Smart Robotic Arm with EMG Sensors

by

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Abstract

The number of disabled people has been dramatically increasing. Whether it is due to natural causes or accidents. A control method of prosthetics arm based on electromyography sensor (EMG) is the right choice. This sensor allows the user to measure electrical activity of muscle using their forearm to control the prosthetic hand to fulfill their needs such as pick up things. Furthermore, by training an Artificial Intelligence model it will help controlling the arm easier for the user. As the AI should be able to predict the state of the hand base on the incoming EMG signals. This prosthetics arm based on EMG sensor will surely improve the life of disabled people.

Contents

1 Introduction

Around 15% of the world's population experience some form of disability, and one of them is being handless either through congenital disability or amputation living without hand is difficult. This project is developed using prosthetic arm with electromyography sensor (EMG). The EMG sensor is easy to apply. It might offers minimal discomfort but in exchange the disabled person quality of life will be improve, allowing them to engage in many of the same activities they participate in before the loss of their hand.

1.1 Project Objectives

- For user to be able to control a robotic arm with an EMG Sensors.
- For amputees to be able to use the arm like using a normal arm.
- Training an AI to be able to predict the arm movement from incoming signal pattern from EMG Sensor.

2 Project Overview

2.1 Overall System Diagram

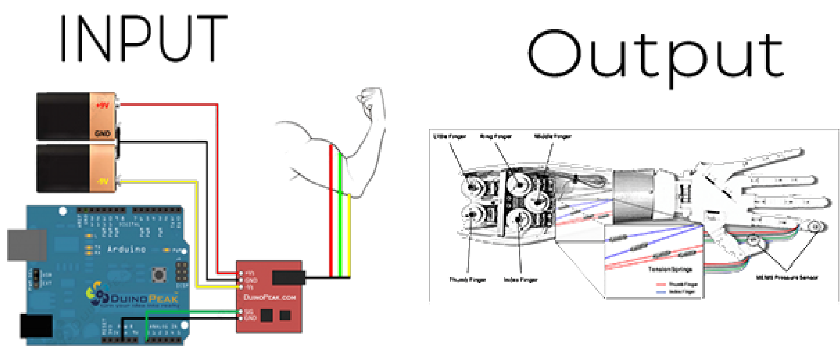

Fig. 1: Emg Sensor Connection with Microcontroller

The diagram above shows the connection of the EMG sensor with the microcontroller, the microcontroller shown in the diagram is Arduino Uno R3. However, we will be using the Raspberry Pi Pico for this for this project instead. The EMG Sensor will output will received using the analog input of the microcontroller. After this we would connect the microcontroller to control the motors of the arm to allow for movement base on the processed output.

2.2 Hardware

2.2.1 Microcontroller

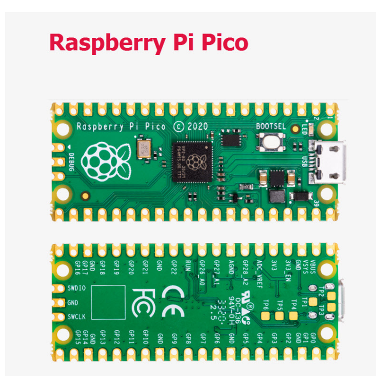

Fig. 2: Raspberry Pi Pico

The Raspberry Pi Pico is a tiny, versatile and flexible microcontroller board based on the Raspberry Pi RP2040 microcontroller chip. It features Dual-core ARM Cortex-M0+ cores run up to 133MHz; 256KB RAM;26 multifunction GPIO pins; and a broad range of interfacing options. This is paired with 2MB of onboard QSPI Flash memory for code and data storage.

We decided to use this microcontroller because of the size and the ARM Cortex processor it uses allows us to be able to use TensorFlow Lite with it.

2.2.2 EMG Sensors

Fig. 3: EMG Sensor

The EMG sensor is one of the most important components of the project. It is used to measure the muscle the activity in the arm. So that we can use the output of the EMG sensor to control the activity of the Robot Arm.

2.2.3 Servo Motors

Fig. 4: Servo

The servo motor is a rotational actuator, that can be control with high precision and efficiency. In this project, we plan on using the servo motor to control the joints of the fingers in the robotic arm, according to the prediction given by the AI. Currently, we haven't decided on the torque needed for the servo motor.

2.2.4 FSR Sensors

Fig. 5: FSR Sensors

Force Sensing Resistors (FSR) is a sensor or a resistor that allows detection of physical pressure, squeezing and weight. It is for measuring the pressure the hand is applying on an object.
Specs:

- Sensor Type : Resistive
- Output Type : Analog
- Operating Temperature : -20 to 85 Celsius
- Costs As Of 8/2022 : 260-290 THB

2.2.5 Power Supply

Fig. 6: Li-Ion Battery

Li-Ion Battery
Lithium-Ion (Li-ION) Battery which Lithium ion moves from negative to positive electrolyte, from an anode to the cathode during discharge and reverse when charging.

Lithium-Ion Battery also has many advantages over other rechargeable battery. Lithium-Ion Battery has a high energy density compare to other battery technology. They are also capable of delivering 3.6 Volts, which is 3 times higher than other batteries. Which allow them to applications which require high-power. They also have a maintenance in order to preserve its battery life.

Table 1: Li-Po VS Li-Ion battery

	Li-Po	Li-Ion
Name	Lithium-Polymer	Lithium-Ion
Voltage Range	3V to 4.2V	3v to 4.2V
Flexibly	High	Low
Costs	Slightly Expensive	Low
Capacity	2 times higher if at same volume	Relatively Lower

2.2.6 3D Printed Prosthetic Arm

As of now we are planning on 3d printing parts of the Arm and assembling them together. We have also look at robotic hands for sale that we will have to assemble and buy motors separately and the programming will still be done by us.

2.3 Software

2.3.1 Arduino IDE

Arduino IDE is an Integrated Development Environment that is use for uploading programs and communication to Arduino Boards or other supported microcontrollers and microprocessors. For this project we plan on using the Arduino IDE's serial plotter to visualize the output pattern from the EMG Sensor. Before using TensorFlow to train the data.

2.3.2 Visual Studio Code

Visual Studio Code is code editor that can do debugging, task running, and version control. Visual Studio Code also allows you to add extensions to help you with your coding experience.

We plan on using Visual Studio Code to do the programming for the project, with Pico SDK and the TensorFlow lite API for C++.

2.3.3 Pico SDK

The Pico SDK or Raspberry Pi Pico SDK allows developers to write programs to the Raspberry Pi Pico using C, C++, or Assembly Language. By providing headers, libraries, and build system necessary for it. We plan on using the Pico SDK in this project because the official TensorFlow lite library does not support the Raspberry Pi Pico board in Arduino. Hence, we have to use C++ in order to use TensorFlow lite with it.

2.3.4 Tensorflow Lite (TinyML)

TensorFlow Lite also called TinyML is a AI Framework designed for microcontrollers or devices with minimal memory. It is written in C++ and requires a 32-bit platform.

With TensorFlow Lite we can use it to train the input from the EMG Sensors and predict the action of the arm making the control of the robotic arm easier.

3 Activities and Progress

3.1 Issues and Challenges

3.1.1 TensorFlow Compatibility Issues

The Raspberry Pi Pico the necessary specs to run the TensorFlow Lite. However, there is no official library for running TensorFlow Lite. The model can be train using TensorFlow in PC and convert to TensorFlow Lite for the microcontrollers later.

3.1.2 Understanding TensorFlow

TensorFlow or Artificial Intelligence in general is a field that we have learnt before but have never really tried to train an AI and deploy it. So it will be a bit challenging for us to understand and try to implement at first. We have to start learning about TensorFlow a bit early because of this.

3.1.3 Programming Raspberry Pi Pico

Raspberry Pi Pico is a newly released microcontrollers by Raspberry Pi since 2021. It is a powerful board but still does not have that many supported libraries that can be use in the Arduino. Thus we have to use C++ in order to program it with the help of Pico-SDK.

3.1.4 Costs of 3D Printing

Currently we are planning on 3D printing the Robotic Arm, however we haven't design it or haven't found any model we can use to estimate the cost yet so we aren't sure of the price. From questing our friends using PCBway website, it can get a bit pricy if there are lots of part and uses strong material.

3.2 Activity and Progress

3.2.1 Progress

The current stage of our project is currently about learning AI and how to use TensorFlow to train and deploy the model. As well as doing initial testing of compatibility between TensorFlow and the microcontrollers (Raspberry Pi Pico), and installing other requirements needed to program the Raspberry Pi Pico using C++. Furthermore, as of 09/09/2022 we have just received the EMG sensor to measure the muscle activity of the arm. We are currently testing out the sensor and seeing the pattern generated by the output of the sensor for example, the pattern given when clenching our fist or relaxing our hand.

3.2.2 Plan

After our initial setup of the project, our first plan is the collection of our training data using the EMG sensor to collect signals responding to each hand movement. After that is the training of our data to be able to predict what movement, the hand is going to do or is current doing by recognizing the incoming signal from the EMG sensor. The next step is deploying the model to and testing the prediction accuracy of the AI using the console. And the final step is to finally connect it to a servo motor that will control the hand movement and do the programming for the microcontroller. The plan may change in the future depending on the problems or simpler ways or solution is discovered.

3.3 Flowchart

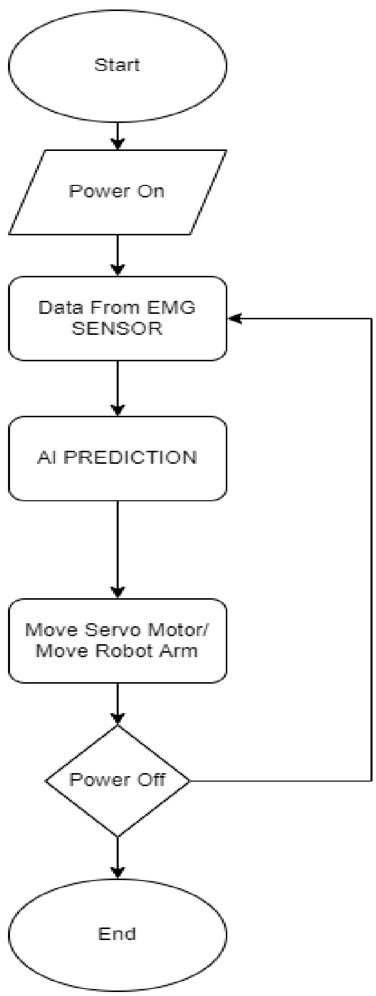

Fig. 7: Flowchart

3.4 Sensor Values

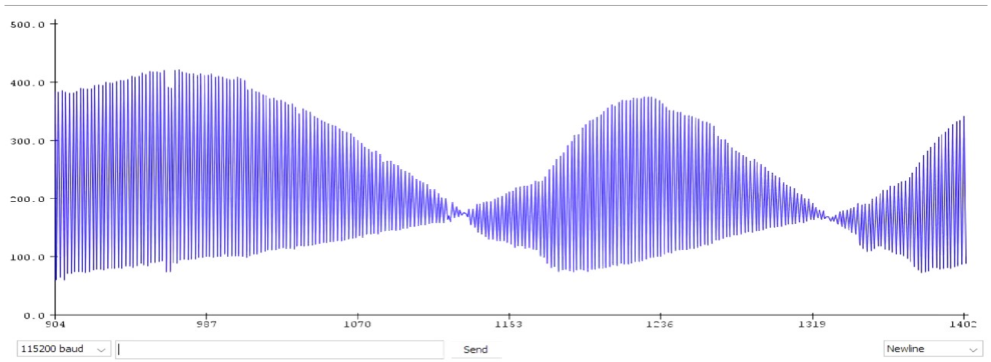

Fig. 8: Output of EMG Sensor

The image Fig. 8 shows the output signal given by the EMG Sensor; In this image we tried clenching our fist and relaxing it, but the given output does not seeems to be correct. This might be due to unsecure wire connection. Or the Sensor placement is not in a place that gives us the best possible results.

4 Conclusion

The smart robot arm project based on the EMG sensor is a project that can help improve the lives of disabled person or amputees. As it allows them to be able to control their arm or missing parts again. This can also be implemented to other projects such as a remote surgery robot that require precise hand movement, or in industrial environment when testing chemicals with out going near it. Currently the project is at its early stages and minor changes may occur in the future.

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