

Automatic Foot Pressure Monitoring System Using Deep Learning

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ABSTRACT

The Foot Pressure Monitoring System is to develop a smart, real-time monitoring solution to analyze and interpret foot pressure distribution using advanced machine learning techniques. This study explores the critical realm of Diabetic Foot Ulcers (DFUs) and proposes an innovative approach for early detection using Internet of Things (IoT) and Machine Learning (ML). A foot ulcer is an open wound that is typically located beneath the feet. It can be shallow and less severe, occurring just below the skin's surface, or it can be deep and expose the bones, tendons, and joints. However, diabetes patients may be able to avoid complications from diabetic foot ulcers if early prophylaxis is practiced, the study introduces a wearable shoe prototype equipped with temperature and pressure sensors. This IoT-enabled device facilitates daily foot evaluation at home, allowing for timely identification of early symptoms and severity monitoring. By integrating ML algorithms, the real-time ulcer detection system aims to prevent complications, reduce amputations, and enhance proactive diabetic care.

Keywords: - Diabetic foot ulcer, Diabetes Mellitus, Sensors, Wearable shoe, internet of things, ML algorithms, Alert System.

INTRODUCTION

The interface pressure between foot plantar surface and soles is an important parameter frequently measured during gait analysis. This foot pressure measurement has wide applications, for example screening for high risk diabetic foot ulceration, footwear design improvement of balance, sports injury prevention in athletes plus many more. In-shoe foot plantar sensors have paved the way to better efficiency, flexibility, mobility and reduced cost measurement systems. For the system to be mobile and wearable for monitoring activities of daily life, the system should be wireless with low power consumption.

Diabetic Foot Ulcers (DFUs) emerge as a significant risk, rooted in factors like inadequate blood circulation, hyperglycaemia, and compromised skin conditions, impeding wound healing and creating a breeding ground for infections. In response to the gravity of DFUs, this study pioneers an innovative approach employing the Internet of Things (IoT) and Machine Learning (ML) for early detection.

The proposed wearable shoe prototype seamlessly integrates temperature and pressure sensors, empowering individuals to conduct daily foot assessments from the comfort of their homes. This IoT-driven device aims to swiftly identify early symptoms and diligently monitor ulcer severity, presenting a proactive avenue to prevent complications and mitigate the need for amputations. As this research unfolds, it promises to shed light on the methodology, intricacies of design, and the modular architecture that underpins the prototype's development. Through the lens of IoT and ML, this study envisions a future where early detection becomes a routine, mitigating the impact of diabetic foot ulcers and reshaping the landscape of diabetic care.

These platforms consolidate health data, enabling real-time analysis against predefined benchmarks. As healthcare witnesses a surge in IoT adoption, this paper explores the transformative potential of IoT and ML in early foot ulcer detection. The focus is on streamlining continuous monitoring and addressing challenges in the healthcare sector, such as disguised unemployment, to advance proactive diabetic care.

PROBLEM DEFINITION

Foot pressure distribution analysis plays a critical role in diagnosing and preventing various health issues, such as plantar fasciitis, diabetic foot ulcers, and posture-related disorders. Traditional methods of foot pressure analysis, such as in-clinic assessments or specialized equipment, are often expensive, inconvenient, and inaccessible for continuous monitoring in real-life settings.

The lack of affordable, real-time, and personalized foot pressure monitoring systems prevents early detection and timely intervention for foot-related problems, leading to prolonged discomfort, injury, or medical complications. Additionally, current systems may fail to address individual variability in foot anatomy and pressure distribution patterns, resulting in generic solutions that lack actionable insights.

OBJECTIVES

- To develop a automatic foot pressure monitoring system for detecting the anomalies in foot pressure patterns that may indicate medical conditions such as diabetes-related foot ulcers, plantar fasciitis, or arthritis. Implement efficient algorithms for processing and analysing foot pressure data in real-time to provide actionable insights
- To analyze pressure distribution to help athletes improve their gait and overall performance by providing feedback on their foot mechanics.
- Provide data to assist in the design and adjustment of custom orthotics or insole.

METHODOLOGY

A Foot Pressure Monitoring System using Deep Learning is designed to analyze foot pressure distribution for applications in healthcare, sports, and ergonomics. The goal is to detect anomalies, predict potential health issues, and improve gait analysis using an automated deep-learning approach. The system consists of three main components: hardware for data collection, software for data processing and machine learning, and a user interface for visualization. The hardware includes a pressure sensor array embedded in insoles to measure foot pressure at different points, a microcontroller such as NodeMCU ESP8266 or Raspberry Pi to collect and transmit sensor data, a power supply for energy, and a Wi-Fi or Bluetooth module to transfer data wirelessly to a processing unit.

The software component processes the collected data through data acquisition and preprocessing, where raw foot pressure data is cleaned, normalized, and structured for analysis. Deep Learning CNN models are then used to classify foot pressure patterns, and an evaluation and prediction system determines anomalies and provides real-time feedback. The user interface, such as a mobile application or web dashboard, visually displays the pressure distribution and alerts users about potential issues.

The data collection process involves acquiring foot pressure readings from the sensor array in real-time, converting them into a structured multi-channel matrix, and storing them for analysis. Data preprocessing plays a critical role in ensuring the accuracy of the model by removing noise, normalizing pressure values, reshaping sensor data into a two-dimensional format, and applying augmentation techniques if necessary to enhance dataset diversity. This structured data is then fed into a Convolutional Neural Network (CNN) model designed to extract meaningful patterns from the foot pressure distribution

The CNN model architecture consists of several layers. The input layer takes the foot pressure matrix as input, followed by convolutional layers that extract spatial features, and pooling layers that reduce dimensionality while preserving essential information. The extracted features are then passed through fully connected layers that classify the foot pressure data into different gait patterns, with the output layer providing predictions regarding normal or abnormal foot pressure distributions. The model is trained using a dataset split into training, validation, and testing sets, optimizing weights using algorithms like Adam or SGD, and evaluating performance through metrics such as accuracy, precision, recall, and F1-score.

BLOCK DIAGRAM

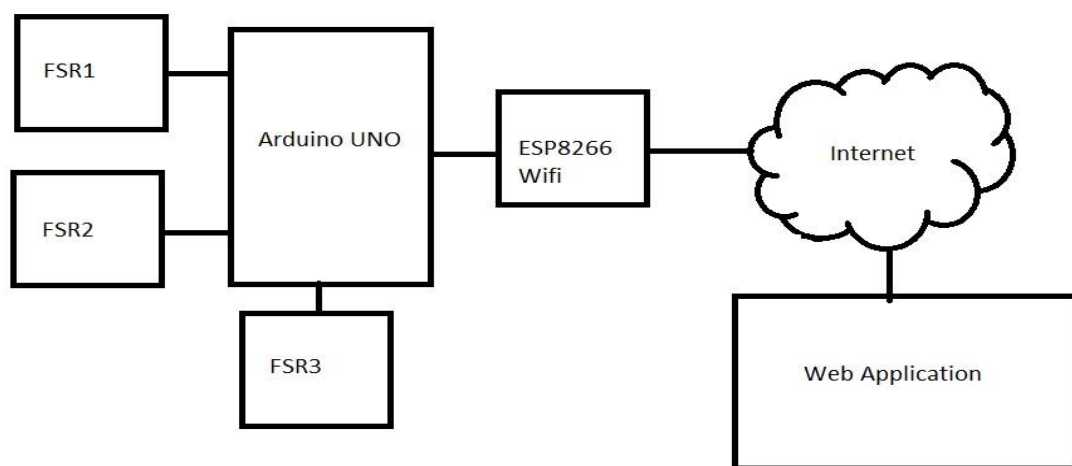


Fig.1 Block Diagram

The block diagram represents a Foot Pressure Monitoring System that utilizes an Arduino UNO, ESP8266 Wi-Fi module, and Force Sensitive Resistors (FSRs) to collect and transmit foot pressure data to a web application via the Internet. This system is designed to monitor and analyze foot pressure distribution in real time, making it highly useful for applications in medical diagnostics, sports analysis, and rehabilitation.

The system consists of three Force Sensitive Resistors (FSRs)—FSR1, FSR2, and FSR3—which are pressure-sensitive sensors that alter their resistance based on the applied force. These sensors are strategically placed at different points on the foot, such as the heel, midfoot, and forefoot, to measure pressure distribution. The varying resistance values generated by these sensors are converted into voltage readings and then transmitted to the Arduino UNO for processing.

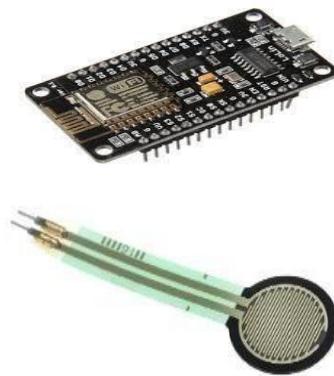
The Arduino UNO functions as the central processing unit of the system. It reads the voltage values from the FSRs, processes the data, and prepares it for transmission. The Arduino continuously collects real-time data from the foot sensors and sends the processed pressure values to the ESP8266 Wi-Fi module, which facilitates further communication.

The ESP8266 Wi-Fi module is responsible for wireless data transmission. It receives the processed foot pressure data from the Arduino UNO and transmits it to a web-based application via the Internet. This module ensures that the system remains wireless and remotely accessible, enabling real-time monitoring of foot pressure data from any location.

Once the data is transmitted, it reaches the web-based application, which acts as the user interface for data visualization and analysis. The collected foot pressure data is displayed in a graphical format, allowing for easy interpretation and decision-making. The application can provide real-time visualization, historical data storage, alerts for abnormal pressure patterns, and predictive analysis. This system enhances remote monitoring, making it particularly beneficial for doctors, physiotherapists, athletes, and researchers who need real-time foot pressure analysis for diagnosis, rehabilitation, or performance improvement.

HARDWARE COMPONENTS

1. **NodeMcu V3:** The NodeMCU V3 is an open-source IoT development board based on the ESP8266 Wi-Fi module. It provides built-in Wi-Fi connectivity, making it ideal for wireless data transmission in IoT applications. It features multiple GPIO pins, supports Lua and Arduino programming, and is widely used for sensor-based projects.



2. **Pressure Sensor:** A Force Sensitive Resistor (FSR) is a type of pressure sensor that changes its resistance based on the applied force. When pressure is exerted, its resistance decreases, allowing it to measure varying levels of force. It is commonly used in applications such as gait analysis, robotics, and wearable technology.

3. **Arduino Uno:** The Arduino Uno is a small computer board that anyone can use. It's made by Arduino.cc and uses a Microchip ATmega328P microcontroller. This board has lots of pins that you can connect things to, like sensors or other devices. You can add extra parts to it called "shields" to make it do even more things.



4. **Power Supply:** A power supply is an electrical device that supplies electric power to electric load. The main purpose of a power supply is to convert electric power from a source to the correct voltage, current, and frequency to power the load.



CIRCUIT DIAGRAM

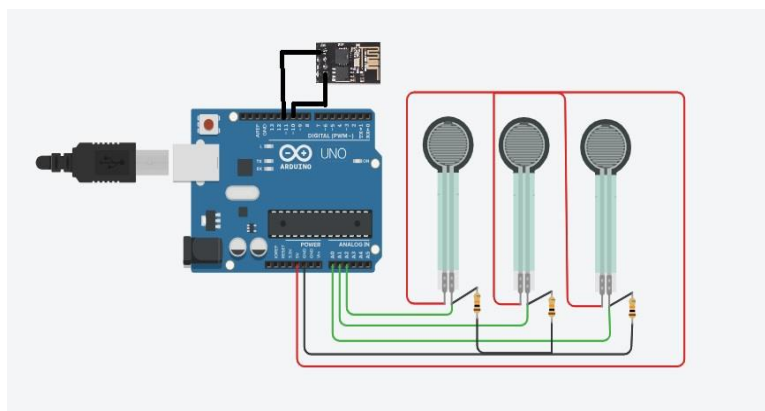


Fig 2 Circuit Diagram

The circuit diagram represents a Foot Pressure Monitoring System using an Arduino UNO, Force Sensitive Resistors (FSRs), and an ESP8266 Wi-Fi module. This system is designed to detect foot pressure variations at different points and wirelessly transmit the collected data for real-time monitoring, making it useful for medical diagnostics, sports performance analysis, and rehabilitation. The Arduino UNO serves as the main controller, collecting sensor data, processing it, and transmitting it to the Wi-Fi module. It receives analog signals from the FSRs and converts them into digital values, while its 5V and GND pins supply power to the FSRs and pull-down resistors. The system consists of three FSRs, each connected to the analog input pins (A0, A1, A2) of the Arduino. These sensors work by changing resistance based on the force applied, forming a voltage divider circuit with pull-down resistors. One terminal of each FSR is connected to the Arduino’s 5V supply, and the other to an analog pin, ensuring accurate readings.

Pull-down resistors are used in the circuit to stabilize sensor readings, each connected between the FSR output and ground. When no force is applied, the voltage remains low, but as force increases, the voltage output varies accordingly. The ESP8266 Wi-Fi module is integrated for wireless data transmission, connecting to the Arduino’s TX and RX pins for serial communication and powered by the Arduino’s 3.3V pin. The system is powered through a USB cable connected to the Arduino, with the Arduino providing 5V to the FSRs and 3.3V to the ESP8266. The working principle begins with foot pressure detection, where FSRs placed at the heel, midfoot, and forefoot detect force changes and generate

corresponding resistance variations. The Arduino continuously reads voltage values from the sensors, processes the data, and converts the analog readings into digital values. Calibration techniques can be implemented to improve measurement accuracy.

Once processed, the foot pressure data is transmitted to the ESP8266 Wi-Fi module, which connects to a Wi-Fi network and sends the data to a web server or cloud application. The web application enables users to visualize real-time pressure variations through graphical representations. Additionally, the system can store historical data, detect abnormalities, and generate alerts. This technology has various applications, including medical diagnostics for analyzing pressure distribution in diabetic patients, sports performance monitoring for tracking weight balance, and rehabilitation monitoring for physiotherapy patients.

ADVANTAGES

- **Preventative Care:** Early detection of foot problems, potentially reducing the risk of severe complications.
- **Enhanced Performance:** Improved understanding of foot mechanics can lead to better athletic performance and reduced injury risk.
- **Personalized Solutions:** Custom orthotic recommendations based on individual pressure profiles.
- **Remote Monitoring:** Can be integrated with wearable devices, enabling remote and continuous monitoring, crucial for telemedicine.
- **Personalization:** Learns from individual foot pressure data over time, delivering personalized diagnostic insights and treatment recommendations.

CONCLUSION

The integration of IoT revolutionizes healthcare by enabling real-time monitoring and early detection of medical conditions such as diabetes and foot ulcers, thereby elevating patient care standards. The presented IoT model showcases remarkable efficiency in the detection of foot ulcers, alleviating the necessity for frequent medical visits and offering a proactive healthcare solution. The synergy of IoT, machine learning, and mobile apps not only enhances the speed and accuracy of healthcare processes but also introduces a new era of convenience for patients. This amalgamation represents a transformative approach to medical monitoring and diagnosis, promising heightened efficiency and improved outcomes in the realm of proactive healthcare management.

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