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Design of a Robust, Ergonomic Myoelectric Handwriting Prosthesis

S. Naffeti[1,*], W. Khadher[1], R. Laabidi[1], I. Chihi[2], T. Rezgui[3]

[1]National Engineering School of Bizerta, University of Carthage, Tunis, Tunisia
[2]Laboratory of energy applications and renewable energy efficiency (LAPER), Faculty of Sciences of Tunis, University of Tunis El Manar, Tunis, Tunisia
[3]Applied Mechanics and Systems Research Laboratory (LASMAP), Tunisia Polytechnic School, University of Carthage, Tunis, Tunisia

[*]Corresponding author. Email address: Sarra.naffeti@enib.u-carthage.tn

Abstract

Myoelectric prosthesis is considered as a powerful solution in solving daily life issues with upper limb amputations, since they're backed by Electromyographic technology which turns muscular activity signals into functional movements. However, picking up these signals requires electrodes attached to the surface corresponding muscles. This presents a lot of problems such as slipping and discomfort, further making positioning the sensors harder. This paper aims to design an adaptive myoelectric prosthesis, specifically dedicated for writing capable to generate handwriting from recorded forearm muscles activities using surface electrodes. It also conserves good signal quality through firm but comfortable and customizable binding to fit the amputated forearm. The proposed Myoelectric prosthesis design allows an intuitive and smooth control of the writing movement while keeping an aesthetic, human-like look.

Keywords: Myoelectric prosthesis, electromyographic, amputation, writing, Myoelectric prosthesis design

1. Introduction

Myoelectric prosthesis is a device that simplifies human life by replacing or reproducing daily human activities such as writing. It is therefore defined as a manipulator designed to move a pen through the muscular contractions generated by the user to set himself in motion (Parker et al, 2006), (Scheme et al, 2010), (Kamavuako et al, 2013), (Chihi et al, 2016,2017) and (Waris et al, 2019).

The functioning of prostheses is generally similar from one prosthesis to another. Electrodes attached in the socket of the prosthesis are in direct contact with the skin. They pick up muscle signals which are sent to control systems of one or more motors placed in the hand. The motors are powered by battery power and trigger the movements of the prosthesis (Clement et al, 2011) and (Chihi et al,2018).

Nevertheless, the functionalities of myoelectric prostheses remain limited. Indeed, there are no prostheses dedicated to writing, so some allow access to few degrees of freedom for users, such as the hand Sensor Speed or the Greifer (Crepin, 2018). Others, such as I-limb Ultra Revolution or Bebionic3 need to be configured to select the desired movements, as well as the number of muscle contractions to be produced to activate one of the pre-recorded movements (Crepin, 2018). These commercial prostheses have the advantage of being very robust and have a relatively simple control system. Despite this, a lack of intuitiveness can be felt very quickly. In addition, the price of the prostheses quickly skyrockets due to the use of very expensive components (Perry et al, 2004), (McNealy and Gard, 2008) and (Clement et al, 2011).

Users are primarily looking for prostheses that best meet their needs in everyday life, as well as prostheses with simple and intuitive control, which allow precise and fast movements.

The main goal of this work is to develop a writing prosthesis, in order to provide a range of useful movements for the user. In addition, emphasis was placed on the need to have a smooth and very intuitive movement prediction for the user. And so, we will have a prosthesis that meets the different requirements of users such as price, aesthetics, resistance and lightness (Clement et al, 2011).

2. Mechanical design of the myoelectric prosthesis

This section aims to present the design of the proposed prosthesis, which is composed of three main parts: the forearm, the palm, and the fingers. This design must take into account certain constraints such as the fixing of the electrodes to have a good quality of the captured electrical signals and the reduction of the cost. For this, we chose DC motor to assure the desired movement. In the present study we are focusing on the handwriting, which can be composed in two movements, the first along the abscissa axis and the second along the ordinate axis.

We added a reducer to the DC motor to increase the output torque. It allows you to modify the speed / torque ratio between the input and output axis of the mechanism. Its advantages are to be economical, space-saving, and to support a large load.

2.1. Description of the mechanism

There are two pulleys at each rotoid connection as illustrated in figure 1: a main pulley and an auxiliary pulley. The cable for actuation is always attached to the distal phalanx and runs along the finger to the base. At each rotoid connection, the cable is passed so that it is between the two pulleys.

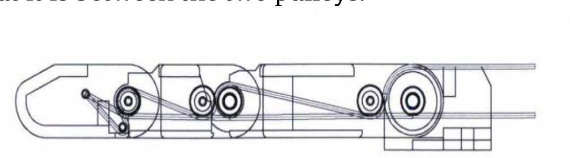

Figure 1. Finger mechanism

2.2. Fingers design

A complete hand model must include the 5 fingers. Despite the variability of handwriting biomechanics, we assumed that only the forceps (index + thumb) are mostly used to maintain the pen and achieve the movement of writing, the other 3 fingers can be considered inactive. For this, only these two fingers were modeled and articulated, and the others can be closed and opened manually. The index finger has 3 phalanges, while the thumb has only 2 phalanges, about the same size as a human finger.

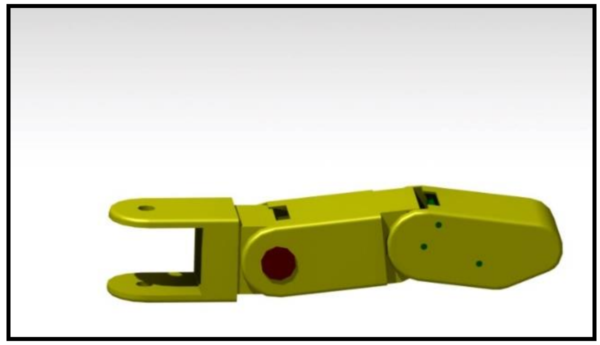

Figure 2: Thumb model

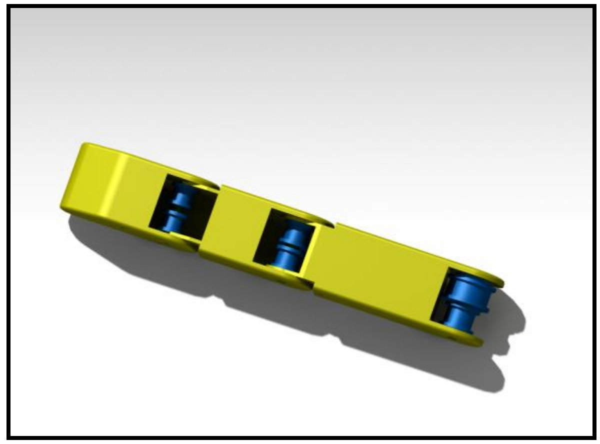

Figure 3: Top view of the index

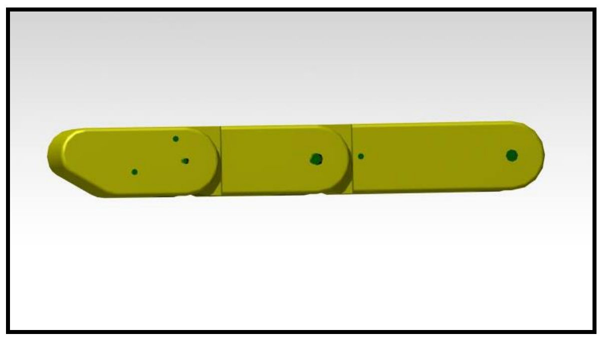

Figure 4: Right view of the index

2.3. The Palm designs

The main part of the prosthesis constitutes the palm, since it is the one that gives it good mechanical resistance and it is on it that practically all the components are fixed.

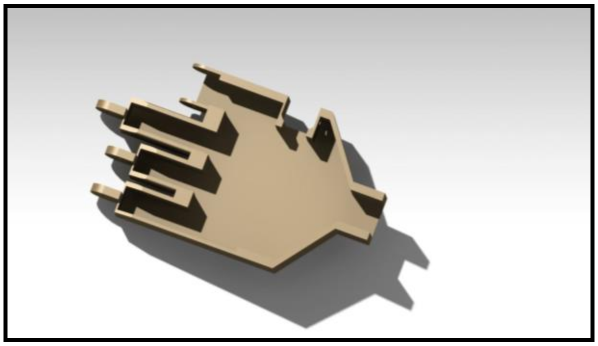

Figure 5: CAD model of the palm

We started by assembling the palm and fingers, as shown in the following figure

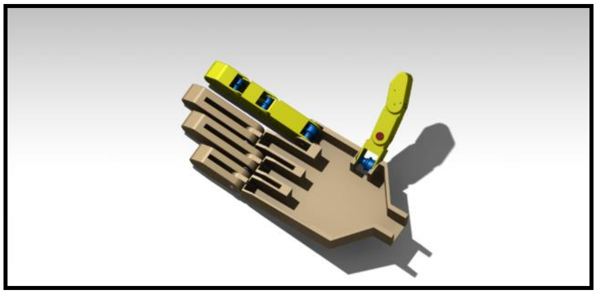

Figure 6: Assembling the palm and fingers

2.4. The forearm designs

The forearm in our prosthesis is modelled in the form of a socket which is a very important element of the prosthesis since it is the part in direct contact with the amputee which makes it possible to link the prosthesis to the residual limb.

This socket consists of three parts:

- Electronic support: this support includes all the necessary electronic elements like the engine, the electronic card, the reducer and the battery (figure 7). Thanks to the latter, the motor performs the requested movement.

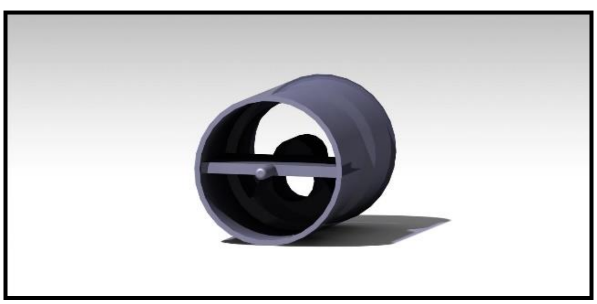

Figure 7: CAD model of the electronic support

- Coupling: this part allows to transmit the engine torque to the wrist, with a mechanism for fixing the latter to the coupling so as to unlock the wrist without letting go of the coupling (Figure 8).

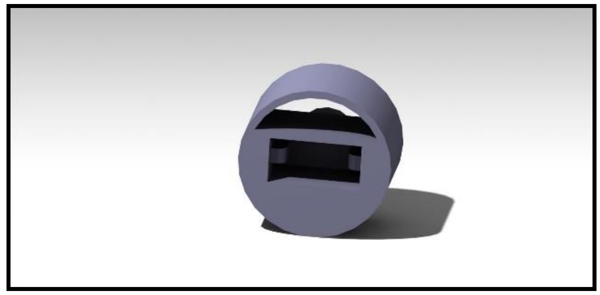

Figure 8: CAD model of the coupling

- Socket: This cylindric form makes possible to connect the electronic part with the residual member (figure 9). It also includes the electrodes which are placed in contact with the skin. This part is fixed by rods wound by scratches (Figure 10).

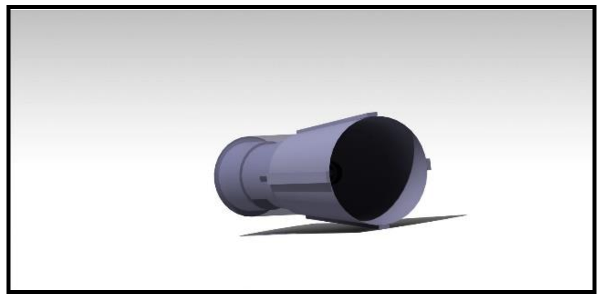

Figure 9. CAD model of the socket

Figure 10: Fixing solution

2.5. Final design

We were, therefore, able to bring together all the components necessary for the myoelectric prosthesis. Figure 11 represents the final assembly of our prosthesis.

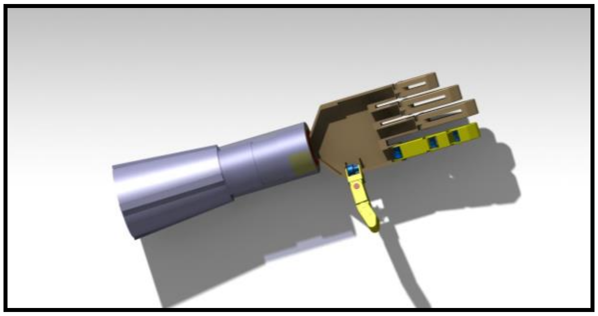

Figure 11: CAD model of the final solution

3. Conclusion

As primary study and promising approach, we developed a design for a hand prosthesis dedicating to writing, developing such specific product could seem economically unviable. Furthermore, prosthesis dedicated only to writing are almost absent from previous research work. While this could infer novelty to our work, it gives little to no guarantee to our design's relevance Despite the fact that our design had to go through a lot of compromises, namely between customization and aesthetics, further advance researches into this field are necessary to lead. First, in order to improve the writing model's precision, understanding the neuromechanics of finger movements during writing through neuromusculoskeletal modeling seems an intriguing approach (Alloush 2015, Mirakhorlo 2018). The quantification of required grip pen's force and involved muscle forces will ameliorate the choice of the actuation's systems to avoid inappropriate muscle force production or in the fingers. Second, appropriate materials and optimized designs could be introduced, namely for the part binding the prosthesis to the arm, since these two require deeper research of their own. Finally, the ergonomics and the customization of the prosthesis should be further studied and validated, due to the lack of patients in the testing phase.

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