

A BIOMECHATRONIC APPLICATION ON PROSTHETICS FOR UNDERGRADUATE ENGINEERING STUDENTS

Faruk ORTES

Department of Mechanical Engineering, Faculty of Engineering, Istanbul University

Hasan Kemal SURMEN

Department of Automotive Technology, Vocational School of Technical Sciences, Istanbul University

Yunus Ziya ARSLAN

Department of Mechanical Engineering, Faculty of Engineering, Istanbul University

ABSTRACT: Human hand prosthetics imply a great challenge to researchers to help regaining the lost motor functions for amputated people. A relatively high amount of labor and budget are required to reach the ordinary prosthetics for amputees. Improvement of assistive technologies has provided to design and manufacture more functional hand prosthetics. Novel tools employed in assistive technology including 3-dimensional printers and user-friendly electronics complementary devices have made a great contribution to prosthetics area with fast and cost effective solutions. Although a significant development of technical facilities has been occurred, prosthetic hands with high functionality could not gain wide currency since the manufacturing and design processes require more educated engineers and biomechanicists. Introducing the design and manufacturing steps of prosthetics for educational purposes in engineering and life sciences could be very effective in order to ease accessing the more functional prosthetics and to increase the prevalence of use. Education of new methodology and devices provides crucial opportunities to enhance the ability and usage of new generation prosthetics. In this study, a prosthetic hand design, control and manufacturing implementations were carried out by undergraduate students in the context of dissertation study. The custom based human hand prosthetics was manufactured according to following steps. Three-dimensional CAD models of prosthetic hand components including palm and fingers were designed in a solid body modeling software. Then, the model parts were printed using 3-D printers and they were assembled. The forces were transmitted to the fingers via elastic strings which were controlled via Arduino controlled servo motor. The programmable motions of servo motors enable to direct control of fingers. Specific education on design, manufacturing and control of human prosthetics has the potential to provide a high impact on obtaining more functional and cost effective prosthetics which enables more people to regain their lost motor patterns.

Key words: Assistive technologies, human hand prosthetics, science and engineering education

INTRODUCTION

Lower limb amputation of human arm represents an important limitation of individuals who survived from partially losing their limbs. Amputated people are exposed to various difficulties in performing many daily life activities. Basically, human hand, which is a critical part of human body, enables to carry out vital motor tasks. Scientific and technological resolution about amputation to regain lost functions of human hand focused on the design and production of prosthetics. Human hand prosthetics are designed and manufactured not only for cosmetics reason, but also contribution to perform lost functions. Prosthetics, which are complementary tools for amputated people, is a kind of assistive technology. Rapid advancements in technology and science affect the production process of prosthesis. By means of new technological facilities, the new generation prosthetics are more functional and able to response to more requirements of patients. 3-dimensional printing technology and electronics devices have contributed to developments of prostheses in terms of fast and cost effective prosthetics production. Several attempts have been made to improve human hand prosthetics [1, 5]. The studies have documented that design and control of prosthetics are critical issues for these assistive devices. Development of technical facilities could enable to reach more functional and precisely controllable prostheses by improving design and manufacturing processes that are employed up to date. In addition to this, introducing and teaching the technical aspects of the novel devices and methodologies could provide an easy access to the more functional prosthetics and to increase the usage rate.

One of the newly developed methods to obtain prototype of models is 3-dimensional (3D) printing technology. There are numerous studies about biomechanical applications of 3D printing method which is based layer by layer production with additive materials [6, 10]. Therefore, this novel method has a great potential to contribute prosthetics production area which requires light and cost effective components.

Another important subject needed to be highlighted is the model library of *Enabling The Future* community [11]. The community includes a group of people from various disciplines and populations would expect different aims and performance from the prosthetics devices. It is also aimed to spread production and using new generation prosthetics benefiting from 3D printer devices. The library, which includes the models of human hand prosthetics from different design perspectives, allows people to improve available designs or to create another one.

In this study, it is aimed to produce a prosthetics hand for educational purposes to make undergraduate students be able to produce prosthetics components. One of the main objects of the study was to use 3D printing technology aiming to provide some functional requirements such as light in weight, easy to produce and labor and cost effectiveness.

METHODS

In order to produce the human arm prosthetics and also to control the entire model, the necessary procedures could be classified as design, printing, assembly and control stages. The details of all work steps are given below.

Design of Components

The components of the prosthetics, which allow individuals to grasp or hold an object, could be designed by according to a wide range of criteria. Therefore, there are many designs for prosthetics limb components in use. In the study, although the elements of human hand prosthetics could be designed specifically in the first step as a self-contained study, a model, namely the raptor hand, was obtained from the model library of the *Enabling The Future* initiative to reduce cost, time and labor expenses. Then, the model taken from the library was imported to a CAD software. The CAD software, which is able to import the (stl) files, is a beneficial tool to monitor the design and observe all the components with detail. The components of the raptor hand model were shown in *Fig. 1*.

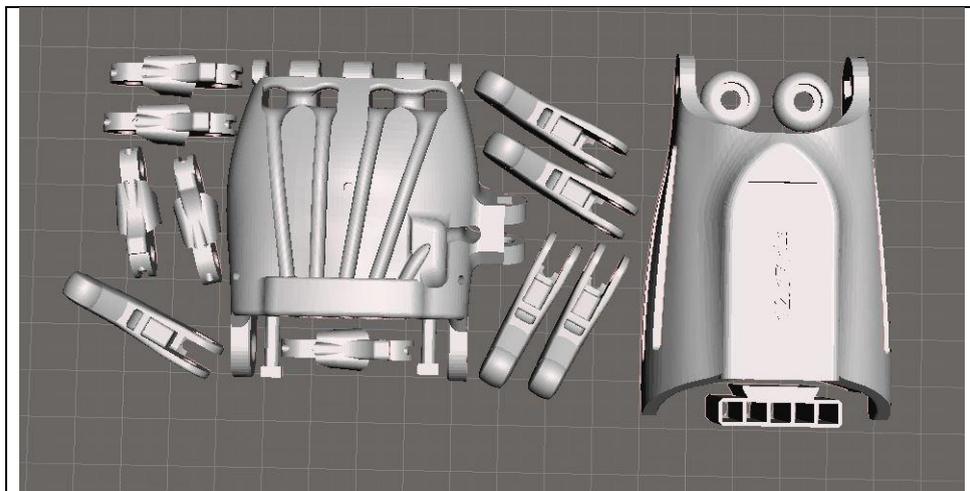


Figure 1. The components of the raptor hand model

Printing Process

Printing process is a critical section of the study. Surfaces of the model components should have a good quality and the material fed into the 3D printer's nozzle should satisfy desired functional requirements, such as flexibility and formability. In this study, printing material was chosen as PLA (Polylactic Acid) which is widely used for educational, medical and engineering purposes. All components were printed using 3D printing device (Ultimaker 2 Extended, Netherlands).

Assembly of Parts

Printed components of human hand prosthetics model was engaged to each other, so that the whole model could be obtained. Palm, joints, fingers and fishing lines are the components of the model and shown in *Fig. 2*.

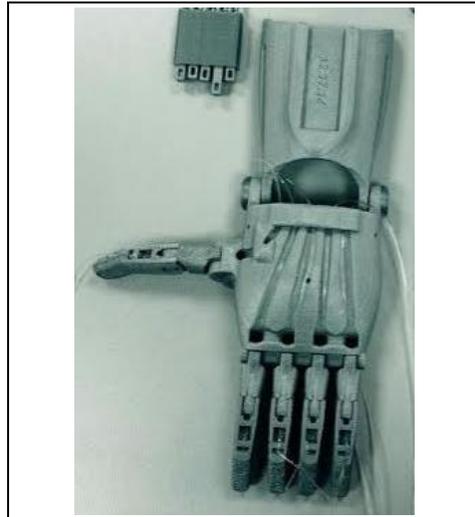


Figure 2. The entire prosthetics model

Control of Prosthetics

Control process is still one of the most challenged issues in the prosthetics area. The main objective of the studies in the literature is to reach dexterous and intuitive control of these artificial hands. However, the amputation level and the limited capability of existing electronic devices, which are used currently in prosthetics, are important barriers for researchers. In this study, the control of prosthetics was carried out by both passive and active approaches. If the subject uses his/her residual limb to move the fingers, the control is called as passive (*Fig. 3a*). However, if the servo motors and electronic circuits based system provides motion of fingers and the whole components of prosthetics, this kind of control is named as active (*Fig. 3b*). For both of the control methods, fishing lines were used to transmit the force and to manipulate the fingers. Additionally, two servo motors and an Arduino Card that is used to drive motors were employed to execute limbs motions in active control.

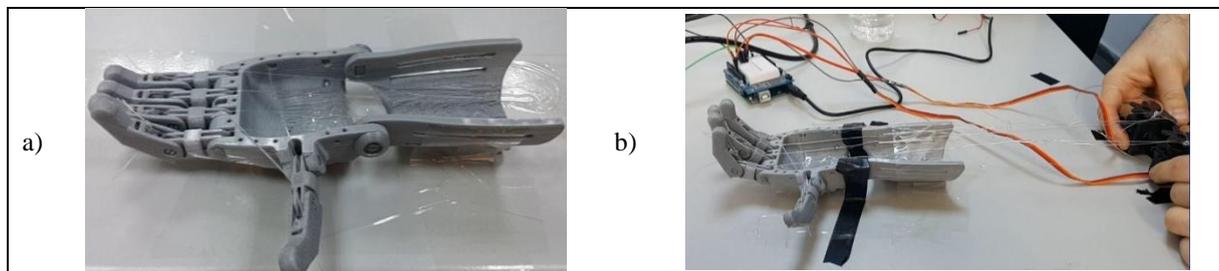


Figure 3. The control types of prosthetics; a) passive and b) active control

RESULTS AND FINDINGS

In this study, the design, production, assembly and control steps of new generation prosthetics are presented and discussed. Moreover, a prosthetics hand was produced using a 3D printer device and could be controlled by means of complementary electronic devices such as servo motors and Arduino card. The control was also implemented both actively and passively. Moreover, it was shown that the obtained prosthetics has the potential to provide similar characteristics to the new generation models in terms of weight and control capability. Additionally, the models enable the operator to modify all the system, if necessary. The components of models can be independently modified. As a result of the study, a tutorial, which includes the design, production, assembly and control steps, was provided for undergraduate students to build their own projects.

The study also contributes to understanding of the effects of technological advances on assistive devices' design and production considerations. The facilities of novel methods such as 3D printing method involving limb components productions promises to reach lighter and cheaper prosthetics designs.

The limitations of the study are the delay in the active control and low surface quality of components obtained from 3D printer device. Future studies about prosthetics should take into account these crucial concerns.

CONCLUSION

Human hand prosthetics, which are devices to compensate the lost functions of amputated people, was produced benefiting from a novel technological facility such as 3D printers. The study includes the procedures for undergraduate engineering students to design and produce prosthetics. It was also shown that the success of the prosthetics design was firmly related to technological improvements.

REFERENCES

- Kyberd, P. J. & Evans, M. & Winkel, S. (1998). An Intelligent Anthropomorphic Hand with Automatic Grasp. *Robotica*, Vol.16, pp 531-536.
- Carrozza, M. C. & Cappiello, G. & Micera, S. & Edin, B. B. & Beccai, L. & Cipriani, C. (2006). Design of a cybernetic hand for perception and action. *Biol. Cybern.*, vol. 95, no. 6, pp. 629–644.
- Touch Bionics Inc., “www.touchbionics.com,” 2009.
- DEKA Research and Development Corp., www.dekaresearch.com, 2008.
- Zecca, M. & Micera, S. & Carrozza, M. C. & Dario, P. (2002). Control of multifunctional prosthetic hands by processing the electromyographic signal. *Critical Reviews in Biomedical Engineering*, vol. 30, no. 4–6, pp. 459–485.
- Peltola, S.M. & Melchels, F. P. W. & Grijpma, D. W. , & Kellomäki M. (2008). A review of rapid prototyping techniques for tissue engineering purposes. *Ann Med* 40:268–280.
- Yeong, W. Y. & Chua, C. K. & Leong, K. F. & Chandrasekaran, M. (2004). Rapid prototyping in tissue engineering: challenges and potential. *Trends Biotechnol.* 22, 643–652.
- Lantada, A. D. & Morgado, P. L. (2012). Rapid prototyping for biomedical engineering: current capabilities and challenges. *Annu. Rev. bioeng.* 14, 73–96.
- Subburaj, K. & Nair, C. & Rajesh, S. & Meshram, S. & Ravi, B. (2007). Rapid development of auricular prosthesis using CAD and rapid proto- typing technologies. *Int J Oral Maxillofac Surg* 36:938–943.
- Lee, M. & Chang, C. & Ku, Y. (2008). New layer-based imaging and rapid prototyping techniques for computer-aided design and manufacture of custom dental restoration. *J Med Eng Technol* 32:83–90.
- <http://enablingthefuture.org/>