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EARLY DIAGNOSIS OF DIABETIC FOOT ULCERS USING AI-BASED IMAGE CLASSIFICATION TECHNIQUES

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Abstract: Diabetic foot ulcers (DFUs) are an advanced complication associated with diabetes mellitus which, if not diagnosed promptly, can lead to severe infections, amputations, and even death. Traditional methods of diagnosis rely heavily on the visual checks by medical personnel, which often is not timely. Detecting DFUs using various forms of AI (Artificial Intelligence) offers an efficient, automated, and timely solution. In this study, we propose a complete framework with AI techniques that underset the deep learning structure, especially convolutional neural networks (CNNs), for the classification and prediction of diabetic foot ulcers. The model employs a set of DFU images to train and validate the model's performance on numerous defined metrics including, but not limited to, accuracy, precision, recall, and F1-score. The experiments performed show the significant role AI can play in improving early DFU detection, a shift that would revolutionize the care of diabetic foot issues and improve healthcare outcomes.

Keywords: Diabetic Foot Ulcer (DFU), Artificial Intelligence (AI), Convolutional Neural Network (CNN), Deep Learning, Early Diagnosis, Medical Imaging.

I. INTRODUCTION

Diabetes mellitus is a long-term condition that impacts millions of people globally. One of the most serious complications arising from this disease is the occurrence of Diabetic Foot Ulcers (DFUs), which result from inadequate blood circulation and peripheral nerve damage. The World Health Organization (WHO) reports that DFUs affect 15–25% of individuals with diabetes at some point in their lives and account for over 85% of amputations related to diabetes. Prompt identification of DFUs is crucial for ensuring timely treatment and avoiding severe consequences. Traditional methods of diagnosis, such as physical exams and manual foot image assessments, are often lengthy and subjective. As a result, there is an increasing demand for smart and automated systems to assist with clinical diagnoses. Artificial Intelligence (AI), especially Deep Learning (DL), presents encouraging outcomes in the analysis of medical images. This study investigates the application of CNNs for the early identification and categorization of diabetic foot ulcers using medical images.

II. RELATED WORK

[1] Early detection of diabetic foot ulcer using IoT and ML authored by Sanjana Berugu, Nagaraju Bajjuri, M. Shiva Reddy, T. Ramya1(2024): 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 chronic metabolic condition with elevated blood glucose levels is called diabetes mellitus. Focusing on Diabetes Mellitus, the chronic metabolic condition leading to DFUs, 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.

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[2] IOT Based Healing Process for Diabetic Foot Ulcer authored by Keerthana S, Gokulraj C, Sivaram N, Vishal.J, Vishva K (2024): In This research, it presents an innovative approach to treat diabetic foot ulcers (DFU) by leveraging Internet of Things (IoT) technology. Through comprehensive data analysis system, DFU progress can be monitored in real time, allowing for timely intervention and improved healing outcomes. The system uses IoT devices to capture images of ulcers, identify the stage of the disease, and provide important insights into the severity of the ulcer. These images are displayed on an LCD screen and sent over the IoT network for analysis. Additionally, the system sends email notifications to healthcare providers to keep them updated on the patient's status and allow them to quickly adjust treatment plans.

[3] Automated Diabetic Foot Ulcer Detection and Classification Using Deep Learning authored by Sunnam Nagaraju, Kollati Vijaya Kumar, B prameela Rani, E laxmi Lydia, Mohamad Khairi Ishak, Imen Filali, Faten khalid Karim and Samih M Mostafa (2023): In this survey, Diabetic foot ulcers (DFU) Detection and Classification is done using Deep learning (DL) refers to the application of deep learning techniques to automatically detect and classify diabetic foot ulcers from medical images. This article introduces a novel sparrow search optimization (SSO) with Deep Learning Enabled Diabetic Foot Ulcer Detection and classification (SSODLDFUDC) technique. The presented SSODLDFUDC technique's goal lies in identifying and classifying DFU. The comprehensive experimental outcomes demonstrate the improved performance of the SSODL-DFUDC system related to existing DL techniques.

[4] An IOT Enabled Early Warning and Prediction of Foot Ulcer authored by Selva Sherin T, Raguraman S, Sowmiya P, Sudha M (2022): In this research, Diabetic foot complication is one among the leading causes of non-traumatic lower extremity amputations. Because of diabetic complications like neuropathy, diabetic patients don't feel any of the pain in their feet. By monitoring the various parameters of the foot and using it for predicting possible occurrence of ulcer we aim to avoid occurrence of ulcers. It had been developed a replacement hardware with accompanying software while evaluating the planning to confirm it helps in taking early preventive measures for the feet and avoid the occurrence of ulcer and further complications. Due to this, it's often unaware of any ulcer or wound formed on their feet.

[5] Detection of Diabetic Foot Ulcer using Knn Algorithm authored by Anjana B, Femin Ali K M, Keerthana A, Adithya K, Nutan Hegde (2022): In this Paper, diabetic foot ulcer is a wound that mostly affects the bottom of the foot and develops in people with diabetes. The proposed method makes use of sensors and the KNN algorithm to detect diabetic foot ulcers. The KNearest Neighbor algorithm is the most basic machine learning method for assessing data similarity. An open source electronics platform called an Arduino board can read inputs and convert them into outputs.This concept eliminates time consuming tasks like routine medical visits and provides real-time updates on the patient.

III. PROPOSED MODEL

Methodology*:*

Peripheral Neuropathy is considered to be the most common complexities found in Diabetic patients caused by long term high sugar levels. This also makes an individual vulnerable to ulcers and severe amputation in extreme cases. The proposed model helps in providing cloud access to the real-time Foot pressure and Temperature of an individual with an SOS alert system to the hospital.

The thresholds have been set using TCSS and based on increased forefoot to rear foot increased pressure ratio. There have been enough pieces of evidence developed till now based on thermal imaging analysis as well as multiple patient's data indicating that the patients with diabetic neuropathy had a higher foot temperature (32°C - 35°C) compared to patients without neuropathy (27°C - 30°C). For a patient with diabetic neuropathy, at midfoot, the peak pressure was significantly different among all groups: control group (139.4±76.4 kPa), diabetic neuropathy (205.3±118.6 kPa) and DNU (290.7±151.5 kPa) (p=0.008). Conventional approaches for analysis of DFU use hand-crafted rendered technique. However, research activities in the publication have displayed that learned attributes by deep neural networks (DNN) have high potential compared to classical hand-crafted features. Wide research was conducted to enhance the outcome of computerization, which is very popular in this sector since they were superior to other techniques. The common method that is utilized in the DL technique in medical image classification is convolutional neural networks (CNNs). The CNNs can efficiently derive valuable attributes for image segmentation, image classification, other vision tasks, and object detection.

With the obtainability of large-scale trained data and high-performing modern application specific integrated circuit (ASICs) and graphics processing units (GPUs)and techniques related to CNNs have enhanced the precision of image classification. Renowned CNNs for general image classifier tasks involve ResNet, AlexNet, EfficientNet, and VGG. Such

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networks generally serve as the pillar of medical image classifier networks or directly enforce medical image classifications by transfer learning (TL) with pre-trained variables on large-scale datasets (e.g., ImageNet). Practically, labelling and collecting medical images were costly. TL was a potential way to overcome the need for medicinal trained data.

Working Principle:

This system is designed to monitor and process pressure data using an integrated network of pressure sensors, an analog-to-digital conversion mechanism, and cloud-based data management for advanced analysis and storage.

The system begins with pressure sensors, which are strategically placed to measure pressure values from various sources or locations. These sensors are sensitive to physical forces applied to them, converting the mechanical pressure into electrical signals. The output of these sensors is in the form of analog signals, which are continuous waveforms directly proportional to the magnitude of the pressure detected. This raw analog data forms the foundation for the system's operation and serves as the input for further processing.

Since the Raspberry Pi or other digital processors cannot directly handle analog signals, an Analog-to-Digital Converter (ADC) is utilized to bridge the compatibility gap.

The ADC plays a critical role in converting the continuous analog signals from the sensors into discrete digital signals that can be processed by digital systems. This conversion is achieved by sampling the analog signal at regular intervals and quantizing it into a digital format. The accuracy of this step is vital, as it directly impacts the quality of the processed data. The output from the ADC is a series of digital values that correspond to the pressure measurements, ready for further processing.

Once the digital signals are generated, they are transmitted to the Raspberry Pi for preprocessing and analysis. The Raspberry Pi acts as the central processing unit in this system, performing tasks such as:

Noise Filtering: Removing any unwanted or irrelevant fluctuations in the data to ensure clean and reliable measurements.

Calibration: Adjusting the raw sensor data to align with standardized pressure scales or units.

Real-Time Analysis: Detecting trends, anomalies, or other actionable insights in the pressure data. This step not only refines the data but also prepares it for advanced analysis or visualization in the next stages.

The processed data from the Raspberry Pi is then transmitted to a cloud platform for further analysis, long-term storage, and remote accessibility. The integration of cloud computing adds a layer of scalability and versatility to the system.

System Design Approach:

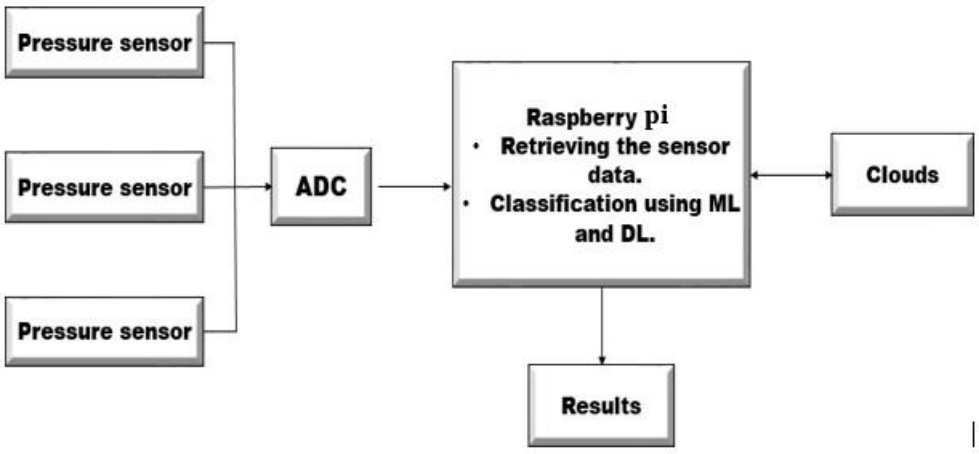

Fig. 1 Block diagram

The fig illustrates the system block diagram where the Pressure Sensors is used to measure foot pressure and next sends the data to ADC which converts analog sensor data to digital form. Later Raspberry Pi Processes sensor data and performs classification using machine learning (ML) and deep learning (DL) algorithms. The processed results are stored or shared via cloud platforms for remote monitoring. Finally, the system provides the diagnosis results, enabling early detection and timely intervention.

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Proposed Workflow:

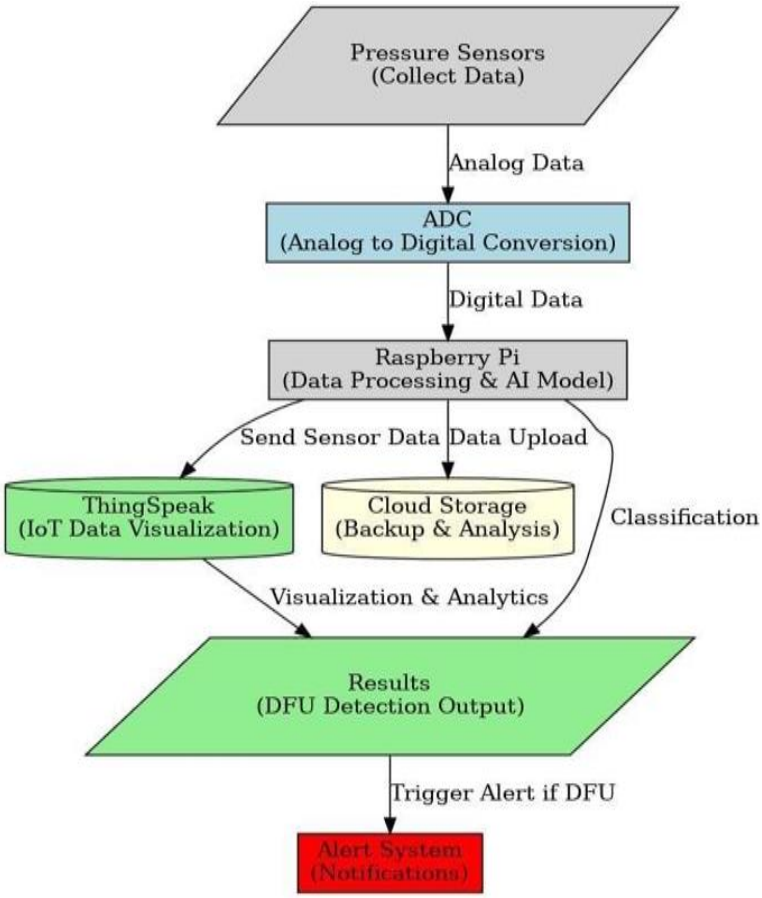

Fig. 2 Flow chart

IV. RESULT

Foot pressure sensing platform system is developed using pressure sensors to early detection of foot ulcer caused by diabetic conditions. The result shows the comparisons of the pressure distribution on foot with different trials to detect the numbness and avoid the foot ulcers. This system can be used for finding the life threatening condition of deaths due to Pulmonary Edema and can be monitored to predict and alert in advance any indication of the body status.

Fig. 3 Hardware setup

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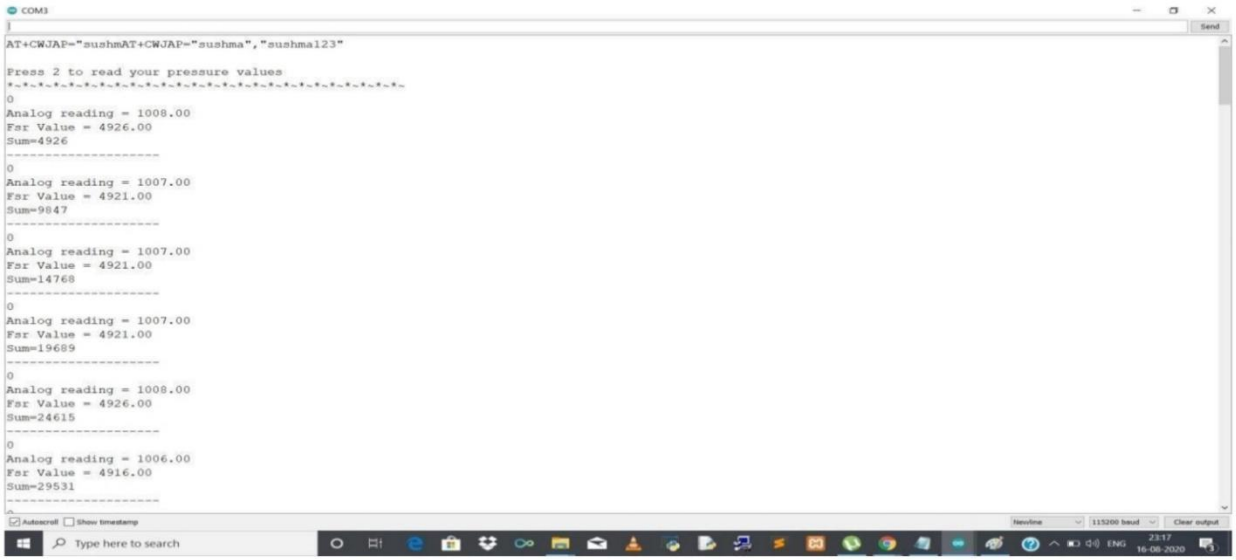

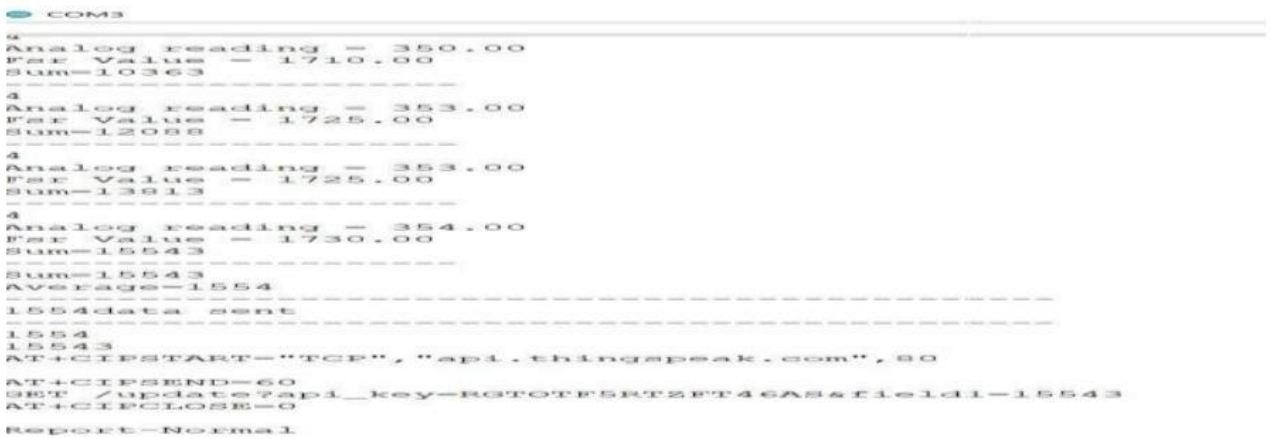

Fig. 4 Results viewed on Serial Monitor

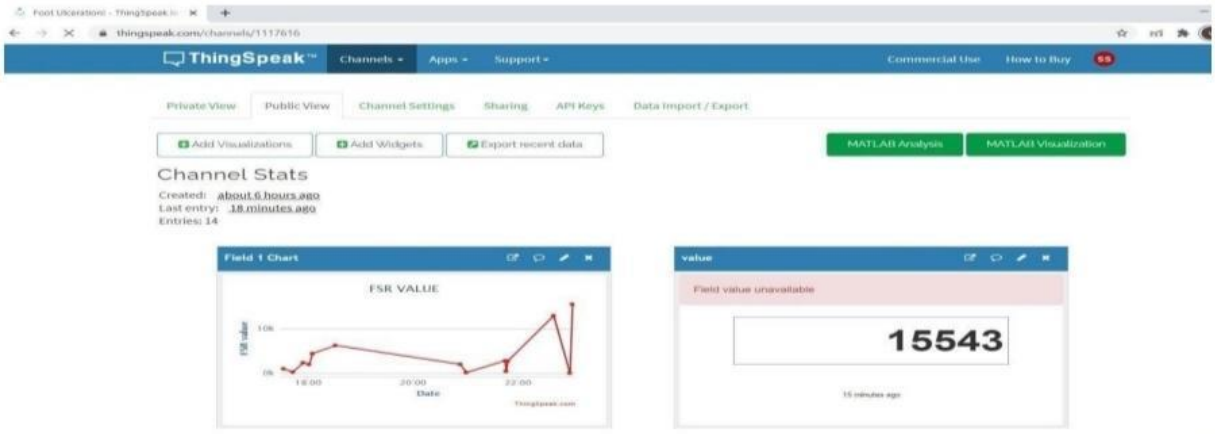

Fig. 5 Results viewed on Thing speak

In our project the threshold values are obtained for a person weighing between 50 -60kgs. If the sensor values do not exceed the defined threshold values, the following result is obtained.

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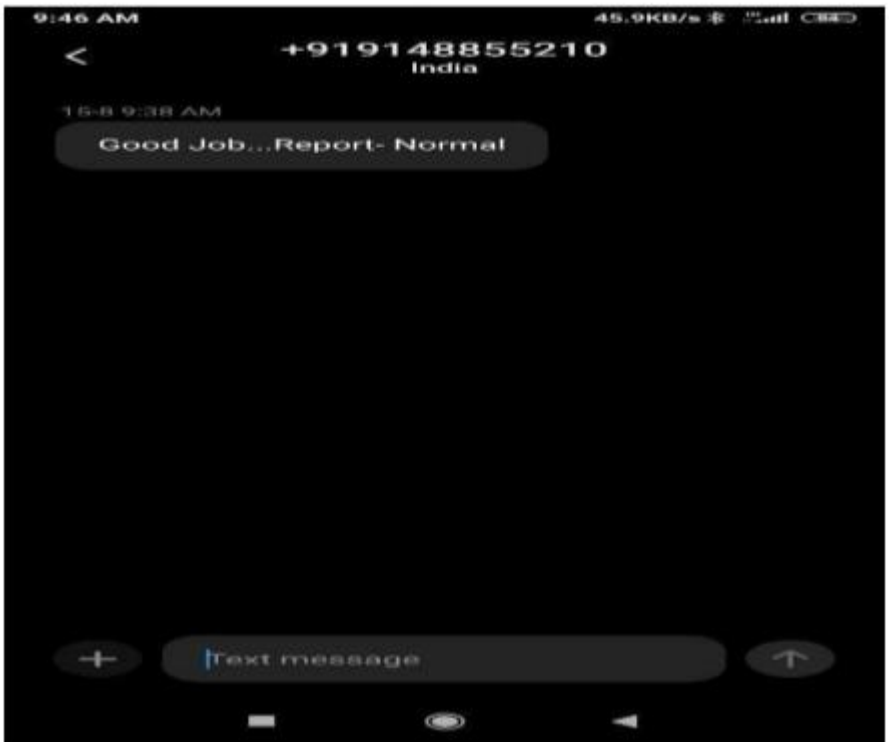

Fig. 6 Results Viewed on Phone

V. CONCLUSION

The proposed technique consists of a Keypad that is used to choose between the calculation of foot pressure values or Heart rate/SpO2 one at a time. Force Sensing Resistor (FSR) is used to measure the foot pressures at 10 different points. The MAX30100 is used to measure heart rate and SpO2. We use Arduino MEGA to obtain data from the above sensors. The data is processed in the Arduino and then sent to the patient's/care-taker's phone as an SMS using the GSM 800C Module. The processed data is also sent to the Things board platform through ESP8266-01(Wi-Fi) Module. Things board is an open source IOT platform for the device management, collection, processing and visualization of data.

This system can aid in deciding suitable footwear for diabetic patients and walking style for a given time based on the data read sensor and shown in the hand held device. It is envisioned that the said technique, developed and tested, is an effective biomechanical system to diagnose various disorders related to foot. Remotely, data can be accessible using GSM and WI-FI modules to resolve many of the medical problems. As a future scope more number of FSR's can be added to the system to increase accuracy. The system can further be developed to alert a nearby hospital in case of an emergency condition and an ambulance can be sent immediately to the patient's location A GPS module can be installed in the system to provide location data to the hospital.

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