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A NEW DESIGN OF LOW COST MYOELECTRIC ARM PROSTHESIS

BY

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Abstract. In recent years, the increase in the number of accidents, chronic diseases, such as diabetes, and the impoverishment of certain developing countries have contributed to a significant increase in prosthesis users. The loss of a particular limb entails numerous changes in the daily life of each user. Therefore, replacing the hand is an urgent necessity. Developing lower arm prostheses will allow the re-establishment of the physical and motor functions reducing the rates of depression. Therefore, the prosthetic industry has been reinventing itself. It is possible to control a prosthesis through the user's myoelectric signals, control known as pattern recognition control. Also, additive manufacturing technologies have gained strength in prosthetics. This type of technology allows the product to reach the user much faster and reduces the weight of the devices. In this article we present a new 3D printed solution which solve the problems of price and the weight.

Keywords: design, 3D printing, prosthesis, cost, myoelectric.

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1. Introduction

The hand movements are performed on the wrist joint. This joint can be flexed and extended along the perpendicular plane to the palm up to about an 80 to 70 degree angle, respectively, Fig. 1. Hand flexion allows the closing of the digital chain, which promotes hand closing. The extension, on the other side, induces the opening of the hand. Phalanges flexion and extension take place around a transverse axis, which passes at the level of the proximal and distal interphalangeal joints (Cordella *et al.*, 2016). The proximal interphalangeal joint does not perform flexion and extension at all. The adduction and abduction movements are performed on the axis of the hand. While the abduction movement makes the fingers move away from the hand axis, the adduction one brings the fingers closer to the hand axis. These movements are performed during the digital extension movement (Saladin, 2008; Seeley *et al.*, 2005).

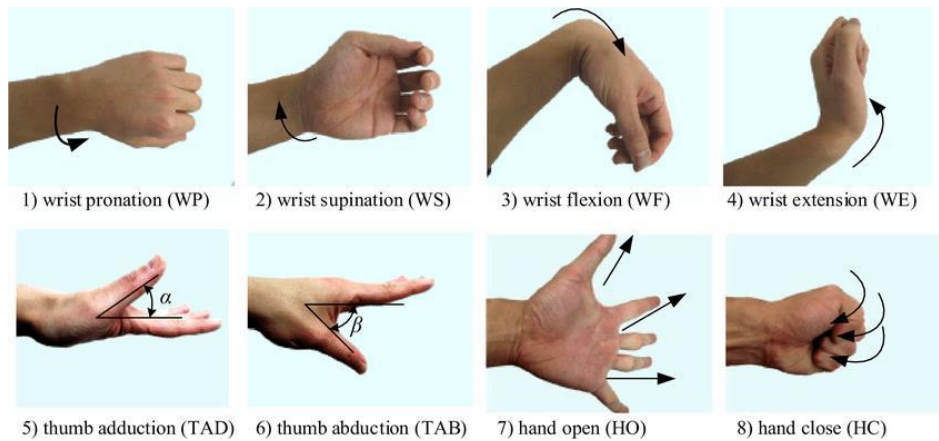


Fig. 1 – Wrist movements (1-4), thumb movements (5,6), basic movements (7,8) (Yang *et al.*, 2019).

Digital grips use two or more fingers to hold an object without the aid of the palm (Yang *et al.*, 2019). Grasping movements are the most precise ones (Fig. 2). The hand starts opening with the fingers' extension and abduction to capture the object. Then, the hand closes through the action of the fingers' flexor muscles and the thumb adductor muscle. The digital grip is a precise movement. The fingers' position is achieved by fixing the wrist, the metacarpophalangeal and interphalangeal joints. Finally, the object is fixed with the thumb opposition and the second and third fingers flexion (Sha'at *et al.*, 2024).

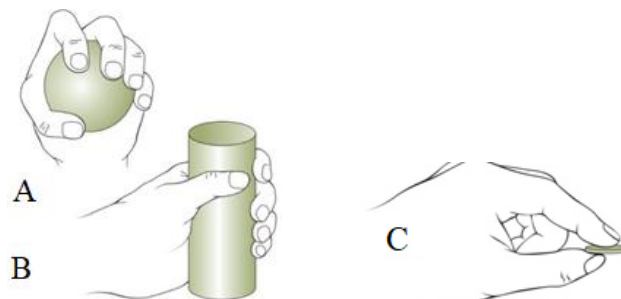


Fig. 2 – Grasp Movements: A- Spherical Grip, B- Cylindrical Grip, C- Tripod Grip (Cech and Martin, 2012).

The upper limb prostheses can be categorized into passive prostheses and active prostheses (Gaine *et al.*, 1997). Passive prostheses are divided into two groups: static and dynamic prostheses. While the fixed prostheses only serve for aesthetic purposes, the dynamic ones allow the patient to grab some objects since they are controlled by internal mechanisms (Li *et al.*, 2018; Maat *et al.*, 2018). Active prostheses perform grasping movements because they are controlled by internal mechanisms. Those mechanisms can be electric actuators or corporal cables. Body-powered prostheses depend a lot on the user, which means that the user has to perform auxiliary movements to promote prostheses movement. Conversely, electrical prostheses do not require any movements from the patient (Li *et al.*, 2018; Maat *et al.*, 2018).

Passive prostheses are the most competitive prostheses in the market due to their low price. For this reason, these prostheses are sought by one-third of the users (Maat *et al.*, 2018). These prosthetic devices have some postural benefits since they restore the body's symmetry, particularly when the user has proximal amputations. These prostheses are usually made of flexible latex, rigid plastic materials or silicone. However, this type of prosthesis is manufactured for cosmetic purposes and therefore does not meet the functional needs of the users. The WILMER Passive Hand Prosthesis (Fig. 3) enables the user to perform some movements because it includes a functional hook (Watve *et al.*, 2011).



Fig. 3 – WILMER Passive Hand Prosthesis by TU Delft.

Body-powered prostheses operate through active hands and operational cables, which move through body movement (Watve *et al.*, 2011). Some of these prostheses, mainly the recent ones, are produced using 3D printing technology. As already mentioned, body-powered prostheses are devices dependent on their user. Therefore, non-elastic cables, which have the same function as the flexors, are connected to a healthy part of the residual limb (elbow or hand). As a result, the movement of the prosthesis structure will depend on the flexion of the healthy structures. Elastic cords and a combination of materials that provide phalanges resistance are used to perform the extensors functions. Body-powered prostheses are reliable devices that can be used in work and dusty environments. For this reason, they are often preferable for workers with outdoor jobs. However, these devices are mechanically inefficient. In most cases, users cannot perform muscular prehensile strength with body-powered prostheses. Raptor Hand (Fig. 4) is a 3D prosthesis composed of a modular tension system that contains elastic and nylon wires. The flexion movement is accompanied by the wrist flexion and the closing movement of the fingers.



Fig. 4 – Raptor Hand.

The Cyborg Beast has 1.5 mm elastic Velcro strings on the dorsal surface of the fingers that allow the passive extension of the finger (Fig. 5). Conversely, the flexion movement is performed by 1 mm non-elastic nylon strands. These strings are placed along the palmar surface of each finger. The materials used were Polylactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS).



Fig. 5 – Limbitless Arm.

Myoelectric prostheses belong to electrical prostheses, which means that they have motors and microcontrollers as well. The received input is the amplitude of the myoelectric signals, which results from muscle activation. Once detected by the surface electrodes, the signals need to be amplified and filtered. The resulting output activates the prosthesis, exercising an autonomous and robust control (Manero *et al.*, 2019). Besides that, these prostheses have more than two degrees of freedom, which is why they are preferable for daily activities. These devices are also noisy due to external factors like fatigue, sweat and external pressures. The residual tissue of the stump and the environment during EMG acquisition increase the noise as well. These types of parameters will increase the response time of the prosthesis and make it move slower. At a mechanical level, the existence of frictional forces on the control cable is decisive for the relationship between the control movement and the movement of the final effector. Despite the overall limitation, there are many industries producing myoelectric prosthetic devices.

The BeBionic hand (Fig. 6) is a top product by Ottobock. It is a comfortable, intuitive and precise hand with fourteen different grip patterns and hand movements. The performance of the individual motors of each finger allows a natural and coordinated movement. This prosthesis has a proportional control that regulates the speed through the strength of the muscles. This prosthesis was designed with engines that optimize the weight distribution, which gives some comfort to the user. An integrated sensor is attached to the hand since it allows varied movements and different thumb positions. The BeBionic includes software and wireless technology that allows the user to customize the available functions according to their lifestyle. The materials chosen for its construction are strong enough to support up to 45kg. The innovative palm design protects the prosthesis from impacts and physical damage and helps to reduce noise.



Fig. 6 – Be-Bionic Arm by Ottobock.

Michelangelo's hand (Fig. 7) is an Ottobock product. This hand has specific characteristics when it comes to finger's control. While a servomotor

controls the thumb, the first and the second fingers, the third and fourth fingers move passively. Multiaxial movement patterns minimize unilateral compensation movements performed by the patient maintaining the body's natural posture. When the prosthesis is activated, it is possible to choose three positioning modes that allow seven different grips. However, as soon as the prosthesis is no longer in use, it returns to its resting position. The material that makes up the fingers is lightweight but resistant, which confers a high precision during the grasping process to the prosthesis. The patient can also choose to use a silicone glove that gives it a more natural look (** Ottobock, Michelangelo Prosthetics).



Fig. 7 – Michelangelo's hand by Ottobock UK.

Myo Plus Prosthesis (Fig. 8), is one of the most recent Ottobock products. It is a myoelectric prosthesis controlled by pattern recognition-based methods. This prosthesis has the extraordinary capacity to learn and interpret the individual movement patterns of the user, through the use of the MyoPlus App. This intuitive control enables the users to adapt their prostheses to their individual needs. However, this prosthesis is not ideal or recommended for daily activities (** Ottobock, Myo Plus).



Fig. 8 – MyoPlus Prosthesis by Ottobock UK.

These devices are controlled essentially by proportional control. This control uses the myoelectric signal of the user to control the speed of the

prosthesis. Therefore, it is possible to conclude that the use of myoelectric signals as a natural control source has brought numerous advantages, mainly because it can be used in commercial devices. Besides that, the use of myoelectric prostheses is becoming more natural. However, there is still a gap between the operational control and the natural appearance of the human hand. The operational control is still slow and, unfortunately, mobile apps control the more complex movements. Besides that, these prostheses are the most expensive prostheses on the market, which means that only some users have access to them. Therefore, it is essential to study the electrical signals for a better understanding of such controller mechanisms. The market price of the myoelectric prostheses is high, between 21000 € and 64000 €.

The lower arm prosthesis that we develop eliminates all the negative aspects presented until now. In the following we present the new solution.

2. New Design of the Lower Arm Prosthesis

The design of the components was a real challenge due to the problems that arose throughout the project. From the illusion of a perfect assembly to the appearance of unjustified inflection points. But the real challenge was to create a prosthesis with human shapes and characteristics. Below are a series of images related to the assembly, parts and components of the prosthesis. In Fig. 9 we present the kinematics of finger movement are presented, showing finger extension and flexion, maximum and minimum position.

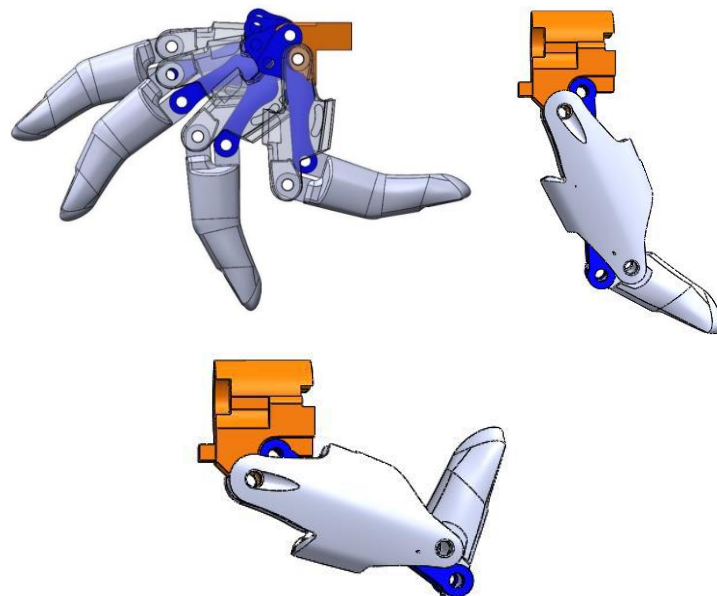


Fig. 9 – View of various finger positions during movement.

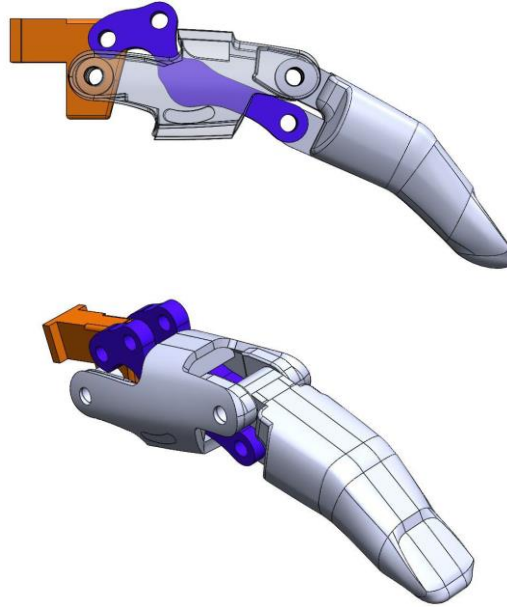


Fig. 10 – The assembly of the ring finger.

In Fig. 10 we present the assembly of the ring finger, the coloured are levers that ensure the transmission of movement.

The assembly plate that acts as the main assembly, Fig. 11. All the designed components are mounted on it. The plate has holes for fixing the forearm, the upper housing and the lower housing. T-shaped and L-shaped channels are used for mounting the fingers. The extruded circle in the lower area acts as an axis on which the thumbs are mounted.

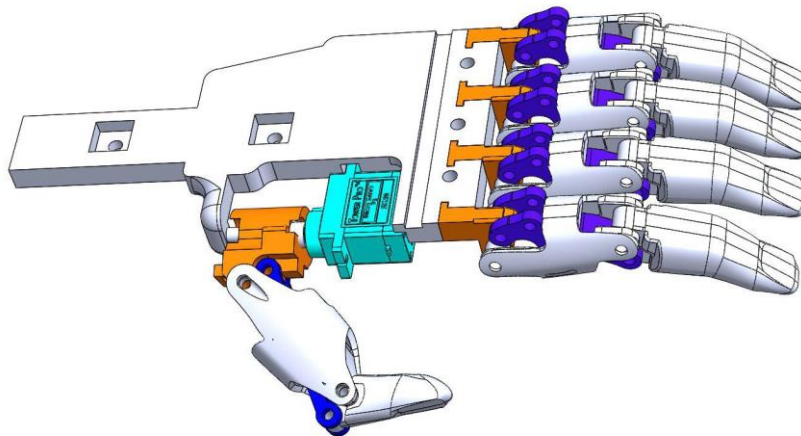


Fig. 11 – The assembly plate with the fingers mounted.

Fig. 12 shows the bulk of the assembly, an overview of all the components mentioned above to achieve the extension and flexion movements of the 4 fingers and the combined movement of finger no. 5 or thumb. By assembling these components we can perform both virtual and real simulations of the mentioned movements. This assembly can give us the opportunity to detect design defects, in order to be able to fix them later.

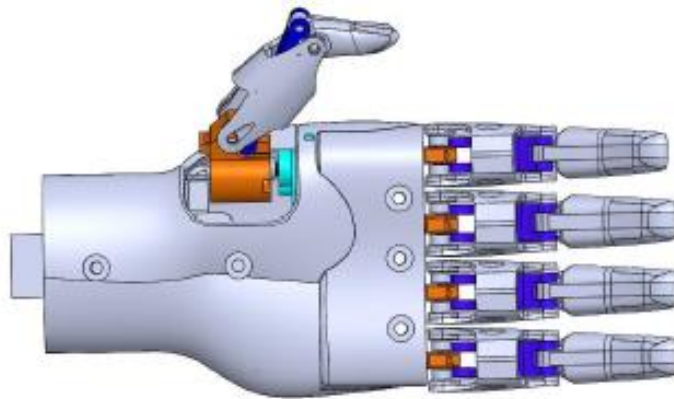


Fig. 12 – Assembly of the hand prosthesis.

The component called the lower arm is shown in Fig. 13. Each color illustrates the assembly of certain components:

- ☐ yellow – mounting the main component
- ☐ orange – mounting the Arduino Pro Micro processor
- ☐ blue – mounting the PCB with the role of connecting the electrical circuits
- ☐ green – mounting the voltage regulator
- ☐ black – mounting the battery

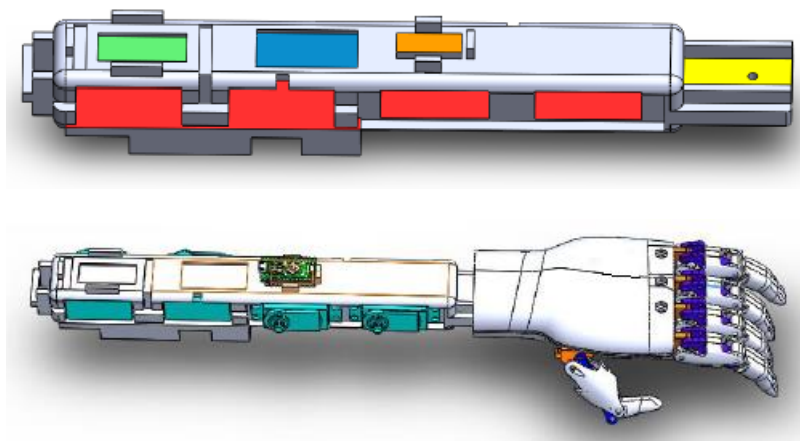


Fig. 13 – Lower arm prosthesis.

The intersection curves generated by the intersection of these planes and the STL model represent the paths along which the extrusion nozzle will deposit the materials for the object and the support structure. The SML (Stratasys Machine Language) file, which contains the extrusion head paths, is then sent to the machine by the transfer software. The preprocessing software is Stratasys Fortus Insight 10.4, for generating the extrusion paths, the thickness of the model material layers (the final part) and the support material (the filler material that will be used to fill the gaps in the final part, which will later be removed) (Munteanu *et al.*, 2021).

[illegible]

The following components were used to operate the prosthesis: Servo MG996R, sensor EMG MyWare, Servo SG90. For programming was use a board Arduino Pro Mini, Fig. 15.

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3. Conclusions

As a main characteristic of the new design of the prosthesis is the cost price which is minimal from the myoelectric type point of view. The price is between 300 € and 500 €. This price make indicate that we obtain a low price prosthesis and is fulfilled one of the main task considering that the demand for prosthesis is mainly manifested in poor countries. The second characteristic would be that the prosthesis should provide as many tasks as possible and these should be controlled by myoelectric sensors.

The solution described in the paper comes to respond to those mentioned previously, having a simple design, with 3D printed parts that are easy to replace in case of malfunctions.

REFERENCES

- Cech D. J., Martin S., *Prehension*, in Functional Movement Development, 2012, pp. 309–334.
- Cordella F., Ciancio A.L., Sacchetti R., Davalli A., Cutti A.G., Guglielmelli E., Zollo L., *Literature review on needs of upper limb prosthesis users*, Front. Neurosci., 10, 1–14, 2016, doi.org/10.3389/fnins.2016.00209.
- Dumitras C.G., Chitariu D.F., Chifan Fl., Lates C.G, Horodincea M. *Surface quality optimization in micromachining with cutting tool having regular constructive geometry*, Micromachines 13(3), 422; 2022, https://doi.org/10.3390/mi13030422.
- Gainé W.J., Smart C., Bransby-Zachary M., *Upper limb traumatic amputees: Review of prosthetic use*, J. Hand Surg. Eur. Vol22, Issue 1, 1997, doi.org/10.1016/S0266-7681(97)8002.
- Li C., Ren J., Huang H.B., Zhu Y., Hu H., *PCA and deep learning based myoelectric Wang grasping control of a prosthetic hand*, Biomed. Eng. Online, vol. 17, no. 107, pp. 1–18, 2018, doi.org/10.1186/s12938-018-0539-8.
- Maat B., Smit G., Plettenburg D., Breedveld P., *Passive prosthetic hands and tools: A literature review*, Prosthet. Orthot. Int., 42(1), 66-74, 2018, doi 10.1177/0309364617691622.
- Manero A. et al., *Implementation of 3D printing technology in the field of prosthetics: Past, present, and future*, Int. J. Environ. Res. Public Health, vol. 16, pp. 1–15, 2019, doi.org/10.3390/ijerph16091641.
- Munteanu A., Chitariu D.F, Horodincea M., Dumitras C.G, Negoescu F., Savin A., Chifan F., *A Study on the Errors Of 2d Circular Trajectories Generated on a 3d Printer*, Appl. Sci. 11(24), 11695, 2021, DOI.10.3390/APP112411695.
- Saladin K. S., *Human Anatomy 5th*, Second Edi. McGraw-Hill International, 2008.
- Sha'at M., Ignat M., Sacarescu M., Spac A.F., Barsan Al., Ghizdovat V., Nazaretian E., Dumitras C.G., Agop M., Rusu C., Ochiuz L., *Multifractal analysis and experimental evaluation of MCM-48 mesoporous silica as a drug delivery system for metformin hydrochloride*, Biomedicines, 12(12), 2838; 2024, https://doi.org/10.3390/biomedicines12122838.

- Seeley R.R., Stephens T.D., Tate P., *Anatomia e fisiologia – Seeley*, 2005.
- Watve S., Dodd G., MacDonald R., Stoppard E.R., *Upper limb prosthetic rehabilitation*, Orthop. Trauma, vol. 25, no. 2, pp. 135–142, 2011, DOI:10.1016/j.morth.2010.10.003.
- Yang D., Gu Y., Thakor N.V., Liu H., *Improving the functionality, robustness, and adaptability of myoelectric control for dexterous motion restoration*, Experimental Brain Research. Vol. 237, 291-311, 2019, doi.org/10.1007/s00221-018-5441-x.
- * * Ottobock company, ‘Myo Plus TR’. [Online]. Available: <https://www.ottobock.com/en-us/product/13E520-61077> [Accessed: 7-May-2026].
- * * Ottobock Company, ‘Michelangelo Prosthetic Hand’. [Online]. Available: <https://www.ottobock.com/prosthetics/upper-limb-prosthetics/solution-overview/michelangelo-prosthetic-hand/> [Accessed: 7-May-2026].

UN NOU DESIGN DE PROTEZĂ DE BRAȚ MIOELECTRICĂ CU COST REDUS

(Rezumat)

În ultimii ani, creșterea numărului de accidente, boli cronice, precum diabetul, și sărăcirea anumitor țări în curs de dezvoltare au contribuit la o creștere semnificativă a numărului de utilizatori de proteze. Pierderea unui anumit membru implică numeroase schimbări în viața de zi cu zi a fiecărui utilizator. Prin urmare, înlocuirea mâinii este o necesitate urgentă. Dezvoltarea protezelor pentru partea inferioară a brațului va permite restabilirea funcțiilor fizice și motorii, reducând ratele de depresie. Din acest motiv, industria protezelor se reinventează. Este posibil să se controleze o proteză prin intermediul semnalelor mioelectrice ale utilizatorului, control cunoscut sub numele de control al recunoașterii tiparelor. De asemenea, tehnologiile de fabricație aditivă au câștigat teren în domeniul protezelor. Acest tip de tehnologie permite produsului să ajungă mult mai rapid la utilizator și reduce greutatea dispozitivelor. În acest articol, prezentăm o nouă soluție imprimată 3D care rezolvă problemele de preț și greutate.