Integrated Wearable Feedback Device for Human Walking

Haley Hoppe, Nathan Moser, Nathan Tom
College of Engineering and Engineering Technology
Northern Illinois University
Dekalb, IL
Z1827745@students.niu.edu, z1843982@students.niu.edu, z1823247@students.niu.edu

I. Introduction

The purpose of the integrated wearable feedback device for human walking is to assist people who have experienced stroke or other neurological pathologies, which have caused them to lose the ability to walk due to damage in their brain or neuromuscular system, with a feedback system based on their performance. People who have lost their ability to walk must go through the rehabilitation process to regain their ability to walk, but rehabilitation is expensive, time consuming, and does not transfer effectively to environments outside of the rehabilitation facility. To solve this issue, the device will be mobile, wearable, and low profile so the user could wear this inside the laboratory environment.

The integrated wearable feedback device for human walking is a sensor, processor, and feedback system which allows for reinforcement learning of walking gait rehabilitation patients to occur in many different environments, which will lead to better patient outcomes, as well as a more complete understanding of the learning process. The system consists of two sensors to measure the relative angle between the thigh and the shank. An Arduino microcontroller is used to record and transmit the data to a computer, and a MATLAB program computes the measured values with desired values set by the client or therapist. The system provides real-time feedback to help the user correct their gait, and to help them regain proper walking form during everyday use. The final component of the system allows the stimulus applied to be corelated to an electroencephalograph (EEG) device to read brain activity. This allows the client to study the effectiveness of different types of reinforcement learning.

To measure relative knee joint angle of the user, inertial measurement units (IMU) will be placed on the user's lower thigh and upper shank. IMUs are used because of their high accuracy output, and their low profile. The data gathered from the IMUs are sent to an Arduino Uno to process the data. At the same time, the EEG device is sent a time pulse via MATLAB program so that brain activity can be analyzed at the significant instances of when a reinforcement feedback is displayed. The Arduino Uno computes the angle between the thigh and the shank by using fused IMU data produced from the gyroscope, accelerometer, and magnetometer.

The Arduino Uno will transfer the measured and calibrated angle to a computer which creates the feedback system. The types of feedback system vary to observe the effects of different feedback strategies. The feedback system displays the set goal and current angle, or in indicator if the goal has been met, while another feedback system will reward, punish, or do both by giving the user a score based on their performance. The data from the EEG helps to conclude which feedback system is most effective for locomotor rehabilitation. The system is shown below in figure 1 as a block diagram.

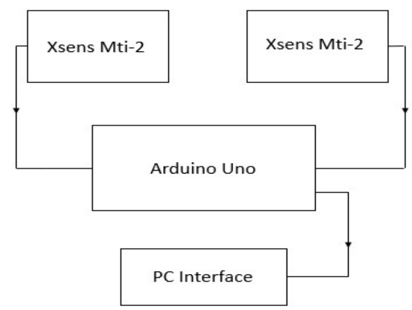

Figure 1: Block Diagram of the system

II. Sensors and onboard processing

This assembly will consist of several components integrated into a system that will provide measurements of knee movements while walking by using sensors which will be placed on the thigh and shank of the user.

The sensors chosen to measure the flex angle between the thigh and shank of the user's leg are two Xsens Mti-2 inertial measurement units. Both sensors were placed in such a manner to rotate around the X-axis. Circuits were constructed to provide power and data transmission in accordance with manufacture recommendations, and 3D printed cases enclosed the completed boards and sensors. The cases were mounted to the leg with Velcro strappings. A 5-pin wiring harness connects the two sensors and the Arduino for processing and communication. This arrangement is shown in figure 2 below.

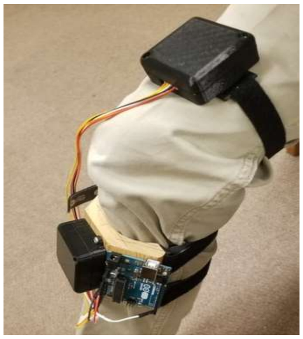

Figure 2: Location of IMU sensors and packaging.

This initial prototype connects the Arduino to a desktop PC via a wired USB connection, to allow for signal processing and feedback as well as powering the microcontroller. In later iterations of the device, an onboard battery will also be fitted to power the Arduino and sensors. This subunit comprises both sensors and a processer, and it outputs a digital signal with angular position to other components of the system.

III. Feedback Results

The sensor angle output is read into a MATLAB script to analyze the recorded gait and provide the user with feedback on their performance. The client, Dr. Hill provided several different types of feedback that were desirable for his research. This feedback is crucial to fulfilling part of the purpose of the device; to test the theory that encouraging patients to find solutions through their own self-guided inspection leads to subjects retaining the learning effect longer. By analyzing the results of the users' learning retention of the walking gait pattern with the variable being the forms of feedback provided, Dr. Hill will be able to determine the most effective form of reinforcement. Figure 3 shows the concept presented at the beginning of the semester course showing a conceptualization of what the scoring system could be represented as.

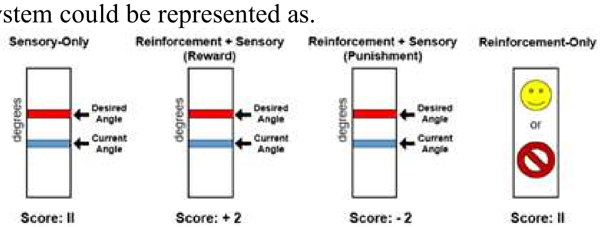

Figure 3 (Hill, 2020). Feedback Options. [1]

Several types of feedback are offered; these include both positive and negative feedback, strictly positive or negative feedback, pictorial feedback, and no score-driven feedback. Feedback would be in the form of points given or taken away, with the user's score displayed throughout the exercise. It could also take the form of positive and negative images such as a smiley face or prohibition sign. By attaching point values to actions, several methods of reinforcement learning could be studied to find the most effective method for maximum skill retainment.

After assembling the sensor system and completing the MATLAB programing, testing was undertaken to validate the methods of feedback. Sample data taken from the system is shown in figure 4 for a portion of a walking exercise.

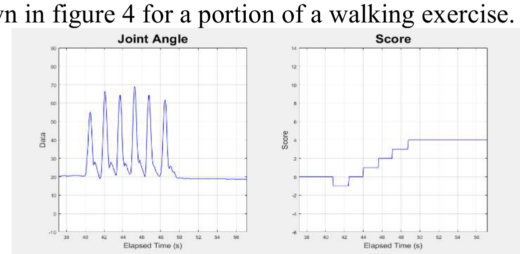

Figure 4: Example data collected displayed near delivered feedback reinforcement.

Negative scores were attributed to the user for steps that fell out of the bounds set by the exercise, and positive scores were given for joint angles in the proper range.

IV. External Integration

Finally, the device must mark the time that feedback was given to the user onto the recorded data of the EEG. By studying learning outcomes and corelating feedback delivery and EEG brain activity data, conclusions can be drawn on the rate and retention of learning for the participants. these three possibilities that exist to offer a real-time evaluation of the user's performance.

The time of score application to the user is sent to the EEG using MATLAB. The program sends a TTL pulse to a parallel port which is connected to the amplifier of the EEG. This feature will be utilized in the lab along with a 32 channel Neruoscan EEG operated in the Joan Popp Motor Behavior Laboratory. The marker signal will cause the EEG recorder to place a timestamp in the brain activity recordings, which will then be able to be examined for the effects of the applied stimulus to brain activity. The EEG analysis allows for conclusions to be made regarding how different exchanges of reinforcement feedback can improve the user's retention of the correct walking gait they are aiming to successfully attain.

Acknowledgements

Dr. Moghimi for his mentorship.
Dr. Hill for his input and positive feedback.
NIU College of Engineering for funding.

References

[1] Hill, C. *Senior Design Presentation* September 2020