CSE 276/276D Final Project Report
Myo Armband Stroke Rehabilitation Games

Combining games and rehabilitation with Myo armband in order to provide physical therapy to stroke patients

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1. Executive Summary

Stroke patients are primarily assigned daily exercises that they must perform at home. However, only one-third of them can complete their tasks. One of the reasons is that people lack of motivation. We proposed that combining video games with rehabilitation could be a huge potential to increase stroke patient's motivation. We successfully extracted the IMU data from Myo-Armband and implemented useful actions to the games. In addition, we designed a new platform which integrated four individual games with different exercises recommended by the therapist. We are looking forward to designing a new interface which has more games, customized gesture controls, and classified level difficulty of exercises.

2. Introduction and Statement of Needs

A stroke is a disease that occurs when a blood vessel that carries oxygen and nutrients to the brain is either blocked by a clot or bursts. It is the number five cause of death and a leading cause of disability in the United States. Each year, over 795,000 people suffer a stroke[1]. Instead of traveling to the rehabilitation facility in hospital which is ineffective and an inconvenience, the patients are primarily assigned daily exercises that they must perform at home. However, only thirty one percent of the stroke patients perform and complete their daily rehabilitation tasks. The main reason for this is lack of motivation.[2] Therefore, our team tried to solve the motivation problem and provide a new interface which combined with games for the stroke patients. The existing video games are not customized for the stroke patients, including Wii, PS4, etc. These games are too intense for people recovering from strokes and almost impossible for many of them in the early stages of recovery to use their muscles to control the games. Therefore, we are trying to use simple games which can also increase the motivation and also provide the function of rehabilitation at the same time.

Our project mainly focused on the arm and hand exercises for the stroke patients. In order to reach the needs for the therapists and patients, we met with Dr. Juile Larsen, an occupational therapist who works with patients recovering from strokes. Dr. Larsen also mentioned that even clench, fist or move the arm around could be challenging for the stroke patients. Therefore, she recommended several exercises that we can implement in the games, including sweeping arm, wrist rotation and flexion, and finger extension.

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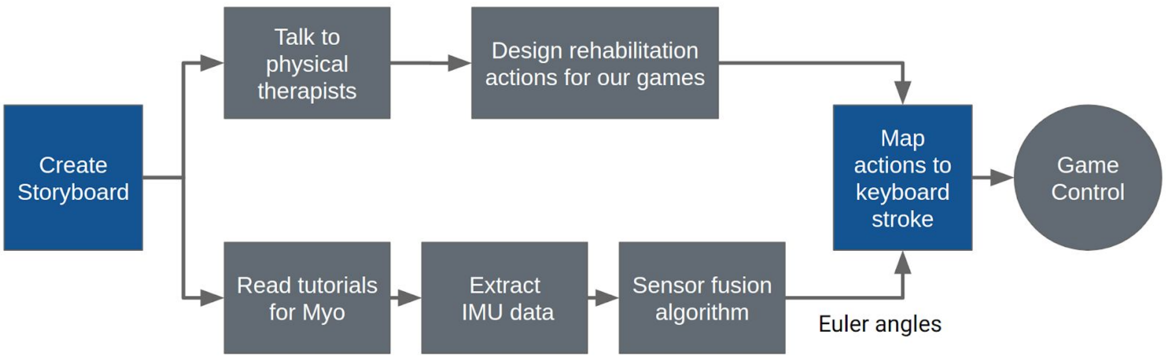
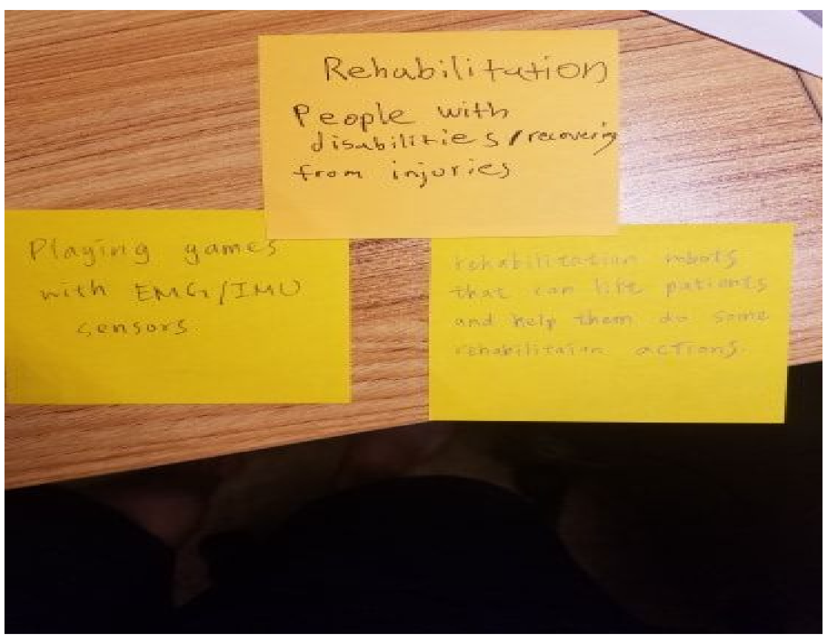
[1] "What is stroke? – National Stroke Association." https://www.stroke.org/understand-stroke/what-is-stroke/. Accessed 13 Jun. 2019.
[2] "How to Stay Motivated During Stroke Recovery | Saebo." 6 Apr. 2017, https://www.saebo.com/stay-motivated-stroke-recovery/. Accessed 13 Jun. 2019.

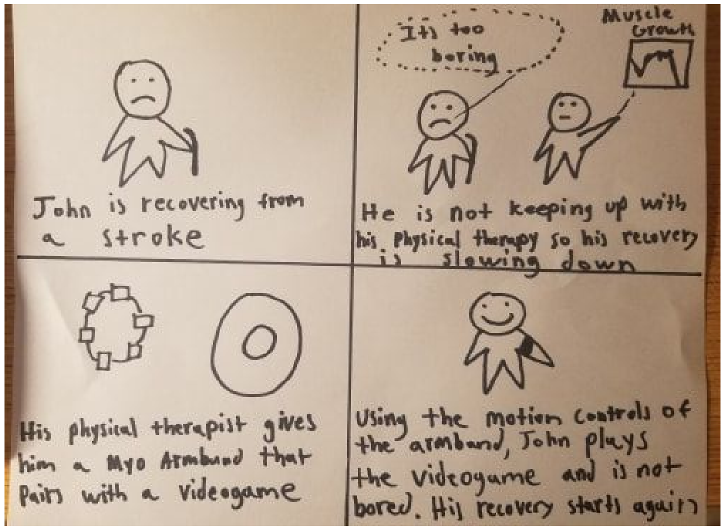
The goal of our project is to provide physical therapy for individuals who are recovering from a stroke or other serious physical injuries. By using a Myo Armband, we will extract IMU data and then use sensor fusion algorithms to map into the game controls. Stroke patients can control simple open source video games that are designed to encourage muscle redevelopment and also increase their motivation by using our interface.

3. Methodology

A. Project design process



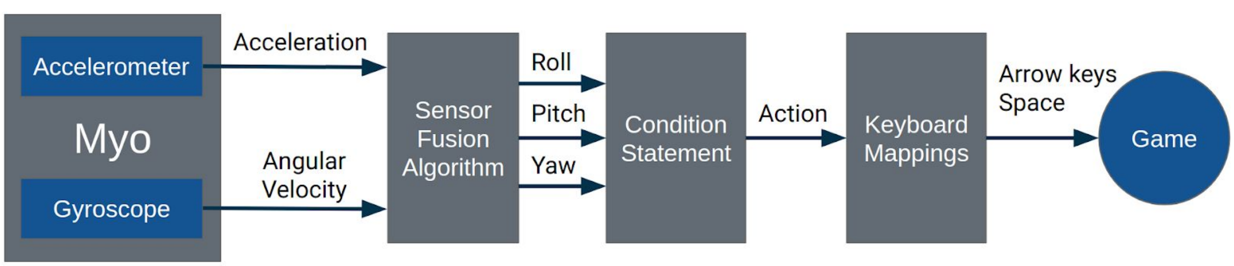




Our design process began with brainstorming ideas in a class activity. We liked the idea of helping people recover from injuries. When we learned that the Myo armband was available for use, we saw how useful the device could be in helping us achieve our goal.

We began the formal design process by creating a storyboard of what we envisioned our final product to look like. From there our design process split into two separate portions. The technical portion involved working with the Myo to extract the Euler angles of the person wearing the Myo. The other portion involved communicating with stakeholders to develop a helpful set of exercises that the Myo would be able to identify. These two processes were combined when we mapped these actions to certain keys on the keyboard.

B. High-level overview diagram



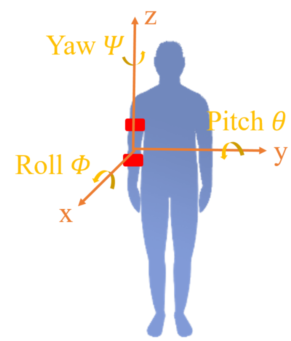
First, we extract IMU data from Myo that mounted on a forearm[3]. By sensor fusion algorithm, the data is transformed into Euler angles to represent the motion of human arms. Each defined rehabilitation motion is mapped to an action in games. Finally, we can use arm motion to control and play games. The whole process is worked with c++ programming under windows environment.

[3] "Myo Script Tutorial Roundup - Myo." 17 Dec. 2014, https://developerblog.myo.com/myo-script-tutorial-roundup/. Accessed 13 Jun. 2019.

C. Technology details

a. Setup

In order to show the arm motion of patients, we put the Myo on the forearm and get the Euler angles of it. Euler angles are composed of roll (φ), pitch (θ) and yaw (ψ) angles, which are the rotational angles about X, Y and Z axis respectively. The coordinate system and the direction of rotation angle we used are shown as the right figure. Using these angles, we are able to obtain the directions and how patients wave or twist their arms.



b. Extracting IMU data

An IMU (Inertial Measurement Unit) is a sensor that reports specific force and angular rate of the human body and it is usually a combination of accelerometers and gyroscopes[4]. There is a 9-axis IMU included in the Myo armband. In our project, we extract the raw IMU data from gyroscopes and accelerometers in Myo. The sample frequency can be up to 50Hz, which is fast enough to report and respond to the motion of human arms.

c. Sensor fusion

The raw IMU data can be further transformed into Euler angles by some sensor fusion algorithms. The extracted IMU data include accelerations and angular velocities, which can both derive Euler angles. Then, we use complementary filter to merge these two data to get the final roll, pitch and yaw angles for the forearm.

I. Euler angles derived from accelerations

The acceleration data given by Myo has three dimensions (X, Y and Z), in units of g, which represents the effect of gravitational field. The relationship between acceleration and Euler angles is illustrated in the following equations.

$$\tan\phi = \frac{A_y}{A_z}$$

$$\tan\theta = \frac{-A_x}{A_y \sin\phi + A_z \cos\phi} = \frac{-A_x}{\sqrt{A_y^2 + A_z^2}}$$

[4] "Myo | #MyoCraft: Logging IMU and Raw EMG Data." https://developerblog.myo.com/myocraft-logging-imu-and-raw-emg-data/. Accessed 13 Jun. 2019.

where φ, θ and ψ is roll, pitch and yaw angles, and Ax, Ay and Az is the acceleration about X, Y and Z axis. Now, we get roll and pitch angles from accelerometers.

II. Euler angles derived from angular velocities

The angular velocity extracted from the gyroscope in Myo also has three dimensions (X, Y and Z), in units of degree/second. To get the Euler angles, we integrate the rate of change in rotation angles with time, adding up every computed result around x, y, and z axis respectively, like the following equation shows:

$$gyroAng_{x,y,z} = gyroAng_{x,y,z} + gyroData \times \delta t$$

III. Complementary filter

We use complementary filter to combine the Euler angles derived from accelerations and angular velocities. Implementation details are shown as the followings:

$$angle = \alpha \times gyroAng + (1 - \alpha) \times accAng$$

where $\alpha = \frac{\tau}{\tau + \delta t}$

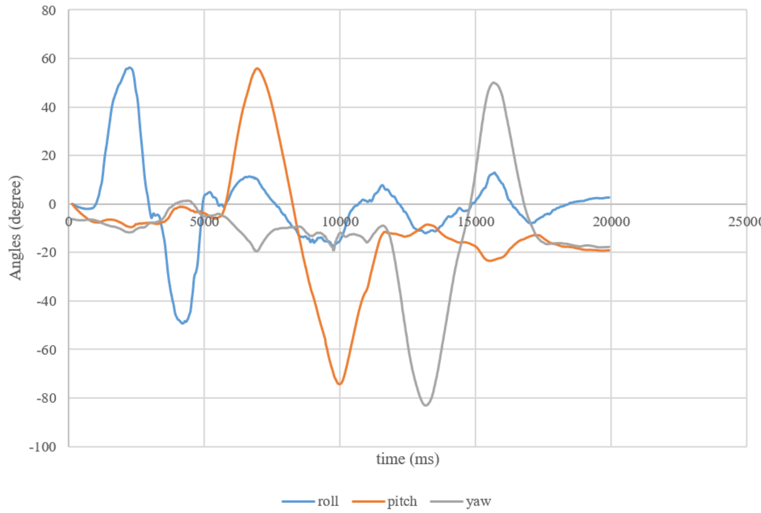
δ t: sample rate, τ: time constant, chosen 1 second

d. Keyboard mapping

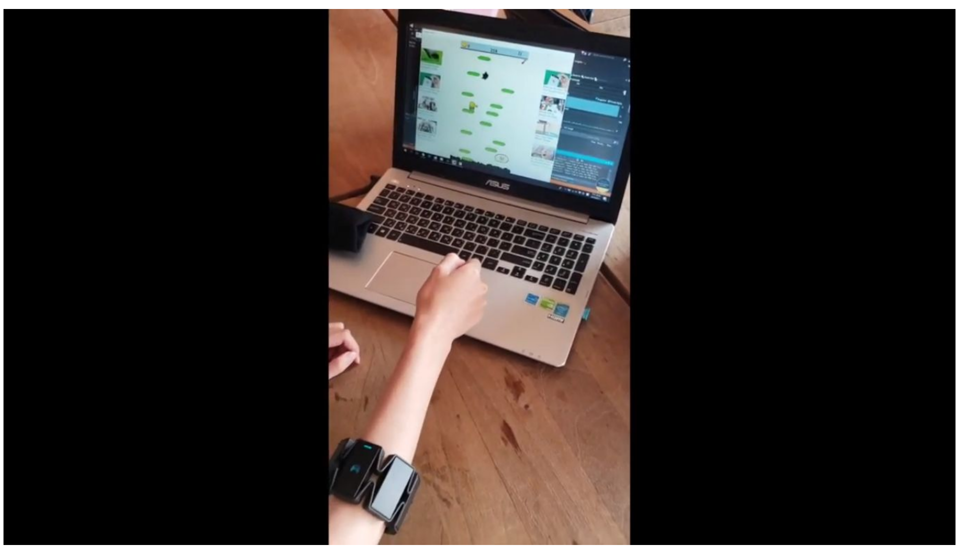
Finally, we integrated the derived Euler angles with some condition statements to detect which rehabilitation action the stroke patient is doing now. Each rehabilitation action maps to a keyboard stroke. For example, if the patient lift his arm, it maps to an up arrow key in the keyboard. There are functions in both Lua and C++ to send keyboard inputs to assigned windows. We utilize these functions and sent the corresponding keyboard inputs to the game. Now, we are able to use arm motion to play a game.

D. Usability-testing methodology

To test the usability, we should check the accuracy of the derived roll, pitch and yaw angles of the forearm. Since we can't get the exact angles of our arm, we could only do a simple experiment to check. We simply rotate the forearm clockwisely and counter-clockwisely. Then, lift the arm to the top and lower it. Last, extend the arm to the most right and then to the most left. And we examine how the Euler angles change. The figure shows that the rotation angle for each axis changes as we expect, from 0 to 90 and back to -90 degree for roll, pitch and yaw angles step by step. Despite some points that human arm can’t reach, the performance of the result is good, which shows our algorithm works.



4. Results



The results of our project were mostly successful. Our stakeholder told us that people recovering from strokes often are told to practice moving their arms in long sweeping motions. Exercises involving the wrist, such as wrist rotation or flexion are also common exercises. We also learned that only patients in the very late stages of recovery would be able to clench their fists. Luckily, all of these movements were movements that the Myo would easily recognize out of the box. However, it was hard to find games where the quality of gameplay would not suffer by switching to motion controls.

We eventually decided that 2048, Mario, and Agario would be good games to integrate with Myo because of their slower pace. We wrote a script for 2048 in which the player must extend their fingers to unlock the Myo, and then move their arm in the direction they wanted the tiles to shift. For Mario, we mapped jumping to wrist flexion and extension. We found a pre existing script for Agario that allowed the player to control their cell by moving their arm in a certain direction. We then created a simple webpage with links to the games, as well as listings of the Myo controls for each game.

The fourth game we wanted to integrate motion controls with was Doodle Jump. We wanted to use wrist rotation to control the movement of the character. However, detection of wrist rotation in Lua was not effective because there was no way to change the sampling frequency. We had to switch to a c++ library to access the data and change the frequency. This created a problem for us, because our group did not have much web development experience and we were not able to figure out a way to execute a c++ file from a website. Therefore our Doodle Jump script must be executed manually.

5. Discussion and Future Work

We believe that our Stroke Rehabilitation Games provide an easy to use and fun alternative to traditional stroke rehabilitation techniques. During our stakeholder meeting, Dr. Larsen seemed to be enthusiastic about the idea and told us she believed that it would help motivate people that However, there are some functionalities of the Myo that we would have liked to implement that we could not due to lack of time and experience. We did not use any EMG data to create any custom poses because it is so different from person to person. We would have liked to try to use Machine Learning to classify the EMG data and create more complicated motions such as recognizing finger rotation or individual finger movements.