MANA REHAB:

A GAME THAT HELPS IN FINE MOTOR SKILLS REHABILITATION

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ABSTRACT

This research involves the study in the fine motor skills rehabilitation process and implementation of the Skeleton Tracking device Leap Motion in creating a game that is beneficial to the stroke patients. MANA Rehab aims to combine the game elements with the rehabilitation modules to help the stroke patients during fine motor skills rehabilitation progress. The reason for the movement disability caused by stroke is because of the blood supply to the brain is disrupted during stroke and causing the damage to the brain. The damage of the brain can never be recovered, causing disability in body movements. However, the brain is able to adapt with the damage done, and regain of the command in body movement is possible with proper rehabilitation procedures. Currently, there are available projects that include the game elements in the stroke rehabilitation process, but none is specifically dedicated to fine motor skills rehabilitation. Hence, there is lacking in engaging elements to motivate the patients in fine motor skills rehabilitation. In addition, there are uncertainties in defining the suitable hardware to be applied in this context. The objectives of this research is to study the modules of stroke rehabilitation modules, determine the suitable hardware to be implemented in a game that helps in fine motor skills rehabilitation, and lastly, to create a game that is beneficial to the fine motor skills rehabilitation. The scopes in this research limits the system development to focus in fine motor skills rehabilitation, Leap Motion is selected as the skeleton tracking device, and Java Script will be used as the platform if the system development. In the end of the research, a system named MANA Rehab is delivered, combining the Leap Motion functionalities with the fine motor skills rehabilitation modules.

ABSTRAK

Kajian ini melibatkan kajian dalam kemahiran motor proses pemulihan halus dan pelaksanaan rangka peranti Penjejakan Leap Motion dalam mewujudkan permainan yang memberi manfaat kepada pesakit angin ahmar. MANA Rehab bertujuan untuk menggabungkan unsur-unsur permainan dengan modul pemulihan untuk membantu pesakit angin ahmar semasa denda kemahiran motor kemajuan pemulihan. Sebab untuk kecacatan pergerakan yang disebabkan oleh strok adalah kerana bekalan darah ke otak terganggu semasa lejang dan menyebabkan kerosakan kepada otak. Kerosakan otak yang tidak dapat dipulihkan, menyebabkan kecacatan dalam pergerakan badan. Walau bagaimanapun, otak dapat menyesuaikan diri dengan kerosakan yang dilakukan, dan mendapatkan semula arahan dalam pergerakan badan adalah mungkin dengan prosedur pemulihan yang betul. Pada masa ini, terdapat projek-projek yang ada yang termasuk unsur-unsur permainan dalam proses pemulihan strok, tetapi tiada yang khusus khusus denda pemulihan kemahiran motor. Oleh itu, terdapat kekurangan dalam melibatkan unsur-unsur untuk memberi motivasi kepada pesakit di denda pemulihan kemahiran motor. Di samping itu, terdapat ketidakpastian dalam menentukan perkakasan yang sesuai untuk diaplikasikan dalam konteks ini. Objektif kajian ini adalah untuk mengkaji modul modul pemulihan strok, menentukan perkakasan sesuai dilaksanakan dalam permainan yang membantu dalam denda pemulihan kemahiran motor, dan akhir sekali, untuk mewujudkan permainan yang memberi manfaat kepada denda pemulihan kemahiran motor. Skop dalam kajian ini menghadkan pembangunan sistem untuk memberi tumpuan di denda pemulihan kemahiran motor, Leap Motion dipilih sebagai peranti pengesanan rangka, dan Java Script akan digunakan sebagai platform jika pembangunan sistem. Di akhir kajian, sistem bernama MANA Rehab diserahkan, menggabungkan fungsi Leap Motion dengan denda modul pemulihan kemahiran motor.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Stroke appears to be the third largest cause of death in Malaysia, only next to heart diseases and cancer. According to National Stroke Association of Malaysia (NASAM), in the year of 2014 itself, an estimation of 40,000 people suffers from a stroke. In other words, a stroke happens every 40 seconds.

The most difficult part of the journey for the stroke survival will be losing some parts of control of their body. To make the matter worse, a stroke can happen to anyone at any age, but the majority cases affect adults. In addition, stroke contributed to 8% of the total death in the country for the year of 2009, and ranked as the 5th principal cause of death in Malaysia. [16]

Stated by the Stroke Foundation of New Zealand, a stroke is a brain attack which occurs when the blood supply to the brain is disrupted. In reality, there are an enormous amount of blood vessel in our brain consistently supply the blood that contains oxygen and nutrients to the brain. When one of these millions of blood vessel bursts or gets clogged due to certain circumstances, that particular part of the brain starts to die. NASAM also state that, if a person having a stroke is not receiving any emergency procedures, his brain will face permanent damage that lead to disability in certain part of the body, or even paralyzed for the rest of his life.

The damaged part of the brain can never be recovered, because brain cells cannot be regrown under the biological capabilities of human beings. However, the missing parts can be relearned, it only takes a few seconds to do all the damage, but it takes years or rehabilitation for the stroke survivors to regain the missing part of the command, or memories.

Another significant challenge for the stroke patient will be maintaining motivation in the rehabilitation. Stroke rehab requires enormous efforts, patience, and the slow yet boring progress may cause the patients becoming demotivated and giving up the rehab. The study indicates that only 31% people with motor disabilities practice the exercises as recommended from the therapists. Lacking in motivation can be an obstacle for the patient to actively involve themselves in the therapy sessions, which eventually affect the overall rehab progress. [17]

To counter with the problem, there are researches and projects regarding the feasibility of implementing the entertainment elements into the rehab process. Evidently, using video games as an alternative for stroke rehab is able to encourage the patients in their daily practices. [17]

1.2 PROBLEM STATEMENT

Fine motor skills involve the cooperation of brain, eyes, and muscles of the fingers that enable our hands to write, grasping objects. It can be considered as one of the crucial skills that we have started to develop from infancy. In fact, fine motor skills are crucial for the daily routine and even life career.

However, fine motor skills can be compromised after stroke as certain parts of the brain are damaged. [1] Occasions such as injuries at the joints or brain damage from stroke will affect the abilities in controlling coordinated body movements with hands, fingers, and even face muscles.

The rehabilitation progress for every patient is differ, referring to the specific conditions of the patient. From a psychological point of view, an individual who faced sudden lost in ability in coordinated body movement and hand dexterity has to withstand frustration due to the physical disability, and the negative emotion will affects the progress of the rehabilitation. [18] Hence, the idea of implementing a serious game in the rehabilitation can be beneficial to the progress of rehabilitation by preparing an entertaining and exciting platform to constantly motivate the patients throughout the long duration of practices.

Video games are potentially useful technologies in improving fine motor skills, which involve the patients' ability to use their hands and fingers. In the market, there are a few existing games designed to aid stroke and coordinated body movement rehabilitation, which majority utilized the benefits from 3D cameras in affordable devices such as Kinect from Microsoft. Some of these games are proven to be beneficial, and had already been integrated as part of the stroke rehabilitation in some rehab centres. [3] Nevertheless, the existing rehabilitation games are mainly focused in gross motor skills. Therefore, there are lacking in engaging elements to motivate the patient to practice in fine motor skills.

More than that, currently there are no existing projects that focused on the fine movement practice specifically. Yet, there are uncertainties in deciding the suitable devices to be implemented in the development of a video game for rehabilitation of fine motor skills.

In summary, the problem statements for this project are defined as:

1) There are no custom-made serious games specifically dedicated to the practice in fine motor skills rehabilitation.
2) There are lacking in engaging elements to motivate the patients to practice fine motor skills in existing systems.
3) There are uncertainties in defining the suitable motion sensor hardware to be implemented in the serious games for fine motor rehabilitation.

1.3 OBJECTIVES

The project planning aimed to achieve following objectives:

1) To study the modules of stroke rehabilitation on the patients' fine motor skills.
2) To determine the suitable hardware to be implemented in a video game that helps in fine motor skills rehabilitation.
3) To create a video game that is beneficial to the process of fine motor skills rehabilitation.

1.4 SCOPES

Referring to limitation in time and resources, this dissertation is limited in the following causes:

1) The focus of the system will be the development of a system targeting on patients faced disability in fine motor skills, which involves the movement of the hand, wrist, and fingers only.
2) Leap Motion Controller will be used as the skeleton tracking devices in the system development.
3) Java Script and LeapJS API will be implemented in this project development.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Fine motor skills are defined as the utility of small muscles in smaller movement and coordination in wrists, hands, fingers, feet, and the toes. One of the examples of movement involving fine motor skills will be picking up objects between thumb and finger, writing, and typing keyboard. In addition, fine motor skills also include the eye-hand coordination. Therefore, fine motor skills required the hands to react accurately referring to the information received from the eyesight. The skills have been learned, practice since infancy. [18]

However, this set of skills can be compromised after stroke as certain parts of the brain are damaged. [1] Occasions such as injuries at joints and brain damage from stroke will affect the abilities in controlling coordinated body movements with hands, fingers, and even face muscles.

A patient who experiences a stroke suffer from limitations in strength, range of motion, and fine motor control. These deficits dramatically limit their ability in performing their daily tasks such as, keyboard typing, writing, and even bathing. A sudden significant decrease in hand dexterity will greatly affect the routine and career of the patient, and the frustration will cause negative impacts to the rehabilitation progress such as demotivation. [19] With the proper care and therapies, fine motor skills can be relearned as the undamaged parts of the brain is able to adapt with certain exercises and games. [2]

These recommendations enable the patients to exercise the muscles in the fingers, as well as motivate the patients to be proactive in the rehabilitation process, for the purpose of stimulating the brain to adapt to the damage done for stroke. [3]

2.2 BIOMETRIC MODEL AND DEGREE OF FREEDOM IN HUMAN HANDS

2.2.1 BIOMETRIC MODEL

Understanding of the kinetic complexity is necessary in speeding up the computation in real time applications. The deeper understanding in the limitation of the human hand biometric model is important in assuring the desired output of the system. Figure 1 shows the joints in human hand skeletons. All the joints are attached to tendons and muscles of the hand to move by contracting and relaxing of specific muscles. [14]

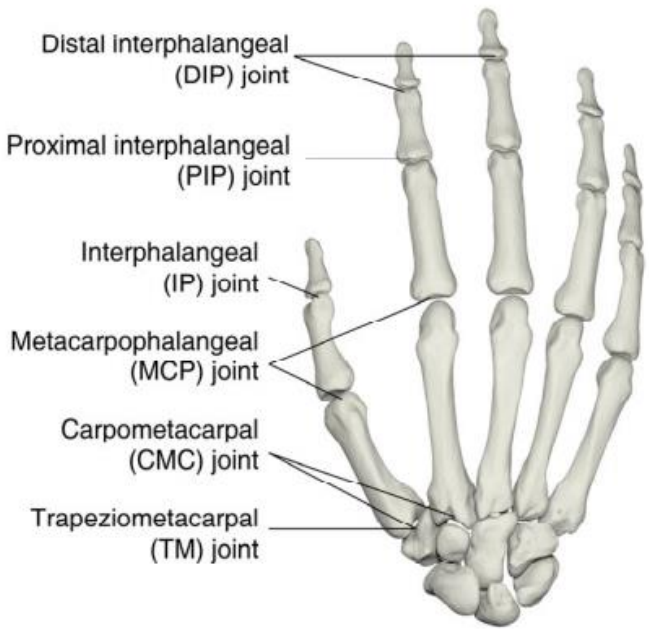
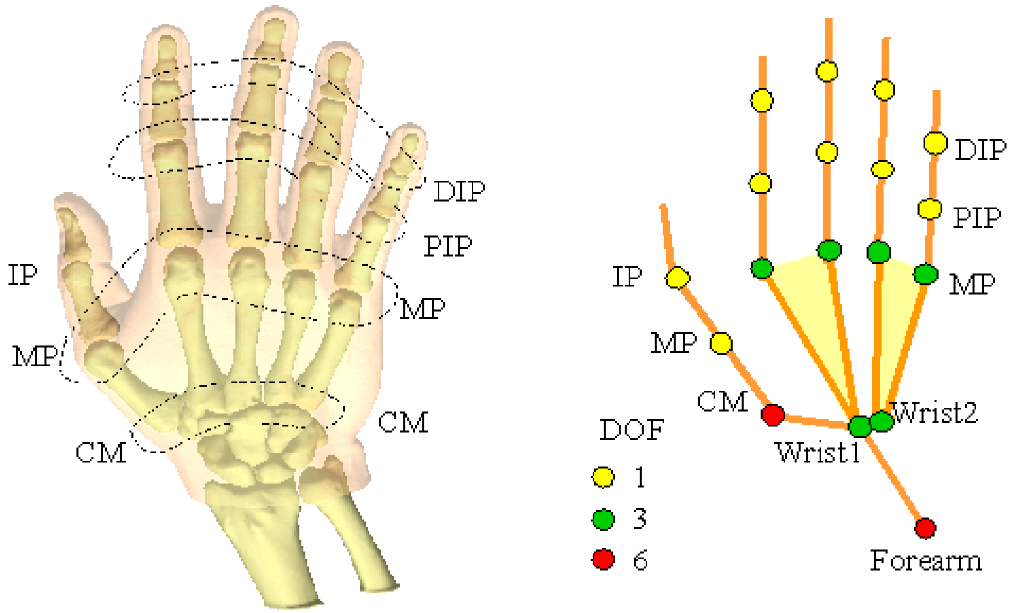


Figure 1 Joints of the right hand

2.2.2 DEGREE OF FREEDOM

A human hand movements are bounded by the limitation referred as the degree of freedom (DOF) in every joint of the human hand skeletons. In terms of the hand kinematical model, there are 27 degrees of freedom in one hand. There is total 21 degrees of freedom for fingers, and the rest is from a translation (3 DOF) and rotation (3 DOF) of palm. [15] The detailed distribution of degrees of freedom is illustrated in figure 2.



Proximal interphalangeal (PIP)

Distal interphalangeal (DIP)

Metacarpophalangeal (MCP)

Figure 2 Degree of freedom in the joints in human hand

Out of these degrees of freedom, the Leap Motion SDK is able to provide only 3 DOF from wrist rotations. However, it is sufficient in the computing of this project. As shown in Figure 3 and Figure 4, the anatomical model of hand can be built based on the leap motion sensor data inputs. [12]

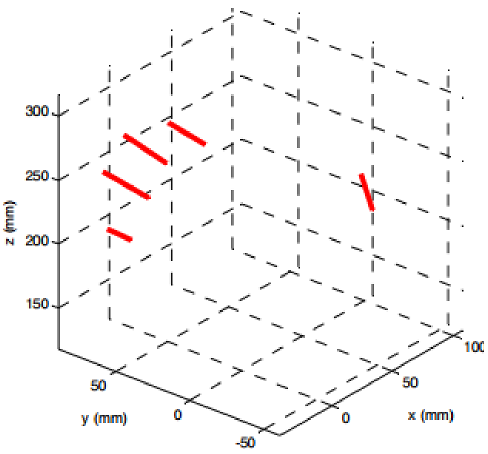


Figure 3 Fingertip position and direction from leap motion SDK.

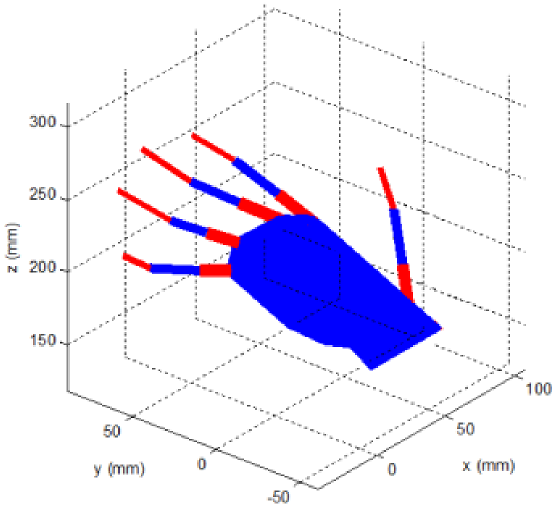


Figure 4 Full hand skeleton model built from leap motion data using inverse kinematics.

2.3 STEPS INVOLVED IN FINE MOTOR SKILLS REHABILITATION

Fine motor activities involve any movement that requires strength, coordination, and precise movements of human hand muscles. As it is essential in the daily routine function, compromised fine motor skills could cause significant negative impacts to the patients. [4]

There are a series of general steps in the rehabilitation of fine motor skills: [5]

1) Strengthen fine motor muscles.

   The first step will be increasing the strength of the muscles of the wrists and fingers. As the patients usually use the unaffected hand as the dominant hand, the affected hand could lose the level of strength before the stroke. Some examples of the activities to improve the strength of the affected hand:

   - Shape clay using the affected hand can be a good way in strengthening fine motor skills muscles, and improve fine motor coordination.
   - Squeezing elastic round objects such as a tennis ball until the limit of the strength to gradually improve fine motor strength.
   - Make a fist as tightly as possible, and hold the fist as long as possible.

2) Coordinate eyes and hand movements.

   One of the important criteria in fine motor skills requires the ability of the patient to interpret the visual perceptions to corresponding physical movements, such as judgments in distance of an object and commanding of body parts to move in directions as we want it to. Examples of activities to improve the coordinate eyes and hand movements:
   - Draw shapes in the air using fingers.
   - Trace lines in pictures, shapes, and letters in dotted lines.

3) Improve fine motor muscle coordination.

   It is possible to improve the ability of fine motor muscles to work more efficiently together for a single task through practicing:

   - Cutting papers according to marked lines into shapes with a pair of scissors.
   - Writing or drawing with various types of utensils.
   - Practice tying shoe laces, strings into knots and bows.
   - Manipulating small objects such as button and unbutton clothing, pull zippers, play video game with joysticks or keyboard.

4) Increase finger dexterity.

   Fine motor activities also require the fingers to function separately, and fingers working together by performing different sets of muscle movements. The dexterity of fingers can be improved by:
   - Typing.
   - Playing piano.

2.4 SERIOUS GAME

Serious games are designed with a priority that is beyond mere entertainment. In this case, the serious game is involving the rehabilitation of fine motor skills of stroke patients. The concern of design in serious game will be providing an interesting platform to assist the stroke patients through the practices that is full of repetition in certain sets of movement. More than that, the game design should encourage the patients in terms of handling the failure in a positive way, as rehabilitation players are more likely to commit in the rehabilitation if they feel that the failure in the game in the game stems from their physical disabilities. [4] Research has shown that applying computer-based motor therapy using the combination of functional training and serious games was more effective than using functional training only, in term of delivering long term benefits in the rehabilitation process. [5]

2.5 REVIEW OF EXISTING PROJECTS

2.5.1 JINTRONIX

JINTRONIX is an interactive rehabilitation program designed to help stroke patients to improve their upper-limb motor functioning. [4] The main concern of this project is to provide cost effective options for the patients in accessing the rehabilitation modules at home. Figure 5 shows the example of JINTRONIX gameplay experience.

Figure 5 Gameplay experience in JINTRONIX

Game Engine:

Microsoft Kinect for Windows software development kit (SDK)

Method:

Applying the Kinect's sensor's 3D camera to capture the movement of 48 skeletal points while performing therapy. The movement data captured by the sensor will be the input to the system to measure, and evaluate the patient's movements. The information collected during the game will be collected for the doctor assess the progress of the rehabilitation. The difficulty of the game is adjusted by the scores of the user, to give a step-by-step improving gaming experience to the users.

Features:

JINTRONIX is equipped with the following features:

- A virtual version of the classic box-and-block test (BBT) evaluates patients' coordination, gross manual dexterity, and motor skills as they (virtually) attempt to pick up blocks one-by-one and put them into a box in a set amount of time. Similar to a computer game, Stroke Recovery with Kinect displays patients' scores as soon as they finish a session, providing immediate reinforcement when scores improve from session to session.
- A separate program displays a target pose on the monitor that the patient assumes. As the target moves, the patient attempts to duplicate the target's position. The patient then receives a Fugl-Meyer Assessment score, based on his or her success.
- An outer-space game enables patients to exercise their reflex and reaction abilities as they guide a spaceship through space while attempting to avoid oncoming asteroids. Stroke Recovery with Kinect tracks the stroke patient's hand trajectory—relative to and in conjunction with the movement of the elbow and/or shoulder.
- Automated documentation helping in exporting the patient's movement data for quick and efficient record keeping to be referred from the clinical point of view.

2.5.2 MIRA rehab

MIRA is a product designed to install elements of gamification into the physical therapies for patients recovering from surgery or injury. Currently, the system is using Microsoft Kinect as the engine. Based on the research, MIRA has a distinct feature to enable clinical side to customize the game settings according to the conditions of the patients. Figure 6 shows the example of MARA rehab gameplay experience.

Figure 6 Gameplay experience in MARA rehab

Game Engine:

Microsoft Kinect for Windows software development kit (SDK)

Method:

MIRA utilizes the sensor's benefits from Microsoft Kinect and combine it with clinical treatments. Game settings customization can be done by the clinical side to ensure that the game is able to deliver an effective rehabilitative experience to the patient.

Features:

MIRA rehab is equipped with the following features:

- Built with multiple pathologies to fit the requirements for the rehabilitation in different kinds of injuries, and specific affected part of the body. The specialist physiotherapists are directly involved in the development to provide modules for rehabilitation that proven to be effective.

- The application is fully customizable, based on the pathology and other patient conditions. Which is one of the important features that ensures the game is beneficial to the patient's rehabilitation progress. Every patient with different conditions can access the game that specifically designed for their needs in rehabilitation.
- The movement data of the game progress will be stored in the database as a reference on how the patient evolves through therapy.
- Patient statistics required in research are constantly gathered by the software, and are accessible for the sake of research.
- The software is well-packaged to be easily installed by the patient at home.

2.5.3 Games control with Leap Motion Controller

The Leap Motion represents a new generation of depth sensing cameras designed for close range tracking of hands and fingers, operating with minimal latency and high spatial precision (0.01mm). Virtual reality (VR) is applied in the simulations of three well-known hand-based rehabilitation tasks: Cotton Balls, Stacking, Blocks, and the Nine Hole Peg Test use a commercial game engine and utilizing a Leap camera as the primary mode of interaction. Figure 7 shows the example of the use of Leap Motion.

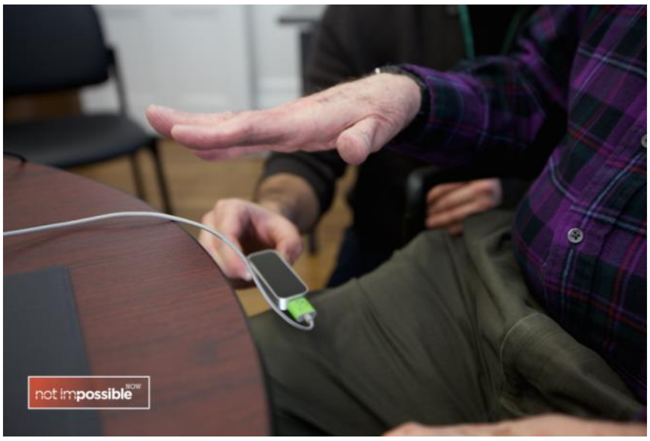


Figure 7 Gameplay experience with Leap Motion Controller.

Game Engine: