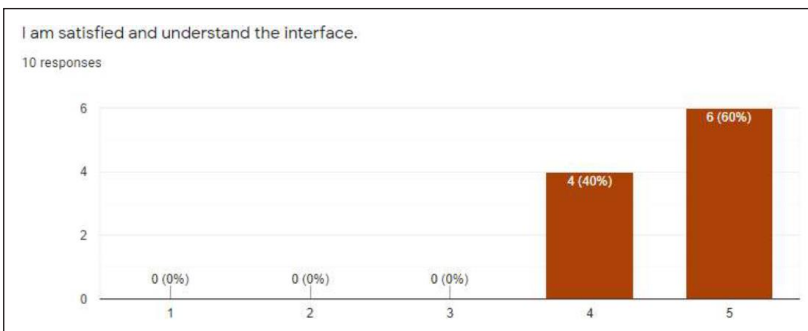
The result of overall satisfaction feedback for the application as shown in figure 17. Based on the feedback and the user experienced

for this study, the result shows that most of the respondents satisfied with the application. It is representing that most of the respondents enjoy during testing this study.

Figure 17

Feedback Satisfaction Application
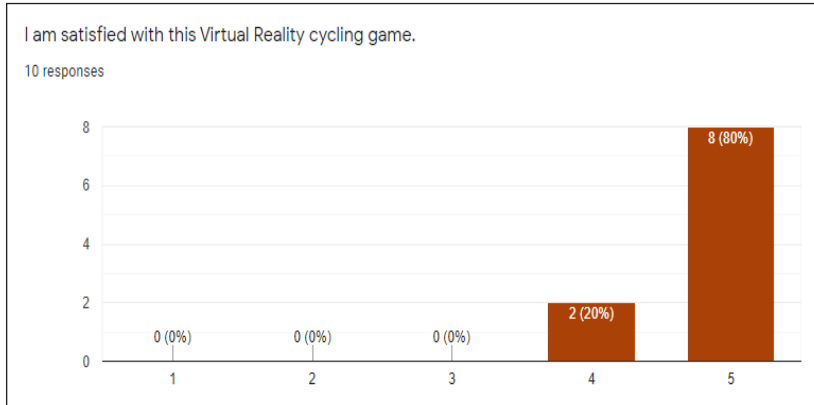
User Acceptance Testing

This section discussed about User Acceptance Testing (UAT). This testing is to analyses on how the users done the task before explained to them the instruction. Method used for this testing is Black Box method where the users must do the task without any guided, explanation or briefing about the project. The purpose of this method is to compare whether the actual result from users testing is like the expected result followed by the task given. This testing done to the main components of the project such as VR rendering and gameplay.

Virtual Reality Rendering Test

Table 2 represented the results for the black box testing for VR rendering. The testing is for analyzing the functionality during rendering the VR environment. The result shows that respondents able to test all the event such as use HTC headset, use HTC controller, VR view and User Interface (UI).

Table 2

Black Box Testing for VR

Event	Expected Results	Actual Results
Use HTC Vive headset	Able to use HTC Vive headset	Users able to use the HTC Vive headset
Use hand controller	Able to move the player using hand controller	Users able to move the player by using both HTC and controller
VR view	Able to move head in any direction	Users able to view 360-degree while moving head in any direction
User interfaces	Able to understand the instructions and interface design	Users can understand the instructions and interfaces design

Gameplay Testing

The data obtained from testing the gameplay components of this study been summarizes in the Table 3. Based on the results, the respondents manage to experience the game mechanics includes game score, game timer and game finisher.

Table 3

Black Box Testing for Gameplay

Event	Expected Results	Actual Results
Game score	Able to collect score and avoid the obstacles	Users able to collect the required score and avoid the obstacles in order to win the level
Game timer	Able to exceed the allocation time by collect the timer element	Users able to win the level with the help of the increment time element as the decrement time element make it more challenging
Game finisher	Able to review the score at the end	Users able to review the score when completed the routes

LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Even though all the objectives have been fulfilled, there are few limitations in this project which can potentially improve by future studies. The first limitation is that the integration of the VR cycling game to the real bicycle. Due to pandemic of Coronavirus (Covid-19), all UTM securities for entering any laboratories has been tightened. This include the closed lab in Antartic Lab in FBME, UTM where the equipment of the bicycle and the rpm tachometer sensor need to be used there. Therefore, we have difficulties to access the lab with real bicycle because to integrate our VR exergame with the cycling hardware might consume days and weeks in that lab to work. The user experience on VR cycling exergame could be more realistic if the integration with the real bicycle can be fulfil. However, to maintain the functionality of the exergame for this project, an initiative action has been used to replace the real bicycle by integrating the VR cycling game with the HTC Vive hand controller to move the player in game. The players can still exert themselves with their hand and upper body movements using the handheld controller. However, there is difficulties to ensure the precisions on player's movement and button tracking in this study. In VR, motion sickness is one of the important things that need to be avoid. Unfortunately, this study required player to move their hand frequently in order to play the game. Therefore, some of the player will experienced the motion sickness especially for the beginner user. No implementation of button tracking using the hand controller also limit the project as player need to wait for every action.

Based on these limitations, there are some suggestions for the enhancement that can be implement for future works. First, future studies especially on current developed system should be implemented with the real stationary bicycle in order to get the realistic experience of cycling. The VR cycling exergame system will be more effective and enjoyable for the players to exert themselves. Furthermore, another future work that can be considered is to put an option button for each interface in the virtual environment. Besides, this project can be enhanced with the addition of the variety game environment for different level. This will make the game became more attractive and user friendly. Finally, this project can improve by added another alternative platform. As this project focus on computer-based platform. Hopefully in future work the project can be built in mobile platform such as Android and iOS.

CONCLUSION

This project aims to develop a cycling exergame that integrate with HTC Vive hand controller in VR. All the proposed objectives in this study have been achieved and all phases in methodology have been successfully carried out. The cycling game has successfully integrated with VR using HTC Vive hand controller. The study has been tested towards its performance, user acceptance, and usability testing. All the requirements for both functionality and non-functionality of the study has produced the outcome as expected. The response from respondents during the usability testing also stated that they are satisfied with the VR cycling exergame and suggest that the game would be more interesting by integrating the VR cycling exergame system with the real bicycle. Based on the overall result, this project has been successfully produced a cycling exergame in VR and significantly improve the user experience.

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