Interactive Design and Development of Real Arm Movements for Application in Rehabilitation

Rafidah Rosman¹, Muhammad Zaidan Abdul Hadi², and Nurulliyana Abu Bakar³

Faculty of Electrical Engineering
Universiti Teknologi MARA
40450 Shah Alam Malaysia
¹rafidah504@salam.uitm.edu.my
²zaidanhadi92@yahoo.com
³nurulliyanaabubakar@yahoo.com

Abstract - An interactive real arm movements for application in rehabilitation is designed and developed. The aim is to encourage hand paralysis patients performing their physical therapy by introducing games application in replacing conventional hand therapy module and methods. In this project, the accelerometer is used for tracking the orientation of the arm. As the arm moves, the values from x, y and z axis from the accelerometer changes and are being read by the Analog Inputs of the Arduino Board. After being read by the Analog Inputs of the Arduino Board, the 3D model moves as well. Solidworks software was used to modeled the hand in which the data is then transferred to Matlab/Simulink using SimMechanicalLink from Mathworks. Lastly, the sensor glove was programmed to work as a controller of games application in hand rehabilitation thus makes it an enjoyable therapy process.

1. Introduction

Recently, advanced technology has contributed significantly in the development of medical field. Physical rehabilitation that are gives disadvantages to hand paralysis patients that require long-term repetitive movement of hand is awaited to be performed by sensor glove to encourage hand paralysis patients enthusiastic in physical therapy instead of human helped. For example, hand rehabilitation is an important case because hand movement is one of the simplest actions in daily life. Generally, hand paralysis is treated with the assistance of a physical therapist. Physical therapist holds and repeatedly moves the paralysis’s fingers affected through the maximum range of its joint angle, as shown in Fig.1. In this case, it takes a few months to improve the range of joint angle to recovery through which finger can move because of uncontrollable muscle tightness and stiffness which make difficulty in movement of finger. Thus, in general, hand rehabilitation is expensive and time consuming. Furthermore, the unavailability of physical therapist underscores the requirement for engineering solutions for physical rehabilitation. Therefore, we aim to develop a hand rehabilitation application that can encourage hand paralysis patients enthusiastic in physical therapy that can act as a substitute for traditional physical therapy.

The new invention of computer technology is developing in the human environment. The ubiquitous
systems are more common and controlling in computing that made to appear anytime and everywhere. The technology of graphical user interfaces (GUI) has changed to gesture interface, capturing the motion of the hands and controlling the devices in more natural and practical. Hand gesture may include multi-touch screen interface, surface computing, camera in gesture recognition and also in gaming industries [1]. Gesture recognition is general to Virtual Augmented Reality (VAR) as the main input system and now become popular just in films like Iron Man and Minority Report [2].

Human Machine Interaction is keeps moving more closely towards the interaction between people and computers from time to time. Human have a good clench and controlling ability with their hands and thereby interfaces like keyboard and mouse are more popular in nowadays. The gesture accordance with sensor glove is been used in sign language operating and training [3], but nowadays it is also used in robotics field to control robot’s arms just wearing a glove [4]. Nowadays, the development of the new technology in interfacing the devices with the computer such as Nintendo Wii, the Apple iPhone and the iPad, SixthSense device developed at MIT Media Lab and the Kinect system for the Xbox [5] in the movement of the system using the devices that act as controller.

In this project, we mainly focus on the real-time input and output of the data from the sensor glove and successfully and accurately grasping the actions. Sensor glove is an electronic device equipped with accelerometer sensor and linear slide potentiometer that senses the movements of hand and finger’s individually, and passes those movements to computer in analog signal continuously. Thus, nowadays sensor gloves are used in many research fields including virtual reality, gaming [1], robotics [4], character recognition and verification [6].

![Figure 1. Rehabilitation Therapy](image)

2. Methodology
The development of this project includes the buildings of the devices which include 3-axis accelerometer, linear slide potentiometers, HC-05 Bluetooth module and Arduino Mega 2560 that applied on a Sensor Glove development. In addition, this topic also covered on how the experimental testing was conducted using MATLAB and Simulink, Solidworks and Arduino (Mega 2560) software. The flow chart below (Fig. 2) shows how it works in the process of the system application.
2.1 Building the Device

As shown in Fig. 3, the linear slide potentiometers are used for tracking the position of each finger. Furthermore, the accelerometer is used for tracking the orientation of the arm. As the arm moves, the values from the x, y and z axis from the accelerometer changes and are being read in the Analog Inputs of the Arduino Board. After being read by the Analog Inputs of the Arduino Board, the 3D model moves as well and application for gaming is functionality (Fig. 4). From Fig. 5, the block diagram of ADXL335 Accelerometer is taken from the datasheet. The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis. Lastly, the circuit schematic of the sensor glove was constructed as shown in Fig. 6.
2.2 The Matlab/Simulink Model

Before building the Simulink model, the Arduino IO Package is installed which included the Simulink library for communication with the Arduino board. Furthermore, by using Arduino IDE, the Arduino board will be uploaded the code that comes with the package to enable the Simulink library. The Simulink model was created and it was organized into six subsystems in each of the block as illustrated in Fig. 7.
• Arduino analog inputs block for the values from the accelerometer and the potentiometers sensor.
• Correction block which the values from Arduino analog inputs.
• PID control block for getting smoother movements.
• Driving block for the joints of the 3D model.
• The 3D Model that is automatically generated using the SimMechanicsLink.
• Sensor block for tracking the position of the arm in 3D model.

Based on the Fig. 7, the Simulink model will be organized into six subsystems.

i. Arduino analog inputs block for the values from the accelerometer and the potentiometers sensor
ii. Correction block which the values from Arduino analog inputs
iii. PID control block for getting smoother movements
iv. Driving block for the joints of the 3D model
v. The 3D Model that is automatically generated using the SimMechanicsLink
vi. Sensor block for tracking the position of the arm in 3D model

2.3 The 3D Model
The 3D Model as illustrated in Fig.8 is a representation of a human arm. The 3D Model was designed using Solidworks and then transferred it into Matlab/Simulink using the SimMechanicsLink from Mathworks as illustrated in Fig. 15. The purpose of transferring it to the Simulink is it will automatically generate an equivalent multibody model in the Simulink.

![Figure 8. The 3D Model Design using Solidworks](image)

3. Results and Discussion
This topic covered on the result obtained from the project analysis. All the results were displayed and illustrated in the figure respectively. A part of hardware assembly is shown in Fig.9

![Figure 9. Hardware assembly of the Sensor Glove](image)

The linear slide potentiometers are used for tracking the position of the fingers. After that, it will be attached to a spring (Fig. 18) to each of the potentiometer. The spring holds the potentiometer slider at
a certain position and as the fingers move the slider is being pulled and the resistance of the potentiometer is changed.

![Image of a potentiometer with a spring](image_url)

Figure 10. Linear Slide Potentiometer attached with a spring

The accelerometer on the other hand is used for tracking the orientation of the arm. As the arm moves, the values from the x, y and z axis from the accelerometer change and are being read by the Analog Inputs of the Arduino Board. After being read by the Analog Inputs of the Arduino Board, the 3D model moves as well.

![Graph of Bending Angle Vs Resistance Measured at Index Finger](image_url)

Fig. 11. Graph of Bending Angle Vs Resistance Measured at Index Finger

Based on Fig.11, the analysis had been made at index finger to measure the resistance of linear slide potentiometer based on the angles of the finger actuated. As a result, the resistance will be increase if the angles of the finger actuated increase.

For the monitoring of the 3D model in the Simulink, when the simulation is running the 3D model will automatically appear in the Simulink as shown in Fig. 12. As the result, the 3D model will move as same with the hand of user that is wear the sensor glove.

![3D Model in Simulink](image_url)

Fig. 12. The View of the 3D Model After Run the Simulation in the Simulink

For the application of Arduino game controller, firstly that it will working when the sensors of the glove capture the movements of the arm. After that, the captured values are sent into the Arduino board of analog inputs. Then, from the Arduino they are sent to the Processing IDE via Serial Communication.
Lastly, from the Processing IDE they are sent to the video game. For applications in video games, analysis has been made through the easy to difficult levels based on the bending of each finger, the finger movement frequency and speed of movement of the each finger in the application of video games. The example for the easy level of the video game that are used in the application which is Super Mario gaming as illustrated in Fig. 13. In this Super Mario gaming, each of the fingers is setting to switch the keyboard key. In this application is used up, down, left and right arrow key are switched into each of the fingers according to the fingers move the slider is being pulled and the resistance of the potentiometer is changed. Besides that, the sensor glove also are working in Need for Speed gaming that is used accelerometer which is to moves the hand to control to turn left and to turn right as shown in Fig. 14 that will give more difficulty to the user.

![Fig. 13. Arduino Game Controller work in Super Mario Gaming](image)

![Fig. 14. Arduino Game Controller work in Need for Speed Gaming](image)

In addition, this project has been analysed to the respondent who like to play video games and do not like playing video games. Based on the analysis made, the sensor glove is act more easily to the respondent who likes to play video games because too common for them to accept and learn new video game controller compared to the respondent who do not like playing video game. However, the respondent did not like playing video games require a short process only to learn control of sensor gloves in a video game if the frequency of use many times.

4. Conclusion

This project has found that generally hand exercises are beneficial in improving strength and dexterity regardless of whether the stroke patient is just beginning to get hand movement or already has good hand range of motion. In addition, there are exercises that can help improve hand functionality that have deteriorated after a stroke. Therefore, the purpose of the current study was to develop a device that enable real arm interaction movements with 3D computer models and for hand rehabilitation monitor and controlling purposely to serve the elderly and the handicapped. Hence, the sensor glove had been able to monitor and controlling to serve the elderly and the handicapped.
Furthermore, the purpose of creating this project is to rehabilitate patients who have problems with the movement of the fingers and hands more enjoyable through the application in the computer games without the need from human aid. In this case, the project has been successful in providing better patient satisfaction and eager to regain their fingers and hands. Besides that, the sensor glove had been able to recognize hand gestures accurately and successfully. Thus, all engineering solutions provide opportunities for hand paralyzing patients to perform their physical therapy.

Last but not least, as the features recommendation the hardware of sensor glove will be made in smaller structure because to give the users feels lighter, comfortable and compatible while wearing the sensor glove. In this case, in future the sensor glove will be upgrade with exchange the linear slide potentiometer to flex sensor that will give more effectiveness and accuracy.

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