Proceedings of the 2023 International Conference on Machine Learning and Automation
DOI: 10.54254/2755-2721/41/20230749

Research on cross-field applications and future prospects of intelligent sensors

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Abstract. The Internet of Things (IoT) has transformed daily life through enhanced internet and communication technologies. Intelligent sensors, like temperature and humidity sensors, have revolutionized smart homes, enabling remote control and enhancing comfort. In agriculture, these sensors monitor soil moisture and crop conditions, optimizing farming practices for increased yields and sustainability. Healthcare benefits from the IoT with sensors in medical devices and wearables, offering real-time patient monitoring and cost reduction. Logistics employs intelligent sensors to track goods, boosting supply chain efficiency. Projects like IoT-based road analysis systems and pest monitoring exemplify data collection and intelligent decision-making, benefiting urban management and agriculture. It can be seen that intelligent sensors have an irreplaceable role in the Internet of Things, so this paper will introduce the technology and working principles of intelligent sensors and discuss the cross-domain applications and future expectations of intelligent sensors. Through literature analysis, it can be concluded that after the intelligent sensor receives the external signal, it will convert the signal into a physical signal related to the measured parameters and process, store, and communicate it so as to realize the detection, control, and data transmission of the environment. This means that intelligent sensors can be widely used in industrial production, environmental monitoring, medical health, and other fields.

Keywords: Intelligent Sensor, The Internet of Things, Medical and Health.

1. Introduction

In recent decades, the rapid development of intelligent sensor technology and the Walktrap algorithm has made it a reliable means to obtain and analyze the characteristics of water vapor [1]. Intelligent sensors are also used in urban construction, using small and inexpensive intelligent sensors to collect and process data, so as to build a wireless sensor network to generate high-resolution air pollution maps of the city [2]. At the same time, intelligent sensors are also closely related to each of our lives, which is different from traditional physical education teaching, which adopts the corresponding prescription for sports teaching, combines teaching with fun for the corresponding health intervention, and realizes the two-way dimensional analysis of compound sports prescription through comprehensive nutrition collocation, so as to improve students' physical and mental health, in order to improve students' physical fitness [3].

These cases are based on intelligent sensors, so we need to further understand intelligent sensors.

An intelligent sensor is a sensor that has the function of information processing. Intelligent sensors with a microprocessor, with the ability to collect, process, and exchange information, are a combination of sensor integration and microprocessor products.

Intelligent sensors have applications in many different fields, such as health care, where they are used for vital sign detection, remote monitoring of medical devices, and drug management. This will be covered in more detail in a later article. Next, this article will discuss the basic composition and working principles of intelligent sensors in detail.

2. The basic composition and working principle of intelligent sensor

This section will introduce the composition of intelligent sensors. An intelligent sensor primarily consists of several key components, including:

(1). Sensor Elements: These are chosen based on the specific detection targets, encompassing various types such as pressure sensors, temperature sensors, humidity sensors, and more.

(2). Signal Conditioning Circuit: This circuit plays a crucial role in processing the weak signals gathered by the sensor elements. It involves tasks like signal amplification, filtering, compensation, and other adjustments aimed at enhancing signal quality.

(3). Microprocessor: The microprocessor takes on the responsibility of performing digital signal encoding and decoding, as well as executing various processing and storage operations, thereby enabling intelligent functionality.

(4). Communication Interface: This interface establishes communication channels, either through wired or wireless means, facilitating data sharing and the exchange of control information with host computers or other connected devices.

After knowing the composition of the intelligent sensor, this paper will introduce its working principle. The working principle of an intelligent sensor varies depending on the target it detects, but usually involves the following steps:

(1). Sensing: Physical quantities are sensed by specialized sensor elements and converted into electrical signals.

(2). Enhancement: The use of auxiliary components such as preamplifiers to amplify and filter the electrical signal in order to better extract and transmit the signal.

(3). Digitization: The processed analog signal is converted into a digital signal, and operations such as compression and coding are carried out to facilitate digital processing.

(4). Transmission: Transmitting the digital signal to the specified location through means such as radio waves, wired cables, and infrared rays.

(5). Processing: The computer or other controller that receives the digital signal performs the corresponding data processing, analysis and storage operations.

2.1. Technical analysis of intelligent sensors

The initial application of MEMS sensors was within the military domain, primarily for the purposes of multi-sensor data fusion, target tracking, and automatic recognition. These sensors are valued for their exceptional accuracy in target positioning. Within the aerospace sector, MEMS technology has been leveraged to manufacture flow sensors that incorporate A/D converters, ensuring their reliability in various applications. To attain intelligence, it is imperative to amalgamate the capabilities of MEMS sensors with signal conditioning, control, and digital processing functionalities. This amalgamation facilitates the realization of essential features such as bidirectional data and instruction communication, seamless digital transmission, localized digital processing, self-calibration mechanisms, and customizable algorithm programming. In the realm of military applications, MEMS-based intelligent sensors are engaged in research focused on long-range air and ocean surveillance, reconnaissance activities (including drone swarms), and the facilitation of multi-region, multi-variable remote sensing through sophisticated intelligent sensor networks. CMOS technology, as the predominant integrated circuit methodology, extends its versatility beyond the manufacturing of digital integrated circuits, including microprocessors, to encompass various sensor types, data converters, and highly integrated

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transceivers. This versatility empowers CMOS technology to excel across a diverse range of applications. Furthermore, CMOS technology has been instrumental in producing dissolved oxygen sensors that integrate D/A converters, finding widespread use in the automotive sector. In the field of biomedicine, CMOS technology has been harnessed to develop turbidity sensors equipped with integrated transceiver functionalities. Digital low-light CMOS-based imaging systems have emerged as the primary imaging technology in military applications. Presently, the exploration of various sensor structures compatible with CMOS technology, along with the development of associated manufacturing processes, constitutes a focal point of research. While specialized MEMS technology is typically applied in the creation of sensors and actuators, the fusion of MEMS with CMOS has engendered a spectrum of innovative integrated technology platforms. These platforms hold promise for enhancing sensor and actuator performance, reducing device and system dimensions, and mitigating costs. Despite the international maturity of some sensor and actuator technologies, the integration of these systems with CMOS platforms, either in three-dimensional configurations or as single-chip solutions, continues to face substantial challenges, notably in terms of achieving high-volume production and cost-effectiveness. As a result, this area has garnered significant attention within the research community. After a general introduction to intelligent sensors, we will further introduce the application of intelligent sensors in medical treatment.

3. The application of intelligent sensors in the field of medical health

Intelligent sensors can be used to detect a patient's physiological parameters, such as heart rate. Blood pressure, etc. At the same time, it allows doctors to use the Internet to detect patients' physical health, diagnose diseases remotely and provide recommendations. In terms of drug management, intelligent sensors can detect patients' drug use, record drug dosages, and give patients reminders when to take medication to improve treatment effects. In addition, intelligent sensors are also used in rehabilitation treatment, sleep monitoring and other aspects. Therefore, it is necessary to recognize the important role of intelligent sensors in the medical field, which can play an irreplaceable role in real-time monitoring and data acquisition, remote monitoring and remote diagnosis, precision medicine and personalized treatment. Intelligent sensors such as MEMS sensors have been widely used in the medical and health fields, and researchers use MEMS sensors to monitor and treat certain specific diseases. The researchers used special underwear and a self-adhesive gel pad to keep the MEMS sensor aligned with the abdomen to detect the condition of bedwetting patients and perform intelligent automatic treatment [4].

Meanwhile, some researchers have developed an epidermal sensor based on Mxene-based epidermal sensors, which is a flexible, self-healing, and high-performance epidermal sensor composed of antibacterial MXene hydrogel that is easy to prepare and can effectively promote wound healing. Flexible Accelerated-Wound-Healing Antibacterial MXene-Based Epidermic Sensor for Intelligent Wearable Human-Machine Interaction [5]. The following section will introduce some innovative applications in the field of healthcare.In addition, there are studies using different intelligent sensors to build platforms that will seamlessly integrate the Internet of Things (such as wearable sensors and smart medical kits) with home health services (such as telemedicine) to improve user experience and service efficiency [6].

4. Three categories of innovative medical sensors

4.1. Flexible sensor technology

Flexible sensor technology is a kind of sensor technology with a flexible structure. Compared with traditional rigid sensors, it has more advantages and application potential. Flexible sensors are usually made of flexible materials, such as flexible polymers, bending conductive materials, nanomaterials, etc. These materials allow the sensor to bend and stretch, allowing it to adapt to different shapes and curved surfaces. Flexible sensors work based on changes in their material's electrical, electrochemical, mechanical, or optical properties. When affected by external forces, pressure, deformation, temperature,

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and other factors, the electrical or optical properties of the sensor will change, resulting in measurable signals.

4.2. Implantable sensor

Implantable sensors are a new type of sensor appearing in recent years that has the characteristics of small size, light weight and strong biocompatibility. Implantable sensors are typically self-powered and transmit wirelessly. Unlike digestible sensors, implantable sensors are usually implanted under the skin or in organs to obtain the user's electrophysiological or chemical signals for transmission, and their important use is to accurately monitor physiological signals to help realize personalized medicine. The difficulty of traditional implanting sensors is that the sensor itself is not degradable, long-term damage to the surrounding tissues or cells in the body will cause secondary infection, and surgical removal will also cause secondary damage. In recent years, biodegradable implantable sensors have gradually stepped onto the stage.

4.3. Digestible sensor

A digestible sensor is a popular new type of sensor in recent years that is usually made of degradable electronic devices. The general digestible sensor is attached to the inside of the pill, powered by the interaction of the pill itself or the digestive tract fluid, and the relevant data detected by the sensor is transmitted to the smartphone or other terminals through the communication module when the sensor works. Compared with traditional gastroscopy and colonoscopy, the digestible sensor is low-cost, convenient to use, and can also reduce patients' pain.

5. Conclusion

This paper focuses on the key role and potential value of intelligent sensor technology in the field of medical health. First, the paper introduces the working principle and technical characteristics of intelligent sensors in detail. Intelligent sensors detect physical, chemical, or biological parameters in the environment through various sensing principles and convert these parameters into electrical or digital signals. These sensors also have data processing and communication functions, enabling real-time monitoring and remote communication. Secondly, the paper emphasizes the key role of intelligent sensors in the field of healthcare. They are used for monitoring physiological parameters, telemedicine, drug management, rehabilitation treatment, sleep monitoring, and other aspects that help improve the quality of medical services and the quality of life of patients. In the future, intelligent sensors will definitely be used in more fields and will become an integral part of building a smart future.

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