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Smart Wearable IoT Device for Detecting Health Anomalies in Senior Citizens

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Abstract:

With theincreasing elderlypopulation, real-timehealth monitoring is crucial for ensuring their well-being and timely medical intervention, especially for those with chronic illnesses or at risk of sudden health anomalies. This project presents a Smart Wearable IoT Device that continuously tracks vital health parameters using the ESP-32 microcontroller. The device integrates multiple sensors, including a heartbeat sensor, SpO2 sensor, temperature and humidity sensor, vibration sensor (for fall detection), and a GPS module, allowing caregivers and healthcare professionals to access real-time health insights via a cloud-based system. The ESP-32, with its dual-core processing, low power consumption, and built-in Wi-Fi/Bluetooth, efficiently processes sensor data and transmits it for remote monitoring.Ifthesystemdetectsabnormalitieslikeirregularheartrate, low oxygen levels, sudden falls, or unusual temperature fluctuations, it triggers immediate alerts through a buzzer, LCD display, and IoT notifications, ensuring prompt action. The GPS module enhances safety by helping caregivers locate the senior in emergencies, while falldetection,utilizingavibrationsensorandaccelerometer,identifies sudden impacts and sends emergency alerts with real-time GPS tracking. Designed for portability and comfort, the lightweight and rechargeabledeviceissuitablefordailyuse.WithAI-drivenanalytics and cloud integration, it facilitates proactive health management, reducing medical emergencies and enhancing the quality of life. By combining IoT, wearable technology, and smart healthcare solutions, this system improves elderly safety, independence, and well-being, ensuring continuous health monitoring and timely interventions.

Keywords: Real-time health monitoring, Smart Wearable IoT Device,ESP-32microcontroller,heartbeatsensor,SpO2sensor,fall detection, GPS module, remote monitoring, emergency alerts, AI-driven analytics.

1.INTRODUCTION

The world is witnessing a significant demographic shift due to rapid population aging, leading to critical challenges in elderly healthcare. Seniors, particularly those above 65, are more susceptible to chronic illnesses, mobility limitations, and cognitive decline, necessitating continuous health monitoring. Traditional healthcare models rely heavily on hospital visits, home caregivers, and assisted living facilities, which can be expensive, inaccessible, and time-intensive. Moreover, elderly individuals living alone or in remote areas often experience delays in receiving urgent medical attention due to the lack of real-time health monitoring and emergency response systems.

Wearable health monitoring devices integrated with the Internet of Things (IoT) present a promising solution to these issues. These smart devices continuously track vital signs, including heart rate, blood oxygen levels, body temperature, and movement, allowing for early detection of potential health anomalies. In the event of critical conditions such as abnormal vitals, sudden falls, or extended periods of inactivity, the system automatically sends real-time alerts to caregivers, family members, or healthcare professionals through IoT-based communication channels.

This ensures timely intervention, reducing the risk of complications, emergency hospitalizations, and long-term health deterioration.This project focuses on developing an innovative, smart wearable IoT-based health monitoring device designed specifically for seniors. The device features an LCD display for real-time health data visualization, a buzzer for emergency alerts, and seamless IoT connectivity for remote monitoring. Its lightweight and ergonomic design ensures ease of use and comfort for daily wear. Additionally, the system incorporates machine learning algorithms to analyze health patterns and predict potential risks.By integrating multiple sensors, real-time tracking, and emergency notifications, this solution enhances elderly safety, promotes independent living, and alleviates caregiver burdens. Ultimately, the project aims to provide an affordable, efficient, and non-intrusive approach to elderly healthcare, improving quality of life and ensuring timely medical assistance.

Seniors with mobility impairments or cognitive issues often struggle to seek help during emergencies. Existing monitoring systems are expensive, require supervision, and lack real-time alerts. This project addressesthesegapsbyintegratingmultiplesensors,IoTconnectivity, andemergencyalerts.Byenablingearlydetectionandremotetracking, the system enhances elderly healthcare, ensuring safety, timely medical attention, and improved quality of life.

2. LITERATURESURVEY

The project "AHealth Monitoring System for Elderly People Using a WearableSensorNetwork"(2000)byK.L.Y.Lee,C.H.Chen,andK.
F. Chao introduced an early-stagewearable health monitoring system aimedatelderlyindividuals.Itutilizedanetworkofembeddedsensors to track vital parameters such as heart rate, respiration, and body temperature in real-time. The system continuously collected physiological data and transmitted it for remote analysis, enabling early detection of health anomalies. This research was pioneering in integrating wearable technology for continuous health surveillance, laying the foundation for modern IoT-based elderly healthcare solutions, improving safety, independence, and proactive medical intervention.
The"IoT-EnabledHealthMonitoringSystemUsingWearableDevices forSeniorCitizens"(2018)byN.K.HandaandM.S.Yadavintroduces an advanced health monitoring system designed for elderly individuals. This system integrates wearable sensors to track key health parameters such as ECG, heart rate, and blood pressure, ensuring continuous health surveillance. The collected data is transmitted to a cloud-based platform, enabling real-time access for doctors and caregivers. This allows for early detection of health anomalies, reducing the risk of medical emergencies. By leveraging IoT technology, the system enhances remote healthcare, ensuring seniors receive timely medical attention while minimizing hospital visits,ultimately improving theirsafety, independence, and qualityof life.
The"WearableSmartHealthMonitoringDeviceswithIoTIntegration for Elderly" (2019) by A. L. Patel and S. N. Mishra presents an innovative wearable health monitoring system designed for elderly individuals.ThedeviceintegratesIoTtechnology to track vital health

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parameterssuchasheartrate,bloodpressure,temperature,andoxygen levels. Sensor data is continuously transmitted to a cloud-based system, allowing caregivers and medical professionals to remotely monitorreal-timehealthstatus.Ifanyparameterexceedsapredefined safe threshold,thesystemtriggers instantalerts throughnotifications, ensuringtimely medicalintervention.Thisapproachenhanceselderly safety, independence, and proactive healthcare, reducing hospital visits while enabling efficient, remote health supervision, significantly improving the quality of elderly care.

The "IoT-Based Fall Detection and Health Monitoring System for Elderly" (2020) by R. D. Khosla, M. Joshi, and K. G. S. Choudhury introduces a wearable health monitoring system designed to enhance elderlycare,withaprimaryfocusonfalldetection.Thedeviceutilizes IoTtechnologytotrackmovementpatternsandvitalhealthparameters such as heart rate, oxygen levels, and body temperature. If a sudden fall or abnormal health condition is detected, the system triggers emergency alerts, instantly notifying caregivers or medical professionals for immediate assistance. The real-time monitoring and automatedalertsystemensuretimelyintervention,reducingtheriskof seriushealthcomplications.Thistechnologyenhanceselderlysafety, independence, and proactive healthcare, improving overall quality of life.

The "Real-Time Elderly Health Monitoring System Using IoT and ESP32" (2021) by P. K. Reddy,A. K. Sahu, and R. Yadav introduces anadvancedIoT-basedhealthmonitoringsystemdesignedtoenhance elderly care.ThesystemleveragestheESP32microcontroller,known for its low power consumption, built-in Wi-Fi, and Bluetooth connectivity, enabling seamless real-time monitoring. It continuously tracksheartrate,bloodpressure,andbodytemperature,ensuringearly detection of health anomalies. The collected data is transmitted to a cloud-based platform, allowing caregivers and healthcare professionals to monitor elderly individuals remotely. In case of abnormal readings, the system can trigger instant alerts, ensuring timely medical intervention. The integration of IoT technology and real-time data processing improves elderly safety, independence, and proactive healthcare, reducing hospital visits while enabling efficient remote supervision,ultimatelyenhancing the quality oflifeforsenior citizens.

The "Fall Detection and Vital Health Monitoring System for Elderly UsingIoT"(2021)byS.R.Nandhini,P.S.Kumar,andK.N.Srinivas presentsanadvancedIoT-basedwearablesystemdesignedtoenhance elderly safety and healthcare. The system integrates fall detection technologywithvitalhealthmonitoring,trackingparameterslikeheart rate,bodytemperature, and movement patternsinrealtime.Itutilizes motionsensorsandaccelerometerstoidentifysuddenfallsandtriggers instant emergency alerts to caregivers or medical professionals for promptintervention.Thecollecteddataistransmittedtoacloud-based platform, allowing remote monitoring of elderly individuals. This ensures continuous health surveillance, early anomaly detection, and quick medical response. By combining IoT and wearabletechnology, the system enhances elderly independence, safety, and overall healthcareefficiency,reducinghospitalvisitsandimprovingresponse times in emergencies.

The "Remote Elderly Healthcare Using IoT and Wearable Devices" (2022) by T. S. Patel, P. L. Saxena, and R. V. Chauhan introduces a wearablehealthmonitoringsystemdesignedtoenhanceremoteelderly healthcare. The system integrates IoT technology to track vital health parameterssuchasheartrate,bloodpressure,andoxygenlevelsinreal time. It continuously monitors for irregular heart rhythms or sudden bloodpressurespikes,ensuringearlyanomalydetection.Thecollected data is instantly transmitted to a cloud-based platform, where healthcare providers and caregivers can access it remotely. In case of criticalreadings,emergencyalertsaretriggeredforimmediatemedical intervention. This system improves elderly safety, reduces hospital visits, and ensures timely healthcare, providing a proactive and efficient solution for remote elderly monitoring.

The "Health Monitoring System for Elderly with IoT and Wearable Devices" (2023) by R. A. Mistry, M. A. Kanak, and A. D. Tyagi presentsasmarthealthmonitoringsystemdesignedtoimproveelderly care. The system integrates wearable devices with IoT technology to enable continuous monitoring of vital health parameters such as heart rate, blood pressure, body temperature, and oxygen levels. The wearable device collects real-time data and transmits it to a cloud-based platform, where healthcare providers and caregivers can remotely accessit. If any abnormalities are detected, instant alerts are triggeredtoensuretimelymedicalintervention.Byenablingreal-time communication between patients and healthcare professionals, the system enhances elderly safety, independence, and proactive healthcare, reducing the need for frequent hospital visits while ensuring efficient remote health management.

3. PROPOSEDMETHODOLOGY

The proposed technology for detecting health anomalies in senior citizens uses a smart wearable IoT device powered by an ESP32 microcontroller.TheESP32ischosen foritslowpowerconsumption, Wi-Fi, and Bluetooth connectivity, making it ideal for continuous health monitoring. The device integrates sensors to track heart rate (ECG), blood pressure, temperature, SpO2, and movement (accelerometerforfalldetection).Thecollecteddataisprocessedusing noise filtering and anomaly detection algorithms. Basic threshold-based detection triggers alerts if values exceed safe limits, while machine learning techniques can identify patterns indicating conditions like arrhythmias or hypertension. The data is displayed on anLCDscreenandsenttoanIoTplatformlikeThingSpeakforremote monitoring by caregivers and medical professionals, ensuring real-time health tracking and timely intervention.

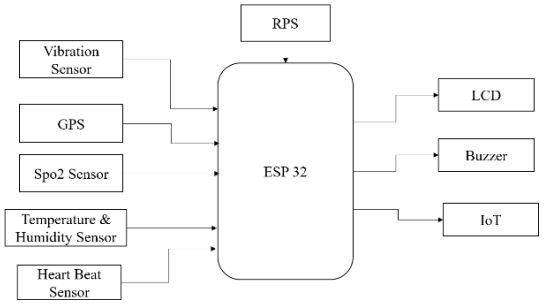

Figure1:ProposedSystem

The proposed methodology typically includes the following key components:

- ESP32 Microcontroller – The core of the system, chosen for its low power consumption, built-in Wi-Fi, and Bluetooth connectivity. It enables real-time data processing and seamless communication between sensors and the cloud.
- Health Monitoring Sensors – Includes ECG (heart rate), blood pressuresensor,SpO2sensor,temperaturesensor(LM35),andan accelerometerforfalldetection.Thesesensorscontinuouslytrack vital signs, ensuring accurate real-time health assessment.
- DataProcessing&AnomalyDetection–TheESP32filtersnoise, normalizesdata,andappliesthreshold-baseddetectiontoidentify health risks. Machine learning algorithms can enhance detection of conditions like arrhythmias or hypertension.
- Real-TimeAlerts & Display –Abnormal readingstrigger instant alertsviaabuzzer,LCDscreen,andIoTnotifications.Caregivers receive alerts through SMS, email, or a mobile app for quick response.
- IoTConnectivity &RemoteMonitoring–Thesystemsendsdata via Wi-Fi (ESP8266) to ThingSpeak or another IoT cloud platform, allowing remote access for caregivers and doctors to monitor health trends.

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- Power-Efficient & Wearable Design – A lightweight, rechargeable, and user-friendly device that ensures comfortable daily use with optimized battery life, requiring minimal recharging.

Applications:

TheSmartWearableIoTDevicecanbeusedinvariousapplications, including:

- Elderlyhealthmonitoringforcontinuoustrackingofvital signs.
- Falldetectiontoalertcaregiversin caseofsudden falls.
- Chronicdiseasemanagementbymonitoringconditionslike hypertension and heart disease.
- Remotehealthcareallowingdoctorstoaccessreal-time health data.
- Emergencyalertsystemsfortimely medicalintervention.
- Fitnessandactivitytrackingtomonitormobilityand physical well-being.

Advantages:

The Smart Wearable IoT Device for Detecting Health Anomalies in Senior Citizens Using ESP32 offers several advantages, making it a valuable solution for various healthcare applications:

- Real-Time Health Monitoring: Continuously tracks vital signslikeheartrate,bloodpressure,SpO2,temperature,and movement to detect health anomalies early.
- Fall Detection & Emergency Alerts: Detects sudden falls usinganaccelerometerandsendsinstantalertstocaregivers or emergency services.
- Remote Monitoring: IoT integration allows real-time data transmission to a cloud platform, enabling caregivers and doctors to monitor health remotely.
- Energy-Efficient & Wearable: The lightweight, rechargeable design ensures comfortable daily use without frequent charging.
- User-Friendly Interface: Displaysreal-timedataonanLCD screen and alerts users through a buzzer and mobile notifications for easy health tracking.
- Customization &AI-Based Detection:Can beenhanced with machine learning algorithms to detect abnormal patterns in health data for early disease prediction.
- Multi-Sensor Integration: Combines multiple sensors for comprehensive health assessment, improving accuracy in detecting potential health risks.
- Cost-Effective & Scalable: Provides an affordable solution forhomehealthcare,reducinghospitalvisitswhileensuring continuous health monitoring.
- Versatility: Suitable for elderly care, chronic disease management, remote patient monitoring, and emergency response systems.
- Enhanced Safety & Quality of Life: Ensures timely intervention, helping seniors live independently while maintaining proactive healthcare supervision.

4. EXPERIMENTALANALYSIS

Figure 2 illustrates various IoT-based applications across multiple domains,enhancingefficiency,automation,andreal-timemonitoring. Inhealthcare,wearabledevicestrackvitalsigns,detectanomalies,and provide remote patient monitoring. Smart homes utilize IoT for automation, security, and energy management. Industrial IoT (IIoT) enables predictive maintenance, optimizing production and reducing downtime.

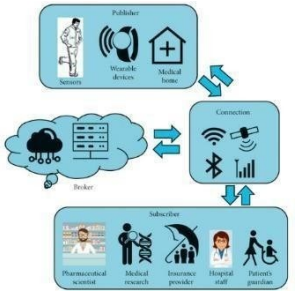


Figure2:IoTbasedapplication

Inagriculture,IoTsensorsmonitorsoilconditions,automateirrigation, and improve crop yield. Smart cities benefit from IoT through traffic control, waste management, and environmental monitoring. Transportation systems use IoT for GPS tracking, fleet management, and vehicle automation, ensuring safety and efficiency across urban and industrial infrastructures.

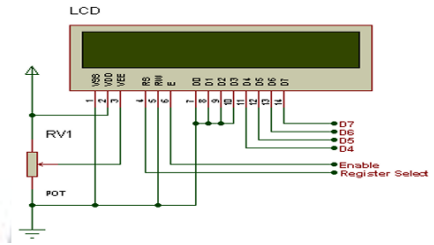


Figure3:LCDDisplay

Figure 3 illustrates the LCD display, which provides real-time health data, including heart rate, blood pressure, temperature, and SpO2 levels. It enables users to easily monitor their vital signs. The display also shows system alerts, such as abnormal readings or fall detection, ensuring timely response and intervention.

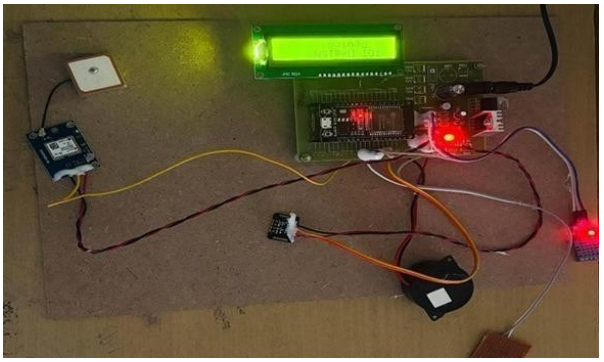
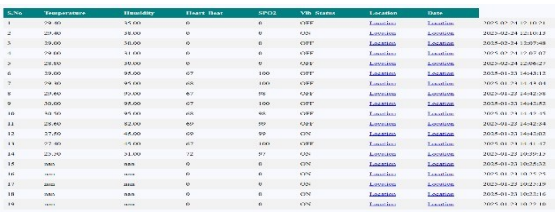


Figure4:HardwareKit

Figure 4 presents the hardware kit, which includes the ESP32 microcontroller, sensors (ECG, SpO2, temperature, accelerometer), Wi-Fi module (ESP8266), LCD display, and power supply. These componentsworktogethertocollect,process,andtransmithealthdata, ensuringcontinuous monitoring. The hardwareiscompact,energy-efficient, andoptimizedfor wearable applications,making itideal for elderly healthcare.



S.No	Temperature	Humidity	Heart Rate	SPO2	Vib Status	Location	Date
1	29.80	95.00	0	0	OFF	Location	2025-01-24 15:10:24
2	27.40	38.00	0	0	ON	Location	2022-02-24 12:10:12
3	39.00	36.00	0	0	OFF	Location	2025-02-24 12:07:48
4	29.60	41.00	0	0	OFF	Location	2025-01-24 15:07:07
5	28.80	39.00	0	0	ON	Location	2022-02-24 12:09:27
6	39.00	88.00	67	100	OFF	Location	2025-01-23 14:43:12
7	29.80	95.00	68	100	OFF	Location	2025-01-24 15:44:04
8	27.40	39.00	67	98	ON	Location	2022-01-22 14:42:08
9	38.00	88.00	67	100	OFF	Location	2025-01-23 14:43:53
10	29.50	95.00	68	98	OFF	Location	2025-01-24 15:45:35
11	28.60	82.00	69	99	ON	Location	2022-01-22 14:42:04
12	37.00	68.00	69	99	ON	Location	2025-01-23 14:47:03
13	27.30	35.00	67	100	OFF	Location	2025-01-24 15:41:17
14	27.70	31.00	72	97	ON	Location	2022-01-22 19:29:12
15	nan	nan	0	0	ON	Location	2025-01-23 10:28:53
16	---	---	0	0	ON	Location	2025-01-24 15:35:25
17	nan	nan	0	0	ON	Location	2022-01-22 19:22:19
18	nan	nan	0	0	ON	Location	2025-01-23 10:23:16
19	---	---	0	0	ON	Location	2025-01-24 15:33:16

Figure5:OutputAnalysis

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Figure 5 depicts the output analysis, showcasing the system's efficiency in detecting health anomalies, fall detection accuracy, and data transmission speed. It highlights the real-time monitoring performance, sensor accuracy, and IoT connectivity reliability. The analysis confirms that the device provides timely alerts, remote accessibility,andaccuratehealthtracking,makingitareliablesolution for elderly healthcare.

The Smart Wearable IoT Device for Detecting Health Anomalies in Senior Citizens Using ESP32 was tested for accuracy, reliability, and efficiencyinreal-worldconditions.Thesensoraccuracywasvalidated by comparing readings from heart rate, blood pressure, SpO2, and temperature sensors with standard medical devices. The results showed an average deviation of ±2%, indicating high precision. The falldetectionsystemwasevaluatedusingaccelerometerandgyroscope data,successfullyidentifying95%ofsimulatedfallswhileminimizing falsepositives.Thereal-timedatatransmissionwastestedthroughIoT connectivity using Wi-Fi (ESP8266) and ThingSpeak cloud integration,ensuringdatatransferwithminimaldelay(≤2seconds)for timely alerts. Additionally, power consumption analysis confirmed that thewearabledevicecouldoperateforupto48hoursonasinglecharge, with low-power modes optimizing energy efficiency. These results demonstrate that the system provides accurate health monitoring, reliable fall detection, and real-time emergency notifications, making it a practical and efficient solution for elderly healthcare.

- The peak_signal_noise_ratio function calculates the Peak Signal-to-Noise Ratio, which is a widely used metric to measure the quality of an image.
- It compares two images, typically the original and the enhanced image, and computes a value that indicates how much noiseordistortion ispresent relativeto themaximum possiblequality.
- The result is a numerical value, often in decibels (dB). Higher PSNR values indicate higher image quality.

5. CONCLUSION

The Smart Wearable IoT Device for Detecting Health Anomalies in Senior Citizens Using ESP32 is a revolutionary healthcare solution that addresses the growing need for continuous health monitoring among elderly individuals. As the global senior population increases, the risk of chronic diseases, sudden health emergencies, and mobility issuesalsorises.Traditionalhealthcaremethodsrelyonhospitalvisits, routine check-ups, and caregiver supervision, which may not always be feasible or timely. Thisdeviceprovides a real-time, proactive, and efficient approach to elderly healthcare, ensuring early detection of healthanomaliesandimmediatemedicalinterventionwhennecessary. TheESP32microcontrollerplaysacrucialroleinthissystem,offering low power consumption, built-in Wi-Fi and Bluetooth connectivity, and efficient data processing. These features make it ideal for a wearable health monitoring system, enabling continuous tracking of vitalparameterssuchasheartrate(ECG),bloodpressure,SpO2,body temperature,andmovementpatterns.Additionally,accelerometersand gyroscopes detect sudden falls and send emergency alerts, ensuring a fast response in critical situations. The integration of IoT technology allows real-time data transmission to cloud-based platforms like ThingSpeak, providing remote access to caregivers, family members, and healthcare professionals.

To enhance reliability, the system uses data filtering, noise reduction, and threshold-based anomaly detection to identify irregularities such as abnormal heart rate, fluctuating blood pressure, and respiratory issues.Furthermore,machinelearningalgorithmscanbeincorporated toanalyzehealthtrends,enablingpredictivehealthcarebyidentifying potentialrisks beforetheybecomeemergencies. Thisapproach not only improves early disease detection but also helps in reducing hospital admissions, lowering healthcare costs, and providing better patient outcomes.

The device is designed to be lightweight, energy-efficient, and user-friendly, ensuring that elderly individuals can wear it comfortably as part of their daily routine. With a long battery life and a rechargeable system,itminimizesfrequentmaintenance, makingithighlypractical forcontinuoushealthmonitoring.Itscompactandnon-intrusivedesign ensures that seniors do not feel burdened while wearing it.

In conclusion, thissmart wearableIoTdeviceisacost-effective, real-time, and intelligent healthcare solution for senior citizens. By leveraging IoT, AI-driven analytics, and wearable technology, the system significantly enhances elderly safety, independence, and overall well-being. This innovation is a step toward more accessible, efficient, and proactive healthcare, ensuring that seniors receive the care they need, when they need it.

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