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Design and Simulation of a Bluetooth Control System based on EEG Signals for Bio-Robotic Applications

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ABSTRACT

This paper presents a wireless control algorithm for five HS-311 servomotors representing the five fingers of a human hand. The EEG brain signals processed in NI-Multisim are fed to the analog input A0 of a first Arduino uno microcontroller, and 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 and closing of a human hand prosthesis. The movements of the said servomotors make it possible to define three actions that can be carried out by a human hand prosthesis, namely the Bluetooth wireless link characterized by a blue LED, the normal operation characterized by the blue and green LEDs and the charging of the prosthesis characterized by the red LED. All these actions are conditioned by push buttons.

Key words: EEG (ElectroEncephalogram), ADC (Analog to Digital Converter), Arduino uno, HS-311 Servomotor, Human hand prosthesis, Bluetooth, Light emitting diode

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1. INTRODUCTION

The control of a prosthesis by thought requires a brain-machine interface. The BMI designates "a direct link between a brain and a computer, allowing an individual to perform tasks without using peripheral nerves and muscles. This type of device makes it possible to control a computer, a prosthesis or any other automated system by thought, without using arms, hands or legs". This definition leads us to distinguish two types of prostheses. Firstly, there are myoelectric prostheses whose equipment, related to the muscular electromotive force, allows to carry out movements according to the electric signals produced by the muscles. These prostheses are therefore not controlled by the brain. Secondly, we find neuroprosthesis which is the subject of this article and whose equipment is related to the central nervous system. These neurological prostheses are controlled by the brain by sending natural electrical signals through the nerves, which are then translated and reproduced by the neuroprosthesis [1].

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?
- Are the actions performed by the said prosthesis accurate?

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:

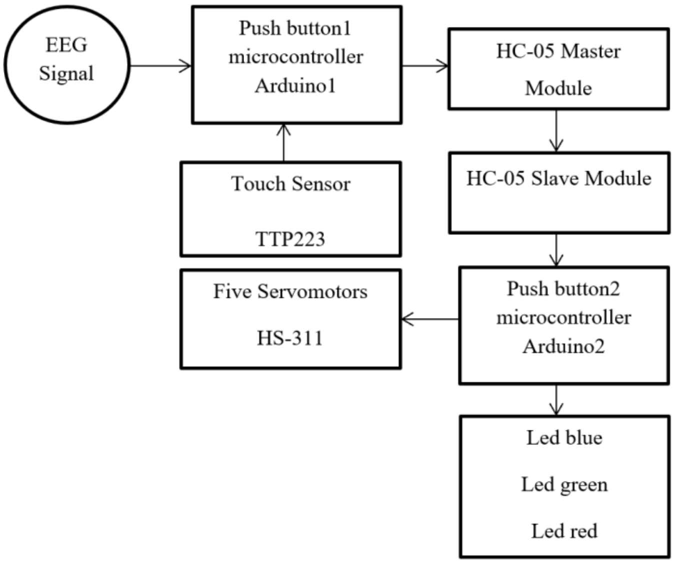


Fig. 1 Block diagram of the process of the human hand prosthesis

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

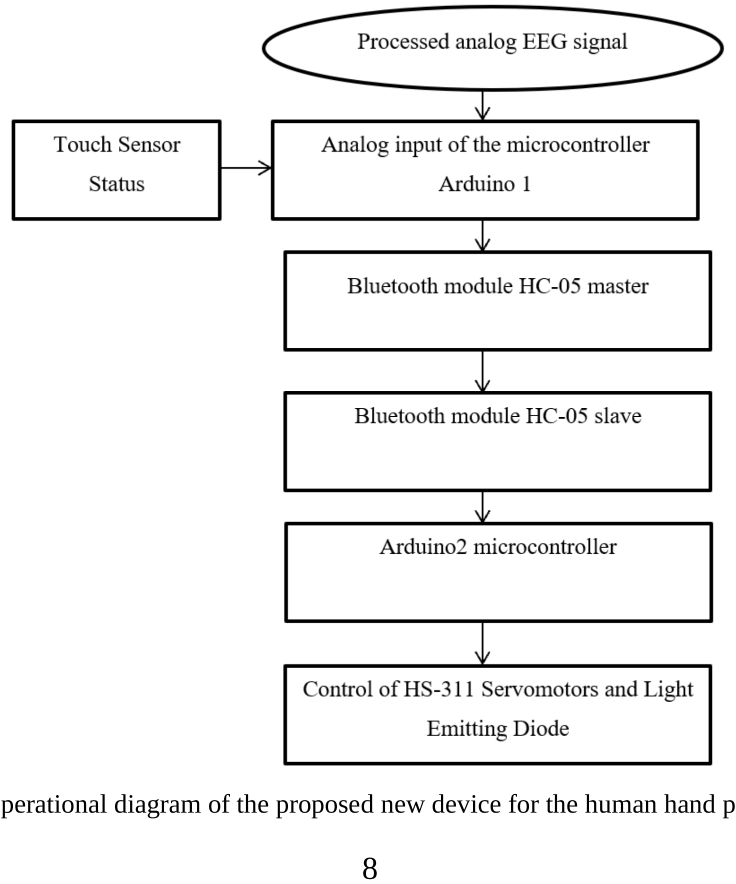


Fig. 2 Operational diagram of the proposed new device for the human hand prosthesis

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

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

2.3. Implementation of Electronic Device

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 the EEG signals processed in NI-Multisim. These data were introduced to the analog input A0 of an Arduino microcontroller1 playing the role of master in this control-command computer 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 its 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 servo motors. The functioning of this computer system is also conditioned by the status of the diodes representing here the status of our human hand prosthesis.

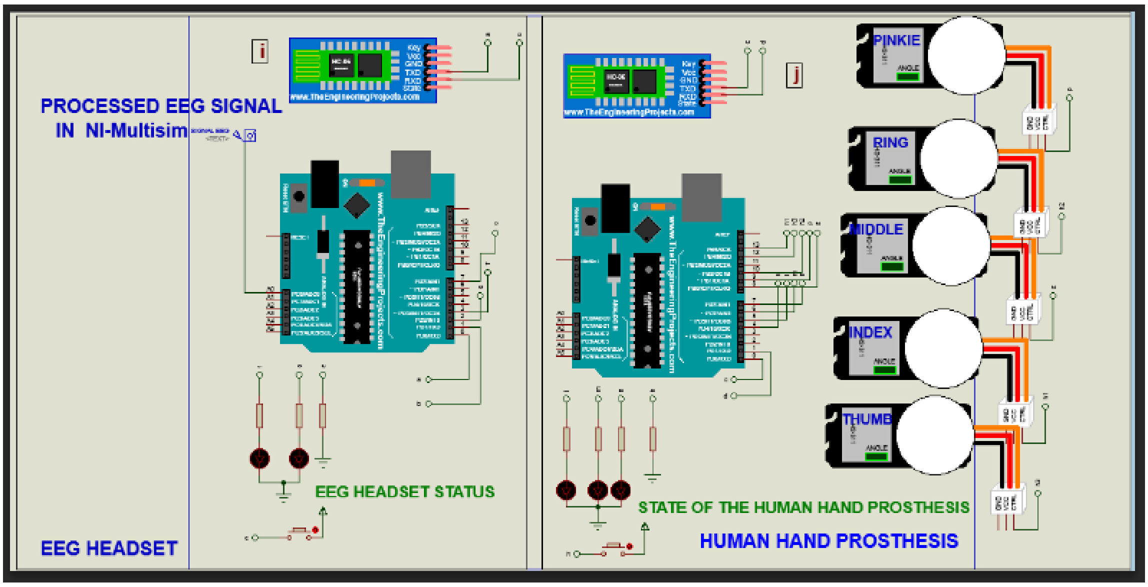
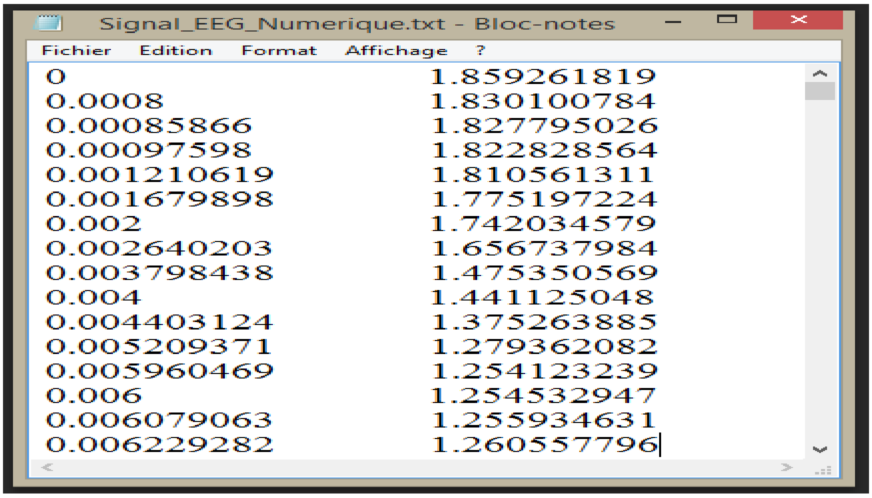


Fig. 3 Virtual model of the human hand prosthesis and the EEG headset

3. RESULTS AND DISCUSSION

3.1. Result of the simulation with monitoring

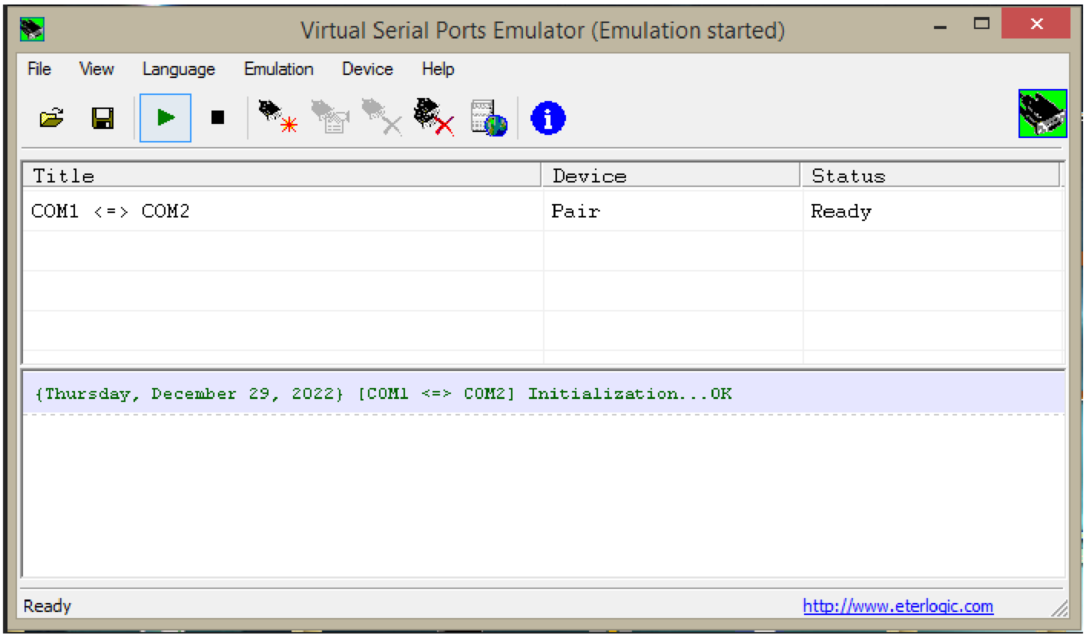
The first step of our simulation with monitoring was to import the EEG brain data processed in NI-Multisim into the Proteus 8 Professional environment. The files of these imported data are presented in Fig. 4



```
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.



Title	Device	Status
COM1 <=> COM2	Pair	Ready

```
{Thursday, December 29, 2022} [COM1 <=> COM2] Initialization...OK
```

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 $i \neq j$ 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 human hand prosthesis;
-Closing of the human hand prosthesis;
-Load of the human hand prosthesis.

3.1.1. Opening of the human hand prosthesis

In this control-command computer system when the push buttons of the master and slave system are at the bàs level the five fingers of the human hand represented here by five HS-311 servomotors let go of the object while rotating in the retrograde direction until reaching a value of -180^0 and the rendering of this simulation is Fig. 6.

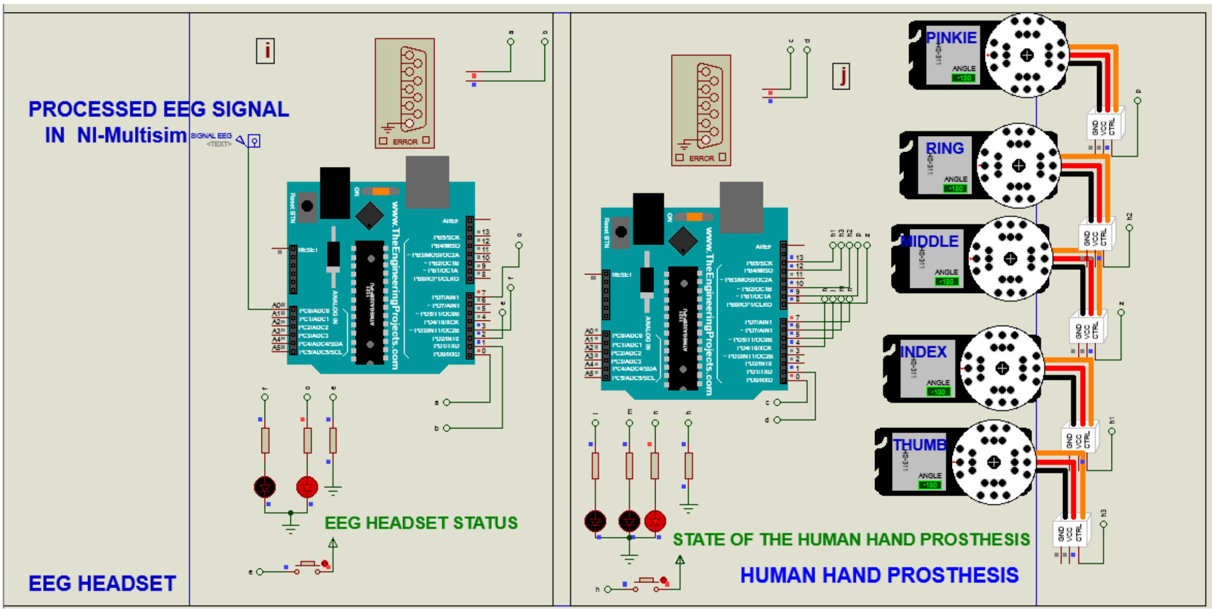


Fig. 6 Virtual model of the opening of the human hand prosthesis

This red light-emitting diode shows us that the human hand prosthesis and the EEG headset are discharged and must therefore be charged. During this charge the prosthesis remains at an inclination of -180^0 i.e. does not hold any object.

3.1.2. Closing of the human hand prosthesis

In this step, our human hand prosthesis representing in this control-command computer system the slave system receives the EEG signal by the Bluetooth technology coming from the master system which allows him to hold the object i.e. to close the five fingers of the human hand designated here by servomotors HS-311 and whose inclinations values are +180^0. For this simulation to take place, it would be necessary that the push buttons of the master system designating here the EEG helmet and that of the slave system designating here the human hand prosthesis are at the high level. The rendering of this simulation is Fig. 7.

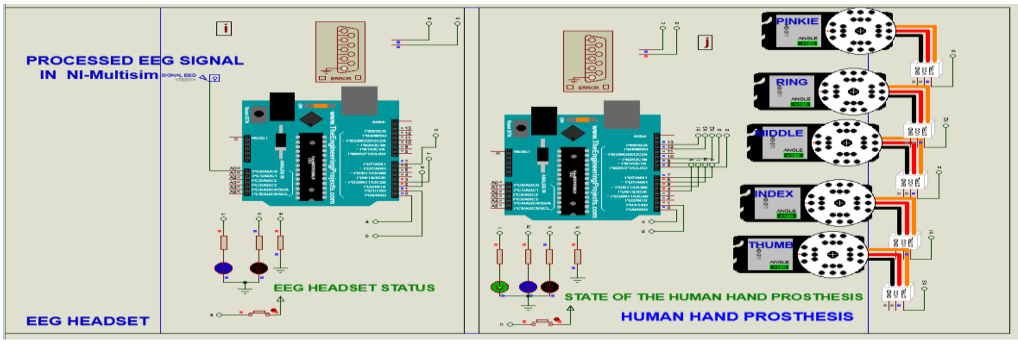


Fig. 7 Virtual model of the closing of the human hand prosthesis

The green LED here indicates that the human hand prosthesis is in action, i.e. that the five fingers are holding an object, while the blue LED indicates Bluetooth communication between the master system and the slave system. 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:

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

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

3.1.3. Load of the human hand prosthesis

In this step the LEDs of both master and slave systems are red indicating here that the EEG headset and the hand prosthesis are fully charged. The rendering of this simulation is Fig.

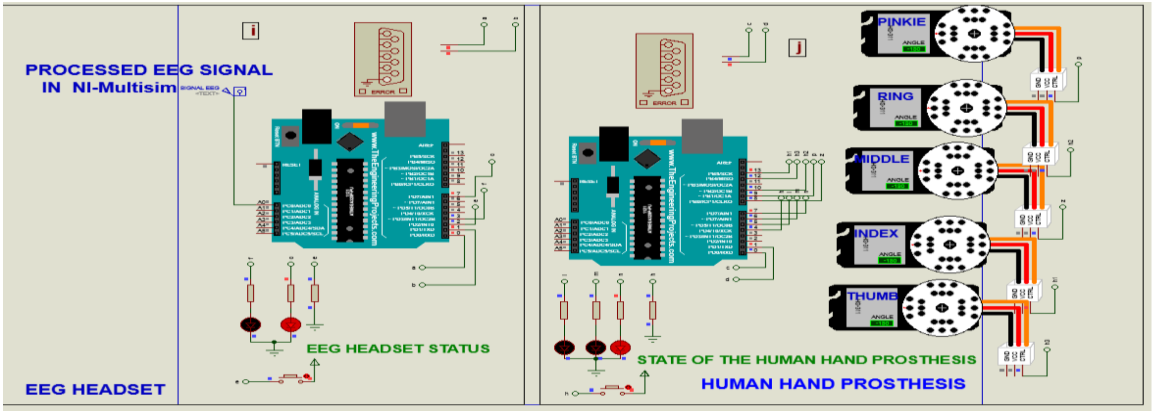


Fig. 8 Load of the human hand prosthesis

During the global load of our computerized control system, the push buttons of the master and slave systems are at low level, the LEDs are in red, the HS-311 servomotors are at an inclination of a value of -180^0 and no object is held during this period representing here the resting period of our system.

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?

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