Proceedings of the 4th International Conference on Biological Engineering and Medical Science
DOI: 10.54254/2753-8818/60/20241387

Research of the application of medical bionic robot

Shenyang Zhou

College of mechanical engineering, Hefei University of Technology, Xuancheng, 242035, China

842866386@qq.com

Abstract. Medical bionic robotics is one of the research hotspots in today's medical field, which is widely used in minimally invasive surgery, soft bionic robots, endoscopic instruments, and so on. Through reading and organizing related literature, this paper will describe the research status of medical bionic robot application in the form of a review, analyze the existing research results, find the research gaps, explore the optimization direction, and try to put forward the corresponding solutions. Medical bionic robot application technology can still be improved in many aspects to realize more comprehensive functions. Current research work not only explores knowledge or problems in specific fields, but also lays a foundation for future research and provides valuable reference information. This reference may include aspects such as methodology, data analysis techniques, experimental design ideas, theoretical frameworks, etc., which can help other researchers to conduct deeper or broader exploration in this field.

Keywords: Bionic robots, medical, surgical, soft structures.

1. Introduction

At the cutting edge of modern science and technology, robotics has become one of the greatest inventions. Robotics technology combines several disciplines and technologies, fused and applied to the body, which has automaticity, adaptability, and intelligence, and has long been at the forefront of scientific and technological research hotspots. In the continuous research process of robotics technology, the author found that the function of robots operating in a traditional mechanical way is very limited, often only able to complete some simple mechanical activities. At the same time, the living organisms in the natural world are able to operate stably for a long period and complete complex actions through unique structural features. To make robots more flexible in the operation process, scholars have begun to try to imitate some of the structural characteristics of living creatures and apply them to robotics, opening up the emerging field of bionic robotics. As a major branch of robotics, bionic robotics can be used in medical technology, assisting or even replacing humans to complete delicate tasks.

Medical bionic robot technology has become mature and has certain advantages in various aspects. In order to further explore the practical applications or shortcomings of this robot technology, this paper will read and collate the scientific research literature on various types of bionic robots in the medical field, analyze and optimize the existing research results, and then study the application and principles of bionic robotics in various aspects of healthcare, look for possible research gaps, and draw conclusions and provide certain references for future research.

DOI: 10.54254/2753-8818/60/20241387

2. Bionic Robot Working Principle

Biological organisms have become the object of imitation for bionic robots due to their structural characteristics, however, how to realize the materialization of biological characteristics, i.e., how to design unique machine structures has become a major research in the field of bionic robotics. First of all, in order to have the characteristics of flexibility, adaptability and safety, researchers have adopted the processing of flexible materials to create bionic robots. Based on existing materials, soft inflatable gloves made of silicone rubber have been studied, which can mimic the bending of human fingers and thus assist in the rehabilitation process of the hand. To create bionic robots with better performance, new materials are more in line with expectations. Deformable hydrogel materials that can be triggered by DNA have been investigated for their ability to respond to external stimuli and produce appropriate feedback, which is crucial for medical applications [1]. In addition, the actuation method of a bionic robot largely determines its functional characteristics. Existing drive methods for bionic robots are roughly as follows: cable drive, pneumatic drive, SMA drive, EAP drive, chemical drive, and so on. Among them, the pneumatic drive has the advantages of lightweight, easy accessibility, no pollution, etc., and is widely used in the field of bionic robots. Researchers can choose the appropriate drive method according to different operating environments to work with bionic robots [2]. Bionic robot technology has been developed in various aspects to have the advantages of high precision, smoothness, flexibility, etc., and is now used in the medical field.

In terms of application, bionic robotics has achieved several research results in the medical field, which can greatly help people perform relevant operations. Wang Kundong et al. studied microsimulation robots in clinical medical diagnosis and treatment, which can realize accurate medical diagnosis and reduce patients' discomfort. Among them, capsule endoscopy is less invasive, non-toxic, minimally invasive, non-invasive, etc., and can be actively controlled or loaded with imaging devices, which provides a good direction for the future development of miniature bionic robotic endoscopy [3]. Li Qiang et al. combined robotics, bionics, medical technology and modern pneumatic technology to study the product of pneumatic artificial muscle, which has the characteristics of flexible and smooth movement, energy saving and high efficiency, good flexibility, smooth and safe, commonly used as a bionic robot knee joint actuator, and can be in the riot control and other hazardous occasions such as the environment of the work of the environment [4]. Sun Chen et al. based on the principle of gastropod movement put forward a in vascular environment of microbionic robotics. The design can effectively resist the impact of liquid and run smoothly on a large-angle slope. By establishing and analyzing the simulation model, the kinematic performance of the structure can be studied and the optimization direction of the design can be obtained [5].

3. Bionic Robotics Applications in Minimally Invasive Surgery

The human body cannot perform highly accurate work for long periods like a machine, so medical machinery is often utilized to assist in minimally invasive surgical operations, and thus scholars have developed bionic robots for minimally invasive surgery. Most of the existing minimally invasive surgical robots are articulated mechanical structures to maintain the stability and accuracy of the output and are widely used in vascular interventional procedures. To make the existing bionic robotics work in a minimally invasive surgical environment, a scheme based on a bionic finger mechanism with a BP neural network PID-based control system is proposed to assist the surgeon in minimally invasive interventional surgical operations. In the scheme, through the vascular interventional robot prototype, the accuracy experiment of the propulsion mechanism was conducted to prove the feasibility of the mechanism, and improvement direction and measures were proposed [6]. In addition, the existing vascular interventional robot makes it difficult to truly realize the operation instead of the doctor, and the motion accuracy is not high, the bionic finger that simulates the movement of the doctor's finger can be used as the twisting mechanism to design the vascular interventional robot based on the bionic finger, and the kinematics simulation can be carried out to prove the reasonableness of the mechanism design [7]. The existing bionic robot technology for minimally invasive surgery has been perfected, and its

DOI: 10.54254/2753-8818/60/20241387

accuracy and stability have reached most of the surgical requirements, further simulation and biological experiments can be conducted to improve the technology.

4. Soft Bionic Robots for Medical Applications

Soft bionic robots are more flexible and lightweight compared to articulated robots and are one of the key projects in bionic robotics in the medical field. Soft bionic robotics technology combines the principles of bionics and the structure of soft body mechanisms to realize the operation of the robot. Soft-body robots have the advantage of natural integration with living organisms, making up for the shortcomings of traditional medical robots, which can analyze the internal environment of the human body and move freely, while significantly reducing the damage caused by bionic soft-body robots to human tissues [8]. Soft bionic robots have the advantage of being compatible with the natural tissues of living organisms and are widely used in minimally invasive surgical procedures. In soft and hard tissue surgery, the soft bionic robot relies on its advantageous characteristics to effectively assist the surgeon's actual operation, resulting in more precise surgery, smaller wounds, less bleeding, and shorter time needed for postoperative recovery [9]. There also exists another similar bionic robotics technology, namely continuum robotics. Its principle is to achieve the purpose of movement and grasping through continuous flexible deformation, and the continuum robot working according to the animal's locomotion mechanism can be very well adapted to various environments, and can achieve accurate grasping for various irregular objects and has a strong ability to avoid obstacles [10]. The application of soft bionic robotics in the medical field is still in the developmental stage, and there are still some defects in materials, control and other aspects, so the research of new soft materials and enhanced bionic intelligent control algorithms may become the future research direction.

5. Bionic Robotics-based Endoscopic Instruments

Bionic robotics is also present in a large number of endoscopic medical devices, for which there have been relevant studies. One solution is a bionic robot based on the wriggling mechanism of earthworms, equipped with piezoelectric-driven artificial muscles, which is useful for the study of endoscopic robotic actuators due to its similarity in expansion and contraction characteristics to those of the earthworm muscles and the absence of drawbacks brought about by air-flow-driven methods [11]. Or proposed active motion endoscopic robot design, typically earthworm and inchworm type robotics, which has a multi-segmented elongated mechanism to adapt to the intestinal lumen environment, can turn flexibly and rely on the body material to generate friction to help propel forward. The basic units of this class of robots are pincer and telescopic, which enables to increase of the pincer force in the intestinal tract and to drive the locomotion unit through a certain step sequence [12]. As far as the prior art is concerned, most of the robotic technologies of this class are limited to energy consumption and generally use towing cables, which pose certain safety hazards. It will be difficult to recover the robot once it fails during the working process. Wireless energy transmission can be attempted after further improvement of the related technology to get rid of the constraints of cables, which can also further increase the accuracy.

6. Conclusion

This study analyzes and summarizes the research on the application of medical bionic robots, which is as follows: roughly introducing the application of bionic robots in medical treatment and introducing examples, and organizing and analyzing the working principle of bionic robots, the application of bionic robots in minimally invasive surgeries, soft bionic robots related to medical treatment, and endoscopic instruments based on the technology of bionic robots and proposing optimization solutions. The future development trend of medical bionic robot application research: follow the development of related science and technology, try to adopt new materials with better performance and integrate more advanced technology to enhance and perfect the medical bionic robot technology in all aspects, so that it can be more widely used; further explore the application of bionic robots in other aspects of the medical field, optimize with the existing technology, amplify the advantages and bring good benefits.

DOI: 10.54254/2753-8818/60/20241387

References

[1] Wang HT, Peng XF, Lin BM. Advances in soft robotics[J]. Journal of South China University of Technology (Natural Science Edition), 2020, 48 (02): 94-106.

[2] Kai-Mei Chu, Hu Zhao, Kai Feng, Jie Wu, Yin-Long Zhu. Research status of soft bionic robot[J]. Forestry Machinery and Woodworking Equipment, 2021, 49 (11): 4-10+16.

[3] Wang Kundong. A microbionic robot for gastrointestinal diagnosis[J]. Science and Technology Perspectives, 2023, 13 (26): 61-64.

[4] Li Qiang, QIN Xiansheng, YING Shenshun. Application of new pneumatic artificial muscles in bionic joints[J]. Hydraulics and Pneumatics,2007,(04):50-54.

[5] S. Chen, S. Qian, J.-y. Huang and B. Chen, "Simulation Analysis on the Bionic Micro Robot Operating in the Vascular Environment, 2010 4th International Conference on Bioinformatics and Biomedical Engineering, Chengdu, China, 2010, pp. 1-4

[6] Chen Shiming, YAN Weiwei, HAN Shipeng, ZHANG Yi. Design and accuracy analysis of minimally invasive interventional robot system[J]. Measurement and Control Technology, 2019, 38 (01): 49-53.

[7] Guang Guoshuai, WANG Li, ZHANG Yi, YAN Weiwei, OU Fangliang, HAN Shipeng. Design and analysis of vascular interventional surgery robot based on bionic finger[J]. Machine Tools and Hydraulics, 2019, 47 (09): 81-84.

[8] Wang LJ. Research on the application and development of bionic soft robot design[J]. China Equipment Engineering, 2023, (12): 26-28.

[9] Hou Taogang, WANG Tianmiao, SU Haohong, CHANG Shuai, CHEN Lingkun, HAO Yufei, WEN Li. Soft robot frontier technology and application hotspots[J] Science and Technology Herald, 2017, 35 (18): 20-28.

[10] Chen Z. Analysis of sensing and path planning technology for continuum surgical robots[J]. Electronic Testing, 2019, (21): 134-135.

[11] Jian Xiaogang, WANG Yefeng, YANG Pengchun. Research progress of bionic robot based on the creep mechanism of earthworm[J]. China Journal of Construction Machinery, 2012, 10 (03): 359-363.

[12] Yan GZ, Chen WM. Advances in intestinal endoscopic robotics[J]. Journal of Biomedical Engineering, 2015, 32 (01): 214-217.