Control of a Robotic Arm Through Facial Expressions: An Exploration of EEG Technology in Prosthetics

Abstract

As biomedical technology continues to advance, and along with it the development of prosthetics, more options become available to mitigate the loss of one or more limbs. Artificial appendages are being given functionalities previously thought impossible, and the creation of a machine that accurately substitutes an arm or leg is just on the horizon. However, there are still practicality issues with these prosthetics, namely, their price and inaccessibility to the average consumer. This project addresses these two concerns by using commercially available tools, Lego Mindstorms and the Emotiv EPOC EEG headset, to create an inexpensive and readily available alternative that retains basic functionality. To accomplish this, a laptop was obtained, and both the arm and headset were connected wirelessly via Bluetooth and USB receiver, respectively. Emotiv's EPOC Control Panel was used to test functionality of the EEG headset. A sample program written for the Lego NXT was used to test the arm. A Java program was then written in Eclipse utilizing both the Emotiv API and Lejos API, which provides a Java Virtual machine on the NXT. The final project is able to handle the transfer of signals produced by the user's facial expressions, translating them to commands sent via Bluetooth to the robotic arm, which can execute the following simple motions: rotate upwards or downwards, turn left or right, and open or close the claw.

Purpose

The purpose of this study is to create an artificial arm capable of simple movement with easily obtained materials utilizing EEG technology.

Introduction

Prosthetics have been in widespread use since they were invented, used to replace missing limbs for amputees or those born without an appendage. The usual perception of a prosthetic is a length of plastic in the shape of the limb, sometimes with built-in joints that can be bent to simulate positioning of the limb. The prosthetics, however useful they are, cannot provide the same utility as an arm or leg made of flesh. Attempts at creating artificial limbs that provide the same movements have been both expensive and intrusive, severely limiting their use in the general public. This study will describe the effort to create a true prosthetic that lacks these shortcomings, in an effort to provide a functioning product that is both affordable and comfortable.

Hypothesis

It is possible to create a true prosthetic through the use of electroencephalography while remaining non-intrusive, removable, and interchangeable.

Variables

The independent variable is the user of the system. In this study, this is also a constant, as there is only one tester. The dependent variable is the success rate of simple tasks – up, down, left, right, open, and close.

Materials

- Emotiv EPOC
- Lego Mindstorms Education kit
- Laptop running Windows 7
- Eclipse w/ Java SDK 7.0
- Emotiv Control Panel
- NXT Programming 2.1

Figure 1: The Emotiv EPOC headset

Procedure

- Robotic arm constructed using Lego Mindstorms
- Sample program created for NXT to test functionality
- Emotiv and NXT connected wirelessly to computer, via USB receiver and Bluetooth, respectively
- Lejos, Bluecove, and Emotiv libraries added to build path
- Preliminary code written
- Code tested for bugs, systems tested
- Data collected by attempting each motion multiple times

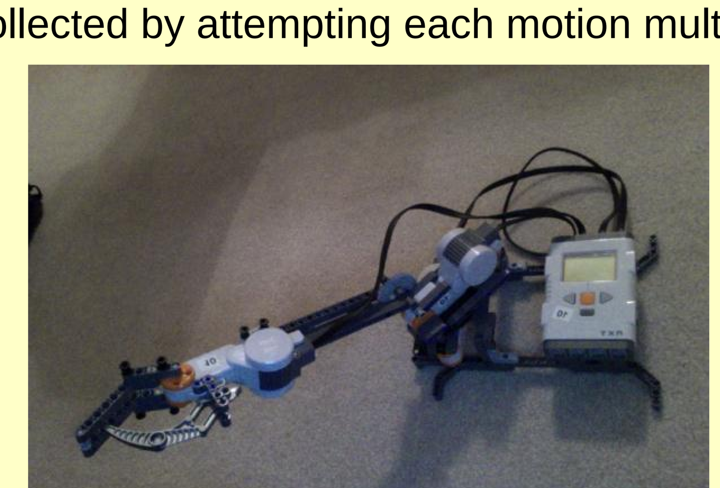

Figure 2: The robotic arm, constructed with Lego Mindstorms

Sample Code

```
//loads up the user profile
String userProfile = "C:/Users/devin/Desktop/arm/devin.emu";
IntByReference userId = new IntByReference(0);
Edk.INSTANCE.EE_LoadUserProfile(userId.getValue(), userProfile);


Pointer eEvent = Edk.INSTANCE.EE_EmoEngineEventCreate();
Pointer eState = Edk.INSTANCE.EE_EmoStateCreate();

int state = 0;


//connects bluetooth
arm = new ArmBlue(waitTime);

arm.right();

if (!arm.isConnected())
{
  System.out.println("Could not connect to NXT");
  return;
}

//RUN
System.out.println("Beginning main loop");

while(arm.isConnected())
{
  Edk.INSTANCE.EE_EmoEngineEventGetUserId(eEvent, userId);
  state = Edk.INSTANCE.EE_EngineGetNextEvent(eEvent);

  if (state == EdkErrorCode.EDK_OK.ToInt())
  {
    int eventType = Edk.INSTANCE.EE_EmoEngineEventGetType(eEvent);
    Edk.INSTANCE.EE_EmoEngineEventGetUserId(eEvent, userId);
```

Figure 3: A sample of ArmControl, the main class of the project. Here the program connects to both the headset and the arm, then begins to execute the main loop.

```
public class ArmBlue
{
  int actTime;
  boolean connected=true;
  NXTConnector connector;

  public ArmBlue(int t)
  {
    actTime = t/2;
  }

  public void connect()
  {
    connector = new NXTConnector();
    boolean isConnected = connector.connectTo("btspp://");
    connected = isConnected;
  }

  public void sendCommand(String command)
  {
    switch(command)
    {
      case "winkL": open();
          break;
      case "winkR": close();
          break;
      case "lookL": left();
          break;
      case "lookR": right();
          break;
      case "brow": up();
          break;
      case "clench": down();
          break;
      case "smile": break;
      default: System.out.println("say what now?");
               break;
    }
```

Figure 4: A sample of ArmBlue, the class controlling the Bluetooth connection to the Lego NXT. The method sendCommand() contains a switch statement that directs a headset signal to the proper method containing the corresponding movement.

Results

After the code was completed and integrated with the arm, each possible motion was tested 10 times.

Motion	Trials	Successful Trials
Up	10	9
Down	10	9
Left	10	8
Right	10	7
Open claw	10	4
Close claw	10	6

On average, 71.67% of trials resulted in correct movement of the robotic arm, a fairly high percentage of success. The relatively low success for open and close claw can be attributed to the adjustments of the headset's sensitivity.

Conclusion

There was a relatively high success rate for each task, indicating that the system is functional. It is therefore indeed possible to create a working prosthetic arm that stays within the bounds of cost and non-intrusion.

Future Research

Future projects should focus on:

- Smoothing out the currently jittery motions of the arm
- Constructing a more flexible arm using similar programming and more degrees of motion
- Removing the computer intermediate so that the headset can communicate directly to the arm
- Allowing the arm to operate off cognizant thoughts, a function supported by the Emotiv

References

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