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European Journal of Advances in Engineering and Technology, 2023, 10(1):32-38

Research Article **ISSN: 2394 - 658X**

Design and Simulation of a Prothetic Human Hand using a Network of EEG and Touch Sensor for Bio-Robotic Applications

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ABSTRACT

This paper presents a wireless control algorithm for five HS-311 servo motors representing the five fingers of a human hand in the presence of a touch sensor. The EEG brain signals processed in NI-Multisim are fed to the analog input A0 of a first Arduino Uno microcontroller, then converted by the ADC of this first Arduino Uno microcontroller. These EEG signals are transmitted to a second Arduino Uno microcontroller thanks to a Bluetooth wireless technology coordinated here by the Bluetooth HC-05 module playing the role of master and slave in this algorithm. This second microcontroller whose role here is slave allows to drive five HS-311 servomotors in action of opening of the human hand prosthesis when this one drops the object and of closing when a human hand prosthesis holds the object. The movements of the human hand prosthesis depend on the logic level of the push buttons, the touch sensor and the status of the light-emitting diodes.

Key words: EEG (ElectroEncephalogram), ADC (Analog to Digital Converter), Arduino Uno, HS-311 Servomotor, Human hand prosthesis, Bluetooth HC-05, LED, Touch sensor

1. INTRODUCTION

In biomechanics, they are difference between an orthotics and a prosthetics. Prosthetics is an artificial device that replaces a missing body part, which may be lost through trauma, disease, (or) congenital conditions. When a person becomes a limb amputee, he or she is faced with staggering emotional and financial lifestyle changes. The amputee requires a prosthetic devices and services which become a life-long event. Prosthesis is an artificial extension that replaces a missing body part such as an upper or lower body extremity. It is part of the field of biomechatronics, the science of fusing mechanical devices with human muscle, Brain, skeleton, and nervous systems to assist or enhance motor control lost by trauma, disease, or defect. An artificial limb is a type of prosthesis that replaces a missing extremity, such as arms or legs. The type of artificial limb used is determined largely by the extent of an amputation or loss and location of the missing extremity. Artificial limbs may be needed for a variety of many transtibial, transfemoral, transradial, and transhumeral prostheses. Here we are planning to fabricate transradial prosthesis, and then we need to choose a mind controlling device to operate the prosthesis with more flexible ways.

From many papers on biomedical and mechatronics we study and analyze the grip force distribution for different prosthetic hands designs and the human hand fulfilling a functional task is taken and from design approach of the prosthetic hand and it's mainly focused on increasing the functionality, cosmetic and controllability of the prosthetic hand From. Many times even experienced electromyographers fail to provide enough information and detail on the protocols, recording equipment and procedures used to allow other researchers to consistently replicate their studies. The values from the above papers are taken into consideration [6].

Faced with this worldwide revolution in neuroprosthesis and the arrival of the billionaire's company Neuralink Elon Musk marked by the presence of invasive brain-computer interfaces, there is still a doubt and even a risk for people with reduced mobility in the world, especially in Cameroon. To reduce this doubt and give hope to people living with a disability, three hypothesis have been put forward:

- What is the non-invasive algorithm to put the human hand prosthesis in motion?
- What hardware tools can be used to implement this algorithm?
-Will the actions of this hand prosthesis be optimal and precise during its movements?

2. METHODS AND TOOLS

To answer the different hypotheses posed in the introduction, we first wanted to study the methods and tools required.

2.1. Methods

The methodology used here is that of computer simulation. This method is structured in two schemes, namely the block diagram and the operational diagram of the new proposed device for EEG signal processing as far as the block diagram is concerned, the device is as follows:

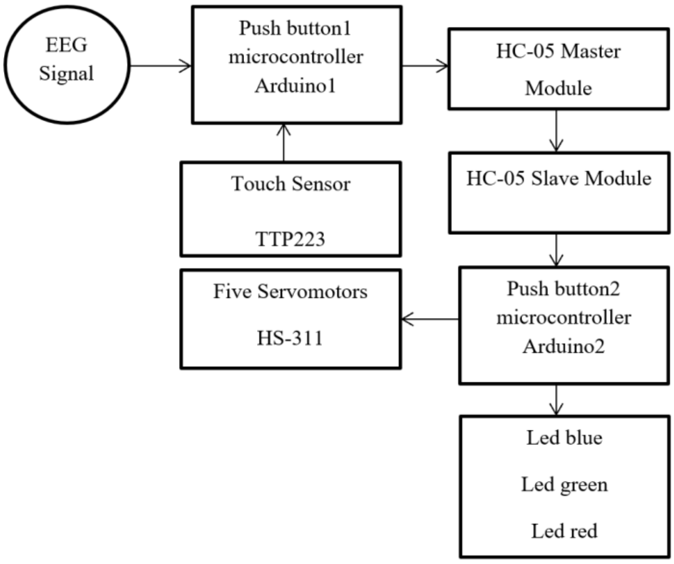


Fig. 1 Block diagram of the process of the human hand prosthesis

And as for the operational diagram of our new EEG signal processing device, the device looks like this:

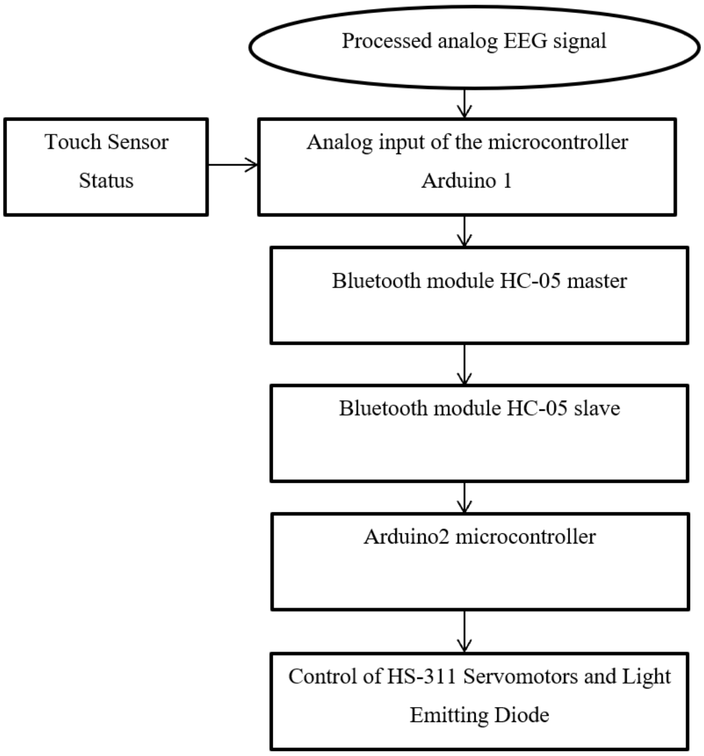


Fig. 2 Operational diagram of the proposed new device for the human hand prosthesis

2.2. Tools Hardware and Software

2.2.1. Hardware tools

The material tools are summarized in Table -1.

Table -1 Hardware tools

Designations	**Specifications**
Arduino Uno board	Microcontroller to create automated mechanisms
HC-05 Bluetooth modules	Allows you to add the Bluetooth full duplex communication functionality
The HS-311 servomotors	Indicate the opening and closing of the hand prosthesis
Push button	Simple switch to control the capabilities of a process
The Blue Led	Indicates Bluetooth status
The Green Led	Indicates normal operation
The red LED	Indicates the load
The resistors	Prevents short circuits
Laptop computer	Allows to realize the monitoring
Touch Sensor	Detects the touch of the object

2.2.2. Software tools

The software tools are summarized in Table- 2.

Table -2 Software tools

Designations	**Specifications**
Proteus 8.13 SP0	Electronic schematic simulation software
Arduino 1.8.10	Programming software for the Arduino board
VSPE(Virtual Serial Ports Emulator)	Software allowing the creation of virtual devices to send and receive data
Notepad	Text editor

2.2. Implementation of Electronic Device

2.3. Following the synthesis of the schematic diagram in Fig. 1, of tables 1 and 2 of the hardware and software specifications, and of the operational diagram in Fig. 2, the last required conceptual element is established in subsection 2.3.1.

2.3.1. Arduino-C++ wireless control application with EEG signal monitoring

To simulate this model, we used EEG signals processed in NI-Multisim. These data were introduced on the analog input A0 of an Arduino microcontroller1 playing the role of master in this computer control system and conditioned by a push button 2. These data are then transmitted in a non-wireless way thanks to Bluetooth technology to another Arduino microcontroller 2 playing the role of slave in this control-command computer system and also conditioned in turn by a push button 1. In this control-command computer system, the first Arduino microcontroller 1 is in charge of driving the EEG headset and the second Arduino microcontroller 2 is in charge of driving the human hand prosthesis whose fingers are designated here by the HS-311 servomotors The operation of this wireless control-command computer system is generally conditioned by the state of the diodes of the push buttons and the tactile sensor whose conditioning is in phase with the voltage of the EEG signal processed in NI-Multisim.

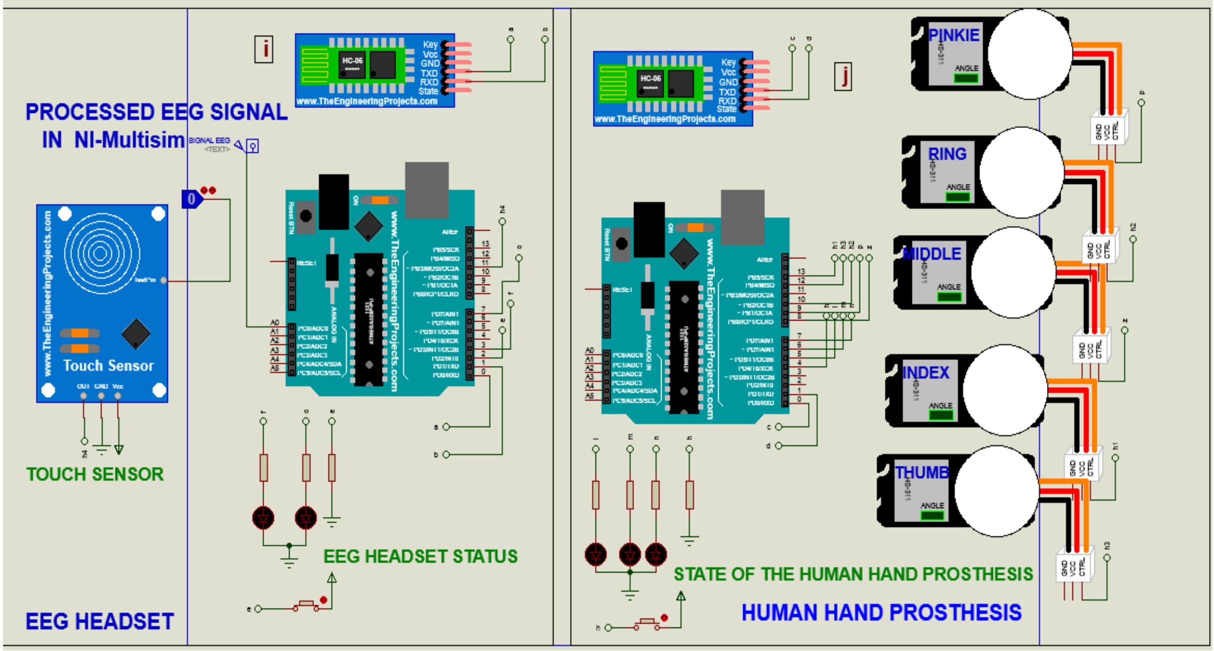
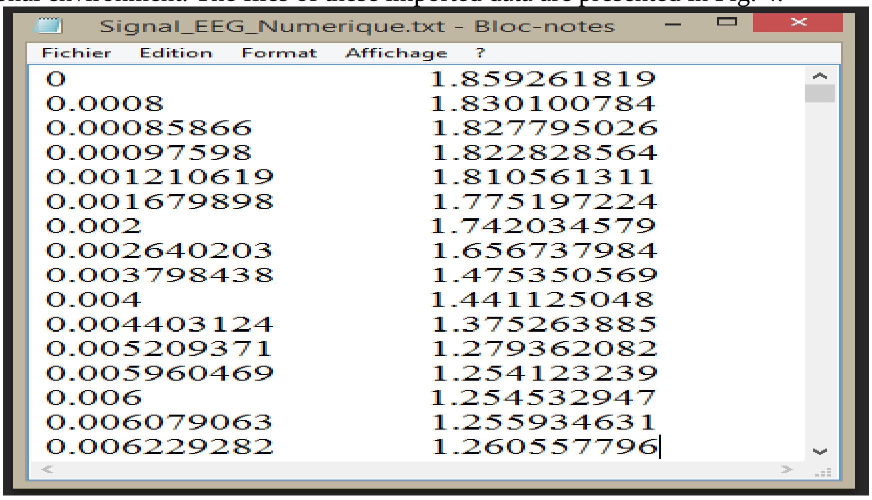


Fig. 3 Virtual model of the human hand prosthesis and the EEG headset in the presence of the touch sensor.

3. RESULTS AND DISCUSSION

3.1. Result of the simulation with monitoring

The first step of our simulation with monitoring was to import the EEG brain data processed in NI-Multisim into the Proteus 8 Professional environment. The files of these imported data are presented in Fig. 4.



Signal_EEG_Numerique.txt - Bloc-notes

Fichier Edition Format Affichage ?

0	1.859261819
0.0008	1.830100784
0.00085866	1.827795026
0.00097598	1.822828564
0.001210619	1.810561311
0.001679898	1.775197224
0.002	1.742034579
0.002640203	1.656737984
0.003798438	1.475350569
0.004	1.441125048
0.004403124	1.375263885
0.005209371	1.279362082
0.005960469	1.254123239
0.006	1.254532947
0.006079063	1.255934631
0.006229282	1.260557796

Fig. 4 EEG signals processed in NI-Multisim

Once the EEG data was processed in NI-Multisim, we proceeded to a coding using the C++ programming language compiled with avr-g++ for the slave computer system and for the master computer system by creating our own functions having in our algorithm very precise functions. In order to achieve this task we used a virtual port emulator allowing to make possible the communication between the two computer systems control-command. This emulator is presented on Fig. 5.

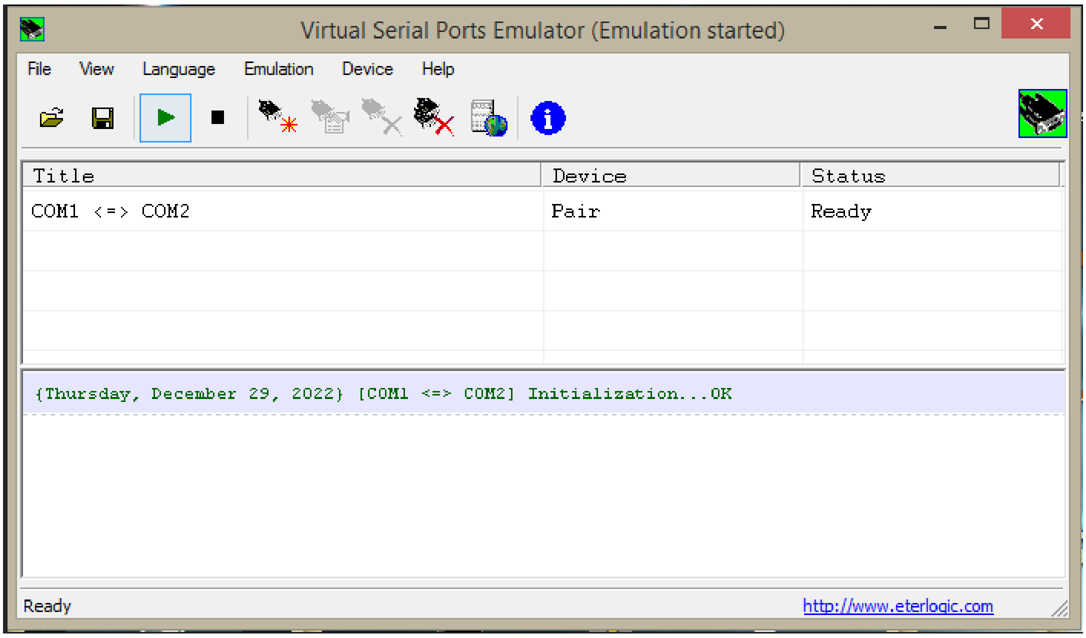


Fig. 5 Virtual Serial Ports Emulator

In this emulator COM1 represents the HC-05 master module characterized here by the signal **i** and COM2 represents the HC-05 slave module characterized by the signal **j**. It is noted that to succeed in this simulation we took **i ≠ j** on the one hand and considered that the exchanges of the EEG data are carried out with the same rate of transmission is 9600 baud on the other hand. Once the connection between the master control-command computer system and the slave control-command computer system was made, we proceeded to the global test of our control-command computer system, namely:

- Opening of the hand prosthesis in the presence of the touch sensor
- Closing the human hand prosthesis in the presence of the touch sensor.

3.1.1. Opening of the hand prosthesis in the presence of the touch sensor

When the EEG signal has a voltage in the range [0.0V; 4.0V] and the touch sensor is active at the low level then the human hand prosthesis releases the object, i.e. the HS-311 servomotors all rotate through an angle of -180^0 and the blue and red LEDs are all lit up indicating respectively the Bluetooth connection between the EEG headset and the human hand prosthesis and the opening of the latter. Note that the push buttons of this system must all be active at high level. The rendering of the simulation is Fig. 6:

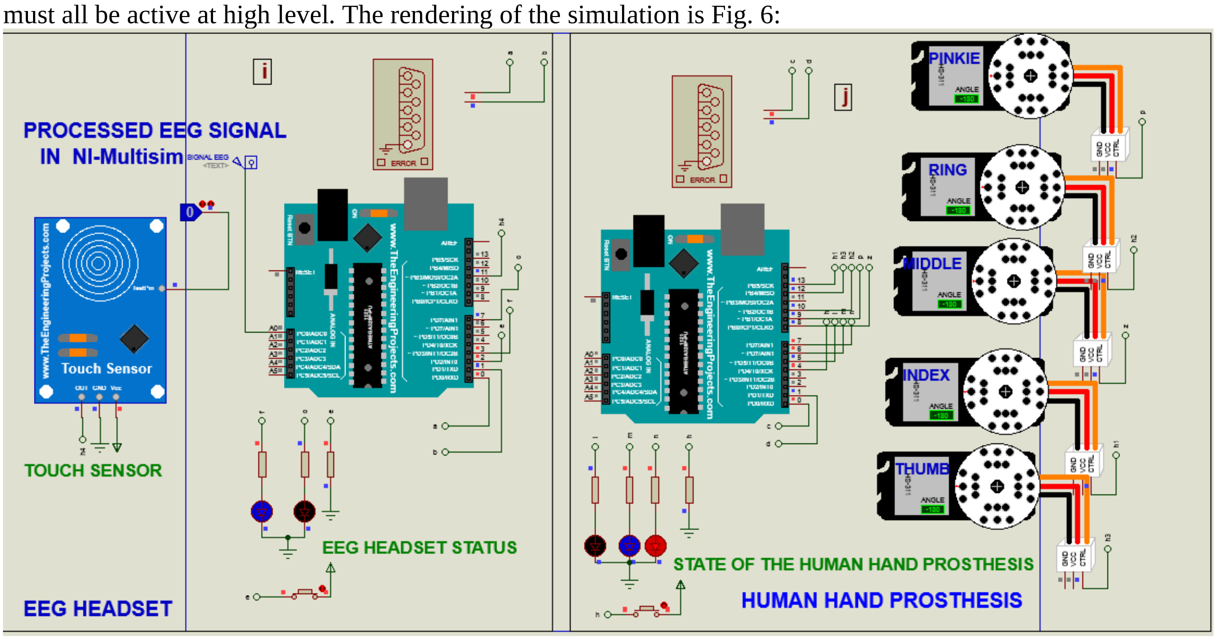


Fig. 6 Virtual model of the opening of the human hand prosthesis in the presence of touch sensor.

3.2.2. Closing the human hand prosthesis in the presence of the touch sensor

When the EEG signal has a voltage in the range [0.0 V, 4.0V] and the touch sensor is active at the high level, the human hand prosthesis is in contact with the object, i.e. the HS-311 servomotors all rotate by an angle of $+180^0$ and the blue and green LEDs are all lit, indicating the Bluetooth connection between the EEG headset and the human hand prosthesis, and the closure of the latter, respectively. Note that the push buttons of this system must all be active at the high level. The rendering of the simulation is Fig. 7:

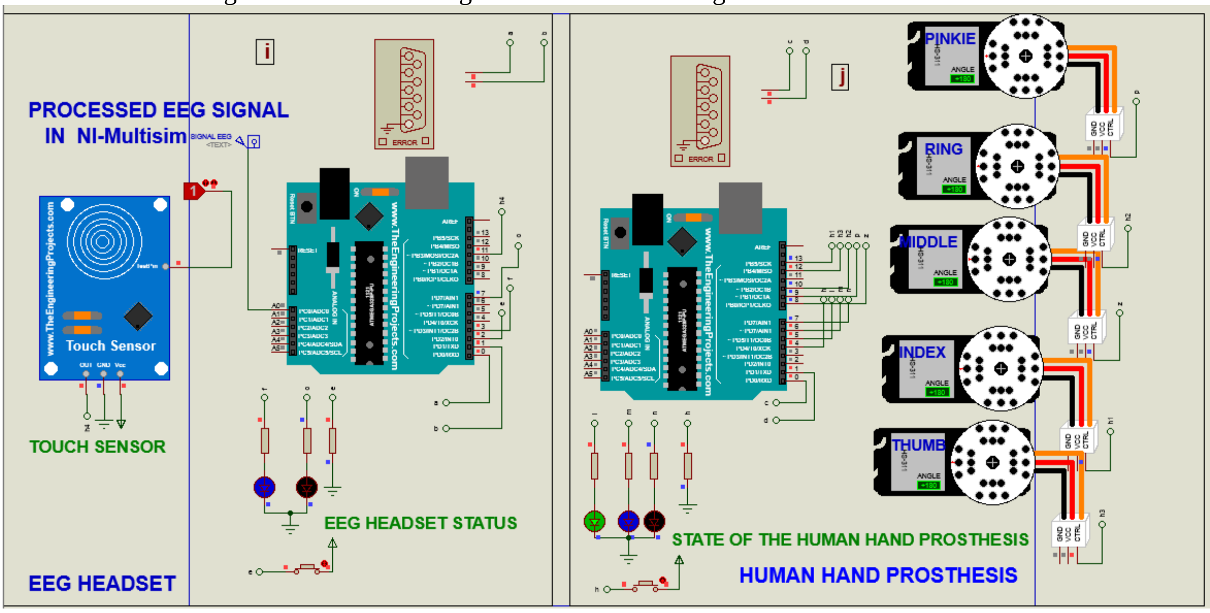


Fig. 7 Virtual model of the closing of the human hand prosthesis in the presence touch sensor

Note that in this simulation we have conditioned in our program the EEG signal in a voltage interval y € [0.0 V, 4.0 V] verifying the following equation:

$$y(x) = 0.00488759x \quad (1)$$

With x € [0.0, 1023.0] represents the measurement scale.

4. CONCLUSION AND PERSPECTIVES

This paper allowed us to realize a wireless Bluetooth computer control system from the EEG signals processed in NI-Multisim. This control-command computer system shows us that it is possible to control a human hand prosthesis by thought, i.e. from the information transmitted by the human brain. The results were simulated in the Proteus 8.13 SP0 environment. These results obtained were satisfactory because here we were able to control in a non-wireless way the slave system designating here our human hand prosthesis. To do this, with regard to the statistical data obtained from the EEG signals processed in NI-Multisim as shown in the following **Table -3.**

Table -3 Statistical data of EEG signals processed in NI-Multisim

Voltage	**≥3.3 V**	**≥3.0 V**	**≥2.5 V**	**≥2.0 V**	**[0.0 V, 1.99 V]**	**Total**
Sample size	**382**	189	272	254	1092	2189
Frequency (%)	**17.45**	8.83	12.42	11.60	49.90	100

In view of this Table -3, we suggest new perspectives for future research based on the results in this article. To wit:

* What materials should be used to make this EEG signal processed in NI-Multisim more positively clamped?
* What efficient algorithm should be implemented to make this enhanced EEG signal have almost zero noise?
* What algorithm should be set up so that our prosthesis can be more intuitive during the contact and non-contact with the objects of its environment?
* Will our model be easy to realize in real form?
* What positive clamping algorithm should be used to make the processed EEG signal less noisy so that the control of the hand prosthesis is optimal operation?

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