



DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics: Games Engineering

**Development of a Game with
Physiotherapical use with help of AR and
VR Technologies**

Uygar Tarakci





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**Entwicklung eines Spiels für den
physiotherapeutischen Einsatz mit
Unterstützung von AR und VR
Technologien**

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I confirm that this bachelor's thesis in informatics: games engineering is my own work and I have documented all sources and material used.

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Abstract

A physiotherapy treatment usually involves multiple sessions and repeating same set of exercises depending on the type and severity of the injury. Due to repetitiveness of the treatment, patient motivation and interest in the therapy decreases over time. As a result effectiveness of the treatment also declines.

A solution to this problem is using motivational and behavioural effects of games to improve the therapy. By turning the therapy session into a fun experience patient engagement to the session can be enhanced. More motivated and engaged patients also promote the efficiency of the therapy.

With the help of the technological developments in the fields of AR, VR and motion tracking, physical aspects of gameplay can be turned into rehabilitative exercises. With this concept in mind aim of this project is to create a game that is usable as a therapy tool.

The game focuses on upper body and hand exercises. In the game the player is in a kitchen and has to grab ingredients from the shelves or from the counter and put them into the bowl in front of him/her. By using the kinect camera to track the movements of the player, the game allows the player to exercise stretching and grabbing movements.

The project will be done in these steps:

1. Research on physiotherapy games
2. Development of the game
3. Expert feedback about the game
4. Documentation of the study

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1 Introduction

1.1 Overview

Improved technologies in fields of motion sensing, augmented and virtual reality allows many different features to be added to games. These features broadens fields that games can be used. These fields include fitness, training (simulations), teaching and many others. One of these fields is physiotherapy and rehabilitation. Rehabilitative games can be as simple as memory exercises e.g. card matching games or can be complicated games to aid various movement exercises.

Aim of this project is to create a game that is fit for rehabilitation on patients with upper body, arm and hand problems. To track body of the player a motion sensing input camera and to track the head of the player and to create a better experience a VR headset is used. The gameplay elements are adjusted to the exercises the patient needs. The aim of the game is reaching ingredients around the kitchen and moving them to the pot in the middle of the screen by grabbing them.

To test and improve the game the feedback from Associate Professor Ela Tarakci and Assistant Professor Nilay Arman from Istanbul University, Faculty of Health Science, Division of Physiotherapy and Rehabilitation is taken. According to feedback the game has been improved and also can be improved further.

1.2 Background

A rehabilitative game is a serious game that its aim to provide a better and enjoyable alternative to the conventional rehabilitation by using the motivational aspects of the gameplay. According to Burke et al. [1] a rehabilitation game should have some features. A rehabilitation game should provide precise data recording to the therapist to evaluate the exercise. It should provide feedback according to level of the exercise. The players should be able to measure their progress with the help of the feedback the game provides. The game should handle the rewarding side by giving advantages for completing tasks and the failure side by giving disadvantages for poor gameplay to

keep the player engaged. It should challenge but not frustrate the player by adapting the difficulty according to the patients abilities and performance.

Borghese et al. [3] identify three key points designing a rehabilitation game. These points are adaptation, monitoring and real-time evaluation of the movements. Just like Burke et al., they also point out the adaptive difficulty the game should have so the game wouldn't be frustrating or tedious to play. The performance of the player should be monitored so the rehabilitation can be executed correctly and the player should get feedback about his/her performance to understand and improve what he/she does right or wrong. He also remark the game should be well designed so "the patient, while exercising, should feel like a player, focused on having fun while playing the game".

Nixon and Howard [2] define five game design principles to create engaging rehabilitation games. First is an engaging story or context to draw players into a play scenario. Also important is to design a user interface that is intuitive and easy to understand so the players can focus on beating the game. He also points out the importance of immediate feedback when a player does something right or wrong. The game should also encourage player to explore and become familiar with his/her capabilities within the game to gain better control over his/her avatar. And finally The player should be rewarded to keep him/her engaged in the game and encourage to play again to get better rewards.

1.3 Related Work

This project took inspiration from some other rehabilitation projects and applications. Most important one is the Virtual Occupational Therapy Application (Figure 1.1) developed by Barron Associates. This application is developed for the stroke patients to re-learn daily living activities. It uses Kinect sensor to track the movements of the player and its aim is provide a cost-effective rehabilitation option.

Another important project is the OmniVR (Figure 1.2) developed by Acplus. It is a rehabilitation system for aging adults. It uses different mini games for various exercises. Its aim is to prevent or lessen the negative effects of aging through rehabilitation.

The games from the company Fizyosoft (Figure 1.3) are should be mentioned as well. The company develops rehabilitation games focuses on physiotherapy with various technologies such as Kinect sensor and Leap Motion

1 Introduction



Figure 1.1: Screenshot from the Virtual Occupational Therapy Application



Figure 1.2: OmniVR



Figure 1.3: An example of one of the Fیزیsoft games

1.4 Outline

The background of the thesis and the other studies in the field of rehabilitative games is given in section 1.2. Chapter 2 will explain the software and the hardware that has been used. In the chapter 3 the development of the game will be defined in detail. Chapter 4 will describe the feedback from the experts in the field of physiotherapy and in the last chapter the result of the project and the possible improvements to the game will be pointed out.

2 Hardware and Software

In the development of this game various hardware and software has been used on different stages of the development. The required hardware other than a computer and the software is documented in this chapter. Development process will be explained with more detail in Chapter 3.

2.1 Hardware

In this project to track the movements of the player a motion sensing input camera was needed. The camera has to observe the joints of the players body and give their respective position so it can be visualized in the game world and also should be able to recognize the hand gestures to determine if the players hand is in closed or open state. The Kinect camera developed by Microsoft fulfills all the requirements and also most commonly available motion input camera that is available.

2.1.1 Kinect for Xbox 360

Kinect for Xbox 360 is a motion sensing input camera developed by Microsoft in 2010. It has RGB camera, depth sensor, infrared camera and has capabilities such as voice recognition, facial recognition and 3D motion capture. It can detect 20 joints per player. The Kinect for Xbox 360 has been used at the beginning of the development because of availability but later switched out for Kinect for Xbox One for the sake of better gesture recognition.

2.1.2 Kinect for Xbox One

Kinect 2.0 is a motion sensing input camera developed by Microsoft for Xbox One in 2013. Kinect 2.0 has 60 percent wider field of vision and has greater accuracy over its predecessor. It can track 25 joints per player including thumbs. Because of Kinect 2.0's accuracy on hand gestures and its ability to detect hand states and also the SDK support from microsoft for the development with the Unity game engine, Kinect 2.0 has been used as the main motion sensing input camera for this project.

The body of the player is being generated from the data from Kinect sensors and the players hand state is also tracked as well to recognize if the player grabbed or released a game object.

2.1.3 Oculus Rift

Oculus Rift is a Virtual Reality headset developed by Oculus Vr in 2016. The headsets position is tracked by a USB sensor. In this project the headset is used as the main camera to improve the players experience. To prevent problems caused by coordinate differences between Oculus and Kinect the sensors are placed as close as possible and the camera object is fixed to neck joint of the player. As a result of that only rotation values from oculus sensor are used to imitate head movements and the body movements are calculated only from the Kinect sensors.

2.2 Software

2.2.1 Kinect Studio

Kinect Studio is a tool from Microsoft that is used to debug Kinect data. It can be used to read or write different data streams Kinect sensor provides. It has been used to debug if the hand movements are correctly recognized by the sensor.

2.2.2 Oculus Studio

Oculus Studio is the software provided by Oculus VR and it is required to connect and use Oculus VR headset with a computer. Oculus Studio is solely used to connect and if needed fix the connection issues between Oculus headset and sensor with the computer.

2.2.3 Unity

Unity is a cross platform game engine developed by Unity Technologies. The game, subject of this thesis, is developed with 2017.3 version of Unity game engine. Unity provides the versatility to connect two different devices such as Kinect sensor and Oculus VR headset and is also simple enough to provide fast development. Also the Unity asset store has been used to find required game assets. These assets include ingredient models, kitchen props and furniture.

To connect and use Oculus headset the Oculus Integration provided by Oculus Technologies from the Unity Asset Store has been used. The integration package includes

examples and required libraries for the Oculus headset. The exact integration will be explained in Chapter 3. In this project only the camera rotation is calculated by the Oculus library, that's why only the OVCameraRig prefab has been used.

For the Kinect 2.0 the Kinect Unity plug-in 2.0 from Microsoft website has been integrated in the project. This package only works with Kinect 2.0 sensors. To use older Kinect camera the package version 1.8 should be downloaded. The package includes one example scene to show different data streams that can be read from Kinect sensor and also the necessary library for the use of the sensor. The body creation and movement is based on the example from this package from Microsoft.

The oculus package can be found on <https://assetstore.unity.com/packages/tools/integration/oculus-integration-82022> and the Kinect plug-in can be downloaded from <http://go.microsoft.com/fwlink/?LinkId=513177>

3 Development

In this chapter the development process will be explained in detail to explain the design choices. The current version of the game can be found on github.

(<https://github.com/UygarTarakci/BachelorProject>)

3.1 Game World

Game takes place in a kitchen. it consists of only one room and various kitchen furniture. These furniture include a fridge, a sink, an oven, counters, a dining table and chairs, a rug and two shelves. There are also invisible spawn point game objects to set where should ingredients spawn. The spawn points are on the shelves and on the counter in each side of the oven. On the oven there is a cooking pot game object.

The player has to carry the spawned ingredients from the kitchen to the cooking pot. the ingredients and the cooking pot objects have colliders matching their model. To detect collisions Unity engine uses these colliders and also at least one of the objects should have a rigidbody component. If a collision between an ingredient and the cooking pot detected, the ingredient object is removed and another ingredient object is spawned in one of the spawn points randomly.

To carry an ingredient object, the collision between the ingredient and the hand of the player should be recognized. After the body creation, which will be explained in the next section, a collider is set to the hand joint of the body. If a collision between these two colliders is detected, the hand state of the player should be checked. Hand of the player should be recognized as closed to grab the object, if the hand is in any other state the ingredient object will not be grabbed or moved. Hand states are observed by the Kinect sensor and it is recognized as one of the Hand states the Kinect SDK provides. These states are by default Unknown, NotTracked, Open, Closed and Lasso. More states can be added if necessary but in this project the states Open and Closed are sufficient. One of the reasons that Kinect for Xbox 360 is dropped for Kinect 2.0 is the ability to track these hand states. Kinect 2.0 can recognize finger and thumb joints it's predecessor cannot so recognize these hand gestures.

To correctly detect the collisions, the objects are set with necessary tags. The ingredients are tagged as "Draggable" and the cooking pot is tagged as "Bowl". The script on the hand joint also checks if the objects it collides with has the tag "Draggable". Likewise ingredients objects also check if they are colliding with an object tagged as "Bowl".

3.2 Body creation

The body of the player is visualized using the data from the Kinect sensor. The Kinect 2.0 can track up to 6 bodies. The bodies created by setting game objects to joints recognized by Kinect and drawing lines to connect them. i. e. a line drawn between hand joint and the elbow joint then between elbow and shoulder and so on. The colour of the lines are also used to show if a part of the body is visible and tracked by Kinect or not. If the lines are red it means that part of the body is cannot tracked and either obstructed or outside of the field of vision of the camera. If the lines green the Kinect can correctly recognize and track that part of the body. The body is scaled twice the size as well so it fits the game world better.

After the hand joint is recognized and the game object representing it is created, the colliders and the script regulating its collisions is attached to it as well. The script controls grabbing, carrying and dropping of the objects. If the hand object collides with an object that has the tag "Draggable" and hand state is closed, the object position follows the hand position. if the hand state is changed after grabbing the object, the object is dropped. If the dragged object collides with the object with the tag "Bowl" the object is destroyed and the new one is spawned.

To correctly imitate the player movement, movement vector should be altered so when player moves forward or closer to the camera the in-game body of the player also move forward or away from the camera. As default movements of the player and the in-game body is mirrored. To fix this problem the movement vector should be determined and altered. This vector can be calculated by saving the initial position of each joint and after each update determining the difference vector between the new position and the old position of the joint. Then the x- and y-components of the vector are reversed. The resulting vector is used to calculate the new position of the joint.

3.3 Adding the VR headset as the main camera

To integrate the Oculus headset the Oculus integration from asset store has been used. The OVRCameraRig prefab from the aforementioned asset package is set as the main camera and after the neck joint is created, the camera position is set as the position of this joint. After the scaling of the body the distance between joints are increased. Meanwhile this creates a better experience with hand movements the head joint stands also higher than expected. That is why using the neck joint instead of the head joint as the camera position creates overall a better user experience.

The Oculus headset determines its position and rotation from the data read from Oculus sensor. Therefore there can be conflicting or different values can be read from Kinect and the Oculus sensors. To prevent positioning mistakes the camera object is set to neck joint of the body so the position value from the Oculus sensor is ignored and value from the Kinect sensor has been used. On the other hand the rotation is calculated by Oculus sensor, To prevent an offset between body rotation and the camera rotation the Kinect and Oculus sensor should be placed as close as possible.

3.4 First testable version

Because there is no VR headset in the testing environment two versions of the game is builded. One with a fixed camera behind the player position and the other one with the VR camera. To quickly build both versions both the main camera and the VR camera game objects are left in the scene in Unity editor, and one of them is disabled depending on the build. Other than mentioned differences everything is the same and both builds require a Kinect sensor.

For faster testing and feedback process some quality of life features are left out of this build. Currently only one ingredient model, an apple, is being used. There is no scoring system and feedback to user is very limited. Nothing other than destruction of the object signals the player that the ingredient is correctly carried to the cooking pot. Player model also can and should improved to be a more lifelike avatar instead of lines and joints.

4 Feedback and Testing

To get a feedback about the game Associate Professor Ela Tarakci and Assistant Professor Nilay Arman from Istanbul University, Faculty of Health Science, Division of Physiotherapy and Rehabilitation are asked to test the game. To get a feedback with and without the VR headset both builds and a gameplay video is sent. Planned testing on patients is later cancelled because of performance issues with the computers in the planned testing facility.

4.1 Expert Feedback

The feedback from the aforementioned experts will be explained in three sections. In the first section the positive aspects of the first demo will be explained. Second section will explain negatives and required improvements to develop a finished product.

4.1.1 Pros

First of all the props in the kitchen and the ability to look around with the VR headset creates immersion and a better overall experience. Headset strengthens the feeling of reality and it is further enhanced with the body model following the players movements.

In rehabilitation the modern approach is task-focused training. As the main focus of the game is the grabbing task, it makes the transition between the game and real life easier. This easier transition creates the possibility for this game to be used on treatment of the patients with neurological conditions such as hemiparesis, which is weakness of one entire side of the body, or other medical conditions with upper extremity problems. To rehabilitate these conditions hand and arm exercises are needed. In the game main movements of the player are reaching and grabbing the ingredients. These movements are same movements from the required exercises and as a result the game can be a useful therapy tool.

4.1.2 Cons and required improvements

One of the most important improvement is user feedback. as of the first version of the game there is no visual or audio feedback that shows the player has completed the task correctly. An audio or visual signal would increase the motivation of the player and create a better experience. Possible signals are for example a tone that can be played if the ingredient correctly carried or a floating score text can appear.

In the version without the VR headset and with the fixed camera the perspective makes it hard to see the position of the ingredient object. That makes it difficult to correctly grab the object. The issue can be solved with better camera placement or a way to move the camera while playing.

For a better sense of reality the kitchen furniture should have hitboxes, so the player collides with the objects such as counters or shelves and doesn't move through them. if the player drops the ingredient object during the carrying process the object must be removed and should effect the score negatively.

There should be levels of difficulty to prevent frustration or boredom caused by too hard or too easy objectives respectively. This can be done in a static way such as predetermined levels or in a dynamic way such as the game adapting the level of difficulty according to players success or failure.

To provide a better feedback to the patient and the therapist the player should be recorded during the game. So the performance of the player can be examined further and a detailed feedback can be given by the therapist

5 Results

In this chapter the results of the project with consideration of the expert feedback will be discussed in detail.

5.1 Results of the first version

First version of the game is not ready to be used as a standalone therapy tool yet. There are many improvements should be made and these will be explained further in the next section. This version has the main game logic and the important features such as body creation and a first person point of view with the help of a VR headset. The game logic should be improved and the game experience should be enhanced further with audio and visual elements. Player can move and control the body intuitively as it mimics the players body and can interact with the ingredient objects. As a result this version of the game is a good start of a rehabilitative game but it is still early in the development. To create a finished rehabilitation game more time and work is needed.

5.2 Possible improvements

The improvements can be categorized as user feedback and game logic improvements. Other than these two categories the overall performance can be improved by simplifying the algorithms such as body creation and movement. Improvements on the hand tracking should be done carefully because Kinect sensor can give false positive or false negative signals depending on the computer and environment. Kinect sensor can recognize the hand in another state even though the player does the right gesture which can lead to a frustrating experience.

5.2.1 User feedback

As of the current version of the game the user feedback is really lacking. The player should notified with an audio or a visual feedback if the player is correctly completed the objective or failed it. A tone can be played after the ingredient object collides with the cooking pot object and another tone can be played if the player drops the ingredient

on the way. The player should also notified where and when an ingredient spawned to prevent the unnecessary effort to look for the ingredient. This can be done with an arrow on the edge of the screen.

One of the most important issues is the sense of reality when the player interacts with the kitchen furniture. Because there is no object in front of the player in real life, player can walk to the places where in game world he shouldn't be able to go. For example inside the counters or into other furniture. This can broke the immersion and can have negative effects on the game experience. One of the solutions to this problem is to make the player stationary so only the upper body movements should be tracked by the Kinect sensor. Because the aim of the game is upper extremity exercises this has no negative effects on the game. But the kitchen or the game world should be altered according to reach of a stationary player.

To provide a feedback to the player regarding to their performance a video recording, which can be taken from Kinect sensor, should be given as an output. So the therapist can determine the next steps in rehabilitation of the patient and also can give specific feedback to the patient about his/her performance

5.2.2 Improvements on game logic

To improve the game logic a difficulty system should be implemented. This can be done either with a level system that is preprogrammed into the game or a dynamic system that decreases or increases the difficulty according the performance of the player. The former solution can be easier to implement yet the latter would be a better solution.

The game should be explained the player at the beginning of the game. This can be done through a simple explanation text or a tutorial level with the help of visual elements such as arrows and text. So the unnecessary confusion about the goal of the game is avoided.

6 Conclusion and Future Work

6.1 Conclusion

In this thesis, development of a rehabilitation game is started. Some key elements such as body tracking, hand gesture analysis using a motion input sensing camera and a first person camera controllable through a VR headset is already implemented. The main focus of the thesis was correctly recognize and track the players body and hand gestures so the game can be used as a rehabilitation tool. Other planned work was giving a feedback to user and the therapist and creating a difficulty system. Currently the game has the ability track the player, recognize hand states such as open and closed and simple game logic. The simple game logic consists of spawning the ingredient objects carrying them around and ultimately to the cooking pot object so the ingredient object is destroyed and a new one is spawned.

Current version of the game can be called an early alpha build of the game. Even though there are many features that are missing, core game components are implemented and can be improved further. To complete the game, more time is required.

6.2 Future Work

Some of the features that are planned left for the future due to lack of time. Main components such as body tracking and hand gesture recognition had to be tested and developed further. Some of the ideas for the future work will be discussed in this section.

A better player model or an avatar that is more humanlike would increase the immersion. Also seeing a hand instead of lines and joints would make it easier for the player to grab and move the objects.

Better visual and/or audio feedback should be implemented so the player can understand if he/she made a mistake or progressing correctly. These can be audios that are played on different situations or simply point systems that pop up on the screen. This

also includes when the player tries to go through a solid object such as furniture in the kitchen. One of the solutions to this problem is changing the game field so the player is never be able to go through solid objects, that means the size of the space tracked by the sensor is the same with thee free space in the game. Another solution would be the limiting player movement in the game. Because the game focuses on upper extremity exercises, this can be done by only tracking the upper body of the player and making the in-game player stationary.

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