Article

Not peer-reviewed version

Smart Health Monitoring System for Elderly Palestinians Using Internet of Things (IoT)

Majdi Jaradat * and Isam Ishaq

Posted Date: 5 June 2024

doi: 10.20944/preprints202406.0302.v1

Keywords: Internet of things (IoT); smart health care; Traditional healthcare; Wearable Devices; Elderly Health Monitoring

Article

Smart Health Monitoring System for Elderly Palestinians Using Internet of Things (IoT)

Majdi Jaradat [1,†,‡], **Isam Ishaq** [2,‡]

[1] Graduate Studies, Information Technology Engineering, Arab American University, Palestine; m.saleh24@students.aaup.edu
[2] Computer Science Department, Al-Quds University, Palestine; isam@alquds.edu
* Correspondence: m.saleh24@students.aaup.edu;

Abstract: Problem: Palestinian demographic landscape is undergoing an increase in the elderly population like many regions across the world. The elderly Palestinians face a unique challenges and problems of limited access to traditional care due to restricted movement, checkpoints, and also for limited healthcare resources. Therefore, the need arose to develop a sensitive and adaptable smart health monitoring system for Palestinian elderly to provide accurate and timely health data to improve well-being and prevent complications. **Method:** The proposed system (SHMS) leverages the Internet of Things (IoT) with appropriate sensors to track vital signs like heart rate, blood oximeter, body temperature and signal from a patient heart. Advanced algorithms analyze the data, generating alerts for potential health risks, triggering timely interventions, and enabling remote consultations. **Results:** This system has the potential to contributes to SDG 3 to significantly improve the health and well-being of elderly Palestinians by providing an accurate, low-power, and low-cost system for remote health monitoring. The system, being wearable, reads vital signs in real-time, overcoming geographical barriers and facilitating remote monitoring, especially in areas with limited healthcare centers and suffered from barriers along the way. The Doctor can suggest the patient's prescription needed based on the momentary condition of the elderly and on previous readings of the sensors, if necessary. Which will also be notified via messages. Moreover, the doctor can take immediate intervention in case of an emergency. By implementing the system, it will be unnecessary for more than 50% of the elderly to visit health care, thus reducing the cost to 50%.

Keywords: Internet of things (IoT); smart health care; Traditional healthcare; Wearable Devices; Elderly Health Monitoring

---

1. Introduction

Palestinian demographic landscape is undergoing an increase in the elderly population like many regions across the world. Which presents unique challenges, particularly in the realm of healthcare. The elderly in Palestine encounter distinctive challenges, expand by limited access to traditional care due to a combination of factors such as restricted movement, checkpoints, and lack of healthcare resources. To address these challenges, an innovative solutions must take into account. One of them, the development of a Smart Health Monitoring System (SHMS) using IoT, specially designed for the elderly in Palestine.

In traditional method, the patients need for regular visit to health care center even for minor problem,which required a lot of time for waiting a doctor to do required checkup,and need more consultation from specialists doctor, but by using the latest technology efficiently, this kind of scenarios could be avoided [1,2]. Through statistics obtained from the emergency department at the Palestine Medical Complex, it is stated that only 50% of elderly patients who visit the hospital need medical intervention, and that 50% of them leave without any medical intervention, and the procedure is limited to conducting tests related to examining the vital signs to them.This leads to the depletion of the efforts of medical teams, which already suffer from a lack of medical staff, in addition to the depletion of the hospital's logistical resources.

By leveraging the transformative capabilities of the Internet of Things (IoT). The proposed Smart Health Monitoring System (SHMS) represents a paradigm shift in elderly care [3]. By choosing integrating appropriate sensors, SHMS tracks vital signs crucial for health assessment, including

 doi:10.20944/preprints202406.0302.v1

heart rate, blood oximeter, body temperature and read ECG signal from a patient heart . We leverage advanced algorithms to analyze information in real-time, generating alerts for potential health risks. This not only facilitates timely interventions but also opens remote consultations between specialist doctors staff and elderly patients, reducing dependence on physical proximity to healthcare centers [4].

In this study, the Smart Health Monitoring System (SHMS) for elderly care introduces a developed healthcare solution that integrates technology for real-time monitoring of vital signs among the elderly. Employing a Raspberry Pi as a central broker, it establishes a robust connection with an ESP32 through WiFi. The ESP32 collecting data from vital sign sensors such as body temperature, heart pulse, blood oximeter and read ECG signal from a patient heart in real-time. These data are then transmitted to the healthcare system via a Rest API, facilitated by the Raspberry Pi utilizing MQTT. The system is designed with a proactive approach – in the presence of abnormal vital signs, alerts are promptly dispatched to both the patients and their relatives. This feature enables specialist doctors to intervene directly, ensuring timely and targeted healthcare responses, thus underscoring the potential impact of SHMS in enhancing elderly care as shown in Figure 1.

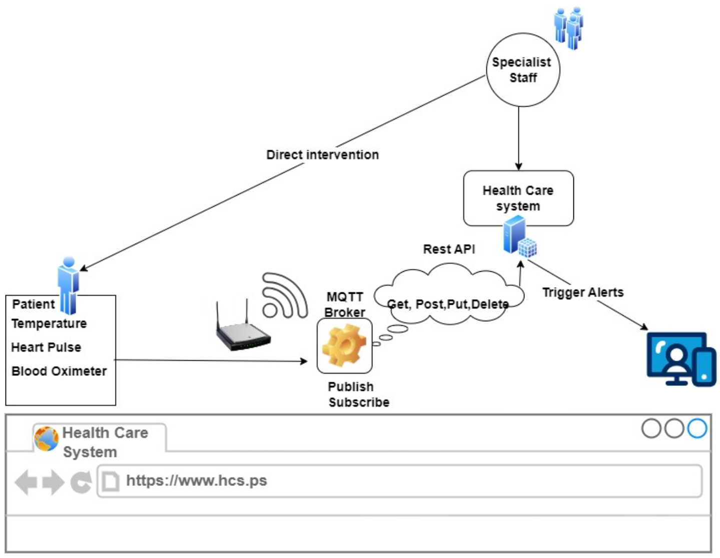

Figure 1. Overall system architecture.

The potential impact of the Smart Health Monitoring System is to offering a comprehensive solution to enhance the health and well-being of elderly Palestinians [5]. Its accuracy, coupled with a low-power and low-cost design, put SHMS as a feasible and sustainable option for remote health monitoring. The wearability of the system allows for continuous real-time monitoring, overcoming geographical barriers and effectively addressing the challenges faced by those residing in areas with limited access to healthcare centers.

2. Literature Review

We explored various researches and developments related to smart health monitoring systems for elderly care using the Internet of Things (IoT). Inorder to gain a full understanding of IoT technology used by smart healthcare monitoring to identify any gaps in the published research to make a strong contribution in that field. In this literature review, we examine and discuss the findings, methodologies, and limitations of several notable research papers in this domain.

In [4] propose an IoT-based patient health monitoring system to address the global issue of untimely and inadequate healthcare for elderly and ill patients outside the hospital environment. Utilizing the Internet of Things (IoT), the system employs Raspberry Pi as a gateway for sensor input devices attached to patients. The collected data is transmitted to a doctor's computer through the internet, enabling remote monitoring and immediate treatment, fostering a technologically advanced approach to medical care. Python and C languages are employed for programming in this innovative IoT-driven medical treatment system.

In [6], emphasizes the role of IoT in providing better medical facilities, even in remote areas. The proposed system involves various medical devices, including wearable devices connected to a Raspberry Pi microcontroller. The system records patients' heart rate, blood pressure, and sends real-time health status information to family members and doctors. Data mining techniques are suggested for analyzing and predicting chronic disorders.

In [7], proposes a smart healthcare system in an IoT environment that monitors patients' basic health signs and room conditions in real-time. Utilizing five sensors, including heart rate, body temperature, room temperature, CO sensor, and CO2 sensor, the system captures data and conveys patients' conditions to medical staff via a portal. The developed prototype demonstrates effectiveness, making it suitable for healthcare monitoring.

In [1] focuses on developing a wearable health monitoring system for elderly patients suffering from chronic diseases. The proposed system integrates sensors for measuring vital physical parameters, such as pulse rate, respiratory rate, and temperature. Data is sent via IoT cloud platform for remote monitoring, and any critical changes trigger alerts to doctors and family members. The wearable device is small, lightweight, and cost-effective.

In [2] propose a healthcare monitoring system that utilizes IoT and focuses on cardiovascular and lung diseases. The system uses wireless devices to continuously monitor patient health, enabling remote monitoring by doctors. It integrates wearable devices, wireless channels, and remote instruments to provide cost-effective healthcare monitoring. The system, based on Raspberry Pi, aims to improve patient diagnosis, reduce hospital visits, and save lives by offering timely treatments. The study positions IoT and Raspberry Pi as versatile platforms for healthcare applications.

The author [8]focuses on developing a smart health monitoring system for elderly individuals. They introduced an interactive real-time (IRT) interface integrated with a multi-lead period-peak detection (PPD) algorithm for electrocardiogram (ECG) processing. By leveraged technological advancements in sensors and microeloctronics. The system aims for accurate monitoring of cardiovascular and other biomedical signals in elderly people especially irregularities in heart rhythms, which need for embedded health monitoring systems has appility to handle complex computations for accurate diagnoses. The final goal is to develop a smart embedded system to monitor elderly people, enabling medical professionals to remotely monitor health and initiate interventions at home.

In the study [9] conducted a survey on the Internet of Things (IoT) in healthcare. They highlight the integral role of IoT in healthcare advancements. The focus on its impact on accessibility and overall health improvement. The escalating use of mobile information devices for health awareness and instant access to fitness applications is the core of their discussion, with a focus on remote health monitoring. The survey anticipates the extensive application of sensing devices in constructing ubiquitous health networks, particularly for elderly care, with enhancing doctor-patient interaction through portable monitoring devices, and the importance of data security and privacy in healthcare IoT applications.

The authors [10] present a low-cost health monitoring system tailored for elderly individuals, leveraging the Internet of Things (IoT). The system leveraging various sensors, including ECG, pulse oximeter, and temperature sensors, transmitting data to the cloud. In case of risk and emergencies, the system notifies the authorized persons via email. The prototype has been tested , and demonstrating efficacy in remote health monitoring, serves as a valuable example, particularly in pandemic scenarios like COVID-19. The proposed model contributes to affordable, integrated personal healthcare solutions for elderly people.

In [11] the authors proposed an IoT-based system for real-time remote health monitoring, using sensors for blood oxygen, ECG, and body temperature. The system employs a pre-trained deep learning model with attention layers for disease classification. It identifies heart conditions and fever, sending critical alerts to authorized personnel. Integrating IoT and deep learning, the system offers real-time monitoring, reducing healthcare costs and improving patient care. The research contributes by developing a high-performance model, achieving 0.98 accuracy in identifying heart issues, and exploring the potential of IoT and deep learning in home healthcare systems.

The study by [12] introduces a cloud-based IoT smart healthcare system for remote patient monitoring, emphasizing the need for advanced digital health technologies, particularly during the COVID-19 pandemic. Wearable sensors are highlighted as essential components integrated into a cloud-based IoT framework for real-time patient monitoring. The architecture of smart healthcare monitoring is discussed, including communication channels, embedded sensors, IoT servers, and cloud storage. The literature review explores the layers of data processing and the application of IoT in remote patient care, providing valuable insights into the evolving landscape of healthcare delivery.

In the research conducted by [5], utilized the Internet of Things (IoT) for health monitoring, and enhancing clinical facilities for patients and aiding healthcare professionals. The proposed solution integrates various clinical devices, such as sensors and online or mobile-based applications, establishing a network-connected system to monitor and record patients' health data and medical information. In this study, aims to develop a comprehensive healthcare system accessible even in remote areas by connecting over the Internet. Which employs wearable devices facilitated by a Raspberry Pi microcontroller, capable of recording vital parameters like pulse and blood pressure. The system is designed to alert patients' relatives and their primary care physician about the patient's current health status and provide full medical information in case of a health-related emergency.

In this study [13], the authors explored an Internet of Things (IoT)-based remote health monitoring system for patients and elderly individuals. The research presents a prototype of a remote health monitoring system that integrates three health sensors: heart pulse sensor, body temperature sensor, and galvanic skin response sensor. They used Arduino Uno and Raspberry Pi. The collected data from the sensors are transmitted to a cloud storage via the Raspberry Pi, allowing real-time updates to the database. The proposed system is more accessible and affordable through user-friendly applications for virtual and remote interactions with patients.

The article authored by [14] underscores the paramount importance of health in daily life and positions IoT in healthcare as a leading area of research that provides enhanced medical facilities for patients while facilitating healthcare practitioners and hospitals. The proposed system incorporates various sensors designed to capture patient data, particularly focusing on monitoring the patient's health condition through heartbeat and temperature sensors. The real-time status of these parameters is displayed locally on an LCD screen. This application, accessible from anywhere globally, interfaces with the Raspberry Pi and sensors, allowing for the wireless monitoring and recording of patients' health data and medical information. Additionally, the web-based application can be accessed on a mobile phone or PC, providing global monitoring capabilities.

The work presented by [15] introduces a Healthcare Monitoring System (HMS) that leverages the Internet of Things (IoT) paradigm and utilizes Raspberry Pi for real-time clinical feedback. The study addressing the significant increase in chronic diseases and the aging population globally, highlighting the need for an efficient Health Monitoring System to provide comfort to individuals. This approach is not only cost-effective but also offers a practical alternative to traditional healthcare, especially benefiting the elderly and patients with chronic conditions who may avoid frequent visits to healthcare institutions. By monitors crucial health parameters, including blood pressure, heart rate, and ECG. The data collected by Arduino UNO, with an additional Pi-camera attached to Raspberry Pi for video data. The server then sends the updated data to a webpage every two minutes.

The research conducted by [16] introduces an Internet of Things (IoT) Based Smart Health Care Medical Box tailored for elderly individuals. The proposed system revolves around a smart IoT-based healthcare system, featuring an intelligent medicine box equipped with sensors and connected to a server for continuous health monitoring. The key functionalities include ensuring patients take the right medicine at the right time and sending email notifications to patients as a reminder. The proposed solution emerges as a practical application in the realm of home healthcare, aligning with the broader digital transformation in healthcare. It emphasizes the potential benefits of real-time monitoring.

The research conducted by [3] introduces an innovative solution named "We-Care," an Internet of Things (IoT)-based Health Care System designed specifically for elderly individuals. The abstract commences by addressing the global challenge of an aging population, emphasizing the growing interest in developing solutions that cater to the needs of elderly individuals. The main objective of the proposed work is to leverage the IoT technology to help the elderly people monitoring their vital signs in real time, with offering mechanisms to trigger alarms in emergencies. The system having effective low power, low-cost, and wireless characteristics.

In summary, the reviewed studies have made significant contributions to the field of smart healthcare monitoring for elderly care. However, several limitations were identified across the studies, including reliability, accuracy, technical challenges, and others. Addressing these limitations in future research will enhance the reliability, generalizability, and practical applicability of remote monitoring for elderly care.

Table 1. Summary of Existing Studies on Smart Health Monitoring Systems for Elderly Care Using IoT

Reference	Objective/Key Focus	Methodology/Technology Used	Main Findings/Contributions
Ahmed et al. (2012) [8]	Smart health monitoring system for elderly individuals	Embedded Health Monitoring Systems, ECG Processing Algorithm	Accurate monitoring of cardiovascular signals, smart embedded system
Pinto et al. (2017) [3]	IoT-based Health Care System named "We-Care" for elderly individuals	IoT, Wireless, Low Power	Monitoring vital signs in real-time, triggering alarms in emergencies
Rohit et al. (2018) [4]	IoT-based patient health monitoring system for elderly care	Raspberry Pi, IoT, Python, C	Remote monitoring and immediate treatment, technologically advanced medical care
Soni (2018) [5]	IoT for health monitoring, enhancing clinical facilities	IoT, Wearable Devices, Raspberry Pi Microcontroller	Comprehensive healthcare system, accessible even in remote areas
Banka et al. (2018) [6]	Providing better medical facilities using IoT	Raspberry Pi, Wearable Devices, Data Mining	Real-time health status information to family members and doctors
Hamim et al. (2019) [13]	IoT-based remote health monitoring system for patients and elderly individuals	IoT, Sensors (Heart Pulse, Body Temperature, GSR), Cloud	Real-time updates to the database, accessible and affordable system
Muqeet et al. (2019) [14]	IoT-based Patient Monitoring System Using Raspberry Pi	IoT, Sensors (Heartbeat, Temperature), Raspberry Pi	Wireless monitoring and recording of patients' health data, global accessibility
Naik et al. (2019) [2]	Healthcare monitoring system focusing on cardiovascular and lung diseases	IoT, Raspberry Pi, Wireless Devices	Continuous monitoring for timely treatments, reduction in hospital visits
Zeb et al. (2019) [15]	Healthcare Monitoring System with real-time clinical feedback	IoT, Raspberry Pi, Sensors (Blood Pressure, Heart Rate, ECG)	Cost-effective alternative to traditional healthcare, real-time clinical feedback
Islam et al. (2020) [7]	Smart healthcare system in an IoT environment	IoT, Five Sensors (Heart Rate, Temperature, CO/CO2 sensors)	Real-time monitoring of basic health signs and room conditions
Al-Mahmud et al. (2020) [16]	IoT-Based Smart Health Care Medical Box for elderly individuals	IoT, Intelligent Medicine Box, Continuous Health Monitoring	Practical application in home healthcare, real-time monitoring
Sumathy et al. (2021) [1]	Wearable health monitoring system for chronic diseases	Wearable Devices, IoT Cloud Platform	Remote monitoring through IoT cloud platform, cost-effective solution
Lakshmi et al. (2021) [12]	Cloud-based IoT smart healthcare system for remote patient monitoring	Cloud, Wearable Sensors, IoT Framework	Emphasis on advanced digital health technologies, real-time patient monitoring

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 June 2024 doi:10.20944/preprints202406.0302.v1

Table 1. *Cont.*

Reference	Objective/Key Focus	Methodology/Technology Used	Main Findings/Contributions
Wang et al. (2022) [9]	Survey on IoT in healthcare	IoT, Mobile Information Devices, Fitness Applications	Impact of IoT on accessibility, health improvement, and doctor-patient interaction
Shaown et al. (2022) [10]	Low-cost health monitoring system for elderly individuals	IoT, Sensors (ECG, Pulse Oximeter, Temperature), Cloud	Affordable, integrated personal healthcare solution, tested prototype
Islam et al. (2023) [11]	IoT-based system for real-time remote health monitoring	IoT, Sensors (Blood Oxygen, ECG, Body Temperature), Deep Learning	Real-time monitoring, high-performance model, reduced healthcare costs

3. Proposed System: Design and Functionality

Our proposed Smart Health Monitoring System (SHMS) is specifically designed to satisfy to the healthcare needs of elderly Palestinians since Palestine suffer from restricted movement, checkpoints, and limited healthcare infrastructure. The system is designed to offer a sensitive, adaptable, and technologically advanced solution that overcomes geographical barriers, ensuring accurate and timely health monitoring.

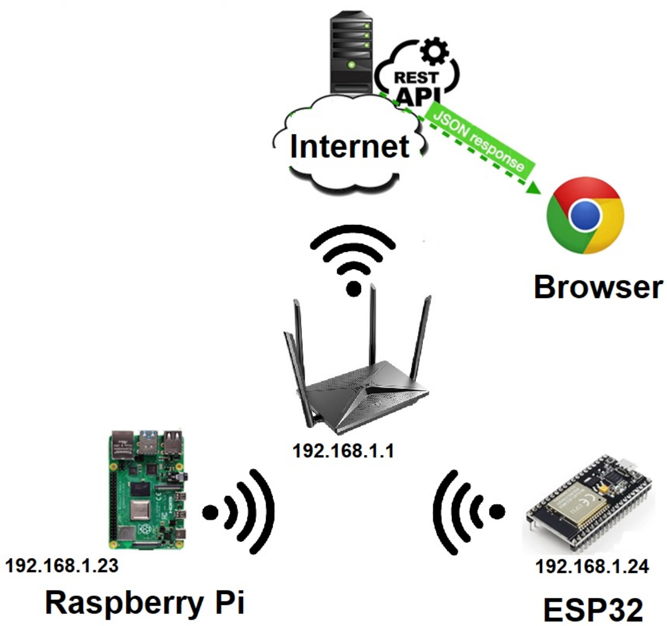

Figure 2. Proposed system architecture.

 doi:10.20944/preprints202406.0302.v1

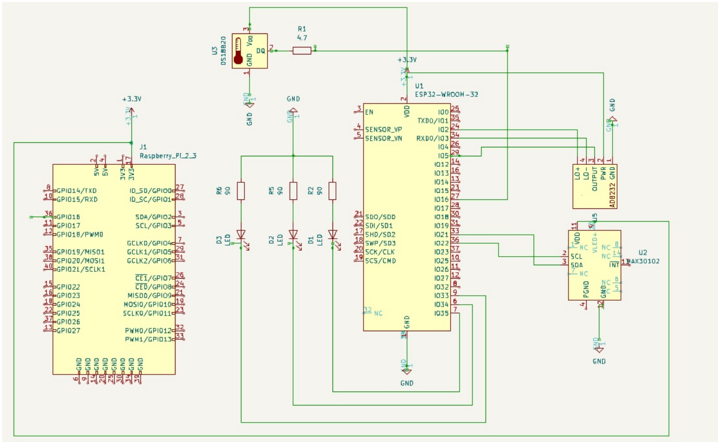

Figure 3. Proposed system Circuit.

3.1. Internet of Things (IoT) Integration

The core of our SHMS lies in its integration with the Internet of Things (IoT) technology. This allows for seamless connectivity between wearable sensors and a centralized data processing unit, facilitating real-time monitoring and analysis of vital health signs.

3.2. Vital Signs Monitoring

The SHMS incorporates a suite of sensors strategically positioned to monitor key vital signs critical for assessing the health of elderly individuals. These sensors include:

Heart Pulse Monitor: A sensor dedicated to tracking heart rate, providing insights into cardiovascular health. Blood Oximeter Sensor: Designed to measure blood oxygen levels, crucial for identifying respiratory and circulatory issues. Body Temperature Sensor: Monitors body temperature, offering early indications of potential infections or abnormalities. ECG ad8232 sensor: Used to read signal from a patient heart and can be observed online from anywhere

3.3. Advanced Data Analysis Algorithms

The collected data undergoes thorough analysis through advanced algorithms, enabling the system to derive meaningful insights. These algorithms are designed to detect patterns, anomalies, and trends in the vital signs data, ensuring accurate assessments of the user's health status.

3.4. Real-time Alerts and Interventions

One of the key functionalities of the SHMS is its ability to generate real-time alerts in response to identified health risks. The system employs a proactive approach, triggering timely interventions or alerts to healthcare providers or family members, ensuring swift responses to emergent health situations.

3.5. Wearable Design for User Comfort

Scince the importance of user comfort and satisfactin, our SHMS is designed as a wearable device. to achieve continuous health monitoring without causing discomfort to the elderly users.

3.6. Remote Consultation Capabilities

The SHMS acts as a bridge for remote healthcare consultations and intervention. By enabling real-time data transmission to healthcare professionals, the system facilitates remote consultations, intervention, reducing the need for physical visits and overcoming geographical challenges that Palestine suffered from scince 1948.

 doi:10.20944/preprints202406.0302.v1

3.7. Low-Power and Cost-Effective Solution

Our system is engineered to operate on low power, ensuring extended battery life for wearable devices. Additionally, the proposed SHMS is designed to be cost-effective, making it accessible to a broader population, especially in areas with limited healthcare resources.

3.8. Security Design

The implementation of the Smart Health Monitoring System (SHMS) for elderly Palestinians using the Internet of Things (IoT) introduces several security concerns that warrant careful consideration. As the system deal with sensitive health data transmitted continuously, from wearable devices to centralized databases, ensuring the confidentiality, integrity, and privacy of this information is very important. To overcome these security concerns, the system should be applied based on the following procedures:

3.8.1. Encryption

Applying end-to-end encryption for all data transmitted between the IoT devices and the central monitoring system to protect data against unauthorized access [18].

3.8.2. Access Control

Building robust access controls, in order to insure that only authorized healthcare staff have access to sensitive patient data [19]. In this case, we implement two-factor authentication to enhance security.

3.8.3. Secure Communication Protocols

We can use protocols like HTTPS for data transmission to protect against eavesdropping and attacks. Device Authentication: In IoT implementation, we should ensure that only legitimate and authorized devices can connect to the monitoring system [20].

3.8.4. Regular Software Updates

The firmware for all IoT devices and servers systems, should be up-to-date with the latest security patches.

3.8.5. Logs Monitoring

We should build a comprehensive logging system to track system activities to detect any suspicious behavior or security incidents.

3.8.6. Physical Security

Ensure physical security for IoT devices and servers to prevent unauthorized access or tampering.

Finally, our Smart Health Monitoring System stands as a comprehensive solution that seamlessly integrates IoT, advanced sensor technologies, and data analytics to address the healthcare challenges faced by elderly Palestinians [21]. The proposed system not only empowers individuals with proactive health monitoring but also establishes a foundation for a resilient and accessible healthcare infrastructure in resource-constrained environments [22].

4. Prototype Implementation

To implement the proposed Smart Health Monitoring System (SHMS) we need the following hardware components: an ESP32 micro controller, a DS18B20 temperature sensor, a MAX30100 sensor for both heart pulse and blood oximeter and ECG ad8232 sensor . Additionally, we must set up a local MQTT broker, for example, on a Raspberry Pi, to facilitate communication between the ESP32 and other devices.

We initialized and configures the ESP32's Wi-Fi connection and MQTT client settings. In order to establishes a connection to the Wi-Fi network and the MQTT broker, ensuring a seamless communication channel. The DS18B20 sensor is used to measure the patient temperature, providing crucial health-related data. Simultaneously, the MAX30100 Pulse Oximeter sensor is utilized to monitor heart rate and blood oxygen levels. The system also includes an ECG module for real-time electrocardiogram data.The ECG ad8232 sensor used to read signal from a patient heart and can be observed online from anywhere..

The MQTT callback function is defined to handle incoming messages on the specified topic, allowing for custom logic to process and react to the received data. The setup function initializes the sensors and connects the ESP32 to the Wi-Fi network and MQTT broker. The main loop continuously reads data from the DS18B20, MAX30100 and ECG ad8232 sensors, then publishes this information to the MQTT broker.

To fully implement the proposed system, we need to customize the MQTT broker settings (IP address and port) and Wi-Fi credentials according to existing network configuration. Additionally, we can extend the callback function to include logic for processing and acting upon the received health data, such as storing it in a central database and triggering alerts in case abnormal issue.

We deploy the ESP32 with the configured sensors in the proximity of the elderly individual, ensuring that the wearable device captures accurate health data. The MQTT broker facilitates seamless communication, enabling remote monitoring and consultations. We can adjust the delay in the loop function to determine the frequency of data transmission based on our desired monitoring interval. This implementation forms the foundation for an accessible, low-cost, and efficient Smart Health Monitoring System tailored for elderly individuals in resource-constrained environments.

To enhanced our system (SHMS) implementation for both elderly and healthcare staff, we have utilize three LEDs green, yellow, and red as visual indicators to provide real-time feedback on the monitored health data. When the data from the DS18B20 temperature sensor, and the MAX30100 Pulse Oximeter sensor, are within normal ranges, the system activates the green LED, while the other LEDs deactivated, signaling that the patient's vital signs are within the normal reading. In cases where the data exceeds the normal but remains within an acceptable range, the orange LED activated, serving as a caution signal to healthcare providers. Conversely, if any of the monitored reading indicate abnormal readings that fall outside the acceptable range, the red LED is activated, while the others are deactivated, alerting health care staff to potential health issues that require immediate intervention [17]. This visual feedback system enhances the interpretability of the data, allowing for quick assessment of the elderly individual's health status, ensuring timely interventions and remote consultations when needed [23]. The overall prototype as shown in figure **??**

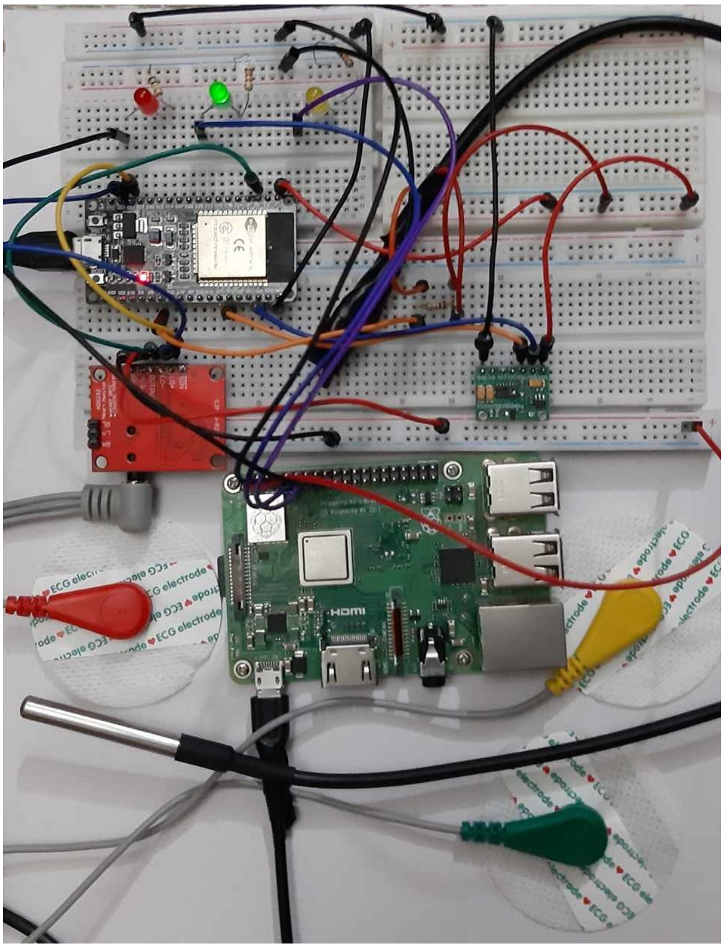

Figure 4. Proposed system Prototype.

5. Prototype Testing

The reliability and effectiveness of the (SHMS) is the corner stone of system succeed, so it is necessary to conduct validating hardware components, verifying communication protocols, and to check the system's responsiveness. The following key aspects are essential for system testing:

5.1. Hardware Validation

The proposed system depends on the accuracy of the hardware components functioning, so, we verified the functionality of the ESP32 microcontroller, DS18B20 temperature sensor, MAX30100 Pulse Oximeter sensor,ECG AD8232 and the incorporated LED indicators. Each component's output is cross-verified against normal and abnormal reading to confirm precise measurements.

5.2. Communication Protocol Verification

We verified the communication between the main two components ESP32 and the local MQTT broker, which hosted on a Raspberry Pi. We checked the data transmission and reception to to ensure seamless and reliable communication. For that, MQTT messages are monitored and analyzed to confirm that health data is being exchanged correctly.

5.3. Data Processing and LED Indication

We simulated different data scenarios to observe the LED responses in varying health conditions. The green LED should activated for normal readings, the orange LED for data slightly exceeding normal but within an acceptable range, and the red LED for abnormal readings requiring immediate

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 June 2024 doi:10.20944/preprints202406.0302.v1

attention. In abnormal readings, the system sends a message to the stakeholders, the elderly and the medical staff, in order to conduct direct intervention.

5.4. System Responsiveness

We checked the changes in health reading sensors in real-time. These changes allow us to assess how accurate the system detects abnormalities and triggers LED indications, to ensure that the SHMS provides timely alerts for potential health concerns.

6. Results and Discussion

In this section, I will review all the results of the measurement scenarios, for some elderly people and at different times, and observe the readings in real time. Before all that, we must know what the normal readings are for a healthy condition so that the readings can be analyzed and abnormal cases can be dealt with.

6.1. Normal and Abnormal Ranges for Health Parameters

In the Table 2, we showed normal and abnormal ranges for health parameters including temperature, heart pulse, blood oximeter levels, and electrical activity of the heart. These health condition parameters can be used in order to discover abnormal readings to deal with them in a way that achieves the health and safety of the elderly and facilitating the identification of abnormal readings that may require a great attention and quick intervention.

Table 2. Normal and Abnormal Ranges for Health Parameters with Heart Rate Monitor details

Parameter	Normal Range	Abnormal Range
Temperature	36.1°C to 38.0°C	>38.0°C
Heart Pulse	60 bpm to 100 bpm	<60 bpm or >100 bpm
Blood Oximeter	95% to 100%	<95%

Note: The Heart Rate Monitor acts as an operational amplifier (op amp) to help obtain a clear signal from the PR and QT Intervals easily.

6.2. Real-Time Health Monitoring Data

In the Table 3 which taken in real time from sensors, particularly the data collected from elderly individuals at different time intervals, provides valuable insights into their health parameters. The MQTT (Message Queuing Telemetry Transport) protocol is employed to efficiently analyze this real-time data. The significance of this functionality lies in its potential to promptly notify both the elderly individuals and the specialist about abnormal vital signs as shown in Figure 8 , allowing for timely interventions and medical consultations. The ability of the system to detect such anomalies in real time showcases its effectiveness in enhancing healthcare for elderly Palestinians. This proactive approach aligns with the system's objective of providing timely and personalized care, ensuring that any deviations from normal health parameters are addressed promptly.

Table 3. Health Monitoring Data

created_at	entry_id	Temp	Heart Pulse	Blood Oximeter
2023-12-30 00:07:29 +0200	2595	36.87426581	64.26016515	91.06876341
2023-12-30 00:17:30 +0200	2596	36.93533116	60.26769043	95.07064031
2023-12-30 00:27:40 +0200	2597	36.34493768	65.08172019	94.35444513
2023-12-30 00:37:49 +0200	2598	36.47630336	67.13167928	93.05675481
2023-12-31 00:26:41 +0200	2599	38.12449635	90.81023869	91.56624776
2023-12-31 00:36:48 +0200	2600	38.81558698	81.34201861	90.59091699

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 June 2024 doi:10.20944/preprints202406.0302.v1

To visually represent health monitoring data in a time series format as shown in Figure 5. Data containing time stamps as well as temperature, heart rate and pulse oximeter readings. We established abnormal thresholds for temperature, heart rate, and oximeter readings, allowing abnormal values to be identified. In the visuals, the green lines represent continuous monitoring of temperature, heart rate, and pulse oximeter levels, respectively. Red marks indicate data points where readings exceed pre-defined abnormal limits, facilitating visual identification of abnormal values. The dashed red lines further emphasize these abnormal thresholds. The resulting visualizations allow clear interpretation of health data, which helps identify abnormal trends and allows timely interventions based on established thresholds. This type of graphical representation is valuable to both healthcare professionals and individuals monitoring their health, because it provides an intuitive and accessible way to assess and respond to deviations from normal health norms.

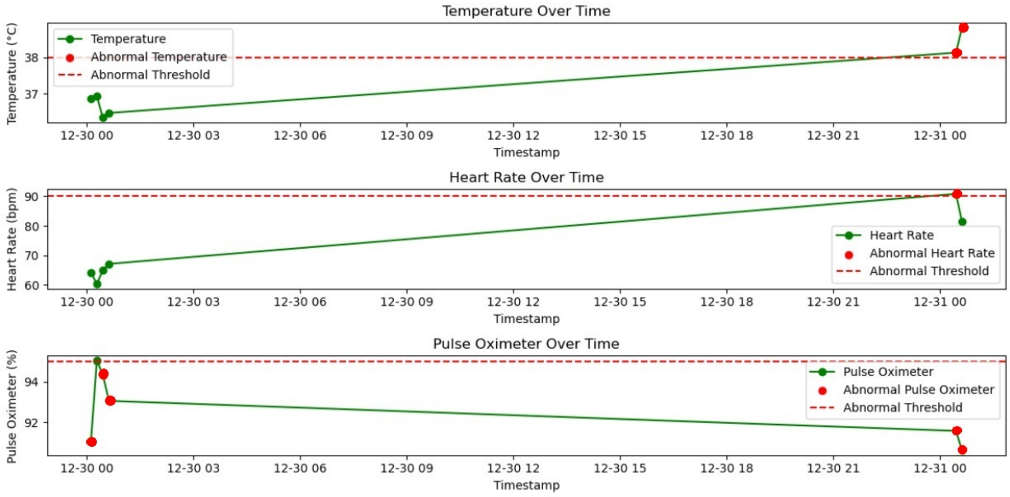

Figure 5. Visualized Data Point For Vital Signs In Different Times.

We tested an electrocardiogram to record the activity of the heart over a period of time. The following ECG graph represents the electrical activity through a series of waves as shown in the figure 6 . The duration and amplitude of these waves can provide valuable information about the heart's health and functioning.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 June 2024 doi:10.20944/preprints202406.0302.v1

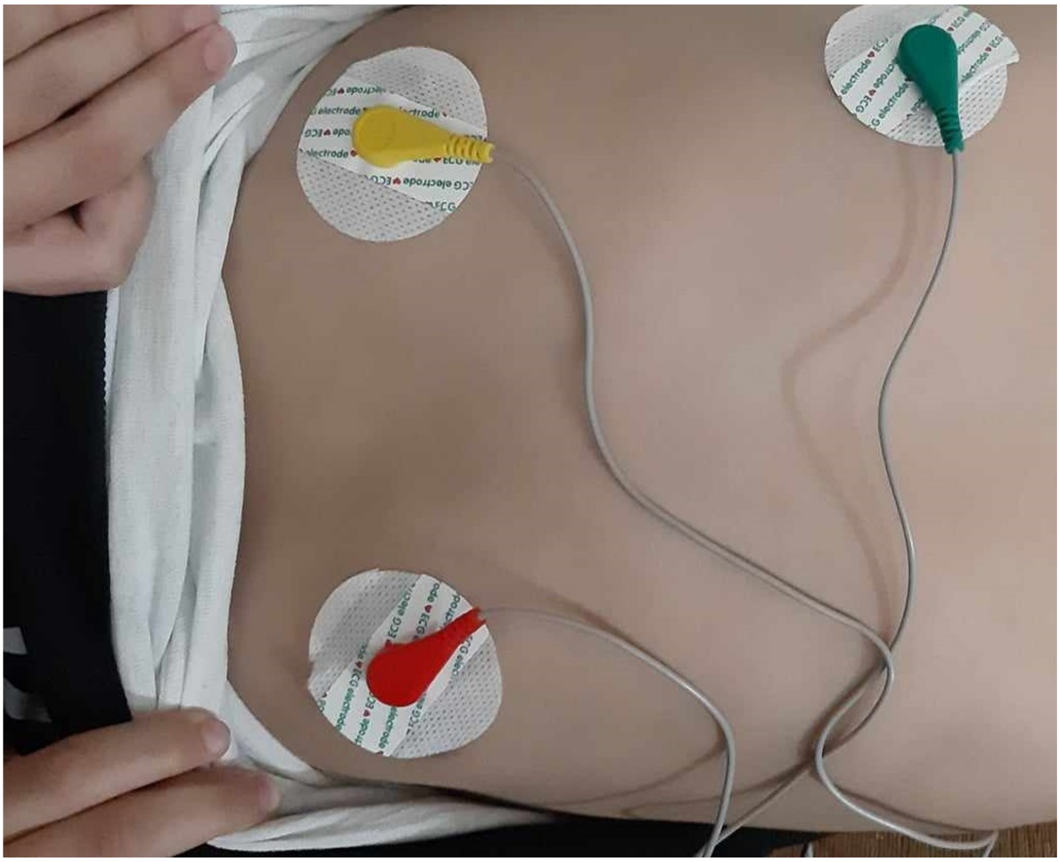

Figure 6. An Electrocardiogram Test .

The graph on Ubidots API as shown in the Figure 7 displays real-time ECG readings. The sensor data, converted to string format, which ensures continuous connectivity, sending data in 250 ms intervals, facilitating remote monitoring of ECG signals on Ubidots' industrial API platform. The analytic reading for the graph will be based on the the Table 4, which showed the normal parameters measurements. Any value or feature that comes outlier and has a strange shape that does not have regularity and rhythm as defined in Table 4 would be considered as an abnormal ECG.

Table 4. ECG Signal Features and their Respective Values (Normal)

FEATURES	VALUES
General Factors	
Heart Rate	60-100 bpm*
R-R Interval	0.6*s to 1.2*s
Heart Rate Variability	+/-10%* to +/-30%*
Waves Amplitude(mV)	Duration(s)
R Wave	0.8*-1.5* 0.035*-0.09*
Segments/Intervals	Duration(s)
QRS Complex	0.06*-0.12*

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 June 2024 doi:10.20944/preprints202406.0302.v1

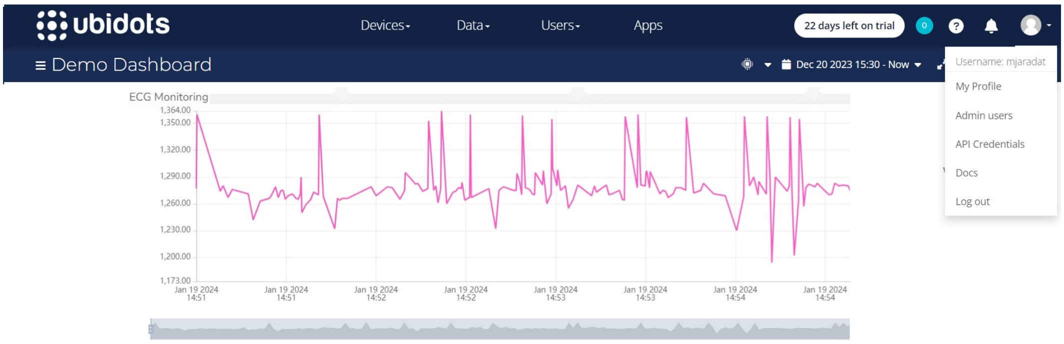

Figure 7. An Electrocardiogram (ECG) Graphs .

6.3. Identification and Response to Abnormal Readings

One noteworthy entry in the dataset, recorded at "2023-12-31 00:26:41 +0200 & 2599," stands out due to abnormal readings. The temperature (38.12°C), heart pulse (90.81 beats per minute), and blood oximeter level (91.57%) deviate from the expected normal range. This abnormality triggers the system to send a targeted alert message to the elderly individual's mobile device as shown in in Figure 8, which promptly notifies the elderly individual through their mobile device..

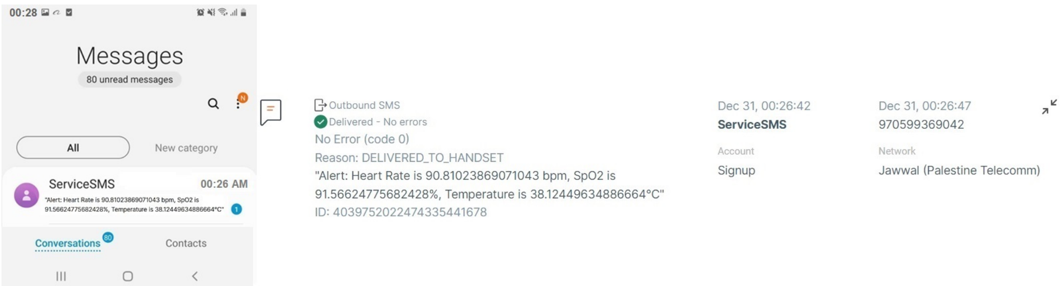

Figure 8. Example of Automated Alert Message by MQTT Messaging System.

The system's ability to detect such anomalies in real-time proves instrumental in providing timely alerts to both elderly individuals and the specialist by using MQTT messaging system as shown in Figure 9 . This proactive approach aligns with the system's overarching objective of delivering personalized and timely care, ensuring that deviations from normal health parameters are addressed promptly.

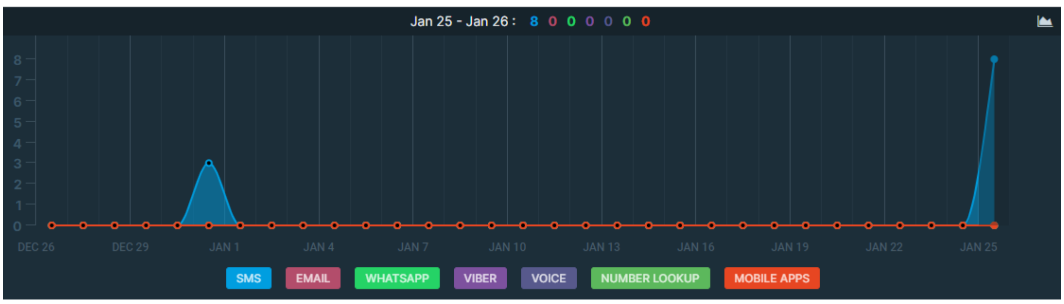

Figure 9. Messaging Chart For Abnormal Vital Signs.

The results and discussions presented confirm the effectiveness of the health monitoring system in identifying abnormal readings immediately. This capability enhances healthcare for elderly individuals, promoting early interventions and medical consultations to keep them safe. The integration of real-time data analysis as shown in Figure 10 and automated alert systems contributes significantly to achieving the overall goal of ensuring the health and safety of elderly Palestinian.

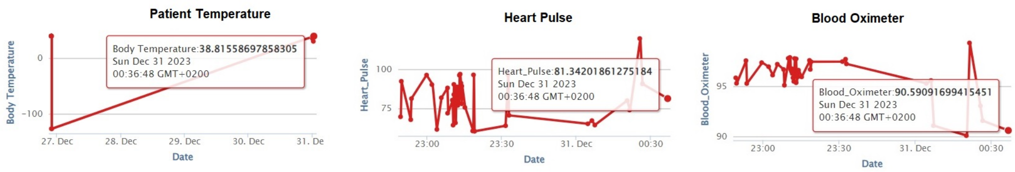

Figure 10. Vital Signs Reading In Real Time.

7. Conclusion and Future Work

In this research, we proved the effectiveness of the proposed system in monitoring the vital signs in real time for elderly people and has the potential to contributes to SDG 3 . The integration of sensors, data analysis and automated alert system has proven effective in identifying abnormal readings immediately, allowing for timely interventions and healthcare support. The ability of monitoring temperature, heart rate, pulse oximeter levels and the electrocardiogram to record the activity of the heart over a period in real time enhances the overall healthcare experience for Palestinian elderly, in line with the goal of providing personalized and timely care, improving the quality of life of seniors and increasing their survival rates by monitoring elderly daily duties especially against falling [24] . In addition to reducing health care costs by reducing the number of visits to hospitals and clinics by 50%. In the future work, the focus will be on making system improvements with regard to expanding monitoring capabilities, including adding additional health parameters and developing the alert system by improving the algorithms used, in addition to using machine learning algorithms to improve the system's capabilities to detect and predict anomalies.

Author Contributions: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, A.M.O.; supervision, writing—review and editing, project administration, I.I. After reading the published version of the manuscript, all authors have given their approval.

Funding: This research received no external funding.

Data Availability Statement: The Internet of Things (IoT) devices owned by the authors produced the data used in this investigation. The data cannot be publicly archived due to privacy concerns and possible security risks involved with releasing raw sensor data. On reasonable request, we will provide anonymised or aggregated data, though. Researchers who are interested might speak with the corresponding author about alternatives for data access.

Conflicts of Interest: No conflicts of interest are disclosed by the authors.

References

1. Sumathy, B.; Kavimullai, S.; Shushmithaa, S.; Anusha, S.S. Wearable Non-invasive Health Monitoring Device for Elderly using IoT. In *IOP Conference Series: Materials Science and Engineering*, 2021, vol. 1012, no. 1, p. 012011; IOP Publishing.
2. Naik, S.; Sudarshan, E. Smart healthcare monitoring system using raspberry Pi on IoT platform. *ARPN Journal of Engineering and Applied Sciences*, 2019, vol. 14, no. 4, pp. 872–876.
3. Pinto, S.; Cabral, J.; Gomes, T. We-care: An IoT-based health care system for elderly people. In *Proceedings of the 2017 IEEE International Conference on Industrial Technology (ICIT)*, 2017; IEEE, pp. 1378–1383.
4. Rohit, S.L.; Tank, B.V. IoT based health monitoring system using raspberry PI-review. In *Proceedings of the 2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT)*, 2018; IEEE, pp. 997–1002.
5. Soni, A.N. Smart devices using internet of things for health monitoring. *International Journal of Innovative Research in Science, Engineering and Technology*, 2018, vol. 7, no. 5, pp. 6355–6361.
6. Banka, S.; Madan, I.; Saranya, S.S. Smart healthcare monitoring using IoT. *International Journal of Applied Engineering Research*, 2018, vol. 13, no. 15, pp. 11984–11989; Research India Publications.
7. Islam, M.M.; Rahaman, A.; Islam, M.R. Development of smart healthcare monitoring system in IoT environment. *SN Computer Science*, 2020, vol. 1, pp. 1–11; Springer.

8. Ahmed, A.B.; Kimezawa, Y.; Abdallah, A.B. Towards smart health monitoring system for elderly people. In *Proceedings of the 4th International Conference on Awareness Science and Technology*, 2012; IEEE, pp. 248–253.
9. Wang, J.J.; Payne, R. A survey of Internet of Things in Healthcare. *EAI Endorsed Transactions on Internet of Things*, 2022, vol. 7, no. 27.
10. Shaown, T.; Shohrab Hossain, M.; Mukur, T.M. Low-Cost Health Monitoring System: A Smart Technological Device for Elderly People. In *Proceedings of Sixth International Congress on Information and Communication Technology: ICICT 2021, London, Volume 2*, 2022; Springer, pp. 851–860.
11. Islam, M.R.; Kabir, M.M.; Mridha, M.F.; Alfarhood, S.; Safran, M.; Che, D. Deep Learning-Based IoT System for Remote Monitoring and Early Detection of Health Issues in Real-Time. *Sensors*, 2023, vol. 23, no. 11, p. 5204; MDPI.
12. Lakshmi, G.J.; Ghonge, M.; Obaid, A.J. Cloud based IoT smart healthcare system for remote patient monitoring. *EAI Endorsed Transactions on Pervasive Health and Technology*, 2021, vol. 7, no. 28, pp. e4–e4.
13. Hamim, M.; Paul, S.; Hoque, S.I.; Rahman, M.N.; Baqee, I.-A. IoT based remote health monitoring system for patients and elderly people. In *Proceedings of the 2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)*, 2019; IEEE, pp. 533–538.
14. Muqeet, M.A.; Quadri, M.U. IoT based Patient Monitoring System Using Raspberry Pi. *vol*, 2019, vol. 7, p. 6.
15. Zeb, K.; Mahmood, A.; Uddin, W.; Khan, M.A.; Kim, H.J.; others. Healthcare monitoring system and transforming monitored data into real time clinical feedback based on IoT using Raspberry Pi. In *Proceedings of the 2019 2nd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET)*, 2019; IEEE, pp. 1–6.
16. Al-Mahmud, O.; Khan, K.; Roy, R.; Alamgir, F.M. Internet of things (IoT) based smart health care medical box for elderly people. In *Proceedings of the 2020 International Conference for Emerging Technology (INCET)*, 2020; IEEE, pp. 1–6.
17. Kulurkar, P.; Kumar Dixit, C.; Bharathi, V.C.; Monikavishnuvarthini, A.; Dhakne, A.; Preethi, P. AI based elderly fall prediction system using wearable sensors: A smart home-care technology with IOT. *Measurement: Sensors*, 2023, vol. 25, p. 100614; Elsevier.
18. Zovko, K.; Šerić, L.; Perković, T.; Belani, H.; Šolić, P. IoT and health monitoring wearable devices as enabling technologies for sustainable enhancement of life quality in smart environments. *Journal of Cleaner Production*, 2023, vol. 413, p. 137506; Elsevier.
19. Krishnamoorthy, S.; Dua, A.; Gupta, S. Role of emerging technologies in future IoT-driven Healthcare 4.0 technologies: A survey, current challenges and future directions. *Journal of Ambient Intelligence and Humanized Computing*, 2023, vol. 14, no. 1, pp. 361–407; Springer.
20. Umer, M.; Aljrees, T.; Karamti, H.; Ishaq, A.; Alsubai, S.; Omar, M.; Bashir, A.K.; Ashraf, I. Heart failure patients monitoring using IoT-based remote monitoring system. *Scientific Reports*, 2023, vol. 13, no. 1, p. 19213; Nature Publishing Group UK London.
21. Godinho, A.; Cardoso, F.; Coelho, P.J.; Pires, I.M. Internet of Things-based care monitoring for the elderly and those with special needs. *Procedia Computer Science*, 2023, vol. 224, pp. 572–579; Elsevier.
22. Shaikh, N.; Kasat, K.; Godi, R.K.; Krishna, V.R.; Chauhan, D.K.; Kharade, J. Novel IoT framework for event processing in healthcare applications. *Measurement: Sensors*, 2023, vol. 27, p. 100733; Elsevier.
23. Almotairi, K.H. Application of internet of things in healthcare domain. *Journal of Umm Al-Qura University for Engineering and Architecture*, 2023, vol. 14, no. 1, pp. 1–12; Springer.
24. Bulcão-Neto, R.; Teixeira, P.; Lebtag, B.; Graciano-Neto, V.; Macedo, A.; Zeigler, B. Simulation of IoT-oriented fall detection systems architectures for in-home patients. *IEEE Latin America Transactions*, 2023, vol. 21, no. 1, pp. 16–26; IEEE.