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Diabeties Prediction Using MachineLearning and Embedded System

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Abstract: Diabetes mellitus (DM) is a chronic metabolic disorder characterized by elevated blood sugar levels, which can lead to severe complications if left untreated. One of the common manifestations of diabetes is peripheral neuropathy, which can result in altered foot pressure distribution. Early detection and management of foot pressure abnormalities are crucial for preventing diabetic foot ulcers and amputations. In this research paper, we propose an intelligent foot pressure analysis system for the early detection of diabetes mellitus.
Keywords: Diabetes mellitus (DM), Non-Wearable Sensor (NWS), Wearable Sensor (WS), Plantar fasciitis (PF)

I. INTRODUCTION

Diabetes mellitus (DM) stands as a formidable global health challenge, its prevalence steadily escalating on a worldwide scale. According to recent statistics from the International Diabetes Federation (IDF), the year 2019 witnessed an alarming 463 million adults grappling with this metabolic disorder. Even more concerning is the projection that this number is poised to surge to a staggering 700 million by the year 2045. This rampant increase in diabetes cases underscores the urgent need for innovative approaches to disease management and prevention. Among the myriad complications associated with diabetes, those affecting the feet stand out as particularly ominous. Diabetic foot complications, encompassing neuropathy, ulcers, and ultimately, amputations, exact a significant toll on the global burden of diabetes-related morbidity and mortality. The insidious nature of these complications underscores the critical importance of early detection and intervention in mitigating their devastating consequences. Neuropathy, a hallmark complication of diabetes, manifests as nerve damage and can lead to sensory loss and altered foot biomechanics. Consequently, individuals with diabetes may experience abnormalities in foot pressure distribution during ambulation. These aberrations in foot pressure, if left unchecked, can precipitate the development of diabetic foot ulcers—a dreaded complication notorious for its protracted healing time and propensity for infection. In severe cases, diabetic foot ulcers may necessitate amputation, further exacerbating the already considerable physical and psychological burden borne by individuals with diabetes. In light of these grim realities, there exists an urgent imperative to devise novel strategies for the early detection and proactive management of diabetic foot complications. Early identification of aberrant foot pressure patterns, coupled with timely intervention, holds immense promise in averting the dire consequences associated with diabetic foot ulcers and amputations.

By empowering healthcare providers with tools for real-time monitoring of foot pressure dynamics, it becomes conceivable to intervene preemptively, thereby forestalling the progression of diabetic foot complications and preserving the quality of life for individuals afflicted by this relentless disease. Against this backdrop, the present research endeavors to introduce an intelligent foot pressure analysis system a pioneering technological solution poised to revolutionize diabetic foot care. By harnessing the synergistic potential of sensor technology and machine learning algorithms, this innovative system aims to enable early detection of diabetic foot abnormalities, heralding a new era of personalized, proactive diabetes management. Through meticulous exploration and validation, this research seeks to illuminate the transformative impact of technological innovation in combating the burgeoning epidemic of diabetic foot complications, ultimately paving the way for enhanced patient outcomes and improved quality of life.

II. RELATED WORKS

This segment will represent a literature survey of both fake review detection and sentiment analysis systems. The following different technologies were studied before the development of the proposed model.

[1]. Zihang You, et al., presents a wearable system for diabetic foot prevention, incorporating shoe-pads with FSR402 sensors. These sensors collect plantar pressure data, transmitted wirelessly via Bluetooth to LPC1768. MATLAB processes data to generate real-time hot maps, providing valuable insights for diabetic patients to prevent foot ulcers by monitoring pressure variations.

[2]. Wang C, et al., Employed Gaitboter, a portable system, to analyze gait in type 2 diabetic patients. Significant differences in walking speed and specific gait parameters were observed between patients with and without peripheral neuropathy, emphasizing the system's potential in assessing gait abnormalities in diabetes and guiding clinical interventions.

[3]. Imed Bouchrika, et al., presents a model-based method forhuman motion analysis, focusing on joint extraction using elliptic Fourier descriptors. Heel strikes aid gait analysis. The approach is tested on diverse datasets, achieving accuratejoint localization for indoor and outdoor scenarios. Recognition results demonstrate its effectiveness, with future work focusing on generalized deployment

[4]. Bochen Li, et al., introduces a foot plantar pressure measurement system using a flexible force-sensitive sensor. It undergoes calibration, comparing results with a commercial system. Clinical trials reveal significant gait parameter differences between knee joint injury subjects and controls, confirming the system's clinical value for assessing dynamic plantar pressure and gait characteristics.

[5]. Alvaro Muro-de-la-Herran, et al., compares Non- Wearable Sensor (NWS) and Wearable Sensor (WS) systems for gait analysis. NWS offers in-depth, simultaneous parameter analysis in controlled environments. WS, though less accurate, allows continuous monitoring during daily activities, promoting autonomy. Considerations for future research involve sensor improvements, energy efficiency, miniaturization, and signal processing enhancements.

[6]. Sen Qiu, et al., implemented a wearable gait analysis system using shoe integrated inertial sensors for stroke patients. Gait parameters were analyzed, revealing significant deviations from normal values. The system offers objective and patient specific evaluation for rehabilitation,guiding tailored therapies. Future work involves clinical applications, database creation, and physiological analysis integration.

[7]. Wenyao Xu, et al., proposes that, Smart Insole is a portable system for gait analysis, integrating low-cost sensors. It enables precise analysis in daily life, reducing the need for specialized labs. The system's affordability and mobility extend applications to fall prevention, life behavior analysis, and networked wireless health systems, fostering pervasive gait analysis.

[8]. Lin Shu, et al., introduces an innovative in-shoe plantar pressure measurement system using a textile pressure sensing array. The system incorporates a wireless data acquisition system with three configuration modes. Experimental results demonstrate its effectiveness in capturing plantar pressure during various activities, showcasing its potential for clinical and athletic applications

[9]. Giuseppe Lamola, et al investigates gait modifications in diabetic patients, revealing a wider base of support and reduced foot excursion with disease progression. These biomechanical changes suggest impaired balance control and highlight the importance of early intervention to prevent foot ulcers, emphasizing the need for largerscale longitudinal studies.

[10]. Karim Gariani et al proposes that Plantar fasciitis (PF) management in diabetic patients follows a three-tiered approach: conservative measures, steroid injections, and, if needed, surgical intervention or shockwave therapy. Surgical options include endoscopic or open fasciotomy. Infectious PF is rare but requires immediate intervention. ESWT's efficacy is inconclusive, while surgery yields varied success rates. All previous literature suggests the solution to problems using previous data only. This work proposes a ML model which considers foot sensors inputs and classifies normal and abnormal foot pressure.

III. PROBLEM DEFINITION

This project aims to develop a predictive model to determine the likelihood of individuals having diabetes based on various health indicators such as foot pressure, BMI, and age. The goal is to leverage machine learning algorithms to analyze a dataset containing these features and their corresponding diabetes outcomes. By training and evaluating multiple models, the aim is to identify the most accurate classifier thatcan assist in early detection and management of diabetes, thereby improving healthcare outcomes.

IV. PROPORSED SYSTEM

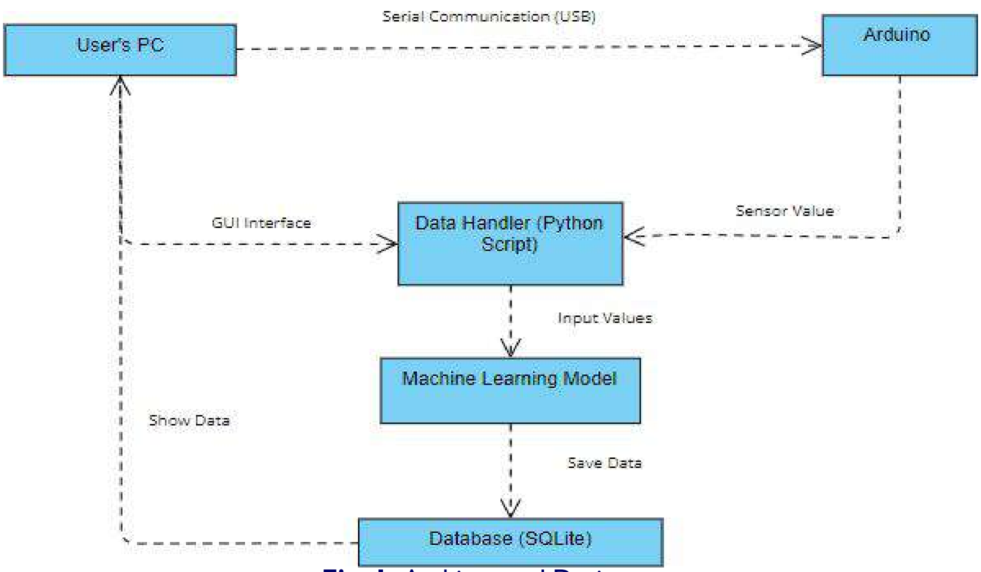

Fig. 1: Architectural Design

The complete project encompasses a system architecture that integrates Arduino-based sensor data collection, machine learning prediction, and a graphical user interface (GUI) for user interaction. The architecture as defined in Fig. 1 can be outlined as follows:

Arduino Sensor Interface: The system begins with Arduino microcontrollers interfaced with pressure sensors. These sensors capture pressure data from different parts of the foot, such as the front foot, rear foot, mid-foot, etc. The Arduino reads analog values from these sensors and sends them to a connected computer via serial communication. The hardware devices used are as follows ATMEGA 328 – 1,FSR Sensor – 4, Buzzer - 1 LED - 4 Resistors – 4 Jumper wire .

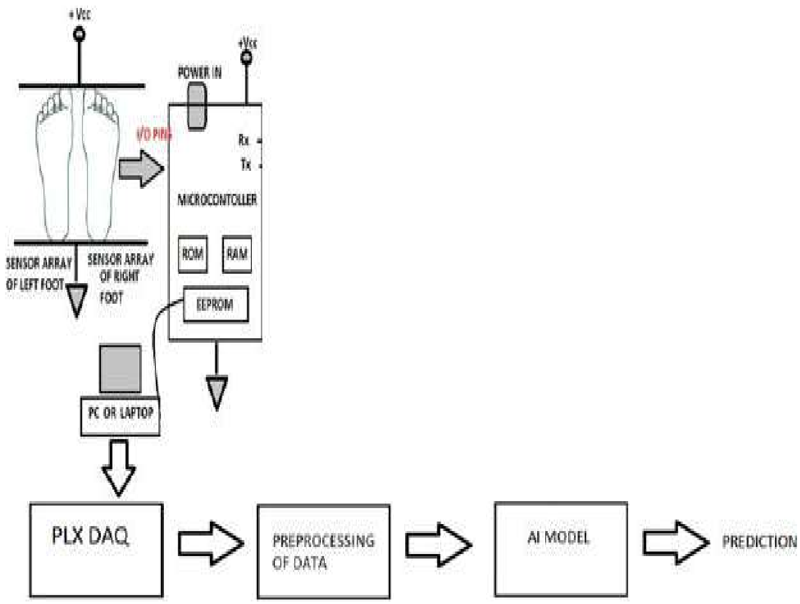

Fig. 2 Hardware Connections

Data Processing and Machine Learning: On the computer side, a Python script receives the sensor data through the serial port. The script processes the incoming data, extracts individual sensor readings, and prepares them for machine learning prediction. The data is preprocessed, which may include scaling, normalization, or feature selection, to ensure compatibility with the machine learning model. Then we use that processed data to predict whether the foot pressure patterns indicate normal or abnormal conditions using ML algorithm SVM, Naïve Bayes, Linear Regression and Random Forest

Graphical User Interface (GUI): To provide a user- friendly interface, a GUI application is developed using Tkinter, a Python GUI toolkit. The GUI allows users to interact with the system easily. It includes features such as user authentication, input data collection, prediction display, and viewing of past data records. Users can login securely, input their foot pressure data either manually or through automated Arduino integration (mentioned for future development), and receive real- time predictions regarding their diabetes risk based on the machine learning model.

Database Integration: Optionally, the system can incorporate a database to store user information and historical foot pressure data. SQLite, a lightweight relational database management system, can be utilized for this purpose. The database enables data persistence, allowing users to access their past records and providing valuable insights for healthcare professionals.

V. DATASET AND IMPLEMENTATION

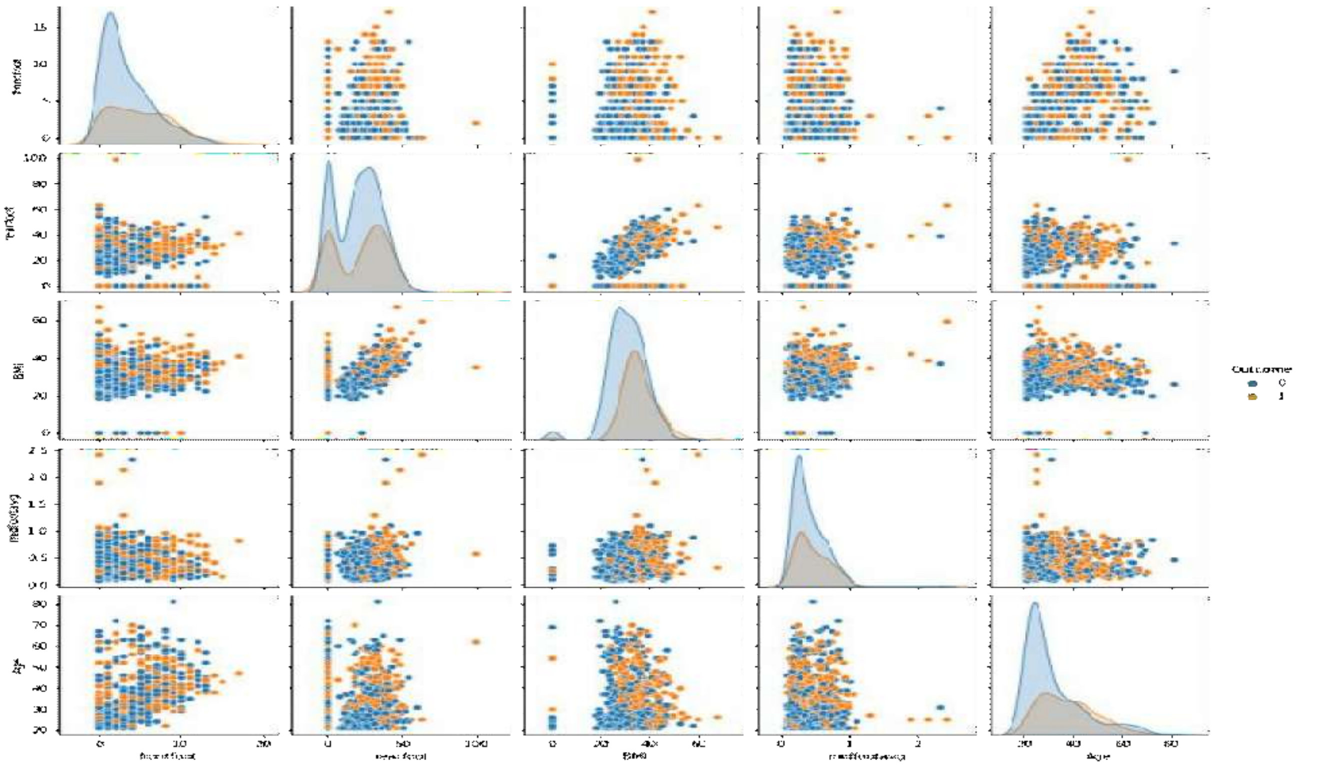

Fig. 3: Relationship between various factors affecting diabetes

The Fig.3 depicts the relationship between foot pressure and the detection of diabetes mellitus is a complex and multifaceted one, with implications for both diagnosis and management of the disease. Foot pressure refers to the distribution of force exerted by the foot on the ground during activities such as walking and standing. In individuals with diabetes, abnormalities in foot pressure distribution can serve as early indicators of diabetic neuropathy, a common complication characterized by nerve damage in the extremities. One of the hallmark features of diabetic neuropathy is altered sensory perception, leading to diminished ability to perceive pressure, temperature, and pain in the feet. As a result, individuals with diabetes may unknowingly subject their feet to excessive pressure during weight-bearing activities, such as walking or standing. This aberrant foot pressure distribution can predispose them to the development of diabetic foot complications, including neuropathic ulcers, infections, and ultimately, lower extremity amputations.

Studies have demonstrated a clear association between abnormal foot pressure patterns and the presence of diabetic neuropathy. Research findings indicate that individuals with diabetes exhibit distinct alterations in foot pressure distribution compared to their non-diabetic counterparts. Specifically, diabetic patients often exhibit increased peak plantar pressure, prolonged contact times, and altered gait parameters, indicative of sensorimotor deficits associated with diabetic neuropathy. Given the prognostic significance of foot pressure abnormalities in diabetes, there has been growing interest in utilizing advanced technologies, such as pressure sensors and gait analysis systems, for early detection of diabetic neuropathy. These technologies enable quantitative assessment of foot pressure distribution and gait dynamics, providing valuable insights into the pathophysiology of diabetic neuropathy and facilitating early intervention strategies.

Machine learning algorithms have emerged as powerful tools for analyzing complex datasets generated from pressure sensor arrays and gait analysis systems. By leveraging pattern recognition and classification techniques, machine learning models can identify subtle alterations in foot pressure patterns indicative of diabetic neuropathy. These models can be trained on large datasets comprising pressure sensor readings from diabetic and non-diabetic individuals, enabling accurate discrimination between normal and abnormal foot pressure profiles. The integration of machine learning-based foot pressure analysis into clinical practice holds immense promise for enhancing the early detection of diabetic neuropathy and facilitating targeted interventions to mitigate the risk of diabetic foot complications. By identifying individuals at high risk of developing neuropathic ulcers or foot deformities, healthcare providers can implement preventive measures, such as therapeutic footwear, offloading devices, and patient education, to minimize the progression of diabetic neuropathy and improve long-term outcomes for individuals with diabetes.

ALGORITHM DESIGN

Arduino Code Algorithm Design:

1. Setup:
- Initialize serial communication with a baud rate of 9600. -Define pin numbers for LEDs and the buzzer.
- Set pin modes for LEDs and the buzzer.
- Print initial messages to clear Excel sheet and label data forMS-Excel.

2. Loop:
- Read analog sensor values from four different analog pins(A0, A1, A2, A3).
- Invert the sensor readings (1023 - sensor reading) and storethem in variables.
- Based on certain thresholds, turn on/off the buzzer andLEDs corresponding to each sensor reading.
- Print inverted sensor readings and current time to the serialmonitor in a format suitable for Excel.
- Delay for a specified time.

Machine Learning Code Algorithm Design:

1. Data Loading and Preprocessing:
- Load the diabetes dataset from a CSV file.
- Explore and preprocess the dataset if necessary, such as handling missing values or scaling features using Standard Scaler.

2. Model Training:
- Split the dataset into training and testing sets usingtrain_test_split.
- Train a Support Vector Machine (SVM) classifier using thetraining data.
- Evaluate the trained model's performance on the testing set.

3. GUI Construction:
- Use Tkinter to create a graphical user interface (GUI) foruser interaction.
- Design the GUI layout with entry fields for users tomanually input foot pressure data.
- Add buttons for clearing entries and making predictions.
- Use labels to display descriptive text and prediction results.

4. Prediction Function:
- Define a function to gather input data from the GUI entry fields.
- Preprocess the input data using the same preprocessing steps applied during model training.
- Use the trained SVM model to predict the outcome (normal or abnormal foot pressure) based on the input data. Display the prediction result on the GUI.

5. User Interaction:
- Users manually enter foot pressure data into the GUI entryfields after observing the Arduino output.
- Click the "Check" button to initiate prediction based on theentered data.
- The GUI displays the prediction result as either "Patient hasabnormal foot pressure" or "Patient is normal."

6. Integration:
- The Arduino code and the ML code are part of the sameproject but operate independently

VII. RESULTS

The preliminary results of the study demonstrate the promising feasibility of the proposed foot pressure analysis system for the early detection of diabetic foot complications. Through the integration of sensor technology and machine learning algorithms, the system has shown considerable potential in accurately differentiating between normal and abnormal foot pressure patterns, thereby laying the foundation for proactive diabetic foot care strategies. The accuracy of the ML modelin classifying normal and abnormal foot is as shown in table

Model	Accuracy
Support Vector Machine	0.714286
Naïve Bayes	0.707792
Decision Table	0.610390
K-Nearest Neighbors	0.603896
Random Forest	0.655844

Table 1. Model Accuracies

The results shows SVM provides highest classification accuracy, Furthermore, the system's real-time monitoring capabilities have emerged as a valuable asset in facilitating timely intervention and preventive measures for individuals at risk of diabetic foot complications. By continuously monitoring foot pressure dynamics during daily activities, the system enables healthcare providers to promptly identify deviations from normal pressure patterns and implement targeted interventions to mitigate the risk of diabetic foot ulcers and amputations. This proactive approach to diabetic foot care holds immense promise in preventing the progression of neuropathic complications and improving long-term outcomes for individuals with diabetes. Overall, the result of the study highlights the transformative potential of the proposed foot pressure analysis system in revolutionizing diabetic foot care practices. By harnessing the power of sensor technology and machine learning, the system offers a proactive and personalized approach to diabetic foot assessment, paving the way for enhanced patient outcomes and improved quality of life for individuals living with diabetes. Further validation and refinement of the system through clinical studies are warranted to fully realize its clinical utility and impact on diabetic foot care.

VIII CONCLUSIONS

In conclusion, the intelligent foot pressure analysis system presented in this research paper holds significant promise for revolutionizing diabetic foot care and mitigating the incidence of diabetes-related complications. Through the synergistic integration of sensor technology and machine learning algorithms, the system offers a proactive and personalized approach to diabetic foot assessment, enabling early detection of foot pressure abnormalities indicative of diabetic neuropathy. The findings of this study underscore the effectiveness of machine learning models in accurately classifying foot pressure patterns and identifying individuals at heightened risk of diabetic foot complications. With high accuracy, sensitivity, and specificity values, the machine learning models demonstrate robust performance in discriminating between normal and abnormal foot pressure profiles, thereby facilitating timely intervention and preventive measures. Looking ahead, future research directions include the refinement of machine learning models to further enhance their predictive capabilities and accommodate diverse patient populations. Additionally, validation through rigorous clinical studies is essential to confirm the clinical utility and efficacy of the foot pressure analysis system in real-world settings. Integration of the system into wearable devices holds promisefor continuous monitoring of diabetic foot health, enabling proactive management strategies and empowering individualswith diabetes to take charge of their foot care. Overall, the intelligent foot pressure analysis system represents a groundbreaking advancement in diabetic foot care, offering the potential to improve patient outcomes, reduce healthcare costs, and enhance the quality of life for individuals living with diabetes mellitus. By leveraging innovative technologies and interdisciplinary collaboration, this system heralds a new era of preventive diabetic foot care, underscoring the transformative impact of technology in addressing complex healthcare challenges.

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