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Robotic Arm Prosthesis Controlled with Myoelectric Muscle Sensor

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Abstract: The development of the design and simulation of a robotich and prosthesis in its modeling phase of parts in solidwork, for 3D printing is shown; the analysis of force, moment and torque applied to each finger, elbow and forearm. In addition, the simulation of the electronic proteusis is system with the application of the arduino code is shown.

INTRODUCTION

In Colombia, bioengineering is a field in development with high applications for the benefit of the human being; many soldiers in Colombia have suffered losses in their upper and lower extremities having as rehabilitation for amputations of legs, adjustable pneumatic prostheses to the step but when it comes to the amputation of an upper extremity, you do not have a prosthesis at low cost that simulates the movements of the human hand.

To begin to give solution to this problem, the design, construction and implementation of a robotic arm prosthesis controlled with myoelectronic sensors has been performed, this prosthesis can move when the amputee between the hand and the elbow performs movement in the forearm muscles by actuating the input signal to the control card and this will activate the servo motor to execute the movement.

The first step was to develop the design for hand printing in 3D, the simulation in proteus of the functioning of the electronic system and the physical implantation of the hand prosthesis with a single type of movement.

MATERIALS AND METHODS

For the 3D design the solid work software was used, for the design of the electronic system the software proteus and arduino one were used, where in the proteus software the operation of the electronic circuit is designed and in arduino the algorithm of control of the plate is made electronics.

Convention for the hand joints: From Fig. 1, we have designed the joints of the hand where:

- Metacarpians (MT)
- Proximal (P)
- Media (M)
- Distales (D)
- Thumb
- I indicated
- Medium
- Cancel
- Little finger

Table 1: Convention for each joint of the fingers

Dedo menique	Dedo anular	Dedo medio	Dedo indice	Dedo pulgar
MTM = Metacrpiano del dedo menique	MTA = Metacrpiano del dedo anular	MTME = Metacrpiano del dedo menique	MTI = Metacrpiano del dedo indice	MTP = Metacrpiano del dedo indice
PM = Proximal del dedo menique	PA = Proximmal del dedo anular	PME = Proximal del dedo medio	PA = Proximal del dedo indice	PP = Proximal del dedo pulgar
MM = Medio del dedo menique	MA = Medio del dedo anular	MME = Medio del dedo medio	MMI = Medio del dedo indice	MMP = Medio del dedo pulgar
MD = Distal del dedo menique	AD = Distal del dedo anular	MD = Distal del dedo medio	ID = Anular del dedo indice	PD = Distal del dedo pulgar

Fig. 1: Joints of the hand

From Fig. 1 only the bones of the hand represented in Table 1 are required, except for the metacarpals; because, for the realization of a movement such as grip, torque and rotation, no movement of the palm of the hand is required as for the thumb.

According to the previous table, the 3D hand model has been drawn in solidwork with the dimensions of an average human hand (Fig. 2 and 3).

Strength of the fingers: To calculate the theoretical force of the finger, let's first look at the situation in which the finger index is fully extended and a force is applied near the tip of the finger.

Strength in the fingers: To calculate the theoretical force of the finger, let's first look at the situation in which the finger index is fully extended and a force is applied near the tip of the Fig. 4 (Elsayed, 2014) Eq. 1:

$$\text{Moment} = \text{Strength*perpendicular distance} \qquad M = F*d \tag{1}$$

In this case the tendon creates a moment near each joint of the finger, at the point where the maximum lifting load is applied, the moments M1 and M2.

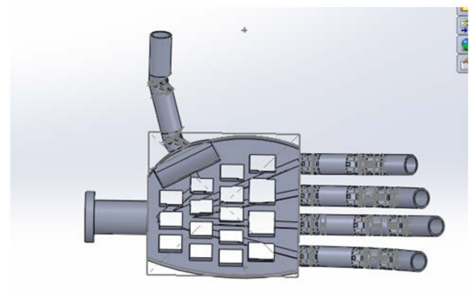

Fig. 2: Hand side view design

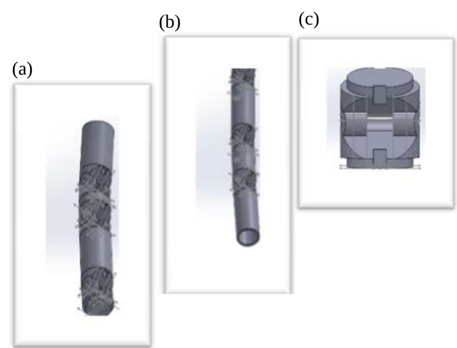

Fig. 3: Fingers and joints, design in solidwork

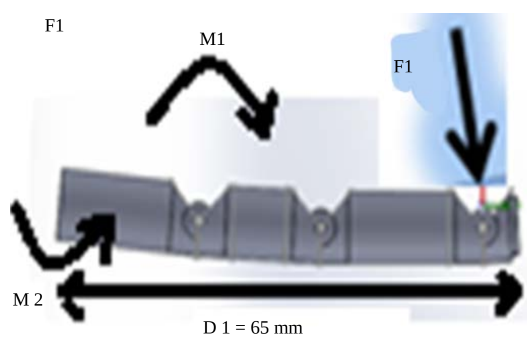

Fig. 4: Forces applied on the ring finger

They are out of balance. We must first determine the tensile force in the tendon. The torque (maximum turning force) of the servos is 10 kg-cm (1 N/m) Eq. 2 and 3:

$$\tau \text{ servod } d = f2 \tag{2}$$

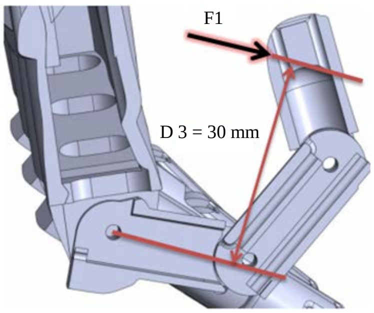

Fig. 5: Forces applied on the index finger (Elsayed, 2015)

$$f2 = 1(N*m)*10\,mm = 10N(\text{tension in the tendon}) \quad (3)$$

f1d1 = f2d2
f1 = (10 N*4.5 mm)/65 mm = 0.70 N
Mass1 = 70 g

This means that by applying a force of 0.70 N to each finger, a mass of 70 g can be lifted; You have to keep in mind that the tips of the fingers, they apply more force as they close more.

When the hand is curved around an object, the forces applied to the index finger are represented as follows Fig. 5. As the perpendicular distance from the requested joint to the knuckle joint is now smaller, the fingertip may apply a greater force.

In this case, each finger can support a mass of approximately 150 g which would give the whole to deliver a lifting/holding capacity of approximately 600 g. max grip of the tip of the finger = 150 grams per finger. The servo has an operating speed of 0.15sec/60°. A complete rotation of the wrist from one palm to the palm position down (180°) therefore takes (0.15/60)*180 = 0.45 sec.

It is then that a tendon must move about 2 cm to move the finger completely extended to fully flexed. Using the formula of the length of the arc Eq. 4:

$$\text{length} = (n°)/(360°)*2\pi r \quad (4)$$

When the length is 2 cm, r is the radius of the custom horns servo (7 mm). We found that the servo should rotate 160 degrees to open/close each finger completely. We find that the maximum time for open/close a finger is (0.15/60)*160 = 0.4 sec (Cirera and Cerio, 2015).

Mioelectric sensors: A myoelectric sensor detects the change of movement in the muscles of the body, to bring them amplified and filtered to the output signal with a voltage of 5 mV, are constituted by a differential amplifier, a stage of filtering noise, a filter passes bands and a resistive capacitive stage for curly voltage filtering,

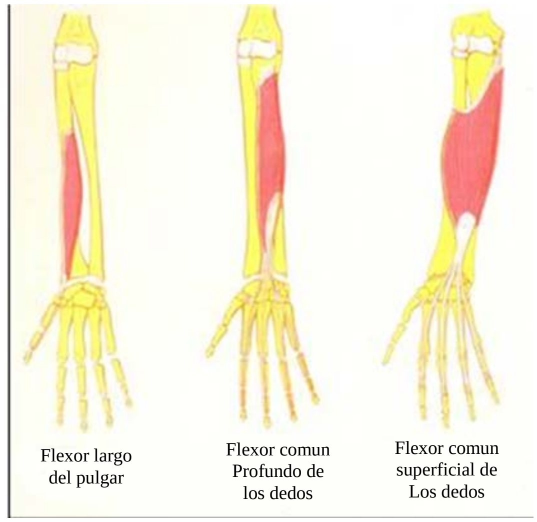

Fig. 6: Location of the myoelectric sensors for each finger

having a DC signal at the output (Mastinu *et al*., 2018). From Fig. 6 it will proceed for laboratory tests to obtain the correctlocation of each finger.

RESULTS AND DISCUSSION

Simulation of the operation of the servomotors in control with the arduino card: A circuit with arduino card is designed which controls five servomotors, where each servomotor controls a finger, the myoelectric sensors are simulated as potentiometers, the switch activates the PC input in parallel with the pushbutton which when the switch is activated, a logical zero is sent to the data receiver input of the card, enabling the option to record within the algorithm built in the software arduino uno In each execution of the button, a new recording of the steps that the servos will execute with the action of the potentiometers is executed. In this initial stage, there is control of the four servos for the four fingers that execute two movements (open and close) while for the thumb soon you will be designing the movements and degrees of freedom of this with respect to the other Fig. 7 and 8.

The program so far, records the movements of the potentiometers and drives the servomotors; this program will be perfected so that the input action of the potentiometers activates the servomotors in microseconds. Why do we use servomotors? Because these can be controlled in speed and position, their movements are generally in a range of 180°, to change the position of the servomotor, a standard pulse of 20 m sec must be applied, so that the servomotor is located in a position of 0°, a pulse of 1 m sec should be applied and 19 m sec between pulse and pulse; to be located at 90 degrees, a pulse of 1.5

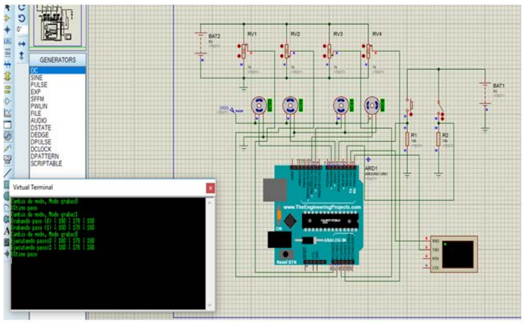

Fig. 7: Electronic circuit of the hand prosthesis

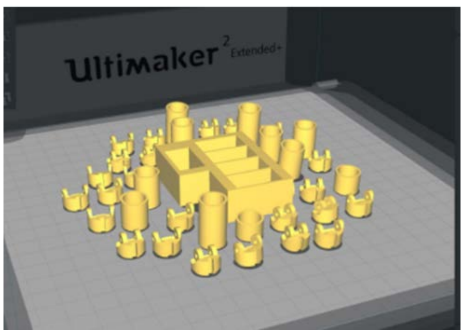

Fig. 8: 3D printing of the hand prosthesis, author Du Nord 3D printing

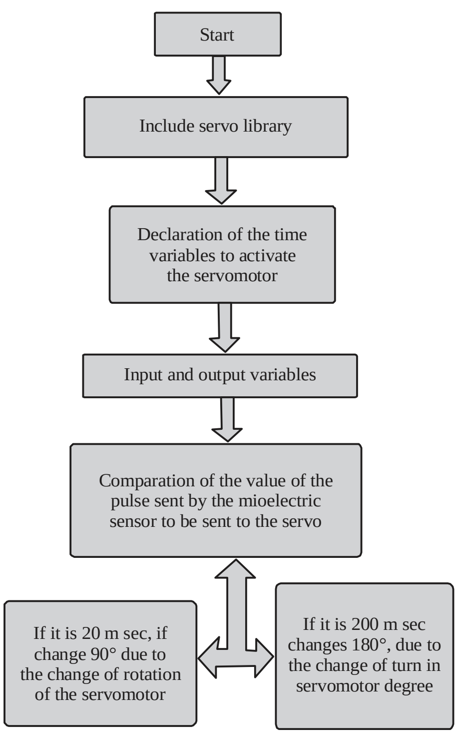

Fig. 9: Flow chart

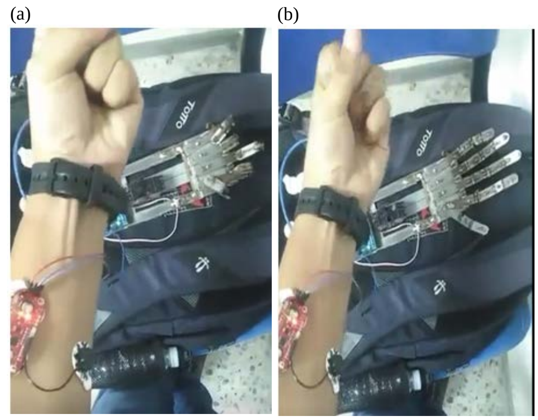

Fig. 10(a, b): Initial prosthesis prototype

msec and 18.5 m sec is applied between pulse and pulse; for the servomotor to be placed at 180°sec, a pulse of 2 m sec and 18 m sec between pulse and pulse must be applied.

3d printing of the hand: Figure 8: 3D printing of the hand prosthesis, author Du Nord 3D printing Fig. 9 and 10.

CONCLUSION

The design has been developed in solidwork for 3D printing of the hand, the algorithm with arduino card has been built and designed for the control of the servomotors, the forces applied to the fingers and their moment of torsion have been obtained. From now on, the kinematics of the robotic prosthesis will be designed, physical tests will be carried out with the servomotors, determining the speed, mobility and adaptability, the algorithm will be modified to obtain faster response from the actuators with respect to the sensors.

RECOMMDETION

So far, we have the prosthesis design for hand in terms of electronic and mechanical system design and simulation of the movement of opening and closing, from this will be the wrist and forearm design, for the analysis of the kinematics of the movement in terms of degrees of freedom; The control algorithm will be built to add degrees of freedom and control of grip types, physical finger-to-finger tests will be performed, an arm prothesis will be designed to the proximal third of the forearm.

Application of controlled prosthesis with myoelectric sensors open and close movement. There is an initial prosthesis prototype which works with a myoelectronic sensor with a servomotor, therefore only makes a movement, open and lose the hand.

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