ECE 445 Project Proposal

Spring 2019

"Learning and Labor"

FOAM PRESSURE-SENSOR BASED CONTROL METHOD FOR CONTROLLING PROSTHETIC HANDS

TEAM 19

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Table of Contents

1. Introduction

a. Objective

Nowadays, prosthetic hands are commonly controlled by Electromyographic (EMG) method which evaluates the electrical activity produced by skeletal muscles. However, the traditional EMG method is not accurate enough, because the measurements of the electrical signal suffer from high level noises come from the users' skin. In addition, due to the physical layout and high cost of EMG sensors, the number of sensors is insufficient to acquire enough data to track the muscle movements precisely.

In this senior design project, our goal is to develop a foam pressure-sensor based method cooperating with the PSYONIC Inc. as an alternative of the EMG method for controlling prosthetic hands, which includes a design of PCB to carry the electrodes array with its corresponding communication peripherals and programing of the communication protocol. The pressure sensor method is more accurate, less noisy and cheaper, and preliminary research[1] shows promising result regarding this pressure-sensing method.

b. Background

The paper mentioned will be the instructions to our methodology throughout the project. It first explains the setup of the whole experiment: A tactile bracelet composed of 10 sensor boards was deployed around the subject's residual limb or the forearm in the case of able-bodied subjects to collect the pressure distributions when a visual stimulus is given to the participants and they should follow the actions indicated. Second, the pressure patterns received from the tactile bracelet will then be passed thorough Neural Networks to classify for future use. As a simple application of machine learning, the data trained will be stored within the master controller chip and be used to guide the mechanical components to respond as a corresponding pattern is detected.

The PSYONIC Inc. has a finished product based on the EMG method, thus we will demo with the prosthetic hand provided by the company with our PCBs and communication protocol. At the same time, we are expecting technical support and funding for extra PCB orders (Separated from the courses timeline).

[1] Castellini, C.; Kõiva, R.; Pasluosta, C.; Viegas, C.; Eskofier, B.M. Tactile Myography: An Off-Line Assessment of Able-Bodied Subjects and One Upper-Limb Amputee. Technologies 2018, 6, 38.

c. High-level Requirements

There are three major requirements for our design:

- Pressure sensors positioned around the forearm of the tester should sense consistent and accurate signals; i.e., the signals due to different muscle movement should be distinguishable from each other.
- Reduce the number of pressure sensors as much as possible, compared with previous research, to simplify the communication protocol as well as overall design complexity and to increase the communication efficiency.
- The software programmed in the processor on the master device should be able to classify different data sets into several groups corresponds to different hand motions, such as clenching, releasing and rotating of hand so that sensed pressure can be translated into commands to control a prosthetic hand.

2. Design

Block Diagram The system we designed will consist of a master device and some pressure modules. The pressure sensors modules will collect pressure data from user and transmit them to the master device. The master device will collect data from pressure sensor modules and communicate with prosthetic hand. Below is a high-level block diagram for our system:

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a. Block Diagram

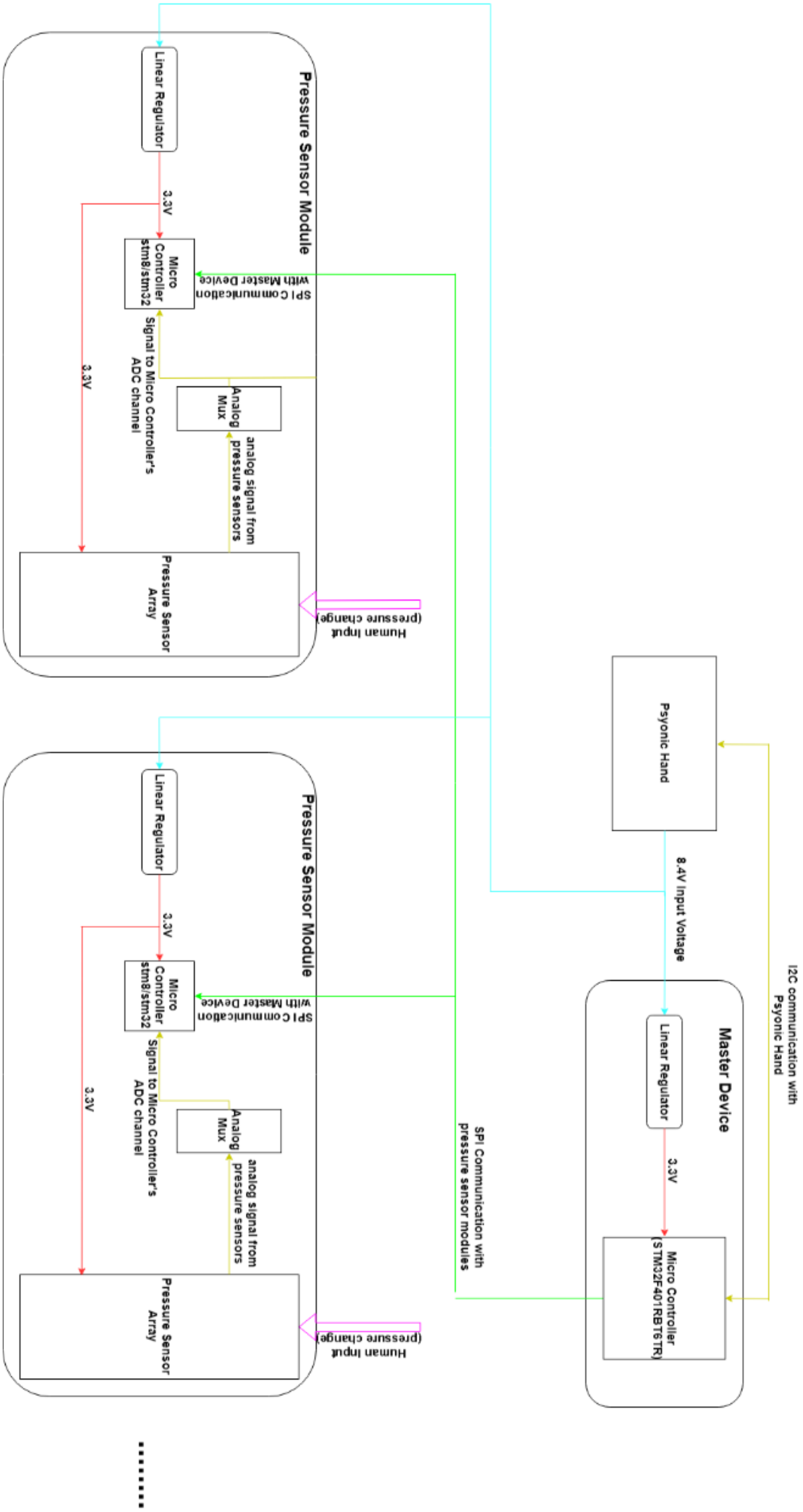

Figure 1: High level block diagram for whole system

b. Physical Design

i. Sensor Module Design

We are planning to design a sensor module consists of a PCB and electric conducting foam on top of it. The design of the PCB will follow the diagram specified in figure 1. Each sensor module will include 16 to 32 sensing units which is a pair of electrodes that are connected to the foam. The electric conducting foam is a conducting foam material that have changing resistance if its shape changed. One side of the foam will be attached to the PCB and the other side will be in contact with human skin.

If pressure is applied to the foam by human skin due to muscle movement and tendon contraction, the change of shape of the foam will lead to change of resistance measurable by the electrodes and the reading signals will then be digitized and propagated to the master microcontroller to be processed.

ii. Arm Bracelet Design

We are planning to include 8 to 12 sensing modules and 1 master controller board in the final prototype and we will cooperate with PSYONIC Inc., to design a forearm bracelet that holds these modules and boards. The design is inspired by the aforementioned research (1). The sensors will be attached to human skins around the forearm and the bracelet will ensure they are properly positioned with sufficient pressure. Potential choices for the material of the bracelet include elastic fabric and hook-and-loop fasteners which should fit testers' arm thickness, provide enough tension and enable adjusting of the position of the sensor modules for testing purpose. The final design and choose of materials may subject to change but the basic idea should remain persistent. PSYONIC, Inc., will be responsible for producing and assembling the final prototype for the arm bracelet. We also plan to connect the master controller we designed to the well-functioning prosthetic hand provided by PSYONIC Inc.

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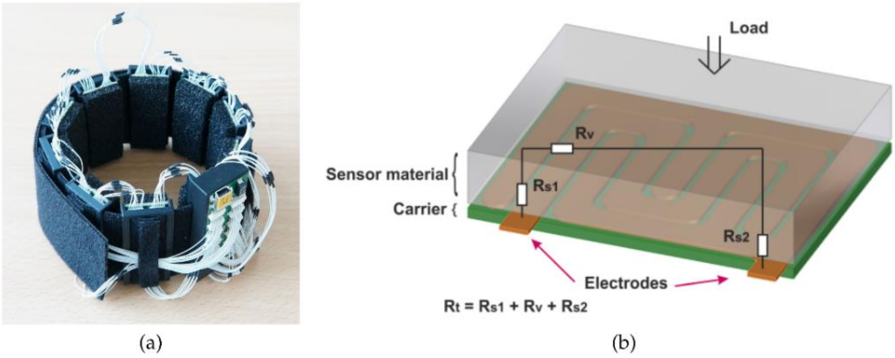

Figure 2: Both figures are referenced from the research paper (1). (a) This figure supports an approximate idea about the bracelet, where multiple rectangular modules are attached to a circular band and each module contains 16 to 32 sensing units (numbers subjected to change during testing) attached to skin with electric conducting foam in between. (b) This figure shows a close look at a single sensing unit on the sensing modules. Pressure will be applied from the top surface of the sensor material which we choose to use electric conducting foam and the resistance of the foam will change in response for the change of pressure. The electrodes on the PCB will be able to detect the change and then the signals read will be propagated to and processed by the master controller.

c. Electrical Design

i. Master Device

Master device will communicate with pressure sensor modules and process data from each pressure sensor module. It will convert the pressure sensor reading to command to control the hand. It mainly consists of a micro controller to communicate and process the data.

Microcontroller

There exist several requirements for the micro controller. First, the micro controller has to be powerful enough to be able to process certain amount of data. It is also required to support various communication protocol to talk with the pressure sensor modules and other parts of the hand. Last but not least, that micro controller is better to be consistent with others used in the hand to simplify the design.

Consider about the requirement, we are going to use the STM32F401RBT6TR microcontroller, which have the following advantage:

- This microcontroller has 256 kB flash/64 kB RAM and operating frequency up to 84MHz. It should be powerful enough to process data from all pressure sensor modules
- This microcontroller has built in UART, I2C and SPI modules which

allow simple communication with other controlling parts of the prosthetic hand.

- The STM32 microcontroller is consistent with the microcontroller that used in other parts of the prosthetic hand built by Psyonic Inc. . Therefore, we can share the same develop environment with other developer of the hand and reduce design effort.

Power Supply

The whole hand is powered by a battery with output voltage approximately 12v. On the other hand, the micro controller we chosen require 1.7v - 3.6v as input voltage. Therefore, some linear regulator is required to convert the 8.4v voltage to 3.3v that we can used. The linear regulator should be able to take about 6-18v as input and convert it to 3.3v voltage. The physical dimension and price of the regulator should be as low as possible.

Communication with other parts of the hand

The hand uses I2C as the protocol to communicate between each of component. Therefore, we will just follow this and use I2C to communicate with other parts of the hand.

Communication with pressure sensor modules

We choose SPI as the communication protocol for the master device to talk with pressure sensor modules. The following paragraph is the analysis of the SPI:

The Serial Peripheral Interface (SPI) is a synchronous serial communication interface specification used for short distance communication, primarily in embedded systems. It requires 4 wires as shown in the figure 5 below (only two modules in example), a clock line (SCLK), a slave select signal for each slave (SS), a master out slave in wire (MOSI) and a master in slave out wire (MISO). SPI have really high communication speed that can go over 10Mbps. However, each salve requires a separate slave select wire and therefore, for 10 pressure sensor modules there will be more than 10 wires, which may be an issue.

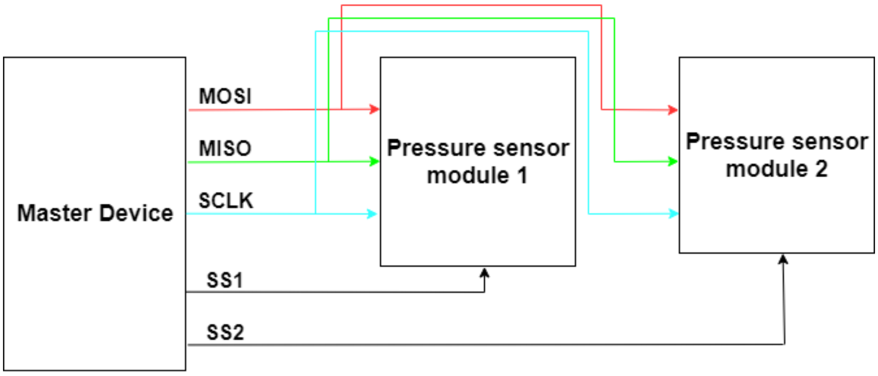

Figure 3: SPI example

ii. Pressure sensor modules

There will be 10 pressure sensor modules each holding 32 pressure sensors. Each pressure sensor modules will also hold a micro controller to acquire the data and transmit the data to the master device.

Microcontroller

There are several requirements for the micro controller on the pressure sensor modules. Since the sampling of the pressure sensor doesn't have to be fast, the micro controller doesn't have to be decent in terms of computation speed. However, due to the size limitation of the pressure sensor modules, the micro controller has to be as small as possible. In addition, since we will rely on the micro controller's built in ADC to digitize the pressure sensor reading, the micro controller should have built in ADC with good resolution (at least 10 bit). Moreover, the micro controller should have SPI peripheral to communicate with the master device. Last but not least, it is preferred to use micro controller consistent with other parts of the hand.

Consider about the requirement, we are considering using the STM8S003F3 micron controller, which have the following advantage:

- The micro controller can run at 16 MHz which should be enough for our purpose. It has a version in UFQFPN20 package which only occupies 3*3mm space.
- The micro controller has a built in 10bit ADC which is enough to digitize the pressure sensor reading. It also has built in SPI peripheral which allows communication between the master device.
- The STM series micro controller is used in other parts of the hand and we have experience developed on this micro controller. Therefore, it can tremendously reduce the design effort.

Power supply

Same as the master device, the pressure sensor module should consist a linear regulator to convert the 12v from battery to 3.3v used by micro controller. The linear regulator should be able to take about 6-18v as input and convert it to 3.3v voltage. The physical dimension and price of the regulator should be as low as possible

Analog Selector

Since on each pressure sensor modules there will be as much as 32 pressure sensors and most of microcontrollers probably don't have that much ADC channel, some analog selector or analog mux will be used to select between pressure sensor readings. There's not so much requirement for the analog selector, just to be small and cheap.

3. Risk Analysis:

The integration of hardware and software should be the biggest uncertainty within our design process. The whole project includes two PCB designs and one software design, and we expect at least two weeks to test and debug the integrated system.

At the very first place, the analog signals need to be processed (A/D and packed up) by the microcontroller and sent to the BUS. Next, our communication protocol should combine and transmit those data packages to the master chip with low latency. Thus, this part is considered as the controlling work of the whole project.

4. Ethics and Safety

Our major safety concern during the design process is the potential circuit short which may lead to extreme high temperature due to current surge if the PCB carries serious bugs or human error while testing. Circuit short hazard could burn down the PCB or scald our skins, and it need to be taken seriously. We won't allow any one in our group working alone with the PCB(s).

Since the prosthetic hand is comprised of many mechanical components, we also need to take precautions to avoid any possible cutting injuries caused by improper operations.

After reviewing the IEEE and ACM ethics, we agree on the following concerns to be presented in our project proposal,

a. IEEE Policies, Section 7, 7.8 IEEE Code of Ethics

8. to treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression

We need to be honest on the performance of our product. Due to current technical limitation, both EMG and pressure-sensing method could only work for the disabled who had amputation surgery below the elbow (and still have working residual limbs). We expect our product to work poorly for those who experienced amputation surgery above the elbow.

This may be a discrimination regarding the degree of disability.

9. to avoid injuring others, their property, reputation, or employment by false or malicious action
&
ACM General Ethical Principles 1.2 Avoid harm.

Our product may injure/harm (bring negative consequence) the user, or the objects hold by the prosthetic hand due to incorrect responds that against user's will. Furthermore, since user could not always control the force it applies to the project precisely, it's very possible that soft items are squeezed.

b. ACM General Ethical Principles

1.6 Respect privacy.

As part of the training process, we need to collect sensitive data from user, such as the pressure patterns for different hand movements and store them into the master chip, which assumes the possibility of user's data leakage if the product hacked or missing.

5. Reference

[1] Castellini, C.; Kõiva, R.; Pasluosta, C.; Viegas, C.; Eskofier, B.M. Tactile Myography: An Off-Line Assessment of Able-Bodied Subjects and One Upper-Limb Amputee. Technologies 2018, 6, 38.