

Applications of Embedded Systems in Medicine: Challenges and Future Trends

Hanlin Zhao*

School of Information Science and Technology, Southwest Jiaotong University, Chengdu, 610097, China

*Corresponding author: hanlin@my.swjtu.cn

Abstract. With the advancement of science and technology, embedded systems play an essential role in the medical field. They have become an integral part of medical equipment, enabling functions such as patient monitoring, diagnosis, and treatment. Embedded systems also improve the work efficiency and accuracy of medical staff. This paper summarizes and reviews the recent applications of embedded systems in medicine. Firstly, it discusses the advantages and challenges of embedded system applications in medicine. Then, it discusses the development prospects and directions of embedded systems in the medical field. Through analysis, it is found that the application of embedded systems in the medical field is developing towards intelligence, miniaturization, and personalization. In the future, embedded systems will become more significant in the medical field, providing convenience to patients with different medical needs and bringing more innovations and changes to the medical field.

Keywords: Embedded system, Medical field, Wearable medical devices.

1. Introduction

The main function of embedded system equipment is to control, monitor, or aid the operation of machines and equipment. With the continuous development and popularization of embedded system technology, its applications are widely used in the medical field. The traditional applications of embedded systems in the medical field, such as cardiac pacemakers and pulse oximeters, are mentioned in [1]. In the past decade, many new technologies have emerged, such as wearable medical devices and medical devices based on optical wireless communication [2]. In recent years, the focus of embedded system applications in medicine is to realize the intelligence, miniaturization, and portability of medical devices through sensor technology, video detection technology, and network technology. These technologies can improve the quality and efficiency of healthcare services, bringing better medical services to patients and medical staff. This article reviews the multifaceted applications of embedded systems in medicine, providing readers with a clearer understanding. It also discusses the challenges and advantages of embedded system applications in medicine. At the same time, this article also points out the development direction of embedded system applications in medicine, which has guiding significance for subsequent research.

2. Embedded applications in the medical field

Embedded system applications in medicine have gradually become a reality. Embedded systems can be used in various fields, such as medical equipment, medical data acquisition and processing, medical monitoring and diagnosis systems, medical treatment, and rehabilitation systems. The following sections will introduce the application of embedded systems in these fields in detail.

2.1. Embedded Systems for Medical Equipments

Medical devices are one of the most important fields of application in the medical field. Embedded systems for medical equipment can greatly improve the accuracy and efficiency of the equipment, making it more convenient to manipulate and use. Medical devices that contain embedded systems are known as medical electronic devices (MEDs). These devices are designed to monitor blood

pressure, blood sugar, heart rate, etc. They can also collect and transmit data on a patient's activity levels, sleep patterns, and medication usage. The data collected by MEDs can be used by healthcare providers to diagnose and treat medical conditions. For the design methods of medical equipment, there are mainly heavyweight methodologies and agile methodologies [3].

The most classic example of embedded systems in medical devices is the pacemaker. The pacemaker can regulate the heartbeat after being implanted into the human body. It contains a microprocessor that controls the heart rate and adjusts to the patient's activity level. Pacemakers also have sensors that detect changes in the heart's electrical activity and adjust pacing accordingly. At present, the embedded automatic control system applied in medical equipment mainly focuses on two aspects. The first aspect is in medical equipment such as portable sphygmomanometer, pulse detection and blood sugar measurement, and the second aspect is in CT, colonoscope, endoscopy, and other large medical testing equipment [4]. Fig. 1 shows a typical block diagram of embedded medical equipment [5].

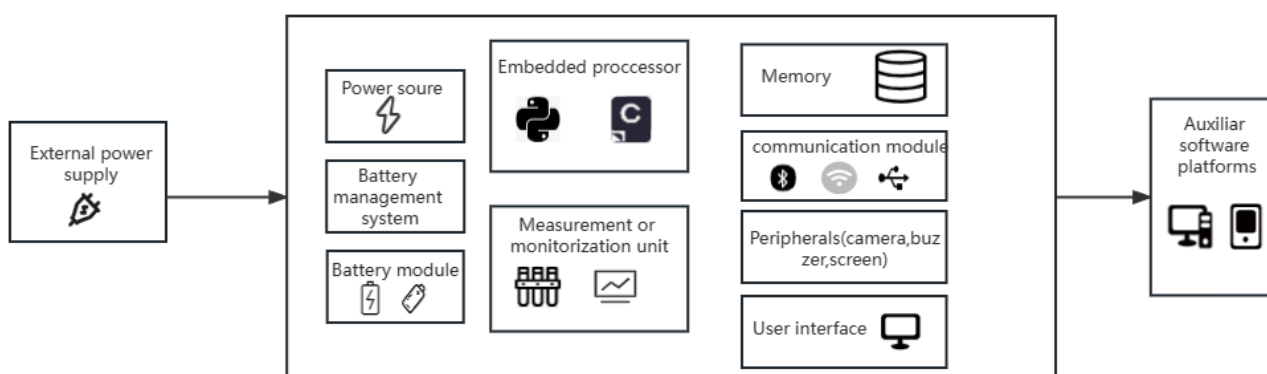


Fig. 1 Module diagram of embedded medical equipment

2.2. Medical Monitoring and Diagnostic Systems

Medical monitoring and diagnostic systems are another application area of embedded system applications for medicine. With the help of sensors and wireless communication technology, embedded systems can well realize monitoring and diagnostic functions. For example, built-in thermal sensors can be used to monitor and collect data to help treat obstructive sleep apnea.

Because of the rapid development of modern communication technology and AI, embedded systems are also being combined with AI to diagnose and predict diseases or help medical staff work. In the past few years, when the COVID-19 epidemic was severe, some researchers have used embedded systems to develop smart pill dispensers that help isolated infected people get drugs, while also reducing the contact between medical staff and infected people and improving medical safety [6]. Various sensors are used in other similar systems to monitor the basic physical signs of patients, such as blood pressure, blood sugar, heart rate, etc. So as to monitor and diagnose the patient's condition in real time. Some real-time disease monitoring and diagnosis suggestions are provided to doctors by these systems through the data processing and analysis functions of the embedded system, so that necessary treatment measures can be taken in a timely manner.

2.3. Medical Treatment and Rehabilitation System

Embedded systems are also widely used in medical treatment and rehabilitation systems. Medical treatment and rehabilitation systems require the use of a wide variety of devices such as electrical stimulators, rehabilitation robots, prosthetics, and more. These devices all require embedded systems to control their functions. Embedded systems can make these devices more precise and efficient for therapeutic and rehabilitation tasks.

For instance, Rehab robots created to address shortage of physical therapists. With robot-assisted therapy, the patient's rehabilitation process will become more stable and effective, and are more likely to recover [7]. The embedded system can make the auxiliary robot move according to the specified

trajectory, so that the user can continuously and passively move their upper or lower limbs, which can improve the effect of rehabilitation training.

Functional electrical stimulation (FES) is also the application of embedded systems in the field of medical rehabilitation. Embedded bionic functional electrical stimulation regulates muscle contraction by generating low energy current pulses [8].

In short, the application of embedded systems in medical treatment and rehabilitation systems has broad application prospects, which can improve the effect and efficiency of treatment and rehabilitation, and can also make the life of disabled people better.

3. Advantages and Challenges of Embedded Systems in Medical Field

3.1. Advantages

An embedded system is actually a dedicated computer system [9], the degree of controllability and customization of embedded systems is very high, because the design for software and hardware is customized according to requirements. As a result, Embedded systems can meet the different needs of equipment in the medical field. Because of the high integration of embedded system hardware and software, the volume and weight of medical equipment can be reduced, and energy consumption can be reduced, thereby reducing the manufacturing cost of medical equipment. Real time is also an essential advantage, In the article [10], the combination of embedded system and deep learning algorithm can quickly and accurately diagnose whether the patient has abnormal heart. For heart disease patients, every second is very important to life.

3.2. Challenges

The first challenge is that the size and material of embedded medical devices are limited. For example, cardiac detonators require light weight, small size, high strength and corrosion resistance of wires [11]. The second challenge is that the embedded devices cannot work for a long time due to energy constraints [12]. Engineers can improve energy efficiency and extend battery life by optimizing software and hardware. The third challenge concerns medical device security and privacy security [13]. For example, For Internet-connected embedded devices, hackers infect devices by developing malware to obtain personal privacy data [14]. These cybersecurity issues still need to be addressed urgently.

4. Development Direction of Embedded System in Medical Field

4.1. New Embedded Systems Technology

Intelligent wearable medical devices (IWMD) are one of the new technologies of embedded systems in the medical field. The use of IWMD can save time and cost, If the device detects problems, these problems will be fed back to the doctor so that the doctor can make a judgment. This has greatly improved the efficiency of medical services and reduced costs. Smart wearable devices have different wearable1 types, such as smart bracelets, smart patches, smart contact lenses and smart belt.

Smart bracelets are the most prevalent IWMD, Smart bracelets are the most common IWMD, which can perform emotion recognition by analyzing heart rate data [15], and can also measure the wearer's body temperature through built-in sensors [16]. Telemedicine is also a new application based on embedded systems, the fundamental purpose of telemedicine is to improve medical services, such as providing medical services to impoverished mountainous areas. Patient satisfaction rates with remote consultations are only marginally different from in-person visits. And telemedicine has many benefits, such as reducing medical expenses, increasing patient convenience and saving social costs. For example, in areas with relatively backward medical resources, remote surgery can be performed through mobile networks, which provides great benefits for patients.

4.2. Future trends

The future development trend of embedded systems in the medical field is mainly intelligence, miniaturization, and personalization. Improve the speed of medical services and provide more convenient services through technological updates.

The IWMD mentioned above shows that the miniaturization and intelligence of embedded systems in the medical science is an inevitable trend. Fig. 2 shows the changes in the global market valuation of wearable medical devices in the past six years. More and more people buy IWMD equipment, the prospect of IWMD is very good.

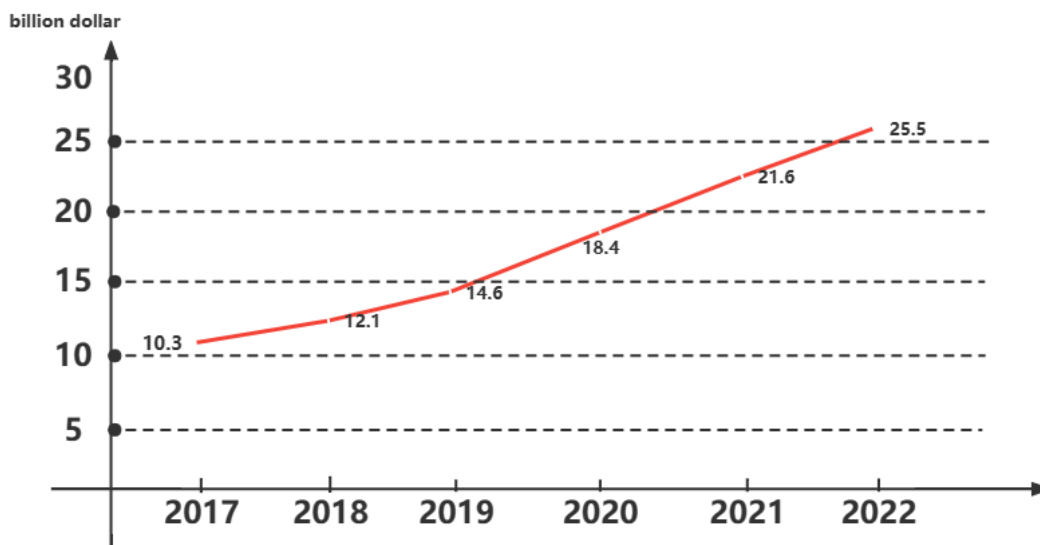


Fig. 2 The changes in the global market valuation of wearable medical devices in the past six years

Personalization is also one of the development trends of embedded devices in the medical field. As people's requirements for medical devices increase, these devices may be customized according to the individual needs of patients. Embedded systems in medical devices will help doctors treat patients based on their condition.

5. Conclusion

Embedded systems have transformed the field of medicine by solving complex problems in patient care, diagnosis and treatment. These systems make medical equipment and equipment more convenient, accurate, fast, intelligent, and personalized, enabling medical professionals to provide better care for patients and improving the efficiency of medical services. Although embedded systems have many advantages, there are still some challenges, such as personal privacy issues. These challenges still need to be resolved.

In the future, embedded systems will develop in the direction of intelligence, miniaturization, and personalization in the medical field. With the advancement of technology and the improvement of embedded systems, the medical field will be greatly changed to benefit society.

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