Learning Game with Stroke Paralysis Rehabilitation for Virtual Reality

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Abstract—The work is presented for arm paresis patients in rehabilitation phase, consisting of an arm movement but slower than normal ones. Since most patients with lacking motivation affect the physical therapy, they are not willing to follow program of rehabilitation. This work aims to design a game for arm paresis patients in rehabilitation phase with virtual reality. The control system is designed using unity, oculus rift and oculus touch. For the system, the game contains three different levels. A goal of level 1 is to drag and drop an object in X radius. Level 2 is to pick up books to bookshelf in Y radius, and level 3 is to pick ingredients to cauldron in X and Y radius. As a results, the satisfaction survey on usage is satisfied. Besides, the game's development should be more varied to make patients have more fun and motivated in physical therapy.

Keywords—rehabilitation, arm paresis, patients, game, virtual reality

1 Introduction

Stroke is a condition in which the brain is ischemic due to aortic stenosis, clogging, or rupture, which causes damage to the brain tissue. The severity of symptoms varies depending on the degree of severity and the location of the brain being destroyed [1]. If it occurs in the central nervous system, or the brain and spinal cord, they will suddenly lose the ability to control body functions [2]. The body has numbness or weakness of the muscles, which results in difficulty moving or sudden immobilization. As such, it is medically called "paresis".

Paralysis is caused by a stroke or blockage, leading to the difficulty in movement [3]. Based on the two stages of cerebral infarction, each patient has a different level of severity according to the area of the brain that lacks blood supply. There are two stages of cerebral infarction. In the first stage, the patient cannot control his or her movements. In the second stage, the movements can be controlled to some degree, but the patient

still has muscle spasms. In the treatment, physical therapy is required according to the doctor's program. Physical therapy must be performed in that specific part of the body regularly so that the body recognizes movements and can move on its own normally. Apart from undergoing physical therapy at the hospital, patients need to return to doing physical therapy continuously through a doctor-prescribed rehabilitation program. In some cases, the patient's motivation for attending rehabilitation programs is lacking due to personal reasons or obstacles encountered during treatment outside of the hospital.

Therefore, if there is an insufficiency of regular physical therapy, it will lead to poor regeneration of muscle cells. As a result of the above problems, games and virtual technology have been applied to physical therapy, designed to be convenient, easy to use, and interesting. It is designed as a simulation game that is not very complicated, using virtual reality technology through the Oculus device, as mentioned above. The researchers came up with the idea of researching and developing physiotherapy games for paralysis patients with virtual technology to make physical therapy more interesting and motivating to do.

2 Related principles and works

We study the principles and the related works in order to conduct this work and develop physical therapy games for paralysis patients with virtual reality technology to stimulate the restoration of the nervous system of paralysis patients. We divide the study topics into the following categories.

2.1 Virtual reality

Definition of virtual reality. Virtual reality, also known as VR, is a computer-simulated environment. Most virtual reality environments are about what vision is all about and are displayed either on a computer monitor or a 3D display device. Users can interact with the virtual environment by using devices such as a keyboard or mouse, as well as remote controls. Simulated environments can also be similar to the real world, such as pilot training simulations, which can be made differently from reality, for instance, in virtual reality games [4].

Devices in the functioning of virtual reality. The working process of virtual reality consists of the key devices, which are head-mounted monitors and remote controls, by collaborating with computer programming software.

1) Head-mounted monitor

The head-mounted monitor, also called a spectacle kit, consists of a pair of glasses that contain a small monitor made of three-dimensional glass, which allows the visibility on the monitor to cover almost all horizontal vision as shown in Figure 1.

Fig. 1. Head-mounted monitor

2) Remote control

The remote control or joy remote can be used instead of touching the screen for the convenience of controlling buttons such as the home screen of the mobile phone. It can scroll up, down, left, right, through the icons of the smartphone, and can be used instead of joy to play games as shown in Figure 2.

Fig. 2. Remote control

Virtual reality working process. When we wear a head-mounted monitor that consists of a small display, it would complement all visualizations with 3D images, which are created with a computer connected to a head monitor [5].

2.2 Paralysis

Paralysis is a symptom of arm, leg, or facial numbness, weakness, or difficulty moving. The body part is still functional, but not normal. For example, there may be numbness, not being able to lift heavy items, being unable to raise your arms, or being unable to clench. Patients can still help themselves in certain activities and have the opportunity to fully recover. When cerebral blood vessels narrow, block, or bleed, oxygen cannot be delivered to brain cells. This may lead to cerebral ischemia, brain cells dying, and loss of control, thus affecting the functioning of organs under the control of the brain and eventually causing paresis [6].

Symptoms of paralysis. Symptoms of paralysis are symptoms in which the arm, leg, or one side of the face becomes numb or weak, but is still functional but unlike usual, such as being unable to handle heavy objects, unable to lift arms, or not being able to clench. They may have double or blurred vision, difficulty speaking or slurred speech, difficulty walking, or difficulty moving.

Causes of paralysis. There are two types of the etiology:

1) Paralysis caused by an ischemic stroke

It is caused by arteriosclerosis, a disease that gradually accumulates in the arterial wall, leading to thrombosis. This leads to insufficient blood supply to brain cells and eventually death. If arterial thrombosis occurs, the symptoms will be more serious than usual. But if the clog occurs in the small blood vessels, it will have weaker symptoms than those caused by the aorta.

2) Paralysis caused by a hemorrhagic stroke

The most dangerous thing is that a torn blood vessel may lead to the death of a patient in a short time. This is the result of hypertension, and the symptoms of hemorrhagic stroke often occur acutely. The patient will experience severe headaches, nausea, and vomiting. This is followed by a distorted mouth, being unable to speak, weak arms, and possibly convulsions or unconsciousness in no time.

2.3 Arm physical therapy for paresis patients

The purpose of rehabilitation is to enable patients to return to normal life or as close to normal as possible. After the development of paresis, rehabilitation is mainly physical therapy, in which patients are forced to exercise their physical movements to restore their muscle consistency [7–9].

Arm physical therapy procedures.

1) Shoulder Flexion Posture

Extend your arms to the front, elbows straight, slowly raise your arm above your head and lower it down as shown in Figure 3.

Fig. 3. Shoulder flexion posture physical therapy

2) Shoulder Abduction Posture

Place your arms on the plane of your body, slowly bring your arms to the sides of your body to shoulder level, then return to the original position as shown in Figure 4.

Fig. 4. Shoulder abduction arm posture physical therapy

Stretch your arms to the back at 90 degrees angle to your upper arms, then stretch your arms out to the back as shown in Figures 5 and 6.

Fig. 5. Physical therapy arm posture: elbow extension posture (1)

Fig. 6. Arm physical therapy: elbow extension posture (2)

4) Elbow Flexion Posture

Extend your arms in front of your body, turn your hands up, and fold your elbows up as shown in Figure 7.

Fig. 7. Arm physical therapy: elbow extension posture

5) Overhead Press Posture

Raise both arms above your head. Stretch your arms straight, pull your arms down the sides of your body, keep your elbows at the same level as your shoulders, and hold them back in the same position as shown in Figures 8 and 9.

Fig. 8. Arm physical therapy: overhead press posture (1)

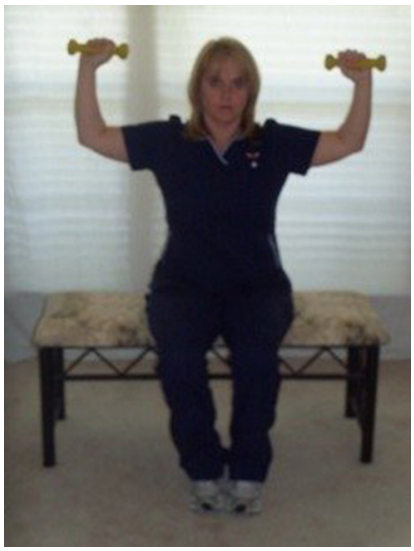

Fig. 9. Arm physical therapy: overhead press posture (2)

6) External Rotation Posture

Keep your upper arms parallel to your body, elbows at a 90-degree angle, extend both arms out front, then slide, and rotate your arms to the sides as shown in Figures 10 and 11.

Fig. 10. Arm physical therapy: external rotation posture (1)

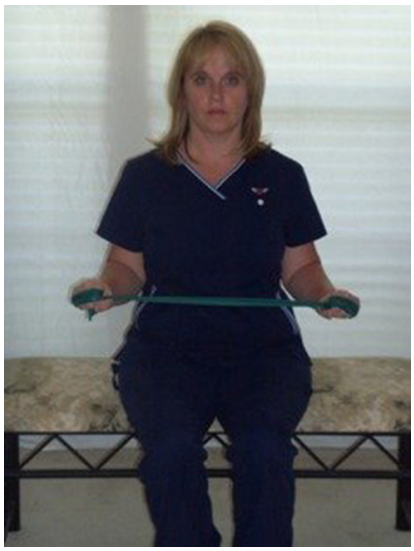

Fig. 11. Arm physical therapy: external rotation posture (2)

7) Internal Rotation Posture as shown in Figures 12 and 13

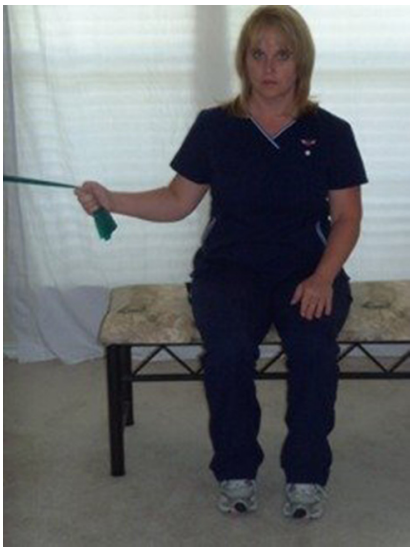

Fig. 12. Arm physical therapy: internal rotation posture (1)

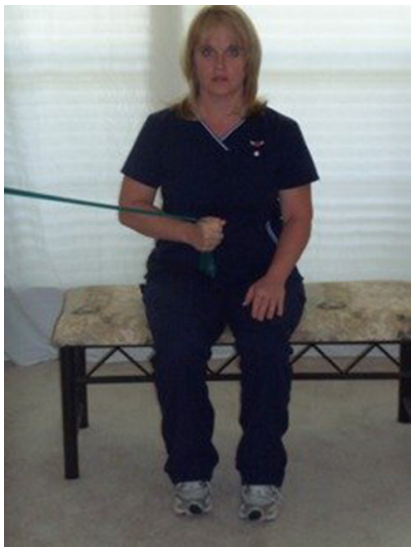

Fig. 13. Arm physical therapy: internal rotation posture (2)

Physical therapy postures used in the game cover the following procedures.

1) Shoulder Flexion posture
2) Shoulder Abduction Posture
3) External Rotation Posture
4) Internal Rotation Posture

2.4 Related works

Smart gloves to assist the VR physical therapy [10].

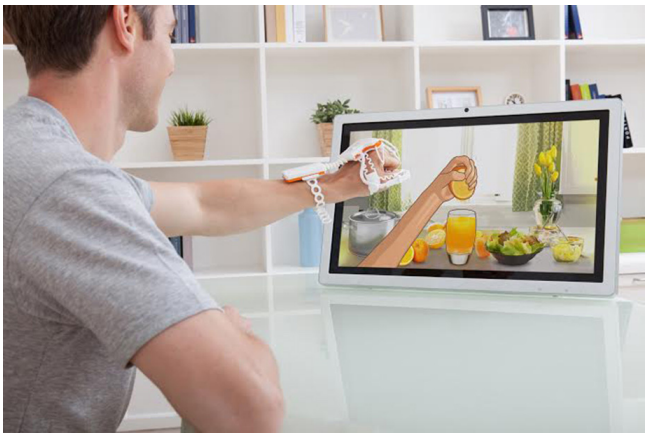

Fig. 14. Use of RAPAEL smart gloves

RAPAEL [11] is a glove equipped with intelligent technology that enables patients to practice hand movements through games in virtual reality (VR) technology, such as pick-up things to place elsewhere games, flight simulator games, firefighting games, and squeeze games as shown in Figure 14. This makes physical activity more enjoyable and encourages patients to do the activity more, and there is a system of physiotherapists who can monitor the session while analyzing the treatment data for how patients are developing and being able to customize the daily schedule of activities to be difficult or easier to fit the patients.

Armband "Myo" therapy game – the game for stimulating arm muscle for the arm muscle weakness patients.

Fig. 15. Myo armband physical therapy game

Myo [12] is a rehabilitation game controlled through the 'Myo' armband as shown in Figure 15. The postures used in physical therapy are applied to control the directions in the rehabilitation game, which results in the patient practicing arm movements, improving the restoration of the patient's arm. The game is designed to have three levels of difficulty in playing, classified according to the posture of physical therapy, from the super-easy level to the most difficult level.

Rehabilitation of arm control for stroke patients by using in-depth monitoring equipment with the games.

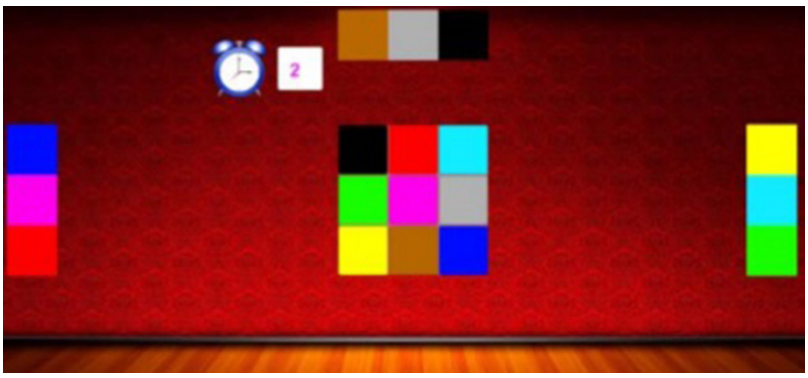

Fig. 16. An example of a rehabilitation game: the color matching puzzle game

The study of restoring arm control for stroke patients using in-depth monitoring devices with games [13] is a visual matching puzzle game, where patients play a game by using Kinect devices to detect body movements and apply movement gestures of hands and arms to control matching puzzle games as shown in Figure 16. To play, pieces of rectangular objects of different colors must be matched with the same-colored target squares in the middle of the screen correctly. Time spent playing is displayed on the upper left side of the screen.

Games for rehabilitation of patients with arm muscle weakness with Kinect equipment.

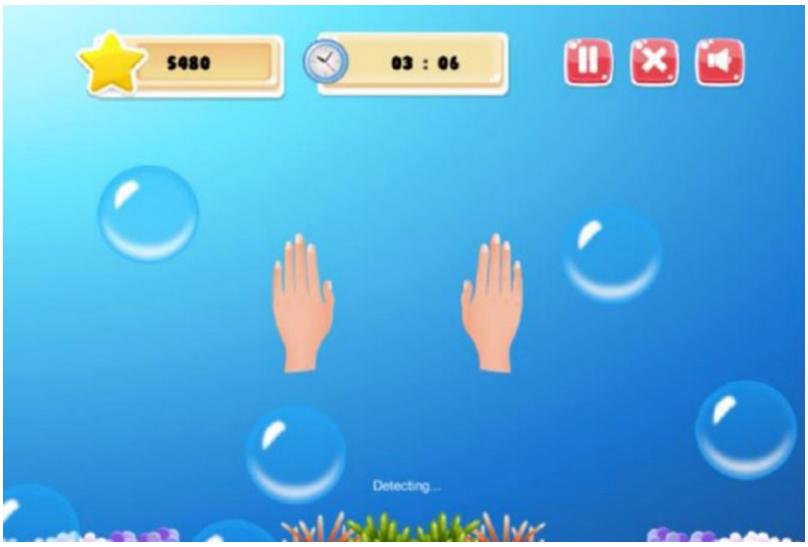

Fig. 17. Bubble Game

Bubble Game [14] is a game that patients can play using a Kinect device to detect the movement of arms and hands to control the game. The system will display the time on the screen, allowing the patient to know how many minutes have passed. The patient has to sweep both arms to touch the bubbles (bubbles) shown on the computer screen as shown in Figure 17. If the patient sweeps his arms to touch the bubbles, they will be scored and notified.

Wii-hab training helps muscle recovery and arm function in patients with sub-acute stroke. Wii-hab games consist of practicing shoulder flexion exercises, shoulder joint rotation outward-inward, elbow flexion, wrist up-down, prone-supine, and clenched fists. Patients will be able to act according to the training programs, such as boxing games, fencing, and cooking games.

3 Method

In conducting research, the researchers studied data from various sources before designing the equipment. We focus on data preparation as good data collection can significantly reduce the errors of creating the work. It allows highly effective operation and is prompt for function testing. The evaluation concludes with quality and satisfaction testing. The process of creating a game for the therapy of paresis patients will be ended with the Oculus Rift, as shown in the following diagram (Figure 18).

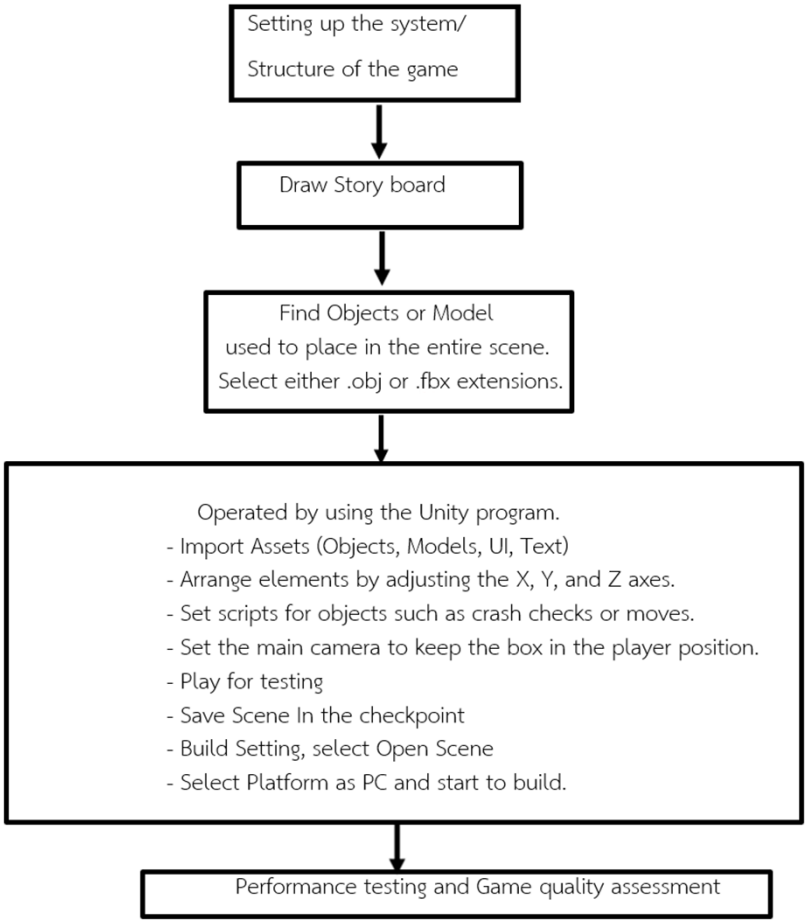

Fig. 18. Research process diagram

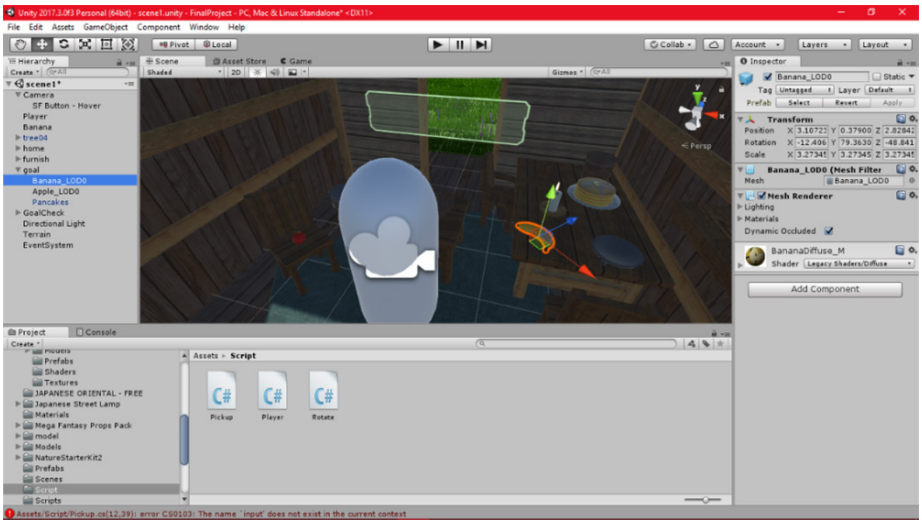

Fig. 19. Placement of objects and scripts, storage, rotation

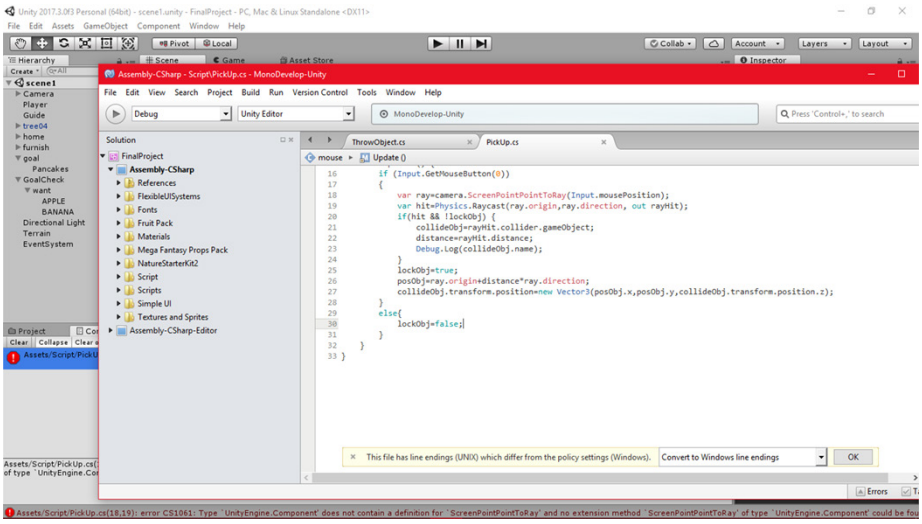

Fig. 20. Script of drag, pick up and drop

Fig. 21. Gaze UI main page

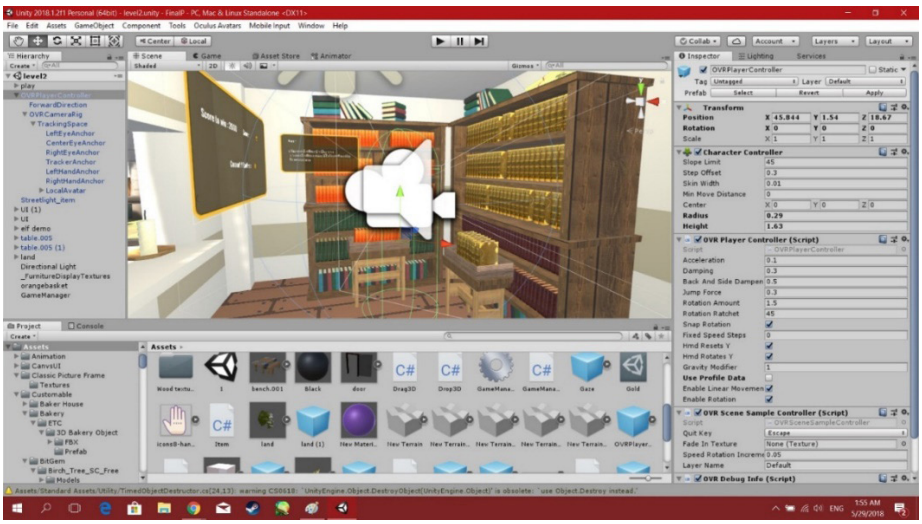

Fig. 22. OVR camera player controller

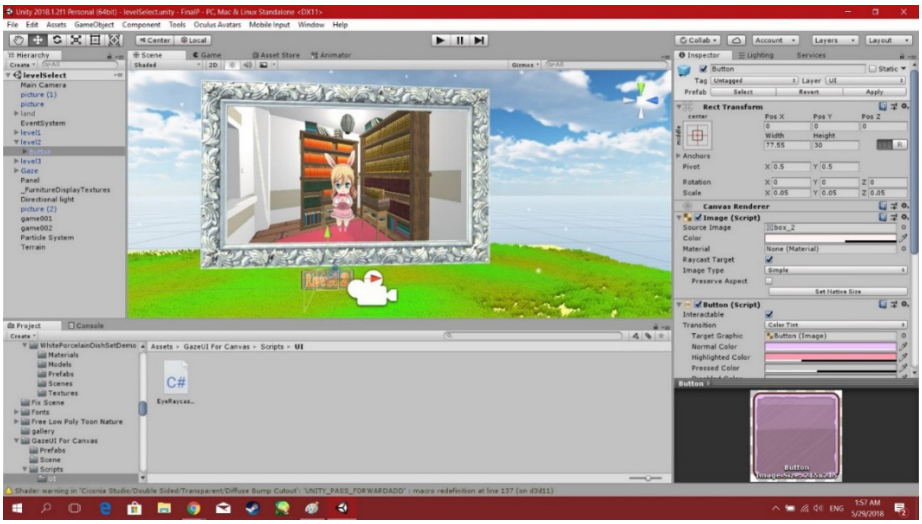

Fig. 23. Interface UI

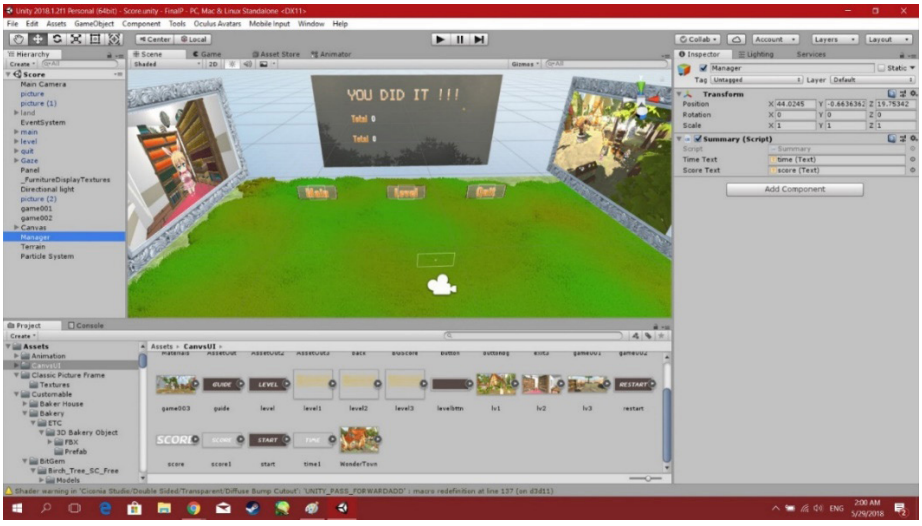

Fig. 24. Score UI

1) Game design process

Patients can play games using the Oculus Touch device to detect arm and hand movements. The game control is divided into three levels. Level 1 allows the patient to simulate picking up one object and placing it in another area without a countdown

as a practice stage. Level 2 will add more timers and objects to pick up. Scores are collected for reference in healing. Level 3 adds more objects to practice the development of patients' arm movements. In terms of design, the game is divided into three steps:

1. Finding assets to be used to design games, such as 3D models and sound effects, which can be downloaded from websites related to 3D models or the Unity Asset Store website

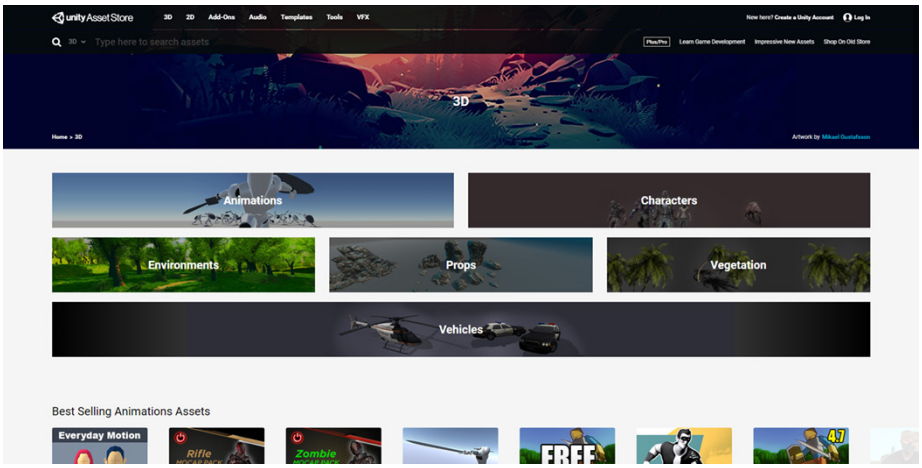

Fig. 25. Unity asset store website

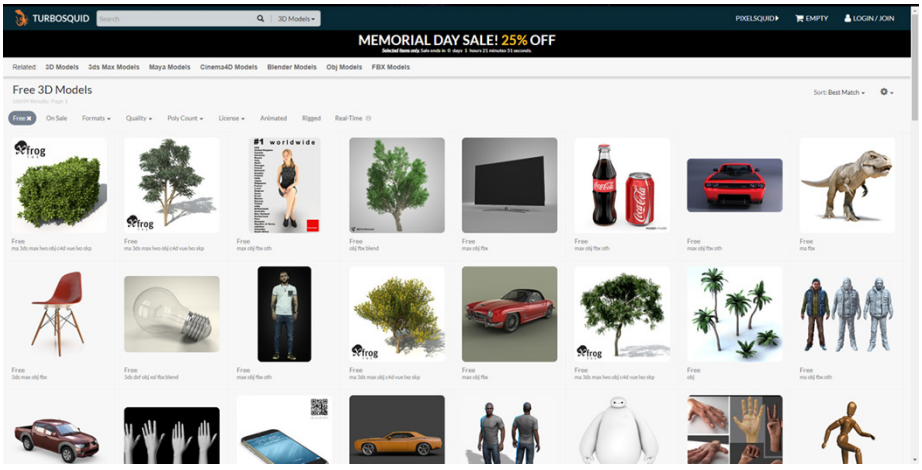

Fig. 26. Turbosquid website

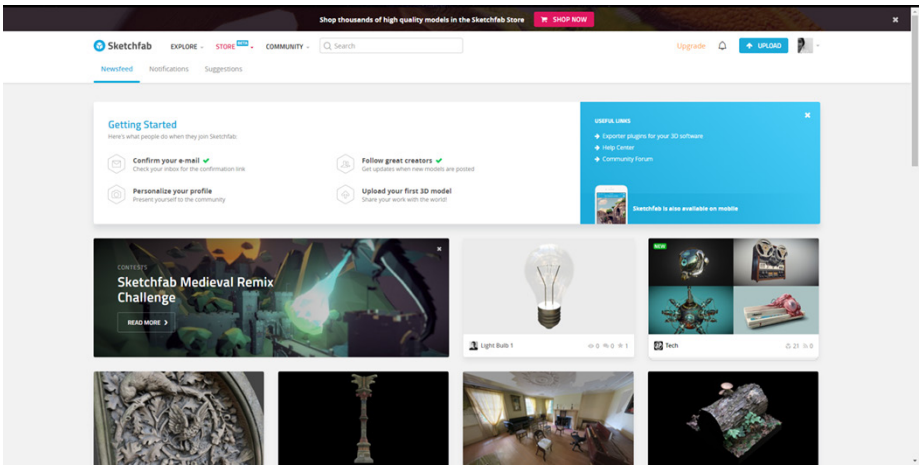

Fig. 27. Sketchfab website

2. Making the in-game scenes, which are divided into two parts: the location and the interior of the scene, such as the house and the building, man, model, and nature, etc.
3. Scripting or code writing to put in an object or (Object) in the game. There are two main parts: the UI Interface and the game itself.
   1) UI interface script is the code of various in-game systems, such as changing scenes, buttons, music, etc.
   2) Game script is the main code of the game, such as walking, lifting, points, etc.
4. Bring models or systems and arrange elements into a scene.
5. Test and run the game for finding mistakes to fix.
6. Build to PC with .exe file.

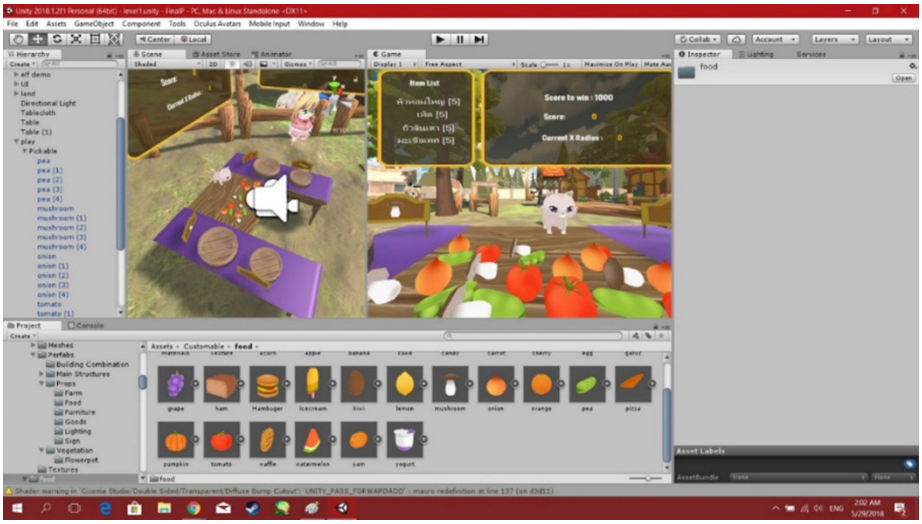

Fig. 28. Scene on level 1

Fig. 29. Scene on level 2

Fig. 30. Scene on level 2

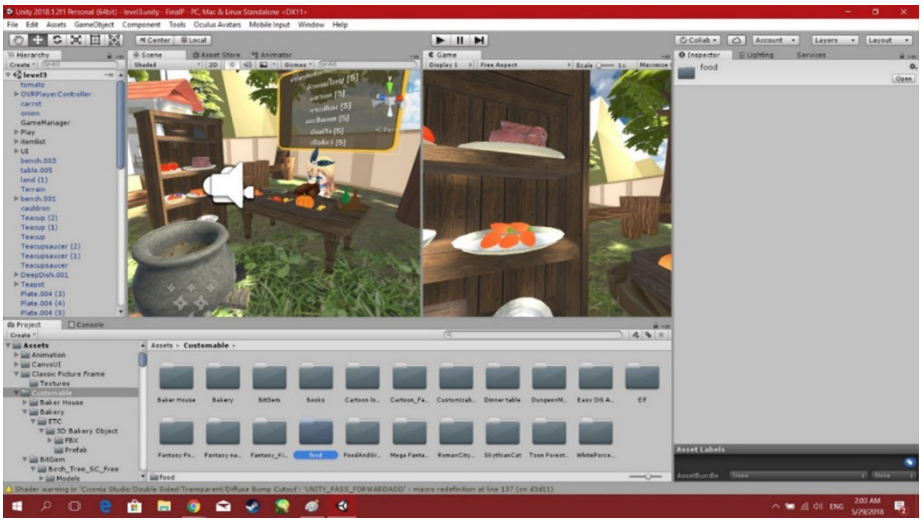

Fig. 31. Scene on level 3

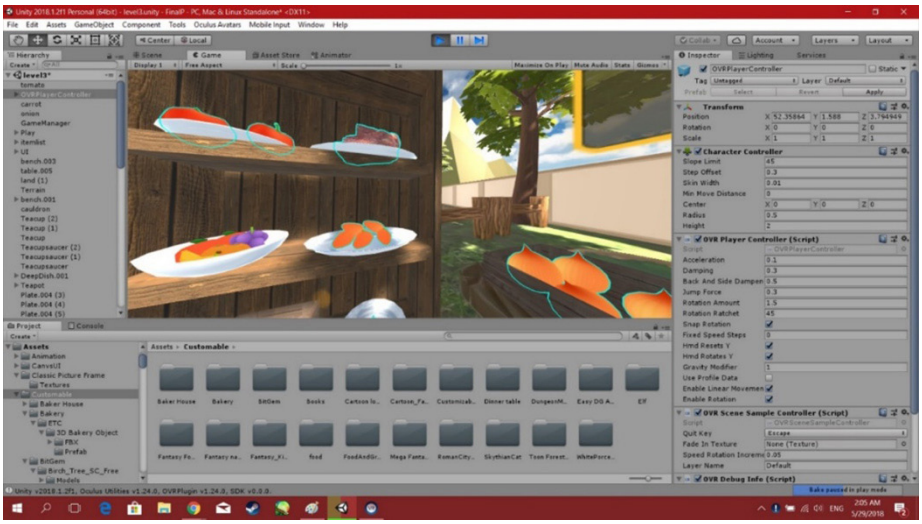

Fig. 32. Scene on level 3

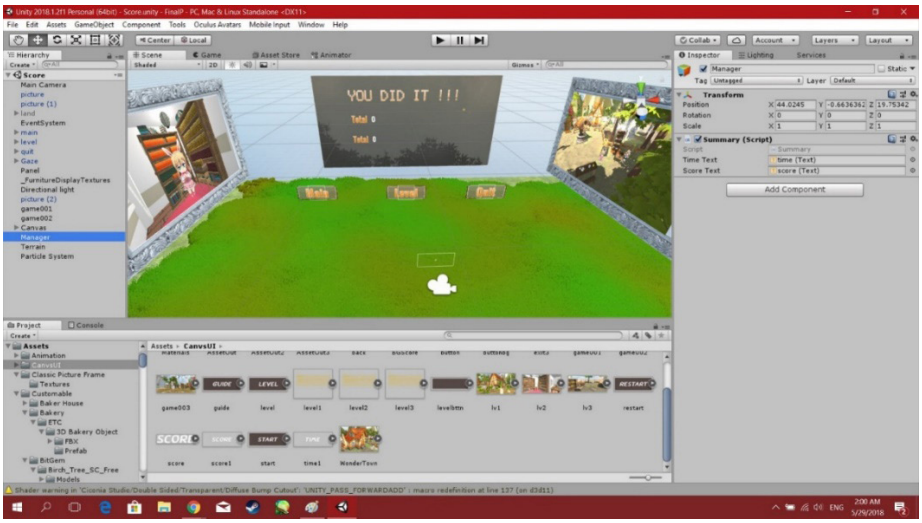

Fig. 33. UI of score page

Fig. 34. Gaze camera on the main page

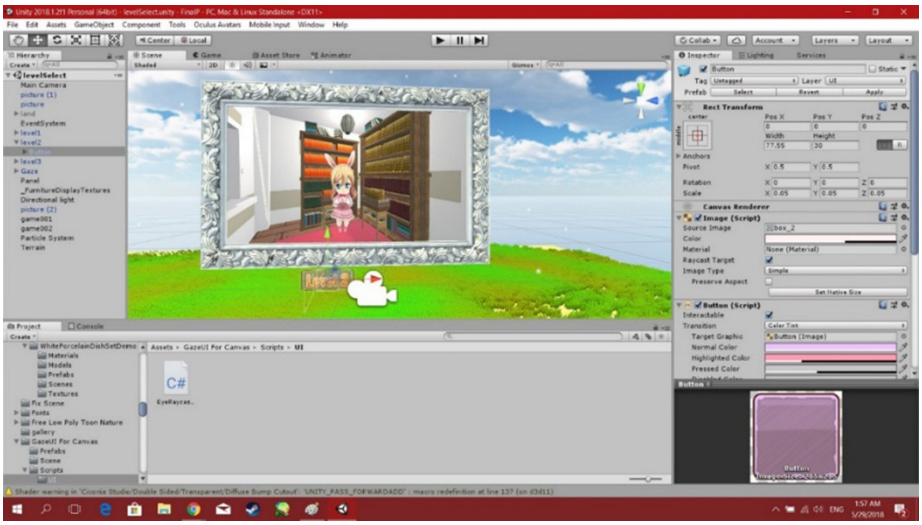

Fig. 35. Level selection page

2) The implementation process of the game

The process of the game will start from the first page. Once the game starts, the system will take the player to the stage selection page. When the stage is selected, it will enter the game page, and at the end of the stage, it will appear in front of the score display, which includes a window showing all scores. The checkpoint button consists of three levels to choose from according to the difficulty level and an exit button as shown in Figure 36.

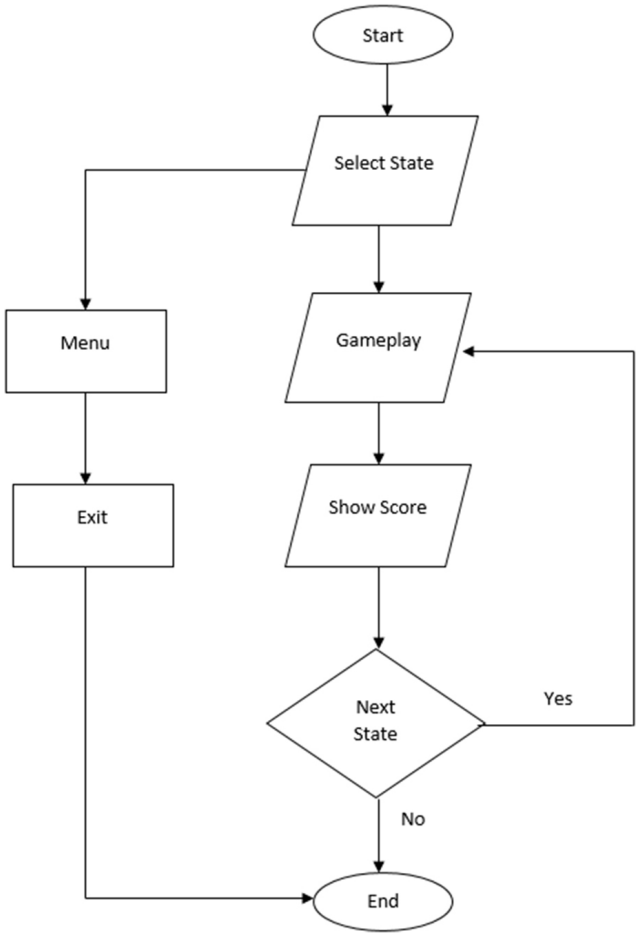

Fig. 36. The game implementation process diagram

The aim of designing and creating the Oculus Rift for physical therapy. Setting guidelines and purposes for designing and creating the Oculus Rift for physical therapy is aimed at comfortable, saving time, saving money, and guiding development to expand the concept of further projects.

Research and development of virtual technology in physical therapy. By using the principles of virtual technology combined with the theory of 3 levels of physical therapy, which is divided into two parts: the part of the game design in therapy and the part of the device by developing physical therapy games for paralysis patients with virtual reality technology. The process of creating a game for the treatment of paralysis patients by having sensors to detect postures consists of two main elements: the part that is the factor used to analyze the physical therapy posture and the part used to analyze the objectives of the work as shown in Figure 37. The operation steps are as follows.

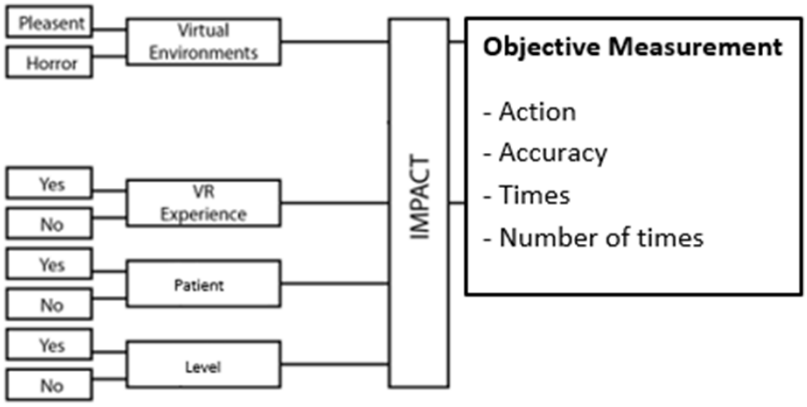

Fig. 37. Function of the physical therapy system

Virtual Environments are the scenes of doing physical therapy. In this process, there are kitchen simulations and book storage scenes for practicing physical therapy in various postures.

VR Experience is the experience of patients practicing physical therapy.

Patient is a patient who practices physical therapy.

Level is a conditioning of the initial use of 3D images that occurs when the image is at the right level. The human eye is visualized in virtual 3D.

Action is the following physical therapy postures:

Overhead Press Arms Physical Therapy Posture (2). The sensor detects the postures as follows:

Raise both arms above your head. Stretch your arms straight, pull your arms down the sides of your body, keep your elbows at the same level as your shoulders, and hold them back in the same position as shown in Figure 38.

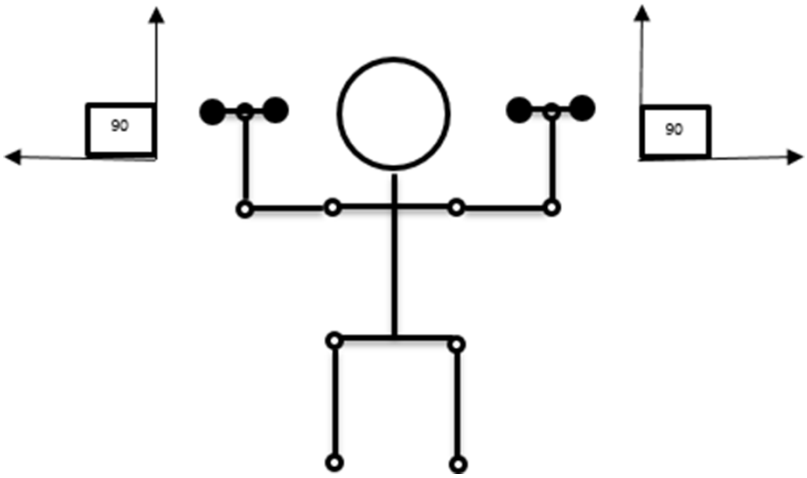

Fig. 38. Arms physical therapy in overhead press posture

Shoulder Abduction Arm Physical Therapy Posture (3). The sensor detects the postures as follows:

Place your arms next to your body, slowly bring your arms to the sides of your body to shoulder level, and then return to the original position as shown in Figure 39.

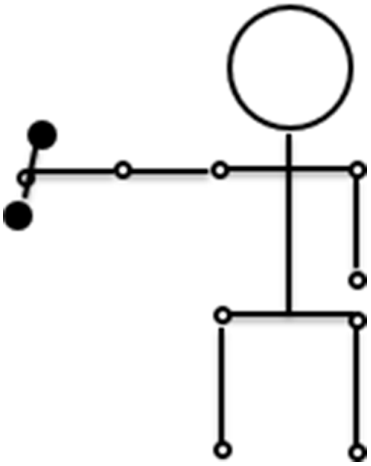

Fig. 39. Shoulder abduction arm physical therapy posture

Shoulder Flexion Arm Physical Therapy Posture (4). The sensor detects the postures as follows:

Extend your arms to the front, elbows straightened, gently raise your arms above your head and lift them down, as shown in Figure 40.

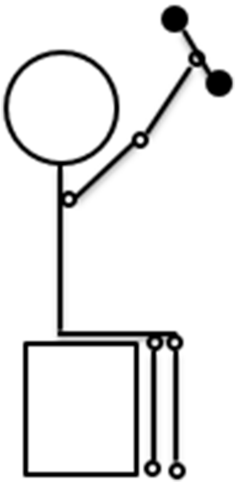

Fig. 40. Shoulder flexion arm physical therapy posture

Elbow Extension Arm Physical Therapy Posture (5). The sensor detects the postures as follows:

Stretch your arms to the back with your arms at a perpendicular angle to your upper arms, then stretch your arms out to the back as shown in Figure 41.

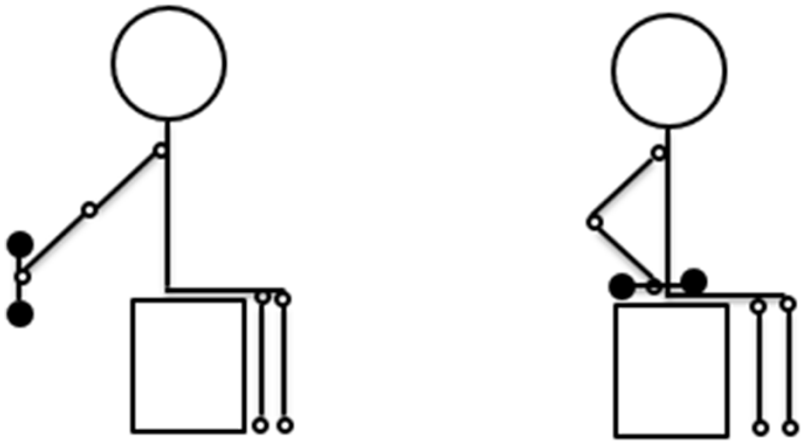

Fig. 41. Elbow extension arm physical therapy posture

Accuracy is an accurate posture detection. Time is the time for doing physical therapy each time. Number of Times is the number of sessions in doing physical therapy.

To perform rehabilitation games for paralyzed patients with virtual reality technology, there are two main elements: the software and the hardware device, aiming to detect arm and hand movement in order to control the game. The stage of the game is mainly designed into three levels.

Level 1 allows the patient to simulate picking up one object and placing it in another place without a countdown as a practice stage.

Level 2 adds more timers and more objects to pick up. The scores are collected for reference.

Level 3 adds more objects to practice the development of patients' arm movements.

The system operation shows the menu button, how to play a game and the end-of-game button, and the function of the physical therapy game of the developed tool. The game process starts from the game start page, allowing the player to see the three-dimensional image of the initial state. When the image is at the appropriate level, the human eye can see these images in 3D virtual reality. By showing working pictures, the game's main page shows the gameplay menu button, how to play the game, and the end game button. Details of the display screen for therapeutic patients enter the checkpoint selection page in which the level of the game in therapy has three levels. The display screen shows the game designed in Level 1 (Level: 1), which aims to have patients use their left and right hands to simulate picking up an object and placing the picked object in the basket as specified by a given problem: the gesture of the x-axis degree, with a gesture of movement from left to right and right to left horizontally, no more than 180 degrees. In this situation, there is no countdown because it is a mode of training, allowing the patient to get to know how the system works.

For the design details in level 2 (Level: 2), the objective is that the patient can use his left and right hands to simulate picking up an object. The scenario is simulated to picking up books in the library and putting them on the shelves depended on the problems using gestures in axial degrees, including both x and y-axis, left-to-right and right-to-left movements, and various directions with no more than 180 degrees. Besides, there is a matter of timer where there's an increasing number of objects used to pick up, which has the effect of scoring points for reference in therapy.

For the design in Level 3 (Level: 3), it aims to allow the patient to use his left and right hands to simulate picking objects, with the scenario simulated as a gesture in a cooking situation, to neatly put the ingredients in the pot as specified by the problem: the posture used will be x-axis and y-axis degrees. At the third level, patients practiced therapy with increased posture and timing. The number of objects used for handling has been increased from level 2 to train the patient's development of arm movements and score-taking results for reference in the therapy.

3.1 Population and samples

Population.

1) A specialist in physical therapy is a physical therapist in geriatric hospitals.
2) Virtual technology and physical therapy game design specialists.

Samples. Medical specialists who are three physical therapists in a geriatric hospital by using purposive sampling.

3.2 Equipment development process

Research, data collection, equipment design and development. The project organizer studied and collected data from different sources before designing and creating whether from the internet, books, and various articles and then applied it to this project to develop a new home rehabilitation device so that paralysis patients can use it at home.

3.3 Game testing and evaluation

Game performance test.
Define the subject of the test requirements.
Define the criteria used to measure test results.
Test by defined topic.
Fix a topic that doesn't qualify and then retest it again.

Data collection tool. The data was collected through six quality assessment questionnaires. The questionnaires were divided into two parts:
Part 1: Measuring medical quality and game design
Part 2: The improvement of problems and suggestions

Statistics used in data analysis.
Find a percentage (%).

$$\text{The calculation formula is } \frac{\text{Value} \times 100}{\text{Number of measurements}} \tag{1}$$

Find the arithmetic mean.

$$\text{The calculation formula is } \bar{X} = \frac{\Sigma x}{N} \tag{2}$$

When $\bar{X}$ = Sample Mean
Σx = The Sum of the Values
N = Total number of people in the sample

Find the standard deviation (SD).

$$\text{The calculation formula is } \sqrt{\frac{\sum f(x_i - \bar{x})^2}{N}} \tag{3}$$

When x_i = Middle Point

Find class interval.

$$\text{The calculation formula is } \frac{\text{Upper Limit} - \text{Lower Limit}}{\text{Number of Classes}} \tag{4}$$

Find sample size from Taroyamane's formula. The tolerance limit is set to 0.05.

$$\text{The calculation formula is } n = \frac{N}{1 + Ne^2} \tag{5}$$

When n = Number of people in the sample
N = Total population
e = Maximum allowable tolerance

Analysis and evaluation. We collected the results by using the quality assessment form with the following actions:

Examine six sets of assessment documents for accuracy and completeness as planned, representing 100 percent.

Analyze the data from the expert quality assessment per game using averages and percentages, and the quality level is set into five levels.

4 Results

According to the study of Unity3D and Oculus Touch data, the purposes were aimed at researching and developing physiotherapy games for paresis patients with virtual reality technology. The performance results are based on the following topics:

4.1 Result of the screen effect designed for the physical therapy game

4.2 Quality assessment results by the experts

Quality assessment results by the medical professionals.
Quality assessment results by the design experts.

4.3 Result of the screen effect designed for the physical therapy game

Screen.

1) The game's main page shows the game menu button, how to play the game, and the end game button as shown in Figure 42.

Fig. 42. Game main page

2) Page showing the level of the game, which has three levels as shown in Figure 43

Fig. 43. Page showing the level

3) The gaming page will show the current level, list of items to pick up, x-and-y-axis systems, required scores, and current scores as shown in Figures 44–46.

Fig. 44. Game page: Level 1

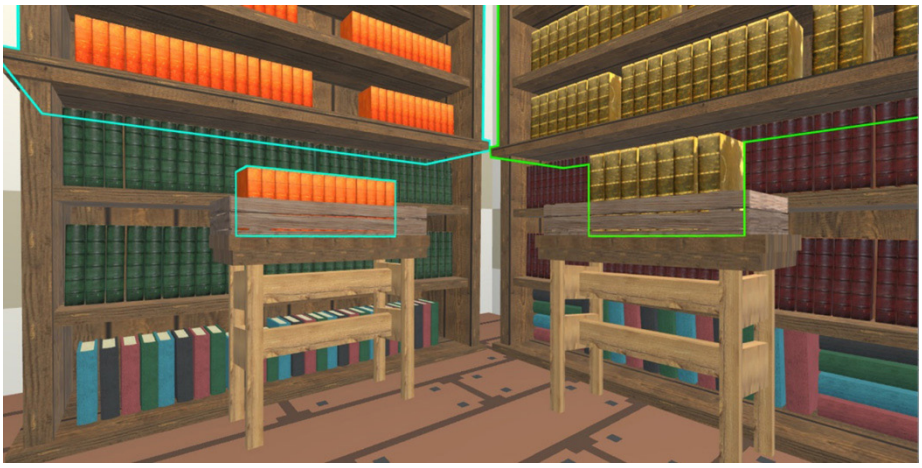

Fig. 45. Game page: Level 2

Fig. 46. Game page: Level 3

4) The player's score page shows the total score and time as shown in Figure 47.

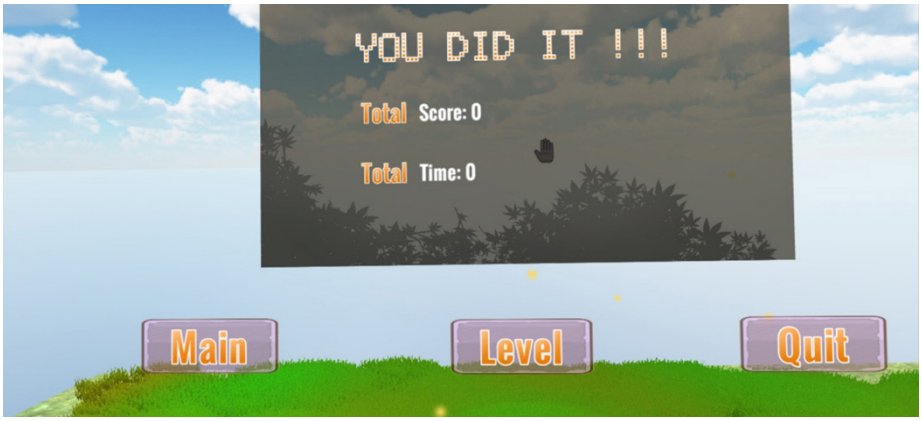

Fig. 47. Score page

5) The Guide page shows the button information as shown in Figure 48.

Fig. 48. Guide page

6) The Tips page shows the missions players need to do as shown in Figure 49.

Fig. 49. Tips page

7) The page shows the scores that must be reached. Current Points x and y-axis degrees as shown in Figure 50.

Fig. 50. The x- and y-axis scores and degrees

8) The page shows all the items that players must pick up and the number of each piece as shown in Figure 51.

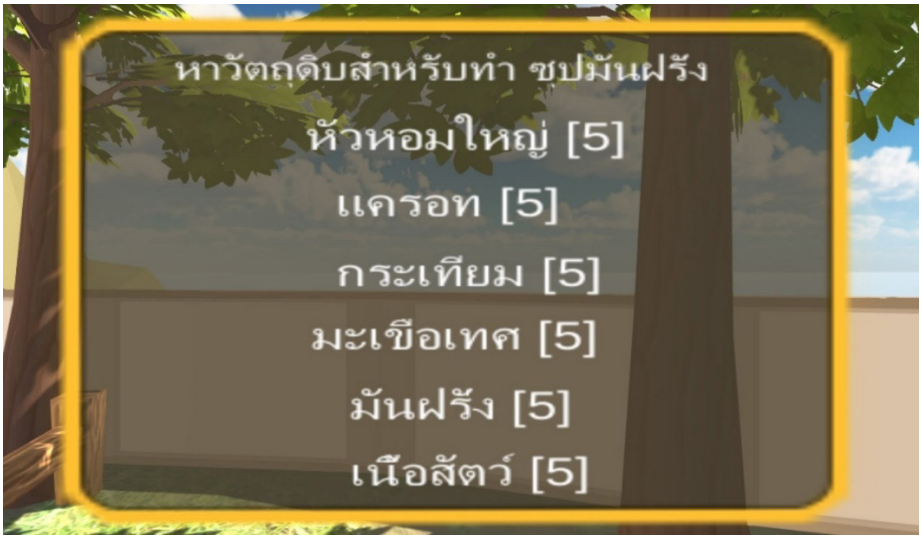

Fig. 51. Showing item page

Guide (How to)

1) When the game is opened, you will find the main page of the game, which has three buttons as shown in Figure 52:
Play: Start playing
Guide: Display information
Exit: Exit the game

Fig. 52. Main game page

2) When you press the Start Game (Play) button, the Level selection page is displayed as shown in Figure 53.

Fig. 53. Level page

3) Once the game level is selected, it will be accessed to the gameplay page, where players will have to pick up the items listed below. By picking it up and placing it in a designated place as shown in Figure 54.

Fig. 54. Gaming page

4.4 Quality assessment results by the experts

We introduced a game of physical therapy for paresis patients with virtual reality technology with a quality assessment form for experts to conduct a quality assessment. The evaluation results are shown as shown in Tables 1 and 2 in which average score level of each question is used to define the average score range for ease of interpretation as follows:

An average score between 4.50 – 5.00 means the quality of the game is very good.
An average score between 3.50 – 4.49 means the quality of the game is good.
An average score between 2.50 – 3.49 means the quality of the game is moderate.
An average score between 1.50 – 2.49 means that the quality of the game is fair.
An average score between 1.00 – 1.49 means that the quality of the game is improved.

Quality assessment results by the medical professionals.

Table 1. Results of quality assessment by the medical professionals on physical therapy games for patients who have arm paresis with virtual reality technology

Assessment Topics	Mean	Standard Deviation	Quality Level
1. Pattern of the game is suitable for doing physical therapy.	3.50	0.50	Good
2. Pattern of the game increases the effective performance in doing physical therapy.	2.00	1.00	Fair
3. The postures used in the game are correct according to the principle of physical therapy.	2.00	1.00	Fair
4. The postures imposed on the game cover the physiotherapy of the arms.	2.50	1.50	Moderate
5. he placement of objects within the game is in the right position.	2.50	0.50	Moderate
6. A certain number of times in each pose makes physiotherapy effective.	3.00	0.00	Moderate
7. The duration of the gameplay is in tune with the length of time takes to perform physiotherapy.	2.50	0.50	Moderate
Total Mean Scores	2.57	0.71	Moderate

From Table 1, the results of the quality assessment of the game by medical professionals were moderate, the average was 2.57, and the standard deviation was 0.71.

When considering the points in each topic, it was found that most of the topics have four moderate-quality which are: the postures imposed on the game, the placement of objects in the game, a certain number of times it takes, and the length of time it takes for physical therapy. There are two topics with a fair level of quality: the pattern of the game and postures that are used according to the principles of physical therapy.

Quality assessment results by the design experts.

Table 2. Quality assessment results by design experts on physical therapy games for patients who have arms paralysis with virtual reality technology

Assessment Topics	Mean	Standard Deviation	Quality Level
1. The game is easy to understand and not complicated.	3.50	0.5	Good
2. The screen and menu are beautiful.	4.50	0.5	Very Good
3. The fonts are beautiful and easy to read.	4.00	1.0	Good
4. The placement of elements of the game is appropriate.	4.00	0.00	Good
5. The in-game scenes are beautiful.	5.00	0.00	Very Good
6. The music is accompanied by the mood of the game.	4.00	0.00	Good
7. The game is smooth, not faltering.	3.50	0.50	Good
8. The format of the game is interesting.	4.00	0.00	Good
9. The game is realistic.	4.00	0.00	Good
10. The use of virtual reality (VR) technology in gaming is appropriate.	4.50	0.50	Very good
Total Mean Scores	4.10	0.30	Good

From Table 2, the results of the game quality assessment by design experts were found to be good, with an average of 4.10 and standard deviations of 0.30.

It was found that most of the topics conclude seven good quality which are: the game is easy to understand and not complicated, the font style is beautiful, the composition within the game, the music is appropriate, the game is smooth and not faltering, the gameplay is interesting, and the game is realistic. There are three topics with a very good quality level: the menu screen is beautiful, the in-game scenes are beautiful, and the use of virtual reality technology in the game is appropriate.

5 Conclusion and discussion

Research and Development of Rehabilitation Game for Paralysis with Virtual Reality can be summarized, discussed, and suggested as follows:

5.1 Summary

We propose a research and development of a rehabilitation game for paralysis based on virtual reality technology, with the game's format of moving items from place to place with controller devices leveled by the x-axis and y-axis movements through virtual reality technology. The quality of research and development of Rehabilitation Game for Paralysis with Virtual Reality was assessed by three medical experts and three design experts. The results show that the quality met the required criteria is about an average of 2.57 at the moderate level and an average of 4.10 at a good quality level, respectively.

5.2 Discussion

According to evaluations from medical professionals, the average is 2.57, the standard deviation is 0.71, as the gameplay model requires the device to be controlled by the arms paralysis patients who have been limited use of hands and fingers. In addition, there are too many objects in each stage, resulting in more difficulty in the patients' treatment. For example, the postures defined at each stage with the x- and y-axes are not covered by the type of paralysis patients.

The evaluation result from the design expert is 4.10, and the standard deviation is 0.30. This is because experts are of the same opinion that virtual reality technology is suitable for physical therapy. The game scenes are beautiful, and the design of the game is appropriate. However, the smoothness of the game is slightly twitchy, and the description of how to play the game may be difficult to understand. As a result, the gamer cannot immediately understand how to play the game.

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