Early detection of diabetic foot ulcer using IoT and ML

Sanjana Berugu¹*, Nagaraju Bajjuri¹, M. Shiva Reddy¹, T. Ramya¹
¹Department of AI&ML, CBIT, Hyderabad, Telangana, India.

Abstract. 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. 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. One of the complications that this condition is frequently linked to is diabetic foot ulcers. 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.

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

1 Introduction

The concern of foot ulcers, prevalent issue of foot ulcers in diabetes mellitus, impacting both type 1 and type 2 diabetes. Type 1, characterized by insulin dependence, stems from a nexus of genetic and environmental factors that trigger autoimmune responses, ultimately leading to the destruction of insulin. On the other hand, type 2, marked by insulin independence, results from lifestyle-induced pancreatic insufficiency.

* Corresponding author: sanjanaberugu@gmail.com

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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. The delineation of severity stages, ranging from stage 0 to 3, underscores the pivotal progression of DFUs, underscoring the critical importance of early detection to avert dire consequences. By bridging the gap between daily life and medical intervention, the wearable prototype embodies a promising stride towards accessible, proactive care. 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.

The integration of IoT into healthcare marks a revolutionary stride, exemplified by smart watches that monitor vital signs seamlessly. 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.

2 Related Works:

2.1 Types of DFU

Neuropathic DFU Neuropathy refers to nerve damage, which is a common complication of diabetes. Neuropathic DFUs occur due to peripheral neuropathy, where the nerves in the feet are damaged. This condition leads to a loss of sensation in the feet, making it difficult for individuals to feel pain or notice injuries. As a result, small cuts, blisters, or injuries can go unnoticed and develop into ulcers. Neuropathic DFUs typically occur on pressure points, such as the soles of the feet.

Ischemic DFU Ischemia refers to reduced blood flow to a particular area. Ischemic DFUs occur when there is inadequate blood supply to the feet due to peripheral arterial disease (PAD), a condition commonly seen in individuals with diabetes. PAD leads to narrowing or blockages in the arteries that supply blood to the feet, resulting in reduced oxygen and
nutrient delivery. The lack of proper blood flow impairs wound healing and can lead to the development of ulcers, usually on the tips of the toes, heels, or other areas of high pressure.

**Neuroischemic DFU** Neuroischemic DFU is a combination of neuropathic and ischemic DFU. It occurs when a person with diabetic neuropathy also has compromised blood flow to the feet due to peripheral arterial disease. In this case, both nerve damage and reduced blood supply contribute to the development of ulcers. Neuroischemic DFUs often appear on pressure points but can also affect other areas of the feet.

![DFU Types](image)

**Fig. 1. DFU Types**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Authors, Title of paper, Year of publishing</th>
<th>Methods used</th>
<th>Strengths</th>
<th>Limitations</th>
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<td>3.</td>
<td>Tulloch, Jack, et al. “Machine Learning in the Prevention, Diagnosis and Management of</td>
<td>Review of ML applications accuracy of model, large-scale data</td>
<td>ML achieved ≥90% accuracy, improved risk assessment</td>
<td>Lack of immediate implementation in healthcare settings, limited to</td>
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3 Research Methodology

3.1 Data Collection

Gathering appropriate data for your problem is the first stage in machine learning. The information is gathered in a CSV format from the cloud. It is critical to verify that the data collected is indicative of the problem you are attempting to address.

3.2 IoT Sensor Integration

IoT sensor integration entails incorporating devices like temperature and pressure sensors into wearable shoes. This real-time data collection enables continuous monitoring of foot health, aiding early detection and proactive management of diabetic foot ulcers through machine learning algorithm.
3.3 Model Selection and Training

In this step, you choose an appropriate machine learning algorithm that best suits your problem and data. The selection of the model depends on whether it is a classification, regression, clustering, or other types of problems. The algorithm selected are Support Vector Machine, Logistic Regression and K Nearest Neighbors. Once the model is selected, it is trained on the pre-processed data by feeding the input features and corresponding target variables (for supervised learning) to the model. The training of the model is done by splitting the dataset into training and testing (50:50) in our case we are considering a 50% training and 50% testing as we will obtain higher accuracy.

3.4 Model Evaluation

The model must be tested to determine its performance and capacity for generalization once it has been trained. Usually, to do this, a different collection of data known as the testing set which wasn't utilized during the training phase is employed. The model's predictions are compared with the true labels or target values in the testing set, and various evaluation metrics such as precision, accuracy, recall are computed to assess its efficiency.

3.5 Model Deployment and Monitoring

When a working model is developed, it may be used to forecast fresh, unobserved data in a production setting. The model's performance should be continuously monitored to ensure that it maintains its accuracy and effectiveness over time. If the performance of the model deteriorates, it may be necessary to retrain the model with new data.

4 Diagrams

4.1 Architectural Diagram

Fig. 2. Architectural Diagram
5 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.

References

1. V. Vijean et al., "Early Detection of Diabetic Foot Ulcers through Wearable Shoe Design," 2022 4th International Conference on Artificial Intelligence and Speech Technology (AIST), Delhi, India, 2022, pp. 1-5, doi: 10.1109/AIST55798.2022.10065150.
6. P. Gupta, N. Gaur, R. Tripathi, M. Goyal and A. Mundra, "IoT and Cloud Based Healthcare Solution for Diabetic Foot Ulcer," 2020 Sixth International Conference on Parallel, Distributed and Grid Computing (PDGC), Wagnaghat, India, 2020,