Rehabilitation Application for People with Motion Impairment

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##### Declaration

I hereby certify that the material, which is submitted in this report towards the award of BSc. Software Design, is entirely my own work and has not been submitted for any academic assessment other than part fulfilment of the above named award.

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Signed…………………………………………….

Date………………………………………………

##### Abstract

Strokes are a leading cause of death in the world and can only continue especially with an ever growing and maturing population. Disabilities can arise from a person who suffered from a stroke leading to impaired speech, loss of physical functions and even the complete neglect to comprehend ones left/right vision. Hospitals are struggling to keep up with the constant need to rehabilitate patients, leading to many having to progress their treatment at home. This can be an expensive and arduous task requiring specialist occupational and physical therapist assistance. The exercises offered to patients are often not completed due to their boring nature. Fortunately, we are in an era of every growing technologies which can assist in these tasks. This paper presents an interactive game which uses free hand motion control to assist with rehabilitation.

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# Introduction

## Introduction

Every year up to 15 million people suffer from a stroke worldwide and of this, five million are left permanently disabled. [1] The disabilities can vary and are both physical and neurological impairments. The neurological disabilities include apraxia which is the inability to execute learned purposeful movements, motor incoordination and hemiparesis (muscle weakness on one side of the body). [2] This usually results in a patient loosing full or part control of their hands. Around 80% of stroke survivors will be effected by notable motor impairment which will require home care. [3] The home care will often involve a therapist helping them complete exercises. Fortunately, a study done showed that repetitive and intensive exercises help a stroke patient recover from motor impairment. [4]

## Research Aims and Objectives

Having established that technologies can be used to improve a stroke survivor’s ability to do rehabilitation exercises and that. I will now propose that using the Leap motion controller as a free hand means to do at home exercises. The approach I will take will see if using the leap will make it possible to gamify rehabilitation exercises. This approach will hopefully prove to more enjoyable than completing the standard mundane exercises. This could encourage patients to complete their required exercises. The goal is to make a gaming experience that is goal oriented, giving the user something to work for during each session. Through use of the leaps state of the art technology of motion control, I hope to restore a stroke patient’s confidence and ability to complete hand movements which will eventually lead them to independence and recovery in the comfort of their own home.

The rest of the paper is organized as follows. Chapter 2 will introduce you to the seminal work in my projects area and identify how my project will address any problems with the subject area. In Chapter 3 the overall system design and implementation will be covered along with the architecture and requirements. Chapter 4 will discuss the testing and evaluation carried out. Finally, in Chapter 5 I will conclude my project by summarising it and talking about the future implications of my work.

# Background Research

## Introduction

To understand the role that rehabilitation plays in restoring function to a patient I will go over a brief history of the current assistance. The initial treatment following a stroke usually takes place in hospital. This can however not lead to the desired attention a patient requires as a study suggests that patients only spend around 13% of their working day in therapy [5]. The rest of this time could be spent therapy or on self-directed exercise. This can lead patients to choose at home therapy as an alternative. A patient is suitable for at home therapy if they only require treatment by one type of rehabilitation therapist [6]. If a patient chooses therapy at home, then they have the advantage of practicing skills in the context of their own living environment. This idea was what appealed to me and lead to the development of an at home rehabilitation platform. This could be achieved by using Unity as an environment to make an application that could be used by users at home. The gamification of these exercise in conjunction with the home setting are reasons that would help a user continue with their treatment.

## Rehabilitation Methods

There have been various attempts and technologies used to help improve motor function. There have been physical robotic aids used for support to help movement of upper extremities. [7] This form of assistance essentially lowers the forces needed for movement of their upper extremities by mechanical intervention. The other technologies include using mechanical gloves to aid in flexibility and increase recovery time. [8] While these options may be beneficial they can be expensive to the user and would still require partial assistance with use. They also have the disadvantage of not altering the exercises, making them remain mundane. The use of lower cost and easily available technologies such as the PlayStation 2 EyeToy and the Nintendo Wii is an alternate means to help motion impairment.

## Rationale

There are many problems with the current work done in the rehabilitation areas and I will now discuss them and how I plan to address them. The first problem with at home therapy is that of price. Occupational therapists can be an expensive aid to patients whose prices average around €250 per visit [9]. To address this problem, I will first assume that the patient has a pc/laptop capable of running my application. Then the price of the Leap is only €70 [10]. This is already a massive saving to the patient and even if we factor in a pc at around €300 its still less of a cost after just two visits.

# System Design

## Introduction

The following chapter will focus on my systems design and implementation. It shows how I planned the system and then used this plan to complete the application. The system design I went for in the end is focused on giving the user a good experience which will lead to them continuing to engage and enjoy the game. This is achieved through having the user’s data stored which can be accessed by the administrator. This gives the necessary feedback of gameplay time needed to alter the game. I will go into more detail about this in the later section but the next section will focus on the systems requirements.

## Requirements

This section will cover all the requirements that were necessary to build my application. It will be split into two sections which include functional and non-functional requirements. Functional requirements focus on what the system should do while non-functional requirements describe how the system works. The functional requirements will be made for the users and is represented in the tables (3.2.1, 3.2.2, 3.2.3) below. They are split up into three categories being the users, gameplay and therapist’s requirements. The user’s requirements focus on what the user will require from the system. The gameplay requirements highlight the elements needed to make the games user interface. Therapists requirements are what a therapist would want accomplished by a patient.

|  |  |  |  |
| --- | --- | --- | --- |
| **ID** | **TITLE** | **DESC** | **DEP** |
| 1000 | There shall be a register system | Used to register a user |  |
| 1001 | The user shall be able to enter their details | Details include their name, email, password and confirm password | 1000 |
| 1002 | The user’s information will be stored | Information will be stored locally on their device | 1001 |
| 1003 | The information shall be error checked | Information entered must be in the correct format | 1002 |
| 1004 | There should be a login system | Used to login a user | 1000 |
| 1005 | The user shall be able to enter their details | Details include their name and password | 1004 |
| 1006 | The information should be checked | Information is checked to see if it correctly matches stored name and passwords and if not if displays an error | 1002 |
| 1007 | The user will be able to use correct login information to progress | If the user’s login information matches the stored information, then the game can begin | 1006 |
| 1008 | The user should have timestamps stored upon login | The players timestamp should be stored locally upon successful login attempt | 1007 |
| 1009 | The user should have a main menu | The main menu should contain a level select and quit button | 1007 |
| 1010 | The user should have a level select menu | The level select menu should contain options to select each level | 1007 |

Users Functional Requirements

|  |  |  |  |
| --- | --- | --- | --- |
| **ID** | **TITLE** | **DESC** | **DEP** |
| 2000 | There shall be a pause menu | The pause menu must stop gameplay and bring up a UI |  |
| 2001 | There should be options on the pause menu | Options on the pause menu can include a resume and quit button | 2000 |
| 2002 | There should be a game over menu | Game over menu pauses gameplay and shows if a level is failed |  |
| 2003 | There should be options on the game over menu | Game over menu will contain a message and give options such as retry and quit | 2002 |
| 2004 | There should be a completed menu | Completed menu pauses gameplay and shows if a level is completed successfully |  |
| 2005 | There should be options on the completed menu | Completed menu will show a message and have the buttons to quit, restart or next level | 2004 |
| 2006 | There shall be a tutorial screen | The tutorial screen will pause gameplay and inform the player on how to play the level |  |
| 2007 |  |  |  |

Games Functional Requirements

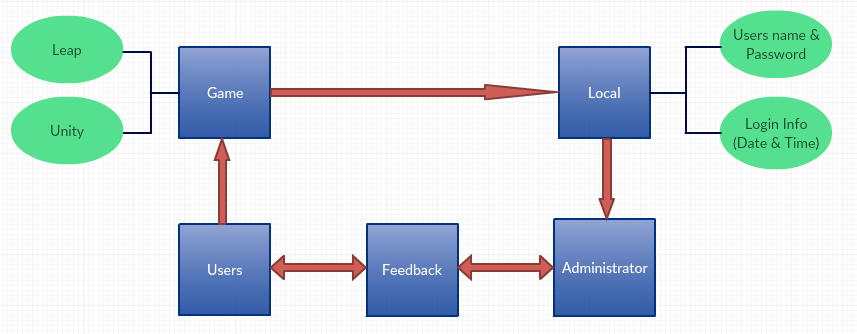
|  |  |  |  |
| --- | --- | --- | --- |
| **ID** | **TITLE** | **DESC** | **DEP** |
| 3000 | The game should incorporate exercises | Exercises should be incorporating the following gestures grasping, pinching and flicking |  |
| 3001 | The exercise should be enjoyable | The exercise can be gamified in a virtual environment with a motion controller to improve enjoyability |  |
| 3002 | The patients must continue to complete their exercises regularly | The duration, time and date of each session shall be determined by login and logout timestamps stored locally. | 1007 |
| 3003 | The application must improve the users motion abilities | The levels should have a progression through levels to accommodate improved motor function | 1010 |
| 3004 | The system must increase a user’s productivity | The gameplay should be goal orientated |  |
| 3005 |  |  |  |
| 3006 |  |  |  |

Therapists Functional Requirements

I will now discuss the non-functional requirements. The first requirement would be of security. The user’s data can be stored locally so there is no risk of an online attack i.e. malware, viruses or attempts to access their information over the internet. The other requirement if that of the software used. All the software used in the system was up to date with the most recent packages being used. The system must have requirements for accessibility. These should include being easy to set up, this can be achieved because the leap requires minimal set up. It only need to be connected to a compatible device and the application can be run from there.

## Architecture

I will discuss the architecture used in my application below with the aid of the diagram below (Figure 3.3.1). The system starts with the users. At this stage the user will interact with the game which uses both the Leap and Unity. The game will send information put into it onto local storage. This information will include the user names and passwords. It also contains their login timestamp and name along with their logout timestamps. Information gathered from this, can then be observed to determine the user’s playtime. The administrator can then give feedback to the users based on their time playing and discuss with them if there are any reasons behind their lack or improved time in-game.



System architecture diagram.

## Design

This section will give an overview of my design process and why I designed my system in my specific way. The application itself would be designed through Unity as the environment because it is compatible with the Leap motion controller and I have previous experience using it which would lead to a shorter learning curve. The Leap motion controller had to be considered in my design as it’s a very suitable technology to translate hand movements into a virtual world.

The application should have various exercises to help a user improve their motor function. This would be integrated into the game by having three main gestures: the grasping gesture, the pinching gesture and finally the flicking gesture. These gestures were chosen because they were found to be used in rehabilitation exercises. The flicking gesture was used as a warm up exercise for the wrist muscles along with helping to give the user a greater range of motion through flexion of the hand. The second gesture I chose was the pinching gesture, this was used to aid in the user’s functional rehabilitation as grasping objects would be used throughout daily life. The final gesture was I chose was a grasping one and this was picked for its benefits when it came to strengthening a user’s grip and helping to improve their endurance. As you can see I chose these gestures to give a broad range of functional movements and exercises to the users which would benefit them more as opposed to a concentrated exercise program. These benefits from using the gestures are shown in greater detail in Table 3.4.1 below.

The next step was to avoid turning these rehabilitation exercises into boring mundane tasks and this was achieved through gamifying them. The game should be considered fun to play and goal orientated to help keep the users attention and retention. To achieve this I set out to design a game that would have goals such as a score to reach and a time to reach that in. It would also contain progression through the levels where each subsequent level would increase in difficulty. The games design is focused on not being tedious and favour interactivity.

The users continued repetition of the exercises in the game and frequency of playing the game is a major factor on their recovery. Knowing this made me want to keep track of when they were logging in and out. Also, I found it important to consider that a user would like to have an application that is easy to follow and avoids confusion. Building on from that idea I wanted to make the user interface(UI) as easy to follow as possible, along with having a clear set of instructions in each level showing what to do. The instructions would act as a tutorial for the user who may be new to levels mechanics. A UI in each level such as a pause screen would also help the player to take a break and continue gameplay later would improve the user’s quality of life experience with the application. The UI could also be used as a visual aid to the player letting them know if they have succeeded or failed in their goals set out through gameplay.

From the above, it’s clear that my research has influenced how I would go about designing my system to suit a user’s needs. Taking all the different things that should be put into the system gave me a clear goal on how to implement them into my project which will be discussed in more detail in the next chapter.

|  |  |  |
| --- | --- | --- |
| **Gesture Type** | **Benefits** | **Appendages used** |
| Grasp | Improved hand eye coordination  Increased hand strength  Improved endurance | All fingers |
| Pinch | Increased range of motion  Improved hand eye coordination | Index and thumb |
| Flick | Improved hand eye coordination  Increased range of motion  Warming up wrist muscles | Wrist |

Table showing gestures benefits and muscles used.

## Implementation

Having established how my system should be designed in the previous chapter, I will now discuss how I implemented those design ideas in this section. In the beginning of my game there was the register and login menu. This menu would act as a starting point to each user. It contained fields to be filled in by the user with the registering side including their name, email, password and password confirmation. This registered user’s information would be checked to see if it was formatted correctly such as having matching passwords, using a long enough username and correct formatting with the email. If all the information was entered correctly, then the user’s information would be stored in a text file locally. The reason for this was to keep the user’s information persistent in case they closed the application. After the registration button was clicked the fields will disappear and confirmation of registration will be shown. The newly registered user can now login through the login fields by entering a registered name and password. If the login information entered was correct and the login button was pressed, then it would bring you to the next screen. If the user successfully logged in, then a timestamp along with the user’s name will be wrote to a separate folder on the hard drive. This was put in to make sure there is a record of who logged in and when so that this information having established that this would be beneficial in the previous section.

The next screen I worked on was the main menu screen. This screen would act as a hub between level select and logging out with corresponding buttons. If the logging out button was pressed, then it would send you back to the register and login menu. At the same time a timestamp would be sent back to the folder with the login information and keep a record of when the user logged out. Having this information makes it possible for me to have measured how long a user was logged in by comparing the login time to the logout time and subtracting them (i.e. logout time – login time = total time in application). This information would be invaluable in seeing what user’s playtimes are like and acts as a feedback to myself as the administrator. The second button on the UI of the main menu would bring you onto the next page the level select.

In the level select page there was a UI that shows all the various levels and difficulties. The nine selectable levels encompassed all the gestures as mentioned in my design. Each of these gestures had their own levels with three stages in total each. The levels can all be selected through clicking on their corresponding buttons. There Is also a return button which functions to bring the user back to the main menu when clicked.

All the stages contain the same UI when paused and during gameplay so I will discuss these first before talking about the individual levels. The UI during gameplay consists of score, goal, lives and timer. The score will go up when certain conditions are met. The goal is determined at the start of each level and acts as an incentive for the user to reach that before the timer runs out or their lives reach zero. The lives are a loose condition because if they are reduced to zero then the game is over and they are reduced if an object hits anything red in the scenes. The timer also acts another lose condition where the game is over when it reaches zero. The timer was a number which was determined at the start of each level and decrements overtime. These elements were added having established that the game should be goal orientated.

I will now discuss the pause menu which was added and would be visible when a user pressed the ‘P’ character. When it was visible the games framerate would be set to zero effectively freezing the gameplay. The UI that then appeared included three options: play, restart and quit. Each button when pressed would carry out their function where the play button would resume the game, the restart button would restart the current level and the quit button would quit back to the main menu. As previously discussed the user would benefit from having a pause menu.

The game over screen is displayed if a user’s life’s reach zero of the timer reaches zero. When it is displayed, the gameplay stops and two buttons appear. The first button is the restart button and when pressed it will restart the level. The next button is the quit button which will bring the user to the main menu if pressed.

The congratulations screen is shown when a user succeeds in completing a level. A level is completed when the score reached the goal score before the timer reaches zero. The congratulations screen displayed three buttons: the next level button, the restart button and the quit button. The next level button will bring the user to the next level in the category which will be a more difficult version of the current completed level. If all the levels in a category are completed, then the next level button will bring the user to the main menu. The restart button will restart the current level when pressed and the quit button will bring the user to the main menu when pressed. This congratulations screen has been implemented to give the user an option to progress with and to give them feedback that a goal has been met.

This brings me onto the next part of my application which includes the gameplay in three categories. Firstly, there was the grabbing game. This game started with a popup screen that told the user how to play the game. This screen acted as a tutorial to the user, informing them on the gestures and goals. The gestures were closed fist and straight hand extension. This exercise was gamified by having the user close their fist to pick up an object and then raise it off the ground. The user would then score by keeping the object raised for a few seconds and not letting it drop. The floor would turn from green to red and if the object was dropped upon the red floor then the lives would decrement. The objects would also randomly spawn at different locations if the player and in different forms. The other two levels were a progression on this level where the difficulty was increased. To achieve this I increased the goal and reduced the timer slightly. These aspects provide an extra challenge to a user that has mastered a previous level and gives them a reason to continue.

Secondly I will discuss implementing the pinching gesture into my applications level. This level started with a tutorial screen instructing the player to use a pinching gesture. The hand gesture in involved pinching an index and thumb together. The goal of this game was to pick up ball objects as they rolled into your grasping range. Then place them either left or right to score while missing them would cause the user to lose lives. The objects would spawn at different locations on the screen and in different sizes. The subsequent levels in this category varied in a few ways to increase difficulty. For example, the objects in the levels would spawn at greater distances and the speed at which the balls rolled towards the user would also increase and the balls themselves would decrease in size. These elements were used to make the make the pinching exercises as interactive and enjoyable as possible.

Thirdly I would like to talk about adding the flicking motion put into my levels. The first level contained a tutorial screen showing off the flicking gesture. This involved moving the hand from a fingertip facing down position to a fingertip facing up position. The goal of this game was to hit objects coming towards the user and send them back towards a scoring area represented as a green space. The levels progressed in difficulty in this category by using several factors. The speed at which the balls came towards the player was increased, the balls spawned at greater distances, the scoring zone got further away and the miss zones on the sides got narrower. The elements listed above keep the player engaged with the gameplay.

A Trello board was used throughout development as a means of keep track of ongoing tasks. The tasks were broken up into user stories and then prioritized using colours with red being urgent, amber for medium priority and blue as optional. The tasks were then put into their columns based on their stage of development weather that be to do, in progress or done. The use of a Trello board was invaluable to my progression in development as it kept me on track and always gave me a way of prioritizing tasks.

To summarise I used aspects from my design to influence how I would implement them into my application. The main idea behind my implementation was to make sure the player got the exercises and gamified them to make them more enjoyable to complete. The implementation of the UI was a way to keep it simple for the users and the tutorial was used to help instruct new users on the game mechanics. The login and register system helped keep track of who and when they logged/out. The next section provides how testing and evaluation was carried out.

# Testing and Evaluation

## Introduction

This chapter contains all the testing and evaluation carried out during my project. The testing was done throughout my project. It provided a way to see if there would be any discrepancies in my specifications. It provided the ability to fix and test bugs before they became a substantial problem in the future of the products lifecycle. This testing was done with the end user in mind to help ensure they were using a function piece of software. The evaluation of my project will encompass the problems faced with my project alone with what I did when faced with them. For these reasons, I found it imperative to conduct thorough software testing and evaluation on my project.

## Testing

The testing processes used by me throughout my project will now be discussed. These methods included both white box and black box techniques. White box testing was the most prominent method used throughout my project.

It involved debugging as I was coding. This included using debug logs placed throughout my code initially to give me an indication of where an error occurred. This was mainly used in unity as a form of debugging. Another version of testing was done with the use of Visual Studio’s debugging software. I used this to step through my code as it was finished to double check the code worked as intended. It was also used as a means of error checking if one occurred.

## Evaluation

I have found that the Leap motion controller is a great tool for a tracking hand movements and representing them on screen however I found that if did have a few limitations. The controller had a difficult time picking up hand movements if the fingers overlapped. This became apparent after some testing and eventually lead to me using gestures that favoured keeping all the fingers visible with minimal to no overlapping. There was also the issue with fine motor control. The controller had problems when trying to rotate objects as it would lose tracking occasionally, likely due to the fingers going out of view and the controller guessing where they could be. Another issue was in regards to the lighting conditions. The controller was very specific with the brightness effecting its sensor. I would have electrical lights on and it would sense it was too bright. I found that while it was daytime and the device not in direct sunlight provided the best results and no issues.

The project evolved a lot since the start of the development. One of the biggest changes was to how the gamification of movements could help people with motion impairments. I started with having a game that focused solely on gestures that included swiping and pointing. These gesturers were not compatible with the recent version of the Leap API and lead me to using and older version. These gesturers also required manual manipulation through their code to function properly. This involved changing their sensitivity and adding functions to allowed them to interact with the scene. The gameplay at this stage resembled that of a popular game Tetris where a gesture would move a block falling towards a gap in the floor with the intention to orientate the block to fit and fall through the opening. It became apparent eventually that this method lacked adequate sensitivity which made registering the inputted gestures a problem. This lead to the inclusion of the up to date API which made registering objects a lot more responsive and was better suited to my project’s needs.

# Conclusions

## Introduction

This chapter provides a conclusion and reflection on how my project came together as a whole. It will provide a summary and demonstrate that I have a clear understanding of the created system. The points that follow will outline what my system did and what I took away from the project.

## Reflection

In this paper, I have shown that the use of free hand technologies in at home rehabilitation has not fully been explore to its potential. I demonstrated the need for bringing game-based rehabilitations to the patient’s home. I have expanded on the at home rehabilitation methods and incorporated the Leap Motion controller. The project showed my ability to plan a system and then follow my plan to complete the system. The report shows that I have done ample background research on the subject area. I gamified the monotonous exercises provided by therapists. In doing this I turned a repetitive process into an interact able and enjoyable experience for the user. The implications of this could lead to users completing their required exercises and thus lead to a faster and more successful road to recovery. I hope to see that the implications of this system will encourage more at home and game-based rehabilitation systems. The application could take in information given by the user and store it locally. This local information could be used to see their login/logout information and from this I could draw conclusions as to whether they played for enough time.

## Recommendations

There are a few recommendations that I think would suit this project and its ideas going into the future. The data given by the users through login/logout could be put into a database. This would allow for a more organised structure through which to view the user’s data. The database could even be configured to store the information online. The storage of this information online would have the benefit of making the password storage more secure. The off-site storage of information would also have the advantage of not requiring any visits to collect data. Encryption of the gathered passwords would also be recommended in the future to ensure each users security is upheld, giving them piece of mind.

Data collection through surveys involving what stroke victims would like in terms of gameplay would be an idea to think about. For instance, they could give valuable information on what is fun, compatible and engaging for them. These answers could then determine how the gameplay is altered to suit their needs. In addition to this data collection a similar survey could be completed in regards to my currently completed application. This data would show where the strengths and weakness of the design lie and provide usefully general feedback.

There is a case to made for using virtual reality in conjunction with my application. This is due to virtual reality becoming an ever more prominent tool used with gaming. It might also provide an added level of interaction and immersion. The immersion could benefit users who might take it as a more enjoyable experience and encourage them to continue playing the application. As time progresses I can assume that virtual reality will become less expensive and become a welcome addition to rehabilitation games.

As has been suggested these recommendations could send this project into the future into many new and exciting directions.

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##### Glossary

##### List of Abbreviations

###### Appendix Title uses ‘Heading 6’

Appendix sub-title uses ‘Heading 7’