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Research Article

Advancements in Sensor Technologies for Remote Healthcare Monitoring

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ABSTRACT

This paper explores recent advancements in sensor technologies that enable remote healthcare monitoring, enhancing patient care and reducing healthcare costs. Innovations in wearable sensors, biosensors, and remote monitoring devices provide continuous, real-time data on vital signs, activity levels, and physiological parameters. These technologies facilitate early detection of health issues, personalized treatment, and improved patient outcomes. The study examines the integration of these sensors with IoT and AI systems for data analysis and decision support. Challenges such as data privacy, sensor accuracy, and battery life are also discussed. This research highlights the transformative potential of advanced sensors in modern healthcare.

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1. Introduction

The Internet of Things (IoT) has become a crucial tool in the rapidly evolving world, connecting devices to the Internet and making them smart. IoT has been used in various fields such as agriculture, home automation, traffic management, delivery management, water supply management, fleet management, smart grid, and energy saving. IoT-assisted wearable sensor systems technology is a booming field in healthcare, providing doorstep diagnosis, easily monitoring and controlling data, and embedding IoT in emergency services, connected homes, smart hospitals, and Electronic Health Records (EHR).

Data collected through intelligent devices and intelligent hospitals can be monitored in real-time, helping researchers make discoveries regarding healthcare, medicine, drugs, and vaccines. To ensure a quick and seamless transfer of data, different wireless technologies and communication protocols are considered. A Wireless Sensor Network (WSN) is a sensor network that is connected wirelessly with the help of different communication protocols. This review compares different deep learning algorithms and the WSN used to analyze and strengthen IoT in healthcare (Mamdiwar et al., 2021). Fig. 1 Shows an outlook of IoT-assisted hospitals for healthcare monitoring.

A smart hospital is built with body sensors, ingestible sensors, EHR, emergency services, remote monitoring, etc., which can be connected to cloud platforms via different communication protocols.

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Fig. 1. An outlook of IoT-assisted hospitals for healthcare monitoring (Mamdiwar et al., 2021).

Creating and managing a WSN requires wearable sensors and different healthcare monitoring systems. Merging all these elements helps achieve smart healthcare. In conclusion, IoT-assisted wearable sensor systems in healthcare offer a promising solution for improving patient care and enhancing the overall quality of life (Albahri et al., 2018).

This study compares various deep monitoring devices and the WSN used to analyze and strengthen IoT in healthcare. Merging wearable sensors and different healthcare monitoring systems helps achieve smart healthcare.

2. Case study

Healthcare is rapidly developing in technology, with remote monitoring of patients offering advantages in an ageing population with increasing health complications. Modern communication and sensor technologies enable patients to monitor vital signs at home, ranging from chronically ill patients to accident victims. Advances in remote healthcare include with-contact and contactless methods, with fall detection systems and applications already familiar. This study reviews recent advances in remote healthcare and discusses issues and directions for future research (Malasinghe et al., 2019).

A comparative study states that monitoring is crucial for elderly healthcare and well-being, as life expectancy increases and birth rates fall. Remote health monitoring, based on non-invasive and wearable sensors, offers an efficient solution for the elderly to live in their comfortable home environment. This paper presents and compares various low-cost and non-invasive health and activity monitoring systems, including textile-based sensors for wearable systems. It also discusses the compatibility of communication technologies and future research challenges in remote monitoring systems.(Majumder et al., 2017). Another study proved that the ageing population is posing challenges in health and social care, necessitating the development of a smart healthcare monitoring system. This system can remotely monitor elderly individuals' health to detect specific disorders, aiding in early intervention. The technology accurately processes and analyzes sensory data, transmitting the disorder detection to appropriate professionals. The proposed system improves clinical decision support and facilitates early intervention practices. Simulation results show low latency and packet loss, making it efficient and cost-effective in data acquisition and manipulation (Al-Khafajiy et al., 2019).

3. Healthcare Monitoring Through IoT-Assisted Wearable Sensor Systems

Wearable IoT devices are increasingly being used in healthcare monitoring to detect, transmit, and analyze data. These devices use sensors like ECG, RFID, BP Sensor, and PIR Sensor, along with microcontrollers like Arduino and Raspberry Pi. Communication protocols include MQTT, BLE, GSM, ZigBee, LoRa WAN, and GPRS. The architecture of IoT-Assisted Wearable Sensor Systems (WSN) for healthcare monitoring involves a wearable sensor that sends data to the cloud via protocols like Zigbee, Bluetooth, or Wi-Fi, which is then processed by a data center. This real-time data is visible to doctors, patients, and caretakers to catch any emergencies.

Wearable sensors are used to create a wearable health monitoring system (HMS) that monitors patients remotely. The sensor data is sent to the cloud via communication protocols like Zigbee, Bluetooth, or Wi-Fi, which are then sent to a data center for further processing. The same data is visible in real-time to doctors, patients, and their caretakers to catch any emergencies. Fig. 2 shows IoT-assisted wearable sensor systems for healthcare monitoring.

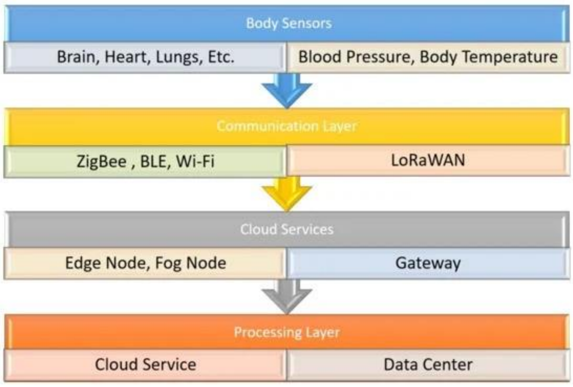

Fig. 2. IoT-assisted wearable sensor systems for healthcare monitoring (Mamdiwar et al., 2021).

Data transfer protocols are standardized formats for transmitting data between devices, such as File Transfer Protocol, User Datagram Protocol, TCP/IP, HTTP, MQTT, and LoRa. Different functional computing paradigms include multiple computers working together, networks of computers forming a data grid, edge computing, fog computing, and cloud computing.

Four communication technologies popular in IoT networks are ZigBee, LoRa WAN, Wi-Fi, and Bluetooth. ZigBee is based on the IEEE 802.15.4 standard and uses the DSSS technique, with a maximum range of 10–100 meters and low power consumption. LoRa WAN is an LPWAN that has gained popularity for its need in IoT networks due to its robustness and range. It has a physical layer called LoRa (long-range), which Semtech creates. Wi-Fi is a wireless communication technology based on the IEEE 802.11 standard and uses the CSMA/CA protocol to access radio channels. Bluetooth 5.2 has better power consumption, more robust security, a higher data rate, and an extended range than previous versions. Fig. 3 shows the data processing life cycle of IoT-assisted wearable sensor systems in healthcare.

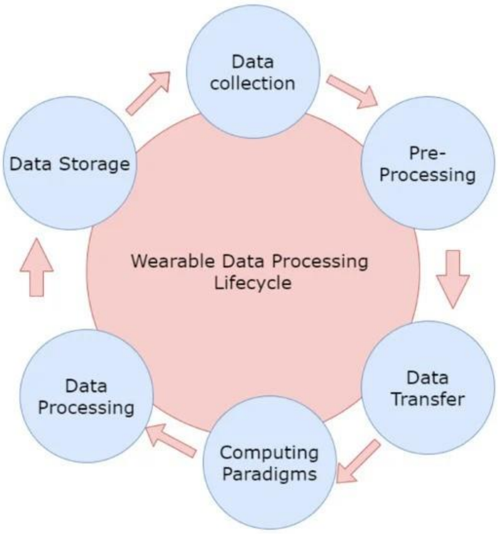

Fig. 3. Data processing life cycle IoT-assisted wearable sensor systems in healthcare.

Interoperability is essential for healthcare products to work seamlessly with each other. Device manufacturers should follow set standards or have standards for wireless communications such as ZigBee, Wi-Fi, etc. and ensure that gateways are available for translating and transmitting data to different devices. Sensor networks deal with two focal issues: data-oriented privacy and context-oriented privacy. Data-oriented privacy focuses on securing the data integrity of collected and transmitted data from sensing systems. Context-oriented privacy prevents attackers from getting contextual information concerning sensor data collected and the location of data sources. Two-factor authentication can be used to increase data privacy.

Security is crucial for HMS, as it is vulnerable to attacks due to wireless communication and large-scale networks. Cryptographic mechanisms, such as RSA and Diffie–Hellman-based cryptography, can be used to encrypt and decrypt data. A cyber-physical system (CPS) technology can also be used for HMS.

4. IoT Support Application for Healthcare Monitoring

IoT-assisted wearables have gained popularity in various fields, including healthcare, where they use various technologies to generate data for monitoring and analysis. These devices can perform personalized services, such as calculating SpO2 content in the blood, to counter the current pandemic. Healthcare wearables play a crucial role in managing patients with heart diseases, strokes, and diabetic patients. The use of WSN technology for cardiac patients, IoMT for diabetic patients, and CPS for whole-body vitals has made significant progress in monitoring vitals(Darwish & Hassanien, 2011). Fig. 4 shows the application of IoT-assisted wearable sensor systems in healthcare.

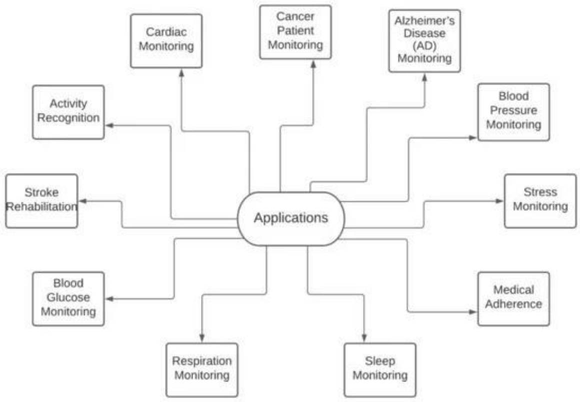

Fig. 4. Application of IoT-assisted wearable sensor systems in healthcare.

The WSN system is a reliable health monitoring system designed for cardiac patients, ensuring continuous monitoring and alerts in emergencies. It includes medical-grade sensors that monitor vital signs such as heartbeat, pulse rate, body temperature, and blood pressure. For critical patients, a real-time ECG is maintained, allowing continuous monitoring. The system's primary functions include obtaining body sensor data, analyzing health status on a smartphone, and transferring bodily information to smartphones through a body sensor network and wireless body area network using ZigBee and Bluetooth technology. Fig. 5 shows the blood glucose monitoring technique.

Respiration monitoring involves using specialized sensors to monitor breathing movements and heart rate, while sleep monitoring uses various sensors to help individuals correct their sleep cycle and maintain a healthy life cycle. An IoT gateway facilitates efficient end-to-end communication between users and doctors in real-time. Blood pressure monitoring is crucial in healthcare, as it is a sign of physical and mental wellness. Wearable devices can calculate blood pressure using various methods, such as sphygmomanometers or heart rate monitoring systems.

A data monitoring system for pregnant ladies has been developed, which analyzes blood pressure, temperature, heartbeat, and dental movements in real-time. The system uses the R-Pi as the central processor and collects vital body signs from the patient.

Healthcare systems also use wearable sensors to collect data from users and patients, such as pulse, oxygen level, temperature, glucose, and other signals indicating abnormalities. Activity detection sensors, such as accelerometers, pulse oximeters, airflow sensors, and oxygen sensors, are essential peripherals in IoT-based healthcare systems, allowing for the detection and management of patient's health.

5. Future Opportunities of Sensor Technology

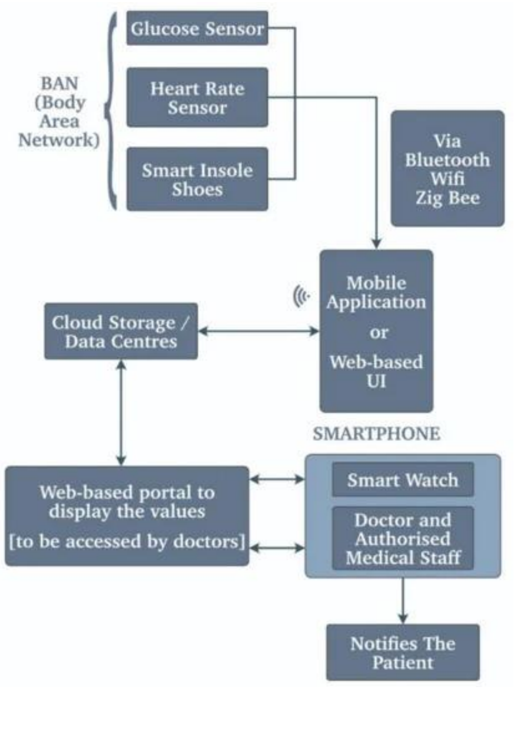

Fig. 5. Blood glucose monitoring technique.

The system for monitoring healthcare patients is evolving with the advent of IoT and wearables, offering the potential for improved functionality and integration of medical-grade sensors (Ahmad et al., 2022).

5.1. Machine Learning:

Machine learning algorithms, including artificial neural networks, logistics regressions, discriminant analysis, and naive Bayes, are being used in the development of telehealth systems. These algorithms can predict diseases in real-time, such as epileptic seizures and strokes, by analyzing patients' vitals. The integration of these algorithms into patients' daily lives can help them take proper medication without the need for a doctor or support staff. The future of telehealth could be more precise, allowing patients to take regular check-ups and medicines without supervision. Fig. 6 Shows future opportunities for IoT-assisted wearable sensor systems in healthcare.

5.2. Fog/Edge:

IoT fog and edge computing have proven effective in reducing latency in IoT applications, particularly in healthcare. These technologies can create latency benchmarks and reliable monitoring systems for real-time applications. In rehabilitation scenarios, fog and edge computing can aid in augmented reality for patient rehabilitation and trauma therapy, enabling patients to move around in the real world without fear of disability.

5.3. Big data:

A critical patient in a hospital is monitored by numerous sensors, providing an accurate picture of their status. These sensors work in real-time, recording vital signs per second, and generating extensive data analysis. This data is crucial for doctors to decide on appropriate medication. Many large hospital chains use centralized servers to store patient data, alerting them to unique card numbers. The potential for e-health systems using machine learning algorithms to prescribe medicines and other required drugs is immense.

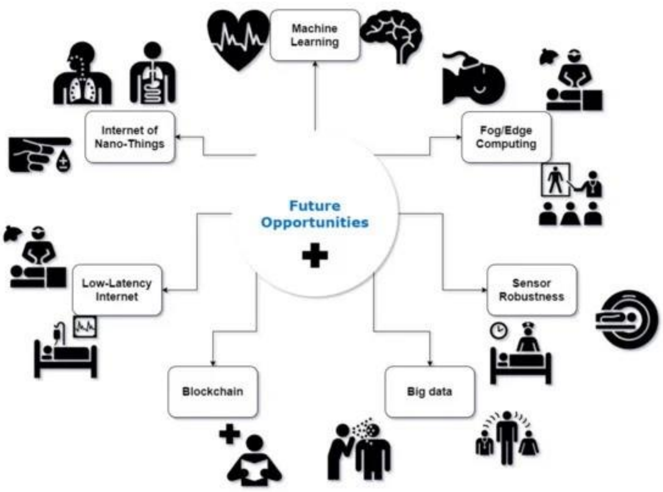

Fig. 6. Future opportunities of IoT-assisted wearable sensor systems in healthcare.

5.4. Blockchain:

Blockchain and cryptocurrency are gaining attention in the pandemic situation due to their potential to enhance security in healthcare databases. Blockchain's ability to secure cryptocurrency can lead to the development of secure IoT-based healthcare systems. This integration of blockchain in IoT and IoMT can ensure data safety and prevent misuse. Blockchain can be used to create smart contract-based service subscriptions, providing a more reliable and efficient healthcare management system.

5.6. Internet of Nano Things:

The Internet of Nano Things is a subset of the Internet of Medical Things, utilizing programmable robots for complex surgeries. These robots can be remotely controlled or fully automated, recording vital parameters like blood pressure, respiration rate, and oxygen level. Nano sensors, injected or implanted in the body, can record these parameters without causing hindrance for the patient. Research is underway to develop automated nanorobots that can be injected into the body and monitored for potential diseases. This precision can help doctors make medical decisions with care and accuracy. Additionally, nanotechnology can be used to fabricate drugs more specifically, making precision medicine the future of pharmacy.

6. Conclusion

IoT systems have significantly improved healthcare monitoring by providing real-time monitoring, enabling foreshadowing of potential abnormalities and severe complications, and eliminating human error. The paper also discusses the importance of CE and FDA approval, the quality of service (QoS), and the open problems that need to be addressed to implement IoT systems on a larger scale. The most common problems with IoT systems in healthcare include the collected data range, sensing capabilities, and size of the sensor. Power consumption is another important issue to address, as the wearable system must be of small size to avoid affecting other parameters. Privacy and the long-term effects of wearable technology are also important considerations. The review is a detailed compilation of IoT wearable technology in the healthcare industry, covering all the advantages and issues faced by the technology. Future scope includes physical implementation with live data collection, analysis, computation, communication technologies, security options, customized sensor arrays, machine learning, and blockchain.

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