Research on Multiple Control Methods for Bionic Hands

Haolun Jiang*

Qingdao No.2 Middle School, Qingdao, Shandong Province, China, 266061

ABSTRACT: With the continuous development of society, the demand of patients for highly accurate and intelligent bionic hands has been increasing, and the control of bionic hands has been greatly improved at this stage, but it is still lacking in precision and sensitivity, and the manufacturing cost is also high. This paper focuses on the most mainstream research on various control methods for bionic hand, lists the specific advantages and disadvantages of different control methods by reading the literature, summarizing and comparing them, and making an in-depth prediction on the future development of the bionic hand. In conclusion, the control mode of the bionic hand still needs to be further studied and combined with different control modes to solve existing problems.

1. INTRODUCTION

The bionic hand is a machine that controls or replaces the human hand using bioelectrical signals generated by processing to control the activities of individual limbs in order to perform the basic functions of the human hand and interact with the external environment. [1] With the development of time, transportation, population growth and natural disasters, the number of people with disabilities is increasing in every country, and the proportion of physical disabilities is the highest among all types of disabilities. Among all prostheses, the use of smart prostheses is becoming more and more popular among people with physical disabilities for the sake of aesthetics and the requirement of basic life functions, which are more comfortable to wear and have a wider range of applications than traditional prostheses. Therefore, the development of this rehabilitation device has very high social importance and excellent economic prospects. However, the international bionic hand is still facing a lot of problems, and even the best-selling bionic hand of the world's most prestigious Otto bock company is still only a single degree of freedom, lacking flexibility and practicality. [2] Therefore, in recent years, the design and use of intelligent bionic hands have become the focus of academic research in the world. In this paper, the author summarizes various control methods for controlling bionic hands, and also makes an in-depth prospect of the development of intelligent bionic hands.

2. BIONIC HAND INTRODUCTION

The bionic hand was first developed in 1963 to help children suffering from the effects of the sedative-hypnotic drug Saridolamine. m The bionic hand structure usually consists of a thumb mechanism, a four-finger mechanism, and a palm mechanism. The four-finger mechanism has the same finger mechanics and movement principles, with each finger consisting of two knuckles and a total of two degrees of freedom. The thumb has a wide range of motion, with three degrees of freedom. The palm mechanism does not have the ability to move, and its main role is to support the thumb mechanism and the four-finger mechanism.

3. VARIOUS CONTROL METHODS OF BIONIC HANDS AND THEIR ADVANTAGES AND DISADVANTAGES

3.1. Bionic Hand Control Based on Myoelectric Signals

3.1.1. Introduction

Surface electromyography signals (SEMGs) are a complex combination of subepidermal electromyographic activity at the surface of human skin, which can be received through surface electrodes. The control circuit of the bionic hand uses the human upper limb EMGs as the signal source, placing the high-voltage electrodes on the human wrist where the signal is strong, and each group of high-voltage electrodes controls the activation of the bionic hand, while the other group of electrodes does the opposite. The following figure shows a more typical bionic hand kong Zhi gu based on myoelectric signals.

*Corresponding author. Email: James.mail_526@qq.com

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

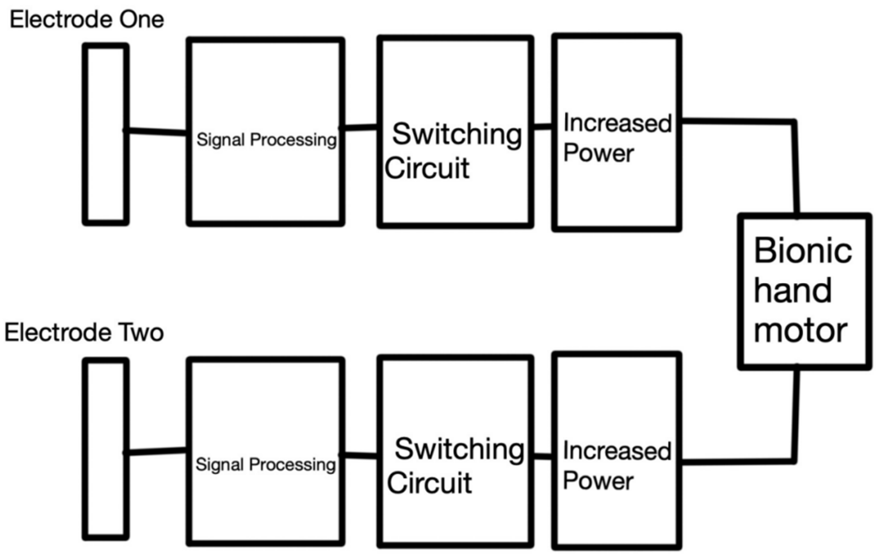

Figure 1 Bionic hand control process based on myoelectric signals

3.1.2. Analysis of Advantages and Disadvantages

EMGs can be collected by surface electrodes, so it can prevent pain and cross-infection to patients due to needle electrode stabbing tendons. In practice, the subjects reported that the operation of the bionic hand is easy to master, and each movement can be ensured without errors as long as they concentrate on it. [3] However, since EMGs are a tiny electrical signal with a range of about 100-5000 μV, and the range is about 100-5000 μV, and the tissues under the skin and in the body have an attenuation function for EMGs information, this leads to noise and interference in the process of detecting EMGs signals, which can greatly affect the detection. In EMGs detection, the two most significant interferences are the 50 Hz industrial frequency interference and movement artifacts. Because of the frequency range of the industrial frequency signal EMGs, it is the most difficult kind of interference to eliminate interference.

The bionic hand control based on EMG signals also faces the problem of identifying and classifying EMGs signals, and the accuracy of current machine learning for the classification of signals decreases with the gradual complexity of hand gestures. The classification of EMG signals can be better handled by using deep learning, a tool with better feature extraction and data fitting ability. However, deep learning is not suitable for daily bionic hand control because of its long computation time and high hardware requirements.

3.2. Bionic Hand Control Based on Elastic Materials

3.2.1. Introduction

The bionic hand with elastic materials uses actuators to autonomously manipulate the torsional deformation of the soft manipulator to capture and manipulate objects. Fluid-elastic actuators, electroactive polymers, and shape memory polymers are all common materials used for gas brakes. However, the internal structure of the fluid-elastic actuator is often due to geometric asymmetry and material anisotropy, resulting in spatial expansion of the internal chamber or spatial distortion of the entire actuator in a certain direction. The spatial distortion of the entire actuator in one direction.

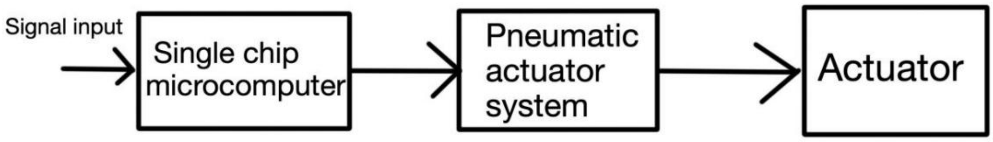

Figure 2 A control method of biomimetic hand based on elastic material

3.2.2. Analysis of Advantages and Disadvantages

The bionic finger is flexible, soft and controllable, and the bionic finger can be synchronized with the human finger through the glove with a stretchable strain sensor. synchronized bending motion of the bionic finger with the human finger, which has potential applications in both rehabilitative medicine and This has potential applications in both rehabilitation and extreme environments. With the rapid development of soft body robots and flexible sensors are rapidly developing, the combination of soft. The rapid development of soft robots and flexible sensors, how to combine soft robots and flexible sensors together to produce fully soft The future of soft robotics and flexible sensors will become a popular research direction.

Due to its flexibility, the soft body manipulator can fit the shape and scale of objects in unstructured and complex natural environments, thus achieving the purpose of capturing and controlling objects. Each finger of the bionic hand is relatively flexible, so it can perform some basic functions of the human hand while also carrying out more complex activities, and can withstand certain loads. However, because the whole body of the bionic finger is made of soft material, the load force of the finger is small, and it is difficult to achieve an effective grip on relatively heavy objects [4], and future research and development may use improved materials and actuation pressure to overcome this problem. At the same time, since some of the elastic material-based bionic hands require gas for actuation, they also carry a certain risk of secondary patient injury due to aging or damage.

3.3. Bionic Hand Control Based on Pneumatic Muscles

3.3.1. Introduction

A pneumatic artificial muscle is a device that is driven by compressed air supplied from outside to make pushing and pulling movements. Pneumatic muscles require an air source to provide power. In bionic hand design, a solenoid proportional valve is usually used to precisely adjust the output air pressure to the pneumatic muscles according to the input signal. Because of its lightweight and high stability, it has been commonly used in rehabilitation devices in recent years. Compared with pneumatic components, the traditional motor-driven method is rigidly driven, which may cause secondary damage in the process of application if it is not careful. The pneumatic muscle-based bionic hand, such as the linkage mechanism conduction pneumatic muscle-controlled bionic hand-designed by Binbin Zhou et al [5], is similar in appearance and size to that of an adult and has a more stable transmission.

3.3.2. Analysis of Advantages and Disadvantages

The pneumatic muscle improves the freedom and force transmission of the bionic hand, and the gripping ability of the object is significantly improved. The intelligent self-aware pneumatic muscle bionic hand can be realized by carrying sensors [6], but the pneumatic muscle still has defects in the control accuracy. In terms of safety, although there is a significant improvement compared to motor-driven ones, there is still a risk of secondary injury to patients due to careless use or aging.

3.4. SMA-Based Bionic Hand Control

3.4.1. Introduction

Compared with other current electronic functional materials, Shape memory alloy (SMA) combines drive function and transmission with the advantages of high energy density and low drive current, which can make small and compact, highly automated, integrated and reliable electronic components. In [7], the research team of Patras University [8] and the University of Victoria, Canada, designed and tested different bionic hands based on the driving characteristics of SMA [9]. Existing SMA-controlled bionic hands usually achieve more efficient actuation by placing multiple SMA filaments in series and using mechanical devices such as dynamic pulleys. The overall structure of zhe zho bionic hand is divided into a finger module, a control module and a heat dissipation module. The finger module adopts the under-driven structure, which can achieve envelope grasping of objects. The modular fingers include the index finger, middle finger, ring finger and little finger, and a right-angle thumb structure is designed according to the layout of the bionic hand.

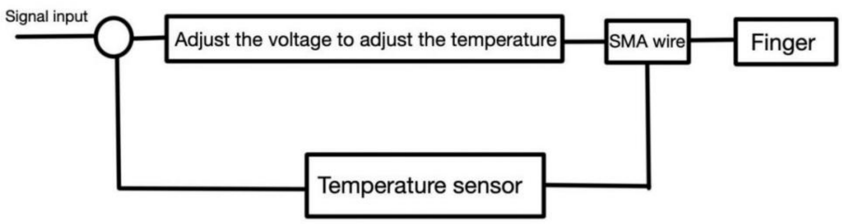

Figure 3 Control flow of a biomimetic hand based on SMA

3.4.2. Analysis of Advantages and Disadvantages

Compared with the drive method of the bionic hand, the SMA-controlled bionic hand is fast in response, suitable for high-speed gripping scenarios and has theoretically outstanding advantages of simple drive system, small footprint, light weight and modularity. However, although the bionic hand with shape memory alloy actuator has been widely developed, in real applications, the contraction movement range of SMA wire is small, so in order to achieve the maximum output movement to meet the movement space of the finger, the actuator part is usually installed directly into the arm [10], which is not compact and intensive.

4. CONCLUSION

In this paper, the author reviewed the existing mainstream bionic hand control methods and summarized the control of the bionic hands based on myoelectric signals, SMA, pneumatic muscles and elastic materials, and listed the advantages and main drawbacks of different control methods and the problems that hinder their development.

With the improvement of technology and the progress of nanomaterials, biology and information technology, the bionic hand will be more civilianized and refined in the future and will be able to enhance the sensitivity and bionic performance of the bionic hand by using electroactive polymers to accomplish the function of artificial muscles. With the continuous research on the brain-computer interface, the bionic hand designed for paraplegic patients is also expected to be realized in the future because people with paraplegia often do not have the ability to move their upper body, these people often need the assistance of bionic hands more.

REFERENCES

1. Li Surui, Li Zhenxin, Yu Yi. Research status and development prospect of intelligent bionic hand[J]. Journal of Xinxiang Medical College, 2015, 32(11):1045-1047. doi:10.7683/xxyxyxb.2015.11.019. 1-2
2. Zhang W-L,Zhang J-Tong,Yang T-Y,et al. Myoelectric signal bionic hand control system based on fusion network[J]. Information Technology and Informatization,2021(6):235-240. doi:10.3969/j.issn.1672-9528.2021.06.071. 1-2
3. Li S.F., Li D.P., Zhang G.X., et al. Research on myoelectric signal control of bionic hand[J]. China Mechanical Engineering,2006,17(5):488-492. doi:10.3321/j.issn:1004-132X.2006.05.014. 4-5
4. Luo Zhaojun, Wang Shuai, Cheng Guanggui, et al. Design, fabrication and control of bionic hands based on elastomeric materials[J]. Journal of Mechanical Engineering,2019,55(11):69-75. doi:10.3901/JME.2019.11.069. 1-2,4-5
5. Zhou B B, Zou Ren L. Design and research of bionic hand based on pneumatic muscle actuation[J]. Biomedical Engineering Research,2020,39(1):68-73. doi:10.19529/j.cnki.1672-6278.2020.01.13.2-3
6. Guan, Q. H.. A study of an intelligent flexible bending pneumatic artificial muscle actuator [D]. Heilongjiang: Harbin Institute of Technology,2017. doi:10.7666/d.D01334429.86-88
7. Wu ZG. Research on new SMA actuator with bionic hand [J]. Mechanical Drives,2021,45(6):159-164. doi:10.16578/j.issn.1004.2539.2021.06.024.1-2
8. ANDRIANESIS K, TZES A. Development and control of a multifunctional prosthetic hand with shape memory alloy actuators [J]. Journal of Intelligent and Robotic Systems, 2015, 78(2):257-289.
9. Bundhoo, V., Haslam, E., Birch, B., & Park, E. (2009). A shape memory alloy-based tendon-driven actuation system for biomimetic artificial fingers, part I: Design and evaluation. robotica, 27(1), 131-146. doi:10.1017/S026357470800458X 1190-1202
10. Huang Chaoyang. A new bionic hand with SMA drive[J]. Mechanical Drives,2019,43(4):165-168,176. doi:10.16578/j.issn.1004.2539.2019.04.031. 1-3