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Review Article

Step-by-Step Guide to Building Wearable Health Devices

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Abstract
In this research, how to build wearable health devices is covered. Wearable sensors that monitor vital signs can potentially be used to evaluate the health of patients. Thus, they can be of great use to both patients and medical professionals in the process of diagnosing illnesses, especially when it comes to taking a patient's body temperature in the case of infectious disorders.

Keywords: *Sensors, Drawbacks, Advantages, Wearables Connected Devices, Heart Rate Variability, Blood Pressure.*

I. INTRODUCTION
According to the National Heart, Lung, and Blood Institute (NHLBI), an additional 1373 fatalities occur in the US each year on average as a result of weather with a heat index of 90 degrees or higher [1]. Although the world is seeing an increase in these severe temperatures, many workplaces have long tolerated them. According to data from the US Department of Labor, 344 work-related deaths resulting from environmental exposure occurred between 2011 and 2019 [2]. This figure, however, is thought to be far less indicative of the true number of heat-related industrial fatalities and injuries [3]. A worker's physical activity raises their body temperature and increases the metabolic energy turnover [4], which enhances their vulnerability to heat-related stress on the body. When the body is unable to expel extra heat, heat stress arises, increasing the risk of disease or damage for workers [3]. Headaches, nausea, weakness, disorientation, higher body temperatures, and decreased urine production are among the common symptoms of heat exhaustion [3]. Additionally, it has been demonstrated that heat stress raises systemic inflammation in the body, which is connected to a number of prevalent health issues [5,6]. Given the detrimental effects of this systemic inflammatory response, both immediately and later, heat stress is a significant risk factor for many chronic disease processes that affect workers. We need to be able to keep an eye on how heat affects employees given the consequences of rising temperatures in different parts of the world [7], [40–41]. The National Safety Council reports that 49% of firms have adopted wearable technology to check employee health risks [8], as well as to supposedly detect sweat rates and skin temperature [40, 41]. The body's natural reaction to heat stress is to raise blood flow to the skin's surface in order to facilitate sweating, which aids in cooling the body. In order to achieve this, blood vessels will dilate and the heart rate will rise, lowering blood pressure [9, 10]. In order to provide early detection of the effects of heat stress on the body, employers should implement a wearable device that can monitor both body temperature [40, 41] and heart rate simultaneously. This is because of the dangerous fluctuation in vital signs that are representative of physiological functioning. Reducing the number of work-related fatalities brought on by working in extreme weather, like heat, may depend on early detection. The current methods for limiting an employee's exposure to heat-related stressors center on estimating the worker's level of heat stress based on clothing, exertion level, and environmental factors like temperature and humidity [11]. Although groups like the American Conference of Governmental and Industrial Hygiene (ACGIH) establish threshold limit values (TLV) based on these factors, workers' reactions to heat are not tailored to their particular circumstances [12]. Monitoring each worker's physiological parameters is crucial to genuinely preventing heat-related injury, even though preventing heat stress based on environmental conditions is a good place to start [12]. To remotely monitor an individual, wearable

sensor systems need three main components: hardware for data collection, hardware for communication, and techniques for data analysis [13]. Sensors that track perspiration [14–16], temperature (core, skin, and rectal) [12, 17], heart rate, variability, recovery rate [12], and perceived exertion are among the wearables linked to the prevention of heat stress [12]. Smart wearable sensors can be used to measure a variety of physiological parameters, including pulse oximetry, blood pressure, pulse pressure, respiratory rate, and electrocardiograph (ECG) tracing [18–23]. These measurements are then recorded in a data acquisition device and sent to a monitoring location. The raw data is often collected by body temperature sensing technologies using either photoconductivity, infrared, thermistor, thermoelectric effects, or photodetector technologies [24, 25]. By using these technologies, it was demonstrated that the core temperature could be estimated with high accuracy (MAE 0.297, MSE 0.133) based on skin temperature and skin perfusion [26]. Core temperature can also be monitored using a radiometer to measure the thermal radiation emitted from the body with high levels of accuracy [27].

II. RELATED WORKS

This article describes an Internet of Things (IOT)-based heartbeat rate monitoring device that is battery-powered and supported by a human kinetic energy harvester, allowing the monitoring period to be extended. An electrocardiogram (ECG) is a stress or exercise device that can monitor a patient's heart rate continuously while they go about their daily activities, such as walking, running, and jumping [28]. The objective of this study was to correlate the vital parameters; including ECG, pulse rate, respiratory rate, temperature, heart rate, oxygen saturation, and blood pressure; derived from Real Time Multi vital remote monitoring (RTMVRM) solution and standard vital monitoring methods in chronic ischemic heart disease patients, stable on medication [29]. The purpose of this study was to determine the usability of the Slate Safety (SS) wearable physiological monitoring system. Methods: Twenty nurses performed a common task in a moderate or hot environment while wearing the SS device, the Polar 10 monitor, and having taken the e-Celsius ingestible pill. Data from each device was compared for correlation and accuracy. Results: High correlation was determined between the SS wearable device and the Polar 10 system (0.926) and the ingestible pill (0.595). The SS was easy to wear and a handy tool for remotely monitoring several participants. Conclusions: The wearable Slate Safety device showed accuracy in determining the worker's heart rate and core temperature without limiting their range of motion. It also offered a platform for remote monitoring of physiological parameters [30]. This paper develops a realtime heart monitoring system taking into account data security, accuracy, cost, and ease of application. The idea behind the system is to give patients and doctors a two-way interface for communication. This study's primary goal is to make it easier for cardiac patients who live far away to receive the most recent medical care, as the low doctor-to-patient ratio may make this impossible otherwise. Under the guidance of experts, 40 participants (aged 18 to 66) are assessed on the developed monitoring system using wearable sensors while holding an Android device, or smartphone. Because of its quick speed, the performance analysis demonstrates that the suggested system is dependable and beneficial. The analysis revealed that the suggested system is affordable, dependable, and easy to use while guaranteeing data security. Furthermore, in emergency situations, the developed system can send warning messages to both the patient and the doctor [31]. This study aims to examine the significance of heart rate monitoring through wearable IoT devices. The literature study method was utilized in this study's data collection; a descriptive data analysis and a qualitative approach were also employed. The findings demonstrate the importance of using IoT wearable heart rate monitoring devices because they are highly beneficial for patient monitoring [32]. This paper focuses on the algorithms for HR evaluation and describes a system for signal acquisition and processing based on a wearable textile device equipped with sensors for measuring chest movement and one-lead ECG. These signals are gathered and sent by an electronic board to a PDA, which then sends them over WiFi to a home gateway, which generates the HR and RespR time series. The data is combined by the home gateway with additional vital signs that are gathered through various devices and sent in XML format to a central repository. From there, a clinical decision support system can use the data to identify early decompensation episodes. The system is prepared for more in-depth testing in an actual clinical setting after successfully completing an initial test phase [33]. This review covers the principles of cardiac signal generation and recording, wearable technology, advantages and disadvantages, with a particular emphasis on the precision and usability of commercial and medical-grade diagnostic equipment that has demonstrated encouraging outcomes in terms of value and dependability. Cloud-based remote monitoring and artificial intelligence integration [42–45] have been developing to speed up data processing, enhance patient convenience, and guarantee data security [34]. In this project, which was motivated by auscultation, a robust heart rate monitoring application and a wearable stethoscope with biocompatible adhesives were designed and put together. First, the adhesives' geometry was improved, and the device's benefits were compared to those of PPG. After that, it was shown on several body arteries. We ran algorithms to make our device resistant to noise from the surroundings and various motion artifacts. Finally, our device's accuracy for continuous heart rate monitoring when compared to the gold standard, an ECG, suggests that our system may offer new wearable technology that could enable early detection of mental illnesses or cardiovascular diseases associated with abnormal heart rates over a variety of time periods [35]. In this work, we present a wearable platform for monitoring heart rate in the 5G ISM band, which operates at sub-6GHz. The custom-printed circuit board (PCB) for data acquisition and transmission, a patch antenna, and an aluminum-nitride piezoelectric sensor make up the proposed device. The results of the experiment demonstrate that the system that is being presented is capable of obtaining heart rate from the posterior tibial artery along with diastolic and systolic duration, which are associated with heart contraction and relaxation, respectively. With a system size of 20 mm by 40 mm and a weight of 20 g, this gadget is lightweight and appropriate for daily use. Additionally, the system enables the use of a single reader to monitor several subjects or a single patient simultaneouslyfrom various body locations. The encouraging outcomes show that the suggested system can be used for Internet of Healthcare Things (IoHT) applications, specifically for Integrated Clinical Environments (ICE) [36]. We present a new integrated portable device that uses Ethernet technology and the widely available internet to provide a convenient solution for remote body temperature and fingertip heart rate monitoring. Heart disease is becoming more common these days. In these situations, patients frequently are unaware of their true conditions, and while it is true that most diseases are curable if caught early enough, this is especially true in rural areas where access to doctors is often limited. We have attempted to create a system that could provide health-related information and assist a person in identifying these fatal but treatable illnesses. The system provides real-time data on body temperature and heart rate [40, 41], which are simultaneously recorded on the portable side and sent to the internet. This technology allows for remote monitoring of body temperature and cardiac health. In the end, this gadget will close the gaps between patients and physicians by offering an inexpensive, readily available human health monitoring solution [37]. This article designs wearable devices using Internet of Things and virtual reality technology to address the shortcomings of the traditional monitoring equipment that make it difficult to measure the daily physical parameters of the elderly and improve the accuracy of parameter measurement. This gadget measures four physical parameters that older people experience on a daily basis: blood pressure, exercise heart rate, plantar health, and sleep quality. Experiments are used to confirm the equipment and measurement method's viability. The experimental findings demonstrated a high degree of accuracy in the reflective photoplethysmography signal-based measurement method, with the subjects' heart rate mean and difference values essentially ranging around 0 BPM and showing good agreement between the estimated heart rate and the reference value. The correlation coefficient between the reference value and the Prs estimate in the blood pressure measurements was 0.81. With the highest correlation coefficient of 0.96 ± 0.02 for subjects' resting heart rates, the device used in the article had a high estimation accuracy; its estimation error rate was 0.02 ± 0.01. Subject B8's Pnth value was higher than that of subject B21's, and subject B8's symptoms were more severe, which was in line with the real circumstances. The wearable gadget was able to recognize the subjects' ocular characteristics and deliver relevant videos to aid in the subjects' slumber. The article offers a technique and tool that let medical professionals ask questions in real time and get usergenerated health advice [38]. Examining sensors and transducers for stroke detection is the goal of this study. Preferred Reporting Items for Systematic Reviews (PRISMA) are used in this study's systematic literature review. After screening and selecting potential articles, 84 were found to meet the inclusion criteria. According to the research findings, artificial intelligence built on the internet of thought—which makes use of sensors and transducers—is presently initiating the development of sensors and transducers for stroke detection. Based on the development of tools that employ sensors and transducers for stroke detection, it is clear that optimizing these devices for this purpose requires careful application, close regulatory oversight, and ongoing innovation in order to help lower the global stroke rate [39].

III. HOW TO BUILD WEARABLE HEALTH DEVICES

Step 1: Define Objectives and User Needs

Particularly at the beginning, start by precisely outlining the aims and purposes of your wearable health gadget. Choose the precise health indicators that it will track, such as stress levels, physical activity, sleep habits, and heart rate. Furthermore, especially in the early phases of development, carry out in-depth market research to comprehend the requirements, preferences, and pain points of your target users. Here are a few things to think about in order to grasp this step more thoroughly.

i. User Demographics:

Recognize the age, gender, occupation, and socioeconomic position of your target customers in order to customize the wearable technology to suit each user's needs and encourage participation in their health management.

ii. Health Goals and Objectives:

Determine the main health aims and goals that your target users hope to accomplish with the aid of your wearable technology.

iii. User Pain Points:

Identify the challenges, frustrations, and limitations that users currently face in managing their health and wellness through conducting surveys, interviews, and focus groups.

iv. User Preferences and Behaviors:

Explore user preferences, habits, and behaviors related to health monitoring and wearable technology usage.

v. Integration with Existing Ecosystems:

Consider how your wearable health device will integrate with existing health and wellness ecosystems, including mobile apps, fitness platforms, Electronic Health Records (EHRs), and telemedicine services.

vi. Accessibility and Inclusivity:

Ensure your wearable health device is accessible and inclusive to users with diverse needs and abilities. Consider factors such as readability, language support, audio feedback, tactile feedback, and adjustable settings to accommodate users with visual, auditory, motor, or cognitive impairments.

vii. Long-Term Engagement and Motivation:

Explore strategies to promote long-term engagement and motivation among users to sustain healthy behaviors and adherence to monitoring routines.

Step 2: Select High-Quality Components and Sensors

After goals are established, such as meeting the needs of people with long-term illnesses, select dependable parts and wearable sensors to ensure robust operation and precise vital sign data collecting. In order to guarantee efficient long-term health monitoring, give top priority on sensor accuracy, sensitivity, response time, and durability. Furthermore, assess various sensor technologies and connectivity choices (e.g., Bluetooth, Wi-Fi, cellular) to ascertain which best suits the needs of your device and enhances the user experience in situations involving remote monitoring. Here are a few sensory technologies to think about while choosing premium parts and sensors:

i. Photoplethysmography (PPG) sensors:

These sensors measure heart rate by detecting changes in blood volume through optical sensors. They are commonly used in wrist-worn devices like smartwatches and fitness trackers.

ii. Electrocardiography (ECG) sensors:

ECG sensors measure the heart's electrical activity to provide more accurate heart rate data and detect irregular heart rhythms. They are often integrated into chest straps or patches for medical-grade monitoring.

iii. Accelerometers:

Accelerometers measure movement and orientation changes, allowing for accurate tracking of physical activity, steps taken, and sleep patterns. They are essential for monitoring activity levels and providing insights into daily movement habits.

iv. Gyroscopes:

Gyroscopes complement accelerometers by measuring rotation and angular velocity, providing additional context for activity tracking and motion analysis.

v. Actigraphy sensors:

Actigraphy sensors use accelerometers to monitor movement patterns during sleep, providing insights into sleep duration, quality, and disruptions. They are commonly integrated into medical wearables to track sleep stages and assess sleep health.

vi. Thermistors:

Temperature-sensitive resistors measure temperature changes and provide real-time temperature data. They are used for monitoring body temperature, ambient temperature, and environmental conditions relevant to health and well-being.

vii. Pulse oximeters:

Pulse oximeters measure blood oxygen saturation levels by analyzing light absorption in arterial blood. They are increasingly integrated into wearable devices to monitor respiratory rate and oxygen levels in real time, especially in situations like sleep apnea or high-altitude activities.

viii. Electrochemical Biosensors:

They are commonly used for monitoring glucose levels in diabetic patients and detecting other analytes relevant to health monitoring. Through biosensor technology, electrochemical biosensors enable precise, real-time biomarker measurement for accurate health assessments.

Step 3: Design User-Centric Interfaces

Creating interfaces with the user in mind the next critical stage is to prioritize accessibility, readability, and simplicity of use. To provide health data in an intelligible fashion, create visually appealing displays and simple navigation processes. Throughout the design process, take usability testing and user feedback into account to improve the interface and maximize user interaction. These are some key elements to take into account when creating a user interface, as they are critical to improving the user experience and encouraging interaction with wearable health equipment:

i. Develop Intuitive Interfaces:

Create interfaces prioritizing ease of use, readability, and accessibility. Design intuitive navigation flows and visually appealing displays to present health data clearly and understandably.

ii. Consider User Feedback and Usability Testing:

Throughout the design process, incorporate user feedback and conduct usability testing to refine the interface and optimize user interaction.

iii. Clarity and Simplicity:

Keep the interface clear, simple, and easy to navigate, minimizing user complexity.

iv. Consistency and Familiarity:
Maintain consistent design elements and patterns familiar to users of wearable devices and mobile apps, promoting ease of use and familiarity.

v. Customization and Personalization:
Enable users to personalize settings and layouts based on their preferences and health goals, enhancing engagement and usability.

vi. Responsive Design:
Ensure the interface adapts seamlessly to different device sizes and input methods, providing a consistent user experience across various platforms and devices.

vii. Accessibility and Inclusivity:
Implement features to accommodate users with diverse needs, such as screen reader compatibility and adjustable settings, fostering inclusivity and accessibility.

viii. Feedback and Guidance:
Provide clear feedback and guidance to users through visual cues and notifications, reinforcing actions and progress and enhancing user engagement.

ix. Data Visualization and Interpretation:
Present health data visually using charts and graphs to make trends and insights easily understandable, empowering users to interpret and act upon their health information effectively.

Step 4: Ensure Data Security and Privacy
Afterward, implement robust security measures to protect sensitive health data from unauthorized access, tampering, or breaches. Integrating strong encryption and secure storage methods to safeguard user data is essential. Clear privacy policies should be established, and user consent for data collection must be obtained. Regular software and firmware updates are necessary to address any security vulnerabilities effectively. Collaborating with cybersecurity experts can further ensure the highest level of user data protection [51, 52] and enhance such devices' overall security posture.

Step 5: Optimize Power Efficiency
Focus on optimizing power consumption to extend battery life and enhance user convenience. Employ energy-efficient hardware designs, low-power components, and power management techniques to minimize energy consumption without compromising device performance. Moreover, implement sleep modes, idle timeouts, and other power-saving features to maximize battery longevity and usability between charges. Integrating energy-saving techniques ensures that devices remain operational for extended periods, empowering users to monitor their health effectively without frequent interruptions for recharging.

Step 6: Conduct Rigorous Testing and Validation
It is essential to carry out thorough testing and validation of your wearable health gadget to guarantee its accuracy, dependability, and functioning in a variety of scenarios. When testing and validating, replicate real-world settings and environments. If device data needs to be compared to established medical standards, do so. In addition, getting thorough input and insights from end users and healthcare professionals during the testing and validation phase is crucial for producing wearable health devices of the highest caliber.

Step 7: Obtain Regulatory Approvals and Certifications
Lastly, to lawfully market and distribute your wearable health gadget, negotiate the regulatory environment and secure the required approvals and certifications. Recognize and abide by consumer safety, data privacy, and medical device laws in your target markets. Additionally, as necessary by regulatory bodies like the FDA (Food and Drug Administration) or CE (Conformité Européenne), compile and submit regulatory documentation, including technical specifications, risk assessments, and clinical data. Work together with legal counsel and regulatory specialists to effectively manage the process and reduce compliance risks [50].

CONCLUSION

Numerous studies on blood pressure and cardiac monitors have been reviewed in preparation for this inquiry. Evidence of their technological achievements and impact on contemporary society has been presented to us [47]. A detailed explanation of the main benefits of tracking your health with wearable technology is provided [48]. Nonetheless, a few potential downsides were also covered in this study [49].

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