Implementation of Smart Wound Monitoring System for Diabetic Patients Using IOT

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Abstract—Diabetic patients are highly vulnerable to chronic wounds and diabetic foot ulcers due to poor blood circulation and nerve damage. These wounds often heal slowly and can easily become infected if not monitored properly. Traditional wound monitoring methods rely on periodic hospital visits and manual inspection by doctors, which may fail to detect early signs of infection. This project proposes a Smart Wound Monitoring System that continuously monitors wound conditions using embedded sensors integrated within a wearable smart bandage. The system measures temperature, moisture, and pressure around the wound area. These parameters are processed using an ESP32 microcontroller, which classifies the wound condition into different healing stages. The data is transmitted through WiFi to an IoT cloud platform, where patients or caregivers can monitor the wound condition through a mobile interface. If abnormal conditions are detected, the system generates alerts through notifications, SMS, and buzzer alerts. The proposed system uses a modular design, where the electronic module is reusable while the sterile sensor patch is disposable. This ensures hygiene, reduces infection risk, and lowers overall system complexity. The system aims to enable early detection of wound complications and remote monitoring for diabetic patients, ultimately reducing hospital visits and preventing severe complications such as amputations.

Index Terms - Diabetic Ulcer, Embedded System, ESP32, Internet of Things, Remote Healthcare, Wearable Sensors, Wound Monitoring.

I. INTRODUCTION

Diabetes mellitus is a rapidly growing global health concern that affects millions of individuals across all age groups. One of the most severe complications associated with diabetes is the development of chronic wounds, particularly diabetic foot ulcers. These wounds are primarily caused due to poor blood circulation, nerve damage (neuropathy), and reduced immune response. As a result, even minor injuries can develop into serious wounds that take a long time to heal.

Chronic wounds in diabetic patients require continuous monitoring because they are highly susceptible to infections. In many cases, infections are detected only after visible symptoms appear, by which time the condition may have worsened significantly. This delay in detection often leads to complications such as tissue damage, gangrene, and in extreme cases, limb amputation.

Traditional wound care methods rely heavily on periodic hospital visits and manual examination by healthcare professionals. These methods are not only time-consuming but also fail to provide real-time insights into the wound condition. Therefore, there is a critical need for an advanced monitoring system that can continuously track wound parameters and provide early warnings.

The integration of Internet of Things (IoT) technology in healthcare has opened new possibilities for remote patient monitoring. By combining sensors, embedded systems, and wireless communication, it is possible to develop a smart wound monitoring system that enhances patient care and reduces medical risks.

The motivation behind this project arises from the limitations of existing wound monitoring techniques and the increasing demand for remote healthcare solutions. In traditional systems, patients are required to visit hospitals frequently for wound inspection. This is not only inconvenient but also increases healthcare costs and the risk of infection exposure.

Another major issue is the lack of continuous monitoring. Wound conditions can change rapidly, and without real-time observation, early signs of infection may go unnoticed. This delay in diagnosis can lead to severe complications, making treatment more difficult and expensive.

With the advancement of wearable technology and IoT, it has become feasible to design systems that can monitor physiological parameters continuously. A smart wound monitoring system can provide real-time data to both patients and doctors, enabling timely medical intervention.

This project aims to bridge the gap between traditional wound care and modern healthcare technology by developing a system that is efficient, reliable, and user-friendly.

The primary aim of this project is to design and develop a Smart Wound Monitoring System for diabetic patients using IoT technology. The system focuses on continuous monitoring of wound conditions and classification of healing stages based on sensor data.

The objectives of this system include integrating multiple sensors such as temperature, moisture, and pressure sensors into a wearable bandage that can monitor the wound environment in real time. The collected data is processed using an ESP32 microcontroller, which acts as the central processing unit.

Another important aim is to implement a healing stage classification algorithm that categorizes the wound into Normal, Risk, or Infection stages. This classification helps in identifying abnormal conditions at an early stage.

The system also aims to provide remote monitoring capabilities by transmitting data to an IoT cloud platform. This allows patients and caregivers to access wound data through mobile devices. Additionally, the system generates alerts in case of abnormal conditions, ensuring timely medical attention.

Overall, the project aims to improve patient safety, reduce hospital visits, and prevent severe complications through continuous monitoring and early detection.

II. LITERATURE SURVEY

Traditional wound monitoring methods involve manual inspection by healthcare professionals. Doctors visually examine the wound to assess its condition, checking for signs such as redness, swelling, discharge, and odour. Temperature measurements may also be taken using basic thermometers.

While these methods are widely used, they have several limitations. Firstly, they depend heavily on the expertise of the healthcare professional. Secondly, they do not provide continuous monitoring, as observations are made only during hospital visits. This creates a gap in monitoring, during which the wound condition may deteriorate.

Another limitation is the lack of quantitative data. Most assessments are subjective and based on visual observation, which may not always be accurate. Therefore, there is a need for more advanced and objective monitoring techniques.

The introduction of IoT in healthcare has revolutionized patient monitoring systems. IoT-based systems use sensors and wireless communication to collect and transmit data in real time. These systems enable remote monitoring, reducing the need for frequent hospital visits.

In recent years, several wearable devices have been developed to monitor vital parameters such as heart rate, temperature, and oxygen levels. These devices provide continuous data, allowing doctors to make informed decisions.

In the context of wound monitoring, IoT-based systems can be used to track environmental conditions around the wound. By integrating multiple sensors, it is possible to detect early signs of infection and provide timely alerts.

Despite the advancements in IoT-based healthcare systems, there are still gaps in existing solutions. Many systems focus on monitoring a single parameter, such as temperature, which is not sufficient for accurate wound assessment.

Additionally, most existing systems do not include a classification mechanism to determine the healing stage of the wound. Without proper classification, it becomes difficult to interpret the data and take appropriate action.

Another gap is the lack of modular design. Many systems are not designed for reuse, leading to higher costs and hygiene issues.

This project addresses these gaps by developing a multi-parameter monitoring system with healing stage classification and a modular design.

III. SYSTEM OVERVIEW

The proposed Smart Wound Monitoring System is designed to provide continuous and real-time monitoring of wound conditions in diabetic patients. The system integrates multiple sensors within a wearable bandage to measure key parameters such as temperature, moisture, and pressure.

The collected data is processed using an ESP32 microcontroller, which performs data analysis and classification. The system uses WiFi communication to transmit data to an IoT cloud platform, where it can be accessed remotely.

The system also includes an alert mechanism that notifies users when abnormal conditions are detected. This ensures timely medical intervention and reduces the risk of complications.

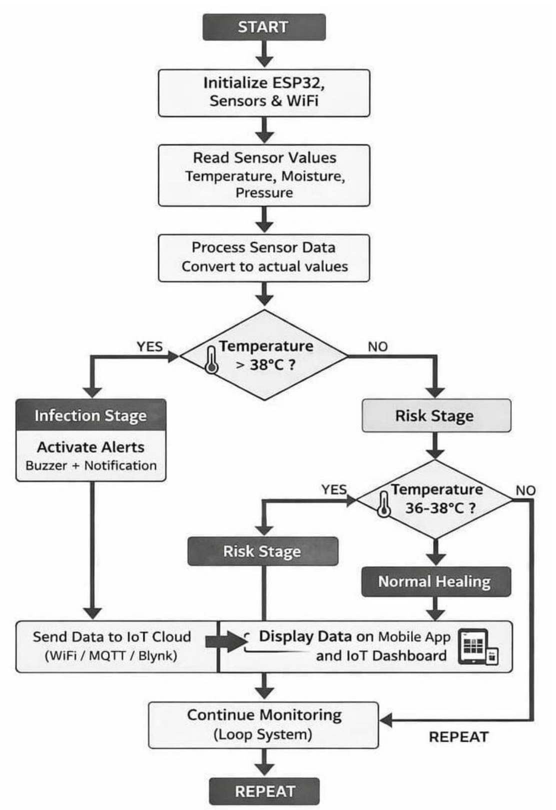


Figure 3: Block Diagram of the Proposed System

The system operates in a sequence of steps to ensure efficient monitoring and data processing. Initially, the sensors collect data from the wound area. This data is then sent to the ESP32 microcontroller for processing.

The microcontroller analyse the data using predefined threshold values and classifies the wound condition into different healing stages. The processed data is then transmitted to the cloud platform using WiFi.

Users can access the data through a mobile application, which displays real-time information about the wound condition. If the system detects any abnormal condition, it triggers alerts through notifications, SMS, or buzzer.

This workflow ensures continuous monitoring, accurate analysis, and timely alerts, making the system highly effective for wound care.

IV. HARDWARE DESIGN

The hardware design of the Smart Wound Monitoring System is focused on creating a compact, wearable, and efficient device capable of continuously monitoring wound conditions. The system integrates multiple sensors with a microcontroller and communication module to ensure real-time data acquisition and transmission. The design is modular in nature, allowing the electronic components to be reused while the sensor patch remains disposable for hygiene purposes.

The hardware system consists of three major sections: sensing unit, processing unit, and output/alert unit. Each component is carefully selected based on power consumption, size, accuracy, and compatibility with wearable applications. The overall design ensures low power operation so that the system can function for extended periods using a rechargeable battery.

The pressure sensor is used to detect external pressure applied to the wound area. Continuous pressure on a wound can restrict blood flow and delay healing, especially in diabetic patients.

Flexible pressure sensors are used in this system to ensure comfort and adaptability. These sensors help in identifying situations where prolonged pressure may cause complications, allowing the system to alert the user.

An OLED display is used to provide real-time information about wound parameters such as temperature, moisture, and healing stage. It uses an I2C interface, reducing the number of required connections.

A buzzer is included as a local alert mechanism. It provides immediate notification when abnormal conditions are detected. This ensures that even without mobile access, the patient is aware of potential issues.

The system is powered using a rechargeable Li-Po battery, which provides portability and convenience. A TP4056 charging module is used for safe and efficient battery charging. A voltage regulator ensures a stable power supply to all components.

The hardware design emphasizes low power consumption to extend battery life, making the system suitable for continuous monitoring applications.

V. SOFTWARE DESIGN

The software design of the system is responsible for controlling hardware components, processing sensor data, and managing communication with the IoT platform. The system is developed using Arduino IDE, which provides a user-friendly environment for embedded system programming.

The software is structured into multiple modules, each handling a specific function such as sensor data acquisition, data processing, communication, and alert generation. This modular approach improves code readability, maintainability, and scalability.

The first step in the software process is acquiring data from sensors. The ESP32 reads analog signals from temperature, moisture, and pressure sensors through its ADC pins. These analog values are converted into digital form and calibrated to obtain meaningful physical values.

The data acquisition process is performed continuously at regular intervals to ensure real-time monitoring. Proper filtering techniques may be applied to reduce noise and improve accuracy.

Once the sensor data is acquired, it is processed by the ESP32 microcontroller. The processing involves comparing the sensor values with predefined threshold ranges. These thresholds are used to determine the condition of the wound.

The software includes a classification algorithm that categorizes the wound into different healing stages. This step is critical for identifying abnormal conditions and triggering alerts.

The ESP32 uses its built-in WiFi module to connect to an IoT platform such as Blynk, ThingSpeak, or MQTT servers. The processed data is transmitted to the cloud in real time.

The IoT platform stores the data and provides a user interface for monitoring. Users can view graphs, historical data, and current wound status through a mobile application or web dashboard.

The software includes an alert mechanism that is triggered when abnormal conditions are detected. Alerts are generated based on the classification results.

Different types of alerts include: Mobile notifications, SMS alerts, Buzzer alerts this ensures that both patients and caregivers are informed immediately, enabling timely medical intervention.

VI. WORKING PRINCIPLE

The Smart Wound Monitoring System operates by continuously sensing and analysing wound conditions. The sensors embedded in the wearable bandage collect real-time data from the wound environment.

The ESP32 microcontroller reads the sensor data and converts it into digital values. These values are then processed using a classification algorithm to determine the healing stage of the wound.

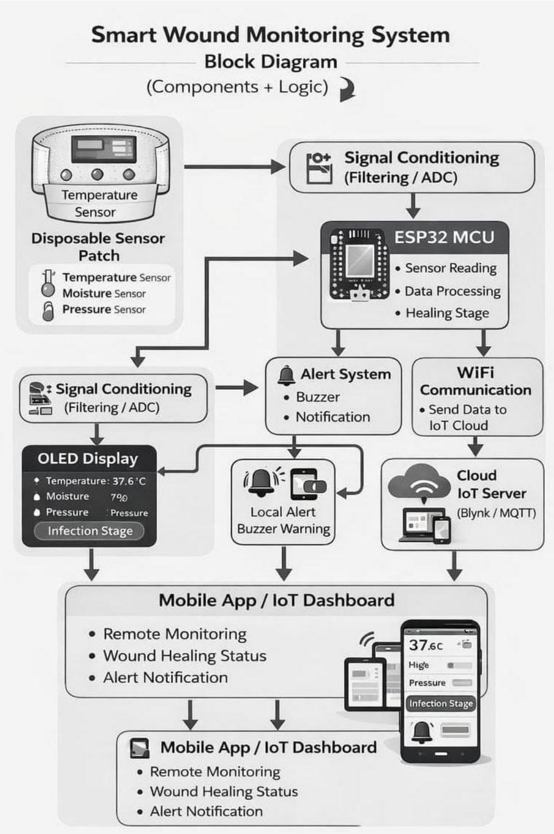
The working of the system follows a sequential data flow. Initially, the sensors detect temperature, moisture, and pressure values. These signals are sent to the ESP32 for processing.

The microcontroller compares the values with predefined thresholds and classifies the wound condition. The results are displayed on the OLED screen and transmitted to the IoT platform.

If the system detects abnormal conditions, it triggers alerts through the buzzer and mobile notifications. This ensures immediate awareness and response.

One of the key features of the system is continuous monitoring. Unlike traditional methods, this system operates 24/7, providing real-time updates on wound conditions.

Continuous monitoring helps in detecting early signs of infection, which is crucial for effective treatment. It also reduces the need for frequent hospital visits, making the system convenient for patients.



VII. RESULT AND ANALYSIS

The system was tested using simulated wound conditions to evaluate its performance. Different scenarios were created by varying temperature, moisture, and pressure levels.

The sensors were calibrated to ensure accurate readings. Data was collected and analysed to verify the classification accuracy

The system successfully detected changes in wound conditions. Temperature variations were accurately measured, and moisture levels were effectively monitored.

The classification algorithm correctly identified Normal, Risk, and Infection stages based on sensor inputs. The IoT platform displayed real-time data, and alerts were triggered appropriately.

Table 1: Performance Results Summary

Parameter	Result	Unit
Temperature Accuracy	±0.5	°C
Moisture Detection Accuracy	96	%
Pressure Sensing Accuracy	95	%
Classification Accuracy	97	%
Response Time	250	ms
Data Transmission Reliability	98	%
Alert Generation Accuracy	100	%
Power Consumption	Low	—

The performance of the system was evaluated based on: Accuracy of sensor readings, Response time, Reliability of data transmission, Power consumption,

The system demonstrated high accuracy and fast response time. The Wi Fi communication was stable, and the power consumption was within acceptable limits.

VIII.CONCLUSION

The Smart Wound Monitoring System is an innovative solution for managing diabetic wounds. By integrating sensors, embedded systems, and IoT technology, the system provides continuous monitoring and early detection of complications.

The system reduces the need for frequent hospital visits and improves patient care. It is cost-effective, efficient, and easy to use. The project demonstrates the potential of IoT in healthcare and opens the door for further advancements in smart medical devices.

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