The Application of Wearable Devices for Daily Health Monitoring

Ruoyang Du*

Sichuan University-Pittsburgh Institute, Sichuan University, Chengdu, Sichuan, 610211, China

*Corresponding author: 2023141520282@stu.scu.edu.cn

Abstract. In the context of the booming wearable device industry, wearable devices equipped with diverse biosensors have rapidly advanced, leveraging portability, real-time monitoring, and accurate detection. These diverse devices can measure multiple health data, achieving various monitoring goals. This paper focuses on categorizing and summarizing the application scenarios of three major types of wearable devices for daily health monitoring. Employing a literature review methodology, this research retrieved, screened, categorized, and summarized articles from academic websites such as CNKI and Web of Science, introducing the detection targets of wearable devices primarily utilizing optical sensors, piezoelectric sensors, and electrochemical sensors. The application scenarios are divided into daily monitoring for healthy individuals and those with chronic conditions, with detailed analyses based on specific scenarios such as sleep, exercise monitoring, cardiovascular diseases, diabetes, Sleep Apnea Hypopnea Syndrome (SAHS), and fall prevention for the elderly. This research summarizes the advantages (portability, real-time monitoring, non-invasiveness) and limitations (accuracy improvement needed, susceptibility to environmental factors, individual differences neglected) of wearable devices. Finally, it outlines future directions for optimizing performance and user convenience, including intuitive diagnostic displays and aesthetic designs.

Keywords: Wearable device; health monitoring; application.

1. Introduction

In recent years, wearable devices such as the Apple Watch have flourished, attracting widespread attention. Currently, in the field of daily health monitoring, wearable devices primarily utilize optical sensors, piezoelectric sensors, and electrochemical sensors to monitor human health data such as heart rate, blood pressure, blood oxygen levels, and sweat in a non-invasive manner through wristbands, hats, watches, and other forms. These devices display health data to users in real time, enabling them to understand their health status instantly. Their portability and timeliness are widely welcomed by consumers.

This research focuses on analyzing the application of wearable devices in daily monitoring. This research introduces and summarizes the types of wearable devices used for daily health monitoring, the objects of detection, and analyzes the corresponding application scenarios of different categories of wearable devices. Additionally, it analyzes the current advantages and limitations of wearable devices. Finally, based on their strengths and weaknesses, it summarizes the future directions for performance optimization and user convenience trends of wearable devices for daily health monitoring. The objective of this article is to analyze the current situation of wearable devices in daily monitoring applications and summarize the advantages and disadvantages of wearable devices on the market. Furthermore, this article derives methods to leverage their strengths and address their weaknesses. Consequently, this research can provide references for future research and development, optimization, and development directions of wearable devices.

2. Wearable Devices for Daily Health Monitoring

2.1. Types of Wearable Devices

Currently, wearable devices used for daily health monitoring are primarily categorized into three major types of sensors: optical sensors; piezoelectric sensors; and electrochemical sensors.

2.2. Detection Targets of Wearable Devices for Daily Health Monitoring

In daily health monitoring, heart rate, blood pressure, and blood oxygen saturation reflect the basic health status of users. Sweat detection, such as measuring the degree of dehydration, primarily reflects users' health status during physical exercise. Therefore, the primary detection targets for wearable devices used in daily health monitoring are: heart rate, blood pressure, blood oxygen saturation, and sweat

2.2.1 Heart rate

Heart rate, as a key indicator for assessing overall health, plays a crucial role in sleep monitoring, exercise detection, and predicting various cardiac diseases. Using piezoelectric sensors and optical sensors is a common method for measuring heart rate. Piyawat Samartkit et al. studied a non-invasive blood pressure, heart rate, and blood pressure monitoring system based on piezoelectric sensors and PPG sensors, achieving real-time heart rate measurement with satisfactory accuracy through experiments [1]. Thus, wearable devices have high feasibility and significant importance for heart rate measurement.

2.2.2 Blood pressure

Blood pressure monitoring is vital for predicting diseases such as hypertension and is also an important indicator for daily health monitoring. PPG sensors are commonly used for measuring blood pressure. Remo Lazazzera et al. proposed a wearable smartwatch based on PPG sensors that avoids inflatable cuffs and achieves continuous blood pressure measurement, with experimental results demonstrating comparable accuracy to professional non-automated sphygmomanometers [2].

2.2.3 Blood oxygen saturation

Blood oxygen saturation, another crucial health indicator, reflects the body's oxygen deficiency and is significant in predicting respiratory diseases. According to research by Wang, the article presents a blood oxygen detection method based on PPG sensors and a method to improve accuracy, enabling wearable devices to measure blood oxygen saturation [3].

2.2.4 Sweat

Human sweat carries a wealth of health indicators. Zhou et al. indicate that sweat sensors based on electrochemical sensors can detect alcohol, vitamin C, and glucose levels in the human body, which is of great significance for health monitoring and designing personalized nutrition plans. Additionally, sweat detection can be used for monitoring bodily functions during exercise [4]. Their article showcases a three-part design for sweat sensors based on electrochemical sensors, demonstrating the feasibility of wearable devices for sweat detection.

3. Application Scenarios of Wearable Devices for Daily Health Monitoring

Based on the above three types of sensors and their detection targets, the main application scenarios for wearable sensors used in daily health monitoring are divided into three categories: daily monitoring for healthy individuals, postoperative recovery patients, and individuals with chronic illnesses and subhealth conditions. These three application scenarios of wearable devices will be analyzed and summarized by presenting some specific applications.

3.1. Daily Health Monitoring for Healthy Individuals

For healthy individuals, the primary focus of their daily monitoring lies in sleep and exercise monitoring. Sleep, as a vital activity for human rest, has become a crucial aspect for people to understand their sleep patterns and make improvements in order to maintain immunity, prevent diseases, and promote health. Exercise, as an indispensable part of life, has gradually shifted people's attention to safety during exercise and how to exercise scientifically. Therefore, this research will next analyze the specific application scenarios of wearable devices in these two areas.

3.1.1 Sleep monitoring

In today's society, many people suffer from sleep problems such as insomnia. Consequently, utilizing wearable devices for sleep monitoring has become essential. By continuously monitoring users' heart rate, blood pressure, blood oxygen levels, and other data during sleep, wearable devices can present this information to users the next day. This allows users to understand their sleep duration and quality, enabling them to take measures such as appropriate exercise to improve and enhance their rest quality, thereby safeguarding their immunity and maintaining normal daily life and routines.

3.1.2 Exercise monitoring

Exercise is an indispensable activity in life, especially for athletes and sports enthusiasts. Ensuring safety during exercise is crucial. Wearable devices can measure users' heart rates and blood pressure in real-time during exercise, providing timely feedback on their physical condition. This allows users to adjust their exercise intensity and volume in a timely manner, avoiding diseases such as sudden death caused by overexertion. Additionally, wearable devices can detect sweat, enabling continuous and real-time monitoring of lactate, glucose, and sweat rate indicators across various environments.

3.2. Daily Health Monitoring for Chronically Ill and Sub-healthy Individuals

In addition to daily health monitoring for healthy individuals, the real-time monitoring capabilities of wearable devices are even more critical for patients with chronic illnesses and sub-healthy individuals. Wearable devices can continuously monitor patients' health data, and promptly detect abnormalities, thereby providing early warnings of disease onset, assisting in managing daily activities conducive to recovery, and helping patients seek medical attention in a timely manner. Below, this research will enumerate three diseases, along with monitoring for the elderly, to specifically analyze the applications and advantages of wearable devices in these areas.

3.2.1 Cardiovascular diseases

Cardiovascular diseases will be analyzed in terms of arrhythmia and hypertension. Arrhythmia typically manifests as symptoms such as tachycardia, bradycardia, irregular heartbeat, and atrial fibrillation. In such cases, wearable devices can detect arrhythmia symptoms by continuously measuring heart rate, enabling patients to seek medical attention promptly. According to the article by Ma et al., unlike traditional electrocardiograms (ECGs) that cannot monitor patients in real-time and invasive devices that pose harm and restrictions to patients, new wearable devices can utilize PPG sensors for real-time heart rate monitoring with highly satisfactory accuracy [5].

Furthermore, hypertension, as a vascular disease, can induce more chronic illnesses, so its diagnosis is also crucial. According to the article by Ma et al., wearable devices based on PPG sensors can record patients' blood pressure in real-time and provide abundant and varied blood pressure data, which has a significant positive impact on doctors' diagnoses and daily disease monitoring [5].
Therefore, due to their continuity and real-time nature, wearable devices have great potential to help predict, diagnose, and monitor cardiovascular diseases.

3.2.2 Diabetes

Diabetes, as a chronic disease, necessitates real-time blood glucose monitoring for effective management. According to Zhou et al., sensors based on glucose oxidase have the potential to detect glucose levels in sweat, aiding in the diagnosis and management of diabetes. They propose the use of

wearable sweat sensors, assisted by glucose oxidase sensing units, for non-invasive glucose detection. Currently, diabetes patches that measure glucose levels in sweat are available, combining portability with real-time monitoring. These patches provide rich and timely data for patients to manage their condition and for doctors to make diagnoses, greatly benefiting patient control and recovery. They also serve as a tool for predicting pre-diabetes[4].

3.2.3 Sleep apnea hypopnea syndrome (SAHS)

Sleep Apnea Hypopnea Syndrome (SAHS) is a highly prevalent respiratory disorder that can cause breathing cessation during sleep, potentially leading to chronic illnesses and even death. Traditional SAHS detection devices are expensive and time-consuming. Moreover, SAHS detection often involves monitoring blood pressure, blood oxygen levels, and heart rate. Therefore, non-contact wearable devices show great promise for respiratory monitoring during sleep. According to Song et al., one of the symptoms of SAHS is apnea, making blood oxygen saturation a key indicator for SAHS detection. The article mentions wristband and fingertip wearable devices for measuring blood oxygen saturation, with satisfactory accuracy [6]. Wearable devices offer affordability, accuracy, and portability in detecting SAHS, presenting a promising outlook for this application.

3.2.4 Fall Prevention for the Elderly

In the daily health monitoring of the elderly population, apart from basic indicators such as heart rate and blood pressure, fall detection is of great importance due to the higher risk of injury and fractures from falls among elderly individuals with osteoporosis. Therefore, wearable devices have significant potential in timely detecting falls or fall tendencies in the elderly. Nandi et al. have designed a wristband based on inertial measurement and heart rate sensors for fall detection[7]. By predicting falls using this device, measures such as cushioned air mats can be implemented to reduce the impact on the elderly when they fall. Additionally, this can alleviate their psychological shock, thereby achieving effective monitoring of the elderly.

4. Advantages and Limitations of Wearable Devices

4.1. Advantages

Firstly, wearable devices boast portability, with their compact appearance and design facilitating ease of use for users, allowing them to be taken into more occasions compared to traditional large-scale detection equipment.

Moreover, their portability enables real-time monitoring. For instance, traditional blood pressure measurement machines require inflating cuffs, making continuous, real-time monitoring impossible. However, current wearable devices based on PPG sensors can measure blood pressure by simply touching the skin, saving time on cuff inflation and enabling real-time monitoring, thus making detection more flexible.

Lastly, most current wearable devices employ non-invasive detection methods, avoiding harm to users, which further highlights their portability.

4.2. Limitations

Although the accuracy of most wearable devices is consistent or similar to traditional detection equipment, there is still room for improvement in accuracy to enable more precise and error-free detection.

While wearable devices are not restricted by the environment, environmental differences can affect device performance, such as dust and air humidity, which may lead to inaccurate detections.

Due to individual differences, people have varying normal heart rates and blood pressures. Some people's heart rates and blood pressures are faster or slower, higher or lower than others. Most current wearable devices only present health indicator data. These devices do not learn from the data to

develop a set of standards suitable for individual users. This hinders more precise detection and diagnosis, as well as timely reporting when indicators are abnormal.

5. Future Development Trends and Prospects for Wearable Devices

Improving the detection accuracy of wearable devices is the primary development direction. Although most wearable devices on the market have reached the standards of traditional detection equipment, due to their portability, people will take them into various environments, where the devices may be significantly affected by environmental factors, thereby impacting their accuracy. Therefore, reducing environmental impact to enhance device detection accuracy will be a future trend.

Currently, most wearable devices present data such as heart rate, blood pressure, and blood oxygen levels directly to users. However, most users are non-medical personnel with a limited understanding of health indicator data standards and what elevations or reductions may indicate in terms of diseases or issues. This can lead to inconvenience for users when using wearable devices. Therefore, integrating wearable devices with artificial intelligence through data learning to summarize health indicator data into specific preliminary diagnostic results will make it more convenient for users.

Furthermore, due to individual differences in normal health indicators, wearable devices can use data learning to summarize personalized health data for more accurate reflections of users' health status for more precise diagnoses.

As intelligent wearable devices, more capabilities can be explored in the future, such as automatically calling an ambulance or contacting friends and family when health indicators are extremely abnormal. However, such features should be based on sufficiently high detection accuracy to avoid social resource wastage due to mismeasurements.

As wearable devices are carried around, their design aesthetics and appearance are also crucial. Currently, common wearable devices are mostly wristbands, watches, and a few wearable T-shirts. Attractive and fashionable appearances can effectively draw consumers' attention, which is another major concern for consumers beyond performance.

6. Conclusion

This paper introduces three categories of wearable devices, analyzes their application scenarios in two contexts, evaluates their current advantages and disadvantages based on these scenarios, and proposes future trends and prospects for wearable devices. By summarizing the application scenarios, advantages, and disadvantages of wearable devices in daily monitoring, this paper systematically describes the current development status of wearable devices, providing an overview of the current situation and research direction references for future research on wearable devices in daily monitoring. Finally, based on the proposed future trends in this paper, research on improving the detection accuracy of wearable devices in various environmental conditions, integrating wearable devices with artificial intelligence to provide users with real-time preliminary diagnostic results, achieving individualized health data provision, and enabling wearable devices to provide timely ambulance calls and family contact functions based on real-time monitoring, have great potential in the future development of wearable devices.

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