Development of a Wrist Rehabilitation Device with Android-based Game Application

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Abstract. Traditional methods of rehabilitation that lacking excitement can contribute to demotivate patients in completing rehabilitation. Thus, interactive and interesting rehabilitation methods are essential to ensure stroke patients continue rehabilitation activity. This project proposes a wireless home based wrist rehabilitation device with an android-based game application (app). The patients will be able to do wrist therapy at home or anywhere with the rehabilitation device. The device is consists of an accelerometer that can measure acceleration in three dimensional space. It is developed in free wrist movement such as roll, pitch and yaw. The accelerometer data is processed by an Arduino Micro, and converted into mouse cursor movement that can be used in an android-based game app for rehabilitation. The game app called “BallGame” is being developed using the MIT App Inventor software. In this work, the hardware development of the rehabilitation device is presented. Furthermore, early development stages of the game app is described where the data from the rehabilitation device is successfully transmitted to the app via Bluetooth communication.

1. Introduction

Physical therapy for the wrist is very significant as the hand is used to perform many functions on a daily basis. Current physical therapy focuses on ensuring that your wrist not only moves but also redeems all the strength it lost during the injured. However, the process of rehabilitation may occur over longer periods of time that vary from two to eleven weeks [1-2]. This is often as a result of patients are unable to absolutely recover from their injury. As a result, they need to visit and create appointments to use rehabilitation devices in rehabilitation centers which can be costly and time consuming.

Wrist rehabilitation takes a long process that requires patience and motivation of the patient and relatives. Patients will require lengthy duration of time to do rehabilitation or treatment in hospitals. Furthermore, literature review shows that the treatment is very complex and expensive due to the utilization of various types of sensors [2-4]. The period of recovery can be reduced if the patient can stay consistently motivated in performing rehabilitation. Therefore, by using home-based rehabilitation device, the patient can do wrist therapy at home or anywhere with reduced cost. There are several researchers that have been developing rehabilitation devices that connect to private
personal computer for home rehabilitation [5-6]. However, although the obtained results are precise, the usage of personal computer at home is not efficient. Therefore, a portable and low-cost wrist rehabilitation devices are necessary to provide maximum level of recovery at home for the patients.

We have been developing a wrist rehabilitation device that motivates patient to stay consistent [7-8]. In this project, an android-based games application is developed to help patient to use the portable wrist rehabilitation device easily without the needs to go to the hospital. The goal is to make them to do rehabilitation therapy consistently anywhere. The game is developed using MIT App Inventor software. Patient can use the rehabilitation device to play android-based game on smartphone wherever we have a tendency to hope that it will support and facilitate patient to try and do wrist rehabilitation systematically and fun.

2. Methodology

2.1. Project Overview

Figure 1 shows the propose system that consists of a portable wrist rehabilitation device with android-based game app. First, patient is required to use the portable wrist rehabilitation device. Then, the data from IMU sensors installed in the device will be sent to Arduino microcontroller for process. The processed data is transmitted to an android-based smartphone app that is developed MIT App Inventor 2 software. The android game will help patient to train flexion-extension and pronation-supination wrist movements.

![Figure 1. The development portable wrist rehabilitation device with android-based games.](image)

2.2. Prototype Development of Wrist Rehabilitation Device

In this subsection, the hardware details about the design of the rehabilitation device is described. Basically, the wrist rehabilitation device is based on the prototype developed in [1-2]. Figure 2 shows the developed wrist rehabilitation device. As shown in the figure, the device is consists of a 3D printed dome-shaped handle that permits flexion-extension and pronation-supination wrist movements. The device is also consists of 3D printed arm supporter located on top of a portable two-tier platform. The circuitry of the device is located in the first tier. Inside the dome-shaped handle is an MPU6050 inertial measurement unit (IMU) sensor to sense wrist motions. In this work, only the 3-axis accelerometer of the IMU is used. Figure 3 shows the location of the IMU inside the dome-shaped handle. The IMU is connected to an Arduino Micro microcontroller board. Arduino Micro is used compared to the Arduino Leonardo microcontroller that was used in the previous works. It is chosen so that a compact and portable device can be produced in the future. It is also smaller in size and cheaper compared to Arduino Leonardo. The Arduino Micro pins that are connected to the IMU are the VCC, GND, SCL and SDA pins. The VCC pin is connected to the 5V pin of Arduino. The GND
pin is connected to GND Arduino pin. Then, SDA pin is connected to the digital two pin (D2) of Arduino and SCL pin is connected to digital three pin (D3). The data from accelerometer inside the IMU are transmitted to Arduino Micro for processing, then it is transmitted to a smartphone app via Bluetooth communication. The Arduino Micro is connected to a HC-06 Bluetooth module as shown in Figure 3.

![Figure 2. The developed wrist rehabilitation device.](image)

![Figure 3. Inside the dome shaped handle.](image)

![Figure 4. Arduino Micro connected with Bluetooth module](image)

### 2.3. Development of Game App using MIT App Inventor
In this work, an Android-based game app is developed for the proposed wrist rehabilitation device. The idea is to develop a game app called “BallGame”. In our previous work, we have developed a desktop computer version of the “BallGame” game app using Unity software [8]. Since it is difficult and costly to use computers for rehabilitation at home, a mobile version of the app was developed for Android smartphone. However, we had several difficulties during the development of the app using Unity. We found that the developed app was unable to be added with Bluetooth function which is only available using the API 10. Therefore, we could not transmit accelerometer sensor’s data to the app via Bluetooth communication. Thus, MIT App Inventor is selected for developing the app.

### 3. Overview of the Developed Apps and Experimental Results

#### 3.1. The Developed App
In this subsection, the preliminary design of the developed app is described and the method to use the app is explained. Prior to use the app, the developed wrist rehabilitation device described in the
previous section must be connected to the smartphone app via Bluetooth communication. Figure 5 shows various screen capture images of the developed app.

Figure 5. Various screen capture images of the developed app.

Figure 5(a) shows the icon of the developed game app called “BallGame” which is installed in an Android smartphone. After turning on the wrist rehabilitation device as shown in Figure 2, the user can push the “BallGame” app icon to start connecting the device with the app. Figure 5(b) shows the screen capture of the smartphone screen once the app icon is pressed. As shown in the figure, the
moving object represents a ball that can move around based on the data of x-axis and y-axis received from the accelerometer. The data of x- and y-axes are shown on the top left of the app. The app records any movement made by the user, so that the collected data can be used for analysis in the future. The button “BT Selection” is to select the available Bluetooth devices. The button “Go to Data x” and “Go to Data y” are the buttons that direct the user to the next screen either to display x-axis data or y-axis data that are shown through plotted graphs of the acquired accelerometer sensor’s data.

Figure 5(c) shows the app display when a user pressed the “BT Selection” button. The button is used to list out all available Bluetooth devices. When the button is pressed, the app displays the list of Bluetooth devices as shown in Figure 5(c). The figure shows that the available Bluetooth connection is only an HC-06 device which is originated from the HC-06 module that is connected to Arduino Micro. Therefore, the user needs to select HC-06 from the list to establish Bluetooth communication between the apps and the rehabilitation device.

Figure 5(d) shows the app screen when it is connected to the HC-06 Bluetooth module. The x- and y-data of the accelerometer sensor are displayed on the top left of the screen. The displayed data are acquired in real-time which is similar with the movement of the accelerometer.

Figures 6(a) and (b) shows the app screen when the user pressed “Go to Data x” and “Go to Data y” buttons respectively. These figures show are used to display x- and y-axis data on plotted graphs. On both figures, “Go to screen1” button is for returning back to the main screen. Furthermore, “Text for ListPicker1” button is used to find available Bluetooth communication if sudden disconnection of Bluetooth communication occurs. When Bluetooth communication is established, the data will be displayed at the bottom of screen. Preliminary experimental results to show the results of data transmission from the rehabilitation device to the developed app are described in the next subsection.

![App screen to show x-axis data.](image1)

![App screen to show x-axis data.](image2)

**Figure 6.** App screen to show x- and y-axis data via plotted graphs.

3.2. Preliminary Experimental Results

In this subsection, the preliminary experimental results to show the usefulness of the developed game app is described. Prior to use the app, a user was asked to turn on the wrist rehabilitation device described in the previous section. Then, the user was asked to follow the steps on using the developed game app described in subsection 3.1. Once Bluetooth communication is established, the user was asked to implement three (3) preliminary experiments using the wrist rehabilitation device and the developed game app: (1) static condition experiment, (2) roll motion experiment and, (3) pitch motion experiment.
Figures 7(a) and (b) show the acceleration on x- and y-axis plotted graphs when there are no movement from the rehabilitation device, meaning that the accelerometer sensor is in static condition. Actually, the raw data values are between 3 and 4 for x-axis data, meanwhile for y-axis data are between 2 and 3, indicating that there is no movement of the accelerometer.

Figure 7. App screen to show x- and y-axis data via plotted graphs.

Figure 8(a) shows the condition of the wrist rehabilitation device when the patient doing the repetitive pronation-supination (roll) motion. Figure 8(b) shows the real-time plotted graph based on raw data of acceleration values on x-axis received from accelerometer. The graph shows the movement of the wrist on x-axis that was processed by Arduino Micro and then, sent to the game app. The peak value in the graph shows the sudden acceleration during roll motion on x-axis. On the other hand, Figure 8(c) shows the plotted graph for repetitive roll motions based on raw data of acceleration value on y-axis. However, both plotted graphs are not showing clear roll motion to the left and right.

Figure 9(a) shows the condition of the wrist rehabilitation device when the patient doing the flexion-extension (pitch) motion. Figure 9(b) shows the real-time plotted graph based on raw data of acceleration values on x-axis received from accelerometer. The graph shows clear acceleration motion of the wrist on x-axis. The graph shows several peaks that indicate the repetitive motions of flexion-extension. On the other hand, Figure 9(c) shows the plotted graph for repetitive pitch motion based on raw data value of y-axis. Since the roll motion is along y-axis, the raw data values are lower compared to the raw data values on the x-axis. Based on these results, it shows that the accelerometer sensor’ data has been successfully transmitted to the smartphone app via Bluetooth communication. However, based on the results, the accuracy of the data acquisition from accelerometer requires further tuning for better precision. The data will be used to move the object (ball) in the developed of our future game app.

4. Conclusion
As a conclusion, an android-based game app for a wrist rehabilitation device has been developed. The game app is developed using the MIT App Inventor and has been successfully tested on a smartphone. The rehabilitation device has been established using Arduino Micro connected to an accelerometer sensor and Bluetooth HC-06 module. The Bluetooth HC-06 is used as the component to wireless the device system with game apps. The data from the accelerometer sensor effective received by the game app via wireless connection. The data will be used to plot the graph for x-axis and y-axis data on the app. From the graphs, an analysis data is making to know the condition of the patients. The data received shows the movement of the users on real-time, so based on the data, the condition of the
patients can be seen through their movements. It can be concluded that the rehabilitation device and game app can provide numerical and graphical results for further analyses. Furthermore, future modification will be done so that a functional device can be developed that can absolutely help to improve patient during therapist at home or anywhere by exercising their wrist through movement for the therapist to strengthen the movement.

Figure 8. (a) Wrist roll motion using rehabilitation device, (b) real-time plotted graph of raw data value on x-axis, (c) real-time plotted graph of raw data value on y-axis.

Figure 9. (a) Wrist pitch motion using rehabilitation device, (b) real-time plotted graph of raw data value on x-axis, (c) real-time plotted graph of raw data value on y-axis.

5. Acknowledgement
The authors would like to thank the Research Management Center (RMC), UTHM and Ministry of Higher Education for sponsoring the research under Tier 1 Research Grant (U865).
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