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Prosthetic Arm using Force Sensor

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Abstract— An Upper limb amputation causes a severe reduction in lifestyle of the affected individual due to inability to perform activities of daily lifestyle. This is a devastating occurrence that limits human activity which can result into physical or mental trauma. In order to provide assistance to the amputee, use of prosthetic devices is becoming more popular. Prosthetic devices can be mechanical or electromechanical devices that mimic the ordinary movement of human parts. In this research work, to mimic the function of the human arm for disabled people and stroke patients, a portable lightweight device which offers automatic, integrated easy to use bionic arm is designed and implemented. By using the concepts of Mechatronics and Robotics in this project aims for a functional prosthetic affordable to everyone.

***Keywords*— Prosthetics, Amputation, Trans-radial amputation, FSR Prosthetics, Sensor-based prosthetics.**

I. INTRODUCTION

Worldwide, millions of people suffer from amputation due to a lack of safety and proper equipment. An amputation causes great restrictions towards daily tasks, along with mental stress to an individual's life. Various safety measures are being implemented to reduce these. When an arm or other limb is amputated or lost, a prosthetic can play a significant role in recovery. For many people, a prosthetic limb can improve mobility and ability to manage daily activities, and provide ways to stay independent. Prosthetics help amputees a lot, but are extremely costly and not affordable for all. Therefore, we aim to design a bionic arm which is affordable for all. There are numerous issues related with myoelectric control, right now the most famous type of prosthetic control. Advances in bionics can assist the lives of many people with lost limbs. To address this challenge, we have built and tested the robot arm. A major part of the project is to provide an inexpensive and easy-to-use mechanism that helps even the impoverished sections community to live a normal life by imitating human arm operators physically, structurally, and as functional elements. The bionic arm which is designed is a portable and light weight, innovative device. Myo-electrodes are costly, require extensive processing to eliminate noise, should now and then be embedded to get the best sign, and regularly get an uproarious signal when utilized remotely. One out of each multiple times, myo-electrodes inaccurately predict muscle bulge. Force sensors, another control technique being tried in this task, measure muscle bulge directly, as opposed to the power delivered by the muscle. Force sensors are cheap, require next to calibration, and are utilized remotely. To test this control strategy, an operational prosthetic hand model was assembled. of your arm flawless, which makes recuperation simpler and makes it more probable that you will actually want to keep on utilizing your arm even after the amputation.

II. OBJECTIVES

Main objectives of this research are: -

A. To plan, design and implement a prosthetic arm that is fully functional with user feedback.
B. To design a cost effective setup.
C. To be able to use the prosthetic arm in daily tasks.

III. LITERATURE SURVEY

There are many problems associated with myoelectric control, which is currently the most popular form of implant/prosthetic control. Myo-electrodes are exorbitant, require broad handling to dispense with noise, should occasionally be installed to get the best sign, and routinely get a loud sign when used distantly. One out of each on various occasions, myo-electrodes erroneously anticipate muscle bulge. Force sensors, another control strategy being attempted in this errand, measure muscle bulge directly, rather than the force conveyed by the muscle. A new control method has been tested in this project to measure the muscle bulge directly, rather than the electricity generated by the muscles. Force sensors are cheap and they require little or no signal filtering and are used on the surface of the human body therefore can be easily replaced.

A. Comparison of finger extension Raw calibration

The figures (a) and (b) represent the noise comparison between EMG sensor and Force sensor (FSR-402) respectively. These figures clearly indicate that EMG sensors gain more noise in outdoor environment and hence are less accurate for the desired output when compared with the FSR-402 force sensor. FSR-402 was henceforth chosen as a replacement to EMG electrodes.

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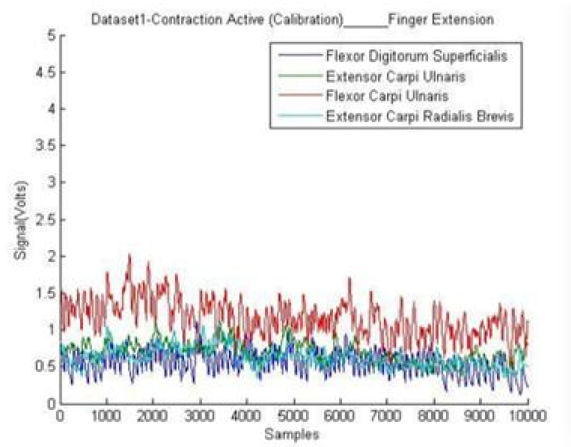
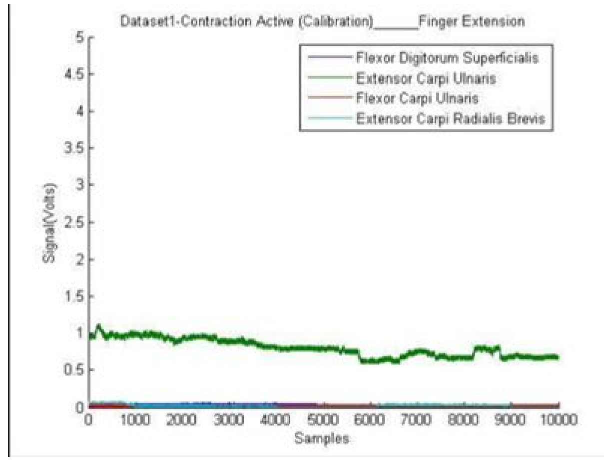
The comparison graphs are below



Graph 1. Sensor data from EMG Sensors



Graph 2. Sensor data from FSR force sensors

The results show that the force sensors can accurately distinguish between different muscles of the arm with minimal training, indicating that in the future they may offer a cheaper, low-maintenance control method for amputees. It is observed that in regular outdoor use, EMG sensors are more prone to noise and require an external noise-filtering circuit which again increases the overall cost. This prosthetic arm can be used by all amputees having any type of upper limb amputation. We place the FSR sensor on the bicep of the amputee, which can be easily removed or replaced If damaged.

B. Trans-Radial Amputation

Trans radial amputation is the incomplete amputation of the arm beneath the elbow, sooner or later along the radial bone. This kind of medical procedure leaves your elbow and the greater part of your arm flawless, which makes recuperation simpler and makes it more probable that you will actually want to keep on utilizing your arm even after the amputation. The basic delicate tissue of the lower arm contains generally avascular designs, for example, belt and tendon making suboptimal cushioning of the lingering appendage. In this way, folds are for the most part made at a 1 to 1 proportion and reflected proximally. Vessels, nerves and muscle stomachs are transacted. For prosthetic fitting, it is desirable over have in any event 4cm of the ulna safeguarded. At times, transposing the biceps tendon to the proximal ulna to help the resting estimation is useful in saving elbow flexion. In the event of frail muscle, specialist will give you activities to play out that will help reinforce your arm and middle, making it simpler to adjust to your fake appendage.

IV. METHODOLOGY

A trans-radial amputated arm has an incomplete forearm whereas the bicep is completely fine if not in some cases after physical treatment the bicep is functional, we placed the FSR-402 on this bicep, when the bicep is flexed the FSR-402 is responsible for this muscle bulge.FSR-402 is a force sensor which measures the muscle bulge, the sensor can be placed on the bicep. The user gives input to the FSR-402 in the form of muscle contraction, this muscle contraction applies force on the sensor, this data is processed by the micro-controller. The threshold limit this set within the microcontroller, this threshold limit is compared with the force measured by the sensor. The microcontroller processes this sensor data and decides the class of motion meaning the decision for the grab or release action is taken by the MG-995 Servo motors. There are 5 Servo motors placed within the arm, one for each finger.

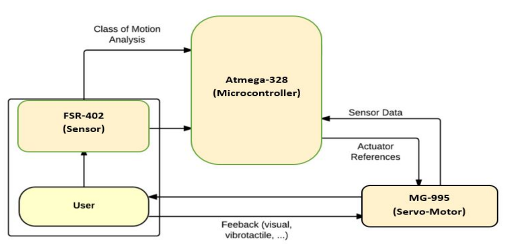


Fig.1. Flowchart of the prosthetic arm

A. Hardware Specification

Table -1: Table of components

Sr. No.	Type	Name
1	Sensor	FSR-402 Force sensor
2	Microcontroller	Arduino- Uno
3	Servo Motor	MG-995

1) *FSR-402:* A force-sensing resistor is a material whose barrier changes when a force or mechanical strain is applied. In other cases, they are also called force-sensitive resistor.

Specifications:

Model：FSR-FA402

Force-measuring-range：100g~10KG

Response-time：<1ms

2) *Arduino-Uno:* Arduino Uno AtMega-328 Arduino is an open-source project that created microcontroller-based kits for building digital devices and interactive objects that can sense and control physical devices. Arduino combines a micro-controller along with all of the extras to make it easy to build and debug projects.

Specifications:

Microcontroller: Microchip ATmega328P.

Operating Voltage: 5 Volts.

Input Voltage: 7 to 20 Volts.

Digital I/O Pins: 14

(of which 6 can provide PWM output)

3) *MG-995:* We decided to use MG-995 as it has strong torque and is durable in daily tasks. MG-995 can handle heavy loads and is functional in harsh day to day conditions.

Specifications:

Operating-voltage:4.8V

Peak-stall-torque:9kg.cm

V. DESIGN ANALYSIS

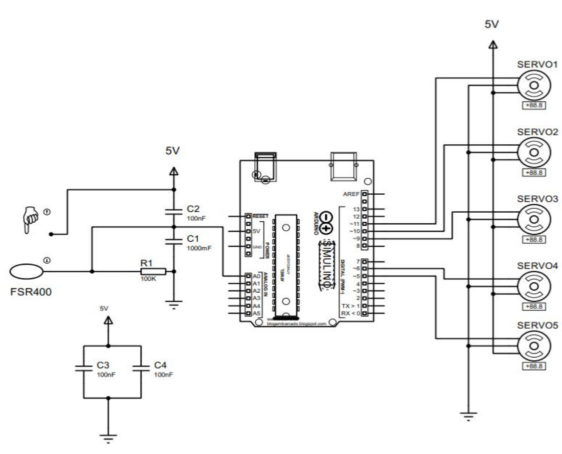


Fig.2. Circuit Diagram

A. Arm Construction

The arm is tendon-based robotic palm meaning the servo motors are connected to the fingers using a nylon string, nylon strings are flexible in nature thus they provide strength and flexibility to the palm whereas, the fixed link robotic palms are not flexible

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and result in friction between the links, this causes a necessity of lubrication and maintenance, thus are not recommended for daily use.

Fig.3. 3D printed palm of the prosthetic arm

The 5 servo motors (MG-995) are placed below the palm, on the forearm which are directly connected to the fingers. When the threshold value is sensed by the force sensor (FSR-402), the microcontroller (Arduino-uno) reads the data and the servo motors are actuated accordingly. When the servo motors are actuated, they pulled the tendon/strings causing the palm to close
The arm is designed using solid-works and then is 3D printed. The parts of the arm are printed separately hence each part of the finger can be replaced on any type of damage and is affordable.

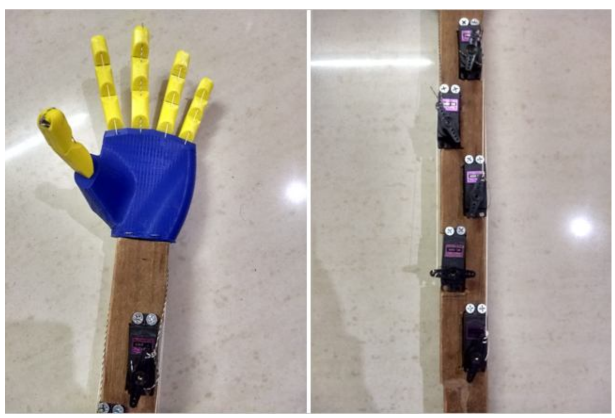

Fig.4. Arrangement of servo motor

B. Software used

1) Arduino IDE: Arduino IDE has been used to write the program and upload it to the Arduino to read the sensor data from the FSR-402, the FSR-402 collects the muscle data, which is then compared to the threshold value.
2) Solid-works: Solid-works has been used to plan, model and construct the 3D arm. We have used the tendon based also known as string based arm due to the flexibility and easy repair and maintenance.
Programming Using Arduino IDE, we programed the FSR to detected muscle bulges in the bicep of the arm in such a way that when the muscle is flexed, a certain amount of force is applied on the FSR sensor which is detected. The Arduino is programmed to capture this value and compare it with the pre-set threshold value which is given to it, if the threshold value is lower than the pre-set value the arm will not act, but if the threshold value is higher than that of the pre-set, the arm will grip.

VI. RESULT

The arm was tested on various types of muscles (Strong muscle and weak muscle condition) and in different conditions and we got the desired output needed for controlling the arm. The conditions in which the arm was tested are as follows. The x-axis indicates the voltage in millivolts and the y-axis denotes the time. We have set the threshold value to 3500 millivolts for the sensor, if the value goes above 3500 millivolts the arm will grip.

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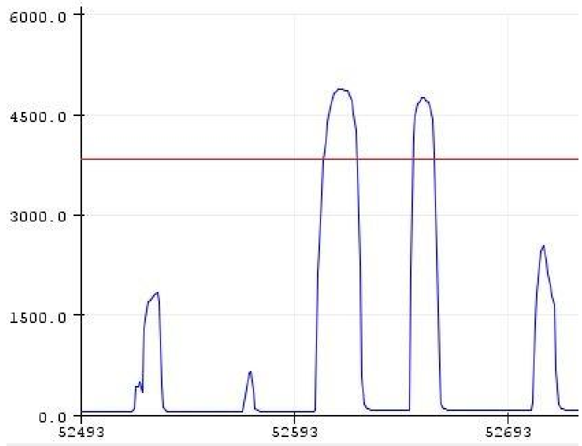
A. FSR Sensor on Bicep with No Load

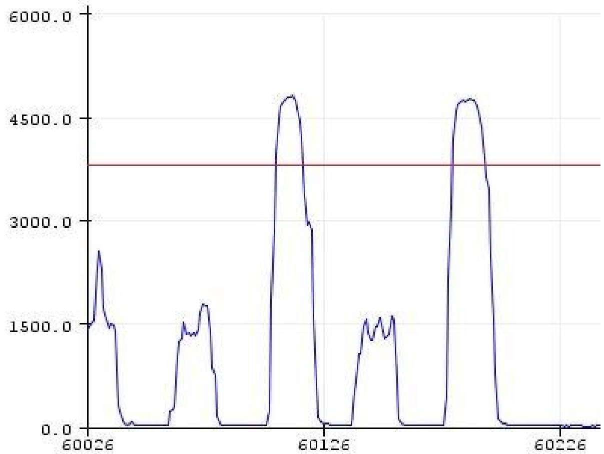
In this case we have placed the FSR sensor on the bicep with no load, the load here refers to the physical force of 2kgs. The 2kgs were used to show that this arm also works for strong muscle flex as well as weak muscles too. The red line on the graph indicates the threshold set in the program for the FSR, to react when the reading from the muscle goes above the threshold.



Graph.3. FSR sensor on Bicep with no load (Weak muscle)

B. FSR Sensor on Bicep with Load

In this condition we have tested the FSR sensor for strong muscle flex conditions, a force (load) of 2kgs was applied on the FSR by the bicep to test whether the FSR reads strong muscle data. The output showed us that the arm is usable by both people with weak muscle and strong muscle. The red line on the graph is the threshold.



Graph.4. FSR sensor on Bicep with load (Strong muscle)

VII. APPLICATION

This arm can be used as a prosthetic device for amputated people, giving them ability to achieve their daily tasks. These bionic arms are available in the market but are expensive and cannot be obtained by all amputees. A modified design will also serve to people suffering from stroke, and will mimic a normal human arm, this arm will have an exoskeleton type construction. These a highly precise version of these arms can also serve the purpose in hard to reach environments by connecting external wiring to the system.

VIII. FUTURE SCOPE

With further research and analysis, the FSR based prosthetics can be made common, this will be affordable by everyone due to the huge cost reduction when compared with EMG based prosthetics. The FSR sensor is more accurate and effective compared to EMG and can be used in daily tasks.

IX. CONCLUSION

As Mechatronics in Medical application is increasing the there is a huge demand for functional prosthetics. A major part of the project is to provide an inexpensive and easy-to-use device that helps even the poorest sections of the marginalized community to live a happy and normal life by imitating human arm operators physically, structurally, and as functional elements. We are trying to combined this solution which will be portable and innovative to carry wherever we go. The main aim of this project is to design and implement a portable lightweight device which offers automatic, integrated easy to use bionic arm, By using the concepts of Mechatronics and Robotics this project aims for a functional prosthetic affordable to everyone.

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