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Soletrack AI: Smart Shoe for Early Diabetic Foot Ulcer Detection & Monitoring

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Abstract: Foot Ulcers (DFUs) are a critical complication of diabetes, often leading to severe consequences such as infections and amputations if not detected early. This paper proposes "Soletrack AI," a smart insole-based healthcare monitoring system that enables early detection and monitoring of DFUs using pressure sensors, cloud connectivity, and machine learning. The system integrates wearable technology with cloud-based platforms to collect real-time foot pressure data, analyze abnormalities, and generate alerts through PushBullet notifications. Using Arduino Mega 2560, ESP8266 Wi-Fi module, Force Sensing Resistors, and cloud dashboards like ThingsBoard, Soletrack AI enables continuous remote monitoring and early intervention for diabetic patients.

Keywords: Diabetic Foot Ulcer (DFU), Smart Insole, IoT Healthcare, Pressure Sensors, Machine Learning, Arduino, ESP8266, Remote Monitoring.

1. INTRODUCTION

Diabetes is a chronic disease affecting millions globally, with one of its most serious complications being the development of Diabetic Foot Ulcers (DFUs). High blood sugar levels lead to peripheral neuropathy and ischemia, reducing pain sensitivity and impairing healing in the lower extremities. Undetected minor wounds can evolve into ulcers, leading to infections and amputations. Traditional methods for DFU detection—visual inspection, thermal imaging, and image-based AI—are often reactive, costly, and unsuitable for continuous monitoring.

Soletrack AI offers a preventive solution through real-time, personalized, and wearable foot pressure monitoring using an IoT-enabled smart insole. By continuously capturing foot pressure data and analyzing it with machine learning models, the system can provide early warnings and reduce the need for frequent physical consultations.

2. PROPOSED SYSTEM

The Soletrack AI system is composed of both hardware and software components. On the hardware side, it uses Arduino Mega 2560 as the central controller, ESP8266 as the Wi-Fi module for data transmission, and Force Sensing Resistors (FSRs) embedded in a smart insole to collect pressure data. Additional components like an LCD display, GSM module, and pulse oximeter support functionality.

On the software side, data collected from sensors is transmitted to the cloud (ThingsBoard platform) for real-time visualization and storage. Machine learning models, specifically Logistic Regression and KNN, classify this data into normal and abnormal categories. Alerts are generated using the PushBullet app to notify caregivers or doctors.

3. LITERATURE SURVEY

Several technologies have been developed to address DFU detection. IoT-based systems, such as those using Node MCU and flexi-force sensors, have enabled real-time cloud monitoring but struggle with power efficiency and data privacy. Smart shoes with embedded sensors provide non-invasive monitoring but often lack robustness in real-world usage. Machine learning approaches using SVM, Random Forest, and CNNs have achieved promising accuracy but are computationally intensive and unsuitable for edge devices.

Innovations in pressure and temperature sensors, like resonant dip-based detection, improve accuracy and reduce sensor misalignment issues. Soletrack AI draws upon these innovations to build a low-cost, scalable, and accurate system that combines real-time sensing, cloud processing, and ML analytics.

Survey of Existing Approaches:

X. Zhang et al. [1] presents an IoT driven system for real-time monitoring of foot ulcers in diabetic patients. It uses Node MCU with flexi-force sensors to measure foot pressure, temperature, heartbeat, and blood pressure, transmitting data to

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a cloud-based platform for remote access. A web and mobile-based application provides real-time alerts to doctors and patients, enabling early intervention and reducing the need for frequent hospital visits. This approach ensures continuous tracking of foot health, helping to detect ulcers before severe complications arise.

S. A. Begum et al. [2] " introduces a smart shoe-based system to detect neuropathy and ulcer risks in diabetic patients. The shoe is embedded with pressure and temperature sensors, along with a vibration motor to assess sensation loss in the foot. It is an IoT-enabled system that transmits real-time sensor data to healthcare professionals, allowing remote patient monitoring and early intervention. The design aims to provide a comfortable and non invasive method for continuous ulcer risk assessment while reducing hospital visits. However, the system has some challenges. It is still in the prototype stage, requiring clinical validation before real-world implementation. Battery life and durability concerns exist due to continuous sensor operation. Additionally, comfort issues may arise, as patients need to wear the shoe regularly for accurate monitoring.

V. Vijean et al. [3] explores the integration of hardware sensors and artificial intelligence for early ulcer prediction. The system uses temperature and pressure sensors combined with machine learning algorithms such as SVM, Decision Tree, Random Forest, and Naïve Bayes to analyze real-time data and detect ulcer risks before visible symptoms. This non-invasive and automated approach aims to improve early diagnosis and preventive care for diabetic patients, reducing complications and hospitalizations.

S. Ramadasan et al. [4] proposes a wearable sensor-based system for real-time foot health monitoring in diabetic patients. The system integrates pressure, temperature (thinfilm), and oxygen saturation (RSO2) sensors, which continuously collect data to assess ulcer formation risks. Using IoT connectivity and a Random Forest Classifier, the system analyzes sensor data and achieves 90.02% accuracy in detecting early-stage foot complications. By providing real-time alerts to both patients and doctors, it aims to enhance preventive care and reduce diabetic foot complications. However, the system presents some challenges. Hardware complexity and multiple sensor calibrations are required to ensure data accuracy.

4. BLOCK DIAGRAM AND SYSTEM ARCHITECTURE

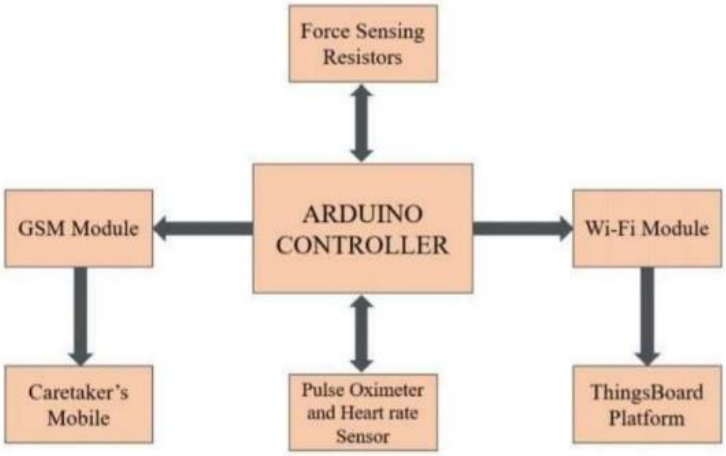

Fig. 1. Block Diagram

The system architecture comprises several modules. The input module collects data from six strategically placed FSR sensors in the insole to monitor foot pressure points. The control module uses Arduino Mega to process and digitize the data. The communication module includes the ESP8266 and GSM modules to transmit the data wirelessly.

A display module shows data in real time via LCD, and the machine learning module processes the incoming data for classification. When abnormal pressure is detected, the notification module sends alerts through the PushBullet app to remote caregiver

Force Sensing Resistors: These sensors detect pressure or force applied to them. Their resistance changes in response to the amount of force

Arduino Controller: This is the central processing unit of the system. It reads data from sensors, processes it, and controls other connected modules.

Wi-Fi Module: This module connects the Arduino to a Wi-Fi network. It enables the system to send data to internet-based platforms.

Plate Detection: Identifies the plate area using contour detection and crops it for character recognition.

OCR Recognition: Uses Tesseract OCR to extract text from the cropped number plate.

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ThingsBoard Platform: This is an open-source IoT platform. It receives data from the Wi-Fi module for storage, visualization, and analysis.

5. IMPLEMENTATION DETAILS

Sensor placement is critical for accurate pressure monitoring. The six FSR sensors are placed at high-risk pressure zones of the insole. These are connected to Arduino Mega, which acts as the central processing unit. Data is transmitted to the ThingsBoard cloud using the ESP8266 Wi-Fi module.

Once uploaded, data is visualized on dashboards and analyzed by machine learning algorithms. Logistic Regression and KNN classify whether the pressure is within safe limits or abnormal. In the case of an abnormal reading, a notification is sent via PushBullet. The modular design allows for scalability and integration of more sensors or other physiological parameters

6. RESULT AND PERFORMANCE ANALYSIS

It represents the outcomes of testing the proposed system for real-time pressure detection and alerting in diabetic foot monitoring. The prototype was evaluated under various conditions to ensure reliable sensor data collection, accurate classification via machine learning models, and proper cloud integration with alert functionalities. The test environment included components such as the Arduino Mega 2560, FSR sensors, the ESP8266 Wi-Fi module, and ThingSpeak and PushBullet services. The system’s ability to differentiate between normal and abnormal foot pressure conditions was validated through a series of functional and integration tests. Each test confirmed the robustness of the data pipeline from physical sensing to cloud visualization and alert delivery. The following sections and snapshots illustrate the key outcomes from these tests. The results demonstrated the system’s effectiveness in providing real-time monitoring, with minimal delay in data transmission and alert notifications. Additionally, the machine learning model showed high accuracy in classifying foot pressure conditions, making it a reliable tool for diabetic foot care

Normal Point : This image shows a scenario where normal foot pressure is applied and sensed by the FSR sensors. The system processes the input, classifies it as "normal," and no alert is triggered. It confirms that under healthy pressure conditions, the model behaves as expected without false alarms. This ensures that the system accurately distinguishes between normal and abnormal pressure, minimizing unnecessary alerts for users and healthcare providers.

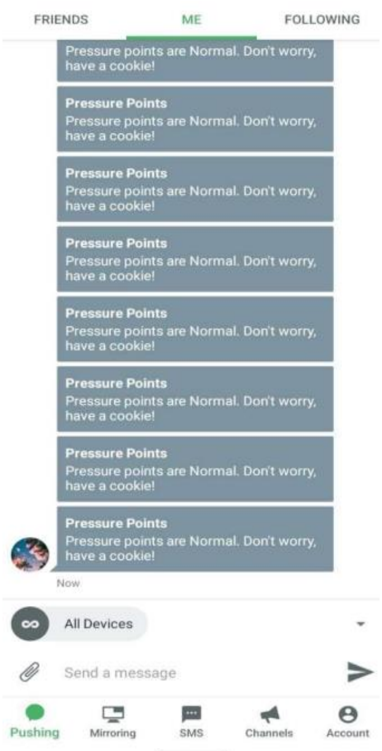

Fig 2. Normal Point

Fig 3. Abnormal Point

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Abnormal Point : This snapshot captures an instance of abnormal pressure detected at a specific point on the foot. The FSR sensor picks up values beyond the safety threshold, prompting the system to classify the reading as abnormal. This leads to data being uploaded to the cloud and a corresponding alert being generated. It highlights the system's capability to detect early signs of high-risk pressure areas. The alert is sent to the healthcare provider or caregiver, enabling timely intervention to prevent potential foot injuries. This proactive approach ensures that at-risk individuals receive immediate attention, improving overall patient care and outcomes.

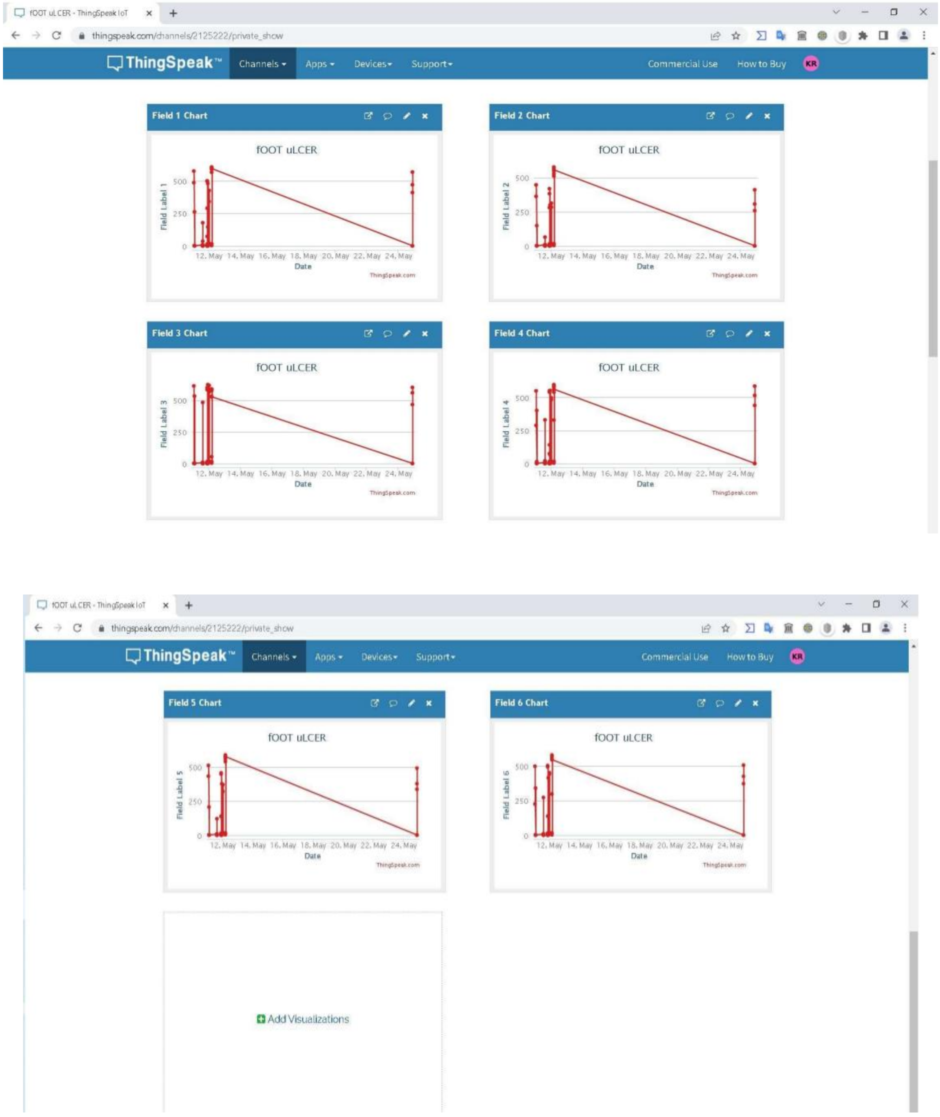

Fig 4. Thing speak Visualization

Here, the graph shown on the ThingSpeak dashboard displays the real-time foot pressure data captured and transmitted by the system. The visual plots help users and caregivers monitor trends and detect abnormalities. It also validates the functionality of the ESP8266 Wi-Fi module and the cloud integration. This real-time visualization enables quick decision-making and enhances the efficiency of remote monitoring for healthcare providers.

7. CHALLENGES AND LIMITATIONS

Despite its effectiveness, the Soletrack AI system faces several practical challenges and limitations. One significant issue is performance degradation in low-light or dark environments, where sensor readings may become unstable or inconsistent due to poor visibility during system setup or maintenance. Similarly, sensor calibration is sensitive to foot orientation and shoe fit, potentially causing inconsistent pressure readings.while machine learning models offer decent accuracy, their predictive capability can be limited by the training dataset size and diversity. Personalized modeling is

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still under development and requires further refinement to ensure reliable detection for all foot types and walking behaviors.

8. CONCLUSION

Soletrack AI demonstrates an effective, real-time, and low-cost solution for early DFU detection. It leverages IoT, cloud, and ML technologies to enable continuous monitoring and alerts, improving diabetic patient outcomes. The system's modularity makes it easy to scale or enhance.

Future work will focus on integrating additional sensors (e.g., temperature, humidity), improving ML classification accuracy using larger datasets, developing a dedicated mobile application, and conducting clinical field trials. Attention will also be given to enhancing data privacy, minimizing power consumption, and improving user comfort

9. REFERENCES

[1] X. Li, Z. Ye, M. Yang, M. Liu, and X. Zhang, "Wireless, Fully Soft, Pressure and Temperature Sensors for Sensitive and Robust Diabetic Foot Ulcer Monitoring," IEEE Sensors Journal, vol. 24, no. 5, 2024.

[2] A. P., B. P. J., G. K. S., T. K. N., R. S. S., and D. D., "Diabetic Foot Complication Avoidance Through a Wearable Sensor and Random Forest Classifier for Automated Evaluation," in Proceedings of the 10th International Conference on Advanced Computing and Communication Systems (ICACCS), 2024.

[3] S. A. Begum, M. Lavanya, K. Bhavya, and B. B. Sree, "Innovative Sensor-Based Approach for Predicting Foot Ulcers Using Machine Learning," in Proceedings of the International Conference on Sustainable Communication Networks and Applications (ICSCNA), 2024.

[4] V. Vijean, W. A. A. W. Ahmad, S. A. Mohammed, R. Santiagoo, R. Palaniappan, R. Ahmad, and A. G. Ahmad, "Early Detection of Diabetic Foot Ulcers through Wearable Shoe Design," in Proceedings of the 4th International Conference on Artificial Intelligence and Speech Technology (AIST), 2022.

[5] P. Gupta, M. Goyal, N. Gaur, R. Tripathi, and A. Mundra, "IoT and Cloud-Based Healthcare Solution for Diabetic Foot Ulcer," in Proceedings of the 6th International Conference on Parallel, Distributed, and Grid Computing (PDGC), 2020.

[6] S. Ramadasan, R. Augasthega, K. Vijayakumar, and S. Prabha, "Detection of Foot-Ulcer from Digital Photographs using MobileNet Variants with Features Fusion," *2024 International Conference on Science, Technology, Engineering and Mathematics (ICONSTEM)*, IEEE, 2024.

[7] A. Khandakar, M. A. A. Faisal, M. E. H. Chowdhury, M. B. I. Reaz, S. H. M. Ali, M. I. S. A. Razak, A. A. A. Bakar, S. Mahmud, and R. A. Malik, "Laser-Induced Graphene-Based Smart Insole to Measure Plantar Temperature," *IEEE Sensors Journal*, vol. 24, no. 2, pp. 1190-1196, 2024.

[8] S. N. Sengottaiyan, M. Eswaran, A. Sungheetha, R. R. Sharma, P. A. L. Pravin, and G. S. P. Ghantasala, "Detection and Classification of Diabetic Foot Ulcers via Cloud-Based Deep Learning Approach," *2024 IEEE Delhi Section Flagship Conference (DELCON)*, IEEE, 2024.

[9] S. Brindha, A. Ramanakrishnan, R. Kirthika, and V. S. Monish Ram, "Advancements in Diabetic Foot Ulcer Detection: A Thermal Imaging Approach," 2024 International Conference on Communication, Computing and Internet of Things (IC3IoT), IEEE, 2024.

[10] A. A. Rao, A. K. Ullal, V. Sriram, S. S. Shetty, V. Chethan, and D. D. Poojary, "PAADARAKSHA - Diabetic Foot Ulcer Detection and Localization Using Deep Learning Techniques," 2024 Second IEEE International Conference on Advances in Information Technology (ICAIT-2024), IEEE, 2024.

[11] A. Ajay, A. S. Bisht, and R. Karthik, "Dense-ShuffleGCANet: An Attention-Driven Deep Learning Approach for Diabetic Foot Ulcer Classification Using Refined Spatio-Dimensional Features," IEEE Access, vol. 13, pp. 5507-5522, Jan. 2025, doi: 10.1109/ACCESS.2024.3524549.

[12] S. N. Sengottaiyan, M. Eswaran, A. Sungheetha, R. S. Rajesh, P. A. L. Pravin, and G. S. P. Ghantasala, "Detection and Classification of Diabetic Foot Ulcers via Cloud-Based Deep Learning Approach," 2024 IEEE Delhi Section Conference (DELCON), pp. 64804-64812, 2024, doi: 10.1109/DELCON64804.2024.10867128.

[13] M. Panahi, S. Masihi, A. J. Hanson, J. I. Rodriguez-Labra, A. Masihi, D. Maddipatla, B. B. Narakathu, D. Lawson, and M. Z. Atashbar, "Development of a Flexible Smart Wearable Oximeter Insole for Monitoring SpO2 Levels of Diabetics' Foot Ulcer," IEEE Journal on Flexible Electronics, vol. 2, no. 2, pp. 61-75, Mar. 2023, doi: 10.1109/JFLEX.2022.3232465.

[14] A. Khandakar, M. E. H. Chowdhury, M. B. I. Reaz, S. H. M. Ali, M. A. Hasan, S. Kiranyaz, T. Rahman, R. Alfkey, A. A. A. Bakar, and R. A. Malik, "A Machine Learning Model for Early Detection of Diabetic Foot Using Thermogram Images," IEEE Transactions on Biomedical Engineering, vol. XX, no. XX, pp. XX-XX, 2024 (pending DOI).

[15] M. Goyal, N. D. Reeves, S. Rajbhandari, and M. H. Yap, “Robust methods for real-time diabetic foot ulcer detection and localization on mobile devices,” IEEE Journal of Biomedical and Health Informatics, vol. 23, no. 4, pp. 1730–1741, Jul. 2019. DOI: 10.1109/JBHI.2018.2868656

[16] Mahdi Saeedi, Hamed Taheri Gorji, Fartash Vasefi, and Kouhyar Tavakolian (2024) "Federated Versus Central Machine Learning on Diabetic Foot Ulcer Images: Comparative Simulations," IEEE Access, Vol.12, pp. 58960-58962. DOI: 10.1109/ACCESS.2024.3392916

[17] Nagaraju, S., Kumar, K.V., Rani, B.P., Lydia, E.L., Ishak, M.K., Filali, I., Karim, F.K., and Mostafa, S.M. (2023) "Automated Diabetic Foot Ulcer Detection and Classification Using Deep Learning," IEEE Access, Vol.11, pp.127578-127579. DOI: 10.1109/ACCESS.2023.3332292

[18] Schmalen, P.G., and Meyer, T. (2024) "Temperature Sensing Insoles for Diabetic Foot Ulcer Diagnostics," IEEE Sensors Journal, Vol.8, No.7, pp.6006704. DOI: 10.1109/LSENS.2024.3407589

[19] Wang, Y., Feng, H., Sun, B., Bai, Y., Hu, S., Yao, J., and Zhao, T. (2024) "Plantar Planar Dual-Array Electrical Impedance Tomography (PPDA-EIT) Method for Early Diabetic Foot Ulcers' Detection," IEEE Sensors Journal, Vol.24, No.23, pp.39759-39761. DOI: 10.1109/JSEN.2024.3483935

[20] Mahdi Saeedi, Hamed Taheri Gorji, Fartash Vasefi, and Kouhyar Tavakolian (2024) "Federated Versus Central Machine Learning on Diabetic Foot Ulcer Images: Comparative Simulations," IEEE Access, Vol.12, pp. 58960-58962. DOI: 10.1109/ACCESS.2024.3392916

