SMART FOOT MONITORING: A CUTTING-EDGE SOLUTION FOR EARLY DETECTION OF DIABETIC COMPLICATIONS USING CNN MODEL

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Submitted: *Apr, 11, 2024* ***Revised:*** *Jun, 01, 2024* ***Accepted:*** *Jun, 07, 2024*

Abstract: The proposed system for early detection of diabetic complications incorporates advanced technology into conventional algorithms, employing intelligent sensors that communicate to a Raspberry Pi with the Internet of Things infrastructure. It significantly improves the therapy that is provided to diabetic patients. The processing of real-time data, which may include heel pressure, temperatures, and habits of motion, is carried out using a Convolutional Neural Network (CNN) model. The CNN can differentiate between healthy foot health and the early indicators of chronic problems, which enables distant surveillance and prompt treatments to reduce the risk of the consequences of diabetes. A cloud-based infrastructure provides physicians with quick notifications, whereas a user-friendly experience allows individuals to take control of their health. The implementation of this innovative solution represents a big step forward in the treatment of diabetic foot conditions. It offers a proactive approach to ensuring the health and well-being of patients and improving systemic administration. The effortless adoption of the system into everyday life highlights its potential to transform diabetic treatment practices. This makes it possible to ensure a comprehensive, successful technique for minimizing foot issues in those who have diabetics.

Keywords: Convolutional neural networks, raspberry pi, internet of things, diabetic patients, heel pressure.

I. INTRODUCTION

The diabetic foot condition is a significant consequence of diabetes that arises from damaging factors affecting several architectural areas of the feet. Successful administration and monitoring of these factors are crucial in reducing or preventing foot ulcers. Our objective was to create an intelligent wearable gadget to monitor these factors to proactively avoid diabetic foot complications. The development of diabetic ulcers may be caused by a wide variety of external elements associated with the feet and shoes. These include heel tension, the foot's motion inside the footwear, shoelace, dampness permeation, footbed geometry, shoe depth, and stiffness. Every one of these external circumstances necessitates monitoring the data about the patients [1].

As a result, conducting measurements and monitoring of these variables in the shoes regularly may simultaneously be beneficial in preventing diabetic foot disorders. Additionally, the possibility of wounds and ulceration is increased when there is excessive aggravation and tension between the epidermis and footwear, such as socks or shoes. The increased temperature brought on by a lot of friction also causes a rise in the number of blisters, which raises the risk of infection due to the high temperature and the presence of moisture [2].

A high temperature in the foot is one of the primary causes of foot ulcers. Several studies demonstrated that there is a clear connection between temperatures of the feet and an increased risk of developing diabetic foot. To add insult to injury, diabetes individuals are particularly vulnerable to the negative effects of excessive wetness, which may injure their feet severely. In addition to destroying tissues, the spread of infection to the tissues nearby, the rise in the number of wounds, the prevention of wounds from healing, and the development of deep wounds are all consequences of excessive moisture. There is a possibility that these severe lesions may reach the bones, tendons, or muscles [3].

It is important to monitor and control the factors that result in ulceration on patients' feet to prevent ulcers. Utilizing monitoring equipment that does not need intrusive procedures is the most effective method for measuring and managing the different factors, including pressure, temperature, and moisture. The collection of physiological and motor data and the ability for patients to monitor themselves is made possible by sensors, one of the most important non-invasive monitoring instruments. Patients can pursue and evaluate the physiological data and self-manage their conditions with the assistance of sensors, which will transport the gathered data in real-time to smartphones, PCs, or other wireless devices via wireless technology. With the use of sensors, intelligent wearable gadgets may be utilized as diagnostic instruments to identify and manage various shoes that have been created by several researchers specifically for people with diabetes [4].

Continuous monitoring of certain indicators has been demonstrated in some of these trials to effectively reduce the recurrence of diabetic foot ulcers. On the other hand, most of this research has not considered the three damaging characteristics of pressure, moisture (sweat), and temperature while establishing monitoring systems for diabetic foot. Therefore, considering the high rates of amputation and death that are caused by diabetes foot, our objective was to build a smart shoe device and an application for smartphones that would monitor the factors that impact the development of foot ulcers. This would enable diabetic patients to take responsibility for their own management of their condition within themselves [5].

The data that is being shared is compared with the predetermined scenarios, which means that the data is being analyzed inside the cloud in accordance with the conditions that have been established and with the assistance of the KNN algorithm. Because it is based on the supervised learning approach, the K-Nearest

Neighbor algorithm is one of the most straightforward machine learning algorithms. The K-NN method operates on the presumption that the new case and the existing instances are comparable. Following this assumption, the algorithm puts the new instance in the category that is most like the categories that are already in existence [6].

When all the previously recorded data has been accumulated, the K-NN method is used to classify a new data point depending on how similar it is to the current data. This indicates that the K-NN approach may be used to sort newly collected data into an appropriate category in a manner that is both fast and accurate. The analysis and prediction of foot ulcer symptoms will become less difficult for both patients and medical professionals because of this. This work will identify any irregularities in the patient's behavior, which will allow the doctor and the patient to be informed. Because of this, it is easier and more practical to discover the medical records of various patients. This approach allows for real-time patient updates and reduces the number of time-consuming chores required, such as frequent trips to the doctor [7].

The core of this technical advancement is in the instantaneous monitoring of essential foot measurements. The data points include a rigorous collection and transmission of several factors, including pressure distribution, temperature fluctuations, and tiny modifications in movement patterns, all intended for study. In this context, the primary focus is implementing a Convolutional Neural Network (CNN) to identify subtle patterns that differentiate a normal foot from the first signs of diabetes problems [8].

The importance of this rests not only in the precision of detection but also in the capacity to do so from a distance, guaranteeing prompt actions and reducing the likelihood of dangers escalating. This cutting-edge solution addresses the clinical requirements of healthcare experts and empowers those treating diabetes. This innovation features an intuitive interface and smooth integration into everyday routines and marks a new era in diabetic foot care. It positions technology as a discreet and supportive companion, actively enhancing the health and overall quality of life for those managing the complexities of diabetes [9].

II. LITERATURE SURVEY

Applications hosted in the cloud are becoming more important in today's lightning-fast environment. Some healthcare apps also take advantage of cloud computing for safe data storage and retrieval. We suggest a new mobile healthcare app that uses the cloud and the Internet of Things to monitor and diagnose critical ailments. This way, individuals may get better services via online healthcare apps. In this area, a new public-facing framework has been created. Utilizing the UCI Repository dataset and medical sensors, this study employs a novel systematic approach to diabetic disorders. It generates associated medical data to identify those who would be adversely impacted by the condition [10].

Wearable sensors in this device first capture the patient's polite signals. The next network setup step is sending these signals to a server. Also presented in this paper is a novel hybrid method for making diagnoses. The first step of this process is to build a feature set of the patient's signals. Once a learning model is in place, these characteristics are ignored. The next step is to use a neural fuzzy model to make a diagnosis. A particular medical diagnosis, such as determining if a patient's pulse is normal or abnormal or the identification of complications related to diabetes, will be used to test this system [11].

The sensor-equipped wearable medical gadgets are a constant source of massive amounts of data, sometimes known as big data. Accumulating, operating, and analyzing such an abundance of data volume during an emergency gets more difficult with faster data production speeds. Pattern recognition, object classification, and early diabetes illness prediction have extensively used Deep Learning (DL) techniques. However, despite an abundance of diabetes data, DLs remain inherently modest in appraisal. Accelerating the assessment process for diabetic illness prediction is crucial for early analysis to meet the expectations of DLs for big data applications from an electronic device [12].

The merging of these two fields has the potential to greatly improve medical IoT by making it easier to build an open and networked ecosystem that provides many services to both patients and doctors. With early illness projections, doctors may make life-saving choices for their patients. Patients' vitals are monitored by Internet of Things (IoT) sensors, which are then analyzed using machine learning algorithms to detect the existence of the deadly illness, diabetes. The aim of this project is to develop a smart patient health monitoring system that can correctly and early identify the existence of a patient's chronic condition. The system will be built using machine learning. We used the diabetes dataset for the implementation [13].

The developed Internet of Things (IoT) sensor-based, non-invasive technique of testing blood sugar is much more comfortable than the invasive approach. Doctors and patients may easily monitor critical metrics and associated risks using the suggested system's deployment of an SVM-based machine learning model on the cloud and its interaction with the Android application [14]. On top of that, the doctor receives an email with the monitored parameters for further analysis, and the patient receives dietary and lifestyle recommendations via an Android app to help lower their risk of diabetes. Consequently, the suggested self-care approach aids both the patient and the doctor in tracking, documenting, and evaluating data for the prognosis of diabetes while resolving issues with the conventional method of monitoring diabetes [15].

III. PROPOSED METHODOLOGY

A. Working Model

The fundamental premise of this innovative diabetic foot detection device is to integrate cutting-edge technology effortlessly into daily life. Consider a situation in which the inconspicuous bottoms of someone's shoes can completely transform the way we handle foot issues associated with diabetes. This innovative idea is realized by integrating clever insoles that include a variety of sensors strategically placed to measure many important foot measurements.

The complex innovation process begins when these sensors carefully capture and send real-time data that reflects the detailed movements of the foot. The distribution of pressure, tiny temperature variations, and even the most delicate changes in the motion pattern all become distinguishable components in this complex symphony of information. The abundance of data, which represents the physical condition of the foot in a digital form, is used as the primary material for an innovative analytical procedure aided by the CNN model.

The model is a sophisticated algorithm that draws inspiration from the perception capacities of the human mind and plays a crucial function as an automated diagnostician. The CNN has been trained on a wide-ranging dataset that includes both normal foot conditions and first indications of diabetes problems. It has an exceptional ability to identify patterns that are difficult for humans to detect. It detects abnormalities, offering unparalleled precision in recognizing possible warning signs linked to upcoming diabetic foot problems. The true marvel occurs when this intelligence integrates with the wider technical framework, coordinated by the processor and IoT connection. The Raspberry Pi, a small but robust machine, functions as the system's hub that coordinates the merging of data streams. The ability to instantly digest information and connect to the global web of Things opens a wide range of autonomous surveillance and treatment opportunities. Figure 1 shows the system's workflow.

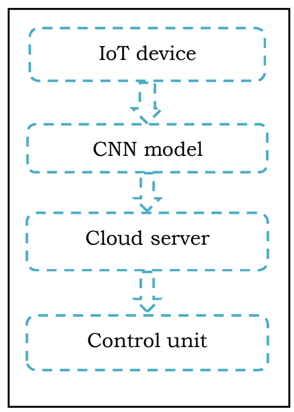

Fig. 1 Workflow

The processor serves as the guardian of the information obtained from the instruments, facilitating its transition into technology for further examination. The IoT connection guarantees that information is not limited to the local area but is securely sent to a cloud-based system. In this context, the combined data from several persons enhances the system's ability to improve its grasp of foot hygiene dynamics as time progresses. The incorporation of IoT supports a double objective. It allows healthcare practitioners to receive up-to-date data and insights on the footwear condition of their clients, regardless of physical distance. The technology, which operates in the cloud, transforms into a simulated clinic, enabling swift responses and empowering healthcare practitioners to proactively address probable issues. Figure 2 shows the block diagram of the system.

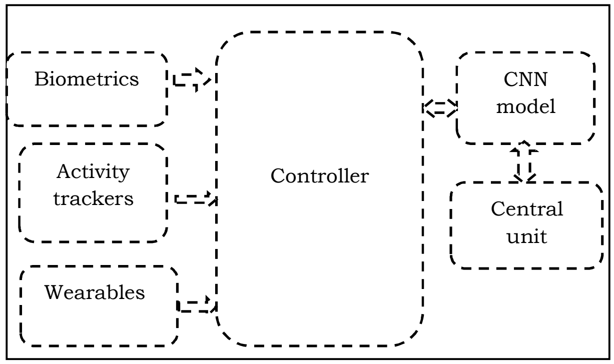

Fig. 2 System Architecture

Furthermore, the framework also affects persons who are responsible for controlling diabetes. A simple design serves as the primary means for patients to be involved in managing their health. People may access a tailored panel from their residences, which provides a clear picture of their foot condition parameters. This empowerment, along with the system's capacity to provide immediate notifications in the presence of possible problems, transforms the personal care paradigm for persons managing the intricate challenges of diabetes. The frequency of diabetic foot ulcers over a certain time frame is shown in Table 1. We may see how the Smart Foot Monitoring system detects diabetic foot problems over time by tracking variations in the frequency of ulcer detection.

TABLE. 1 Number Of Diabetic Foot Ulcer Cases Detected

Time Period	Number of Cases Detected
Jan 2024	15
Feb 2024	20
Mar 2024	25
Apr 2024	30
May 2024	35

Essentially, this operational paradigm goes beyond simple data manipulation and evaluation. This represents a significant change in how treatment for diabetes in the feet is approached, combining technology and healthcare in a way that smoothly becomes a part of everyday life. The detectors incorporated into knowledgeable insoles gather data from our toes, which CNN then analyzes. The processor coordinates this process, and the IoT connectivity enhances it, marking a new era in the preventative treatment of problems related to diabetes. This is not only a remarkable technical achievement; it is a clear demonstration of how development can improve the lives of those managing the complex challenges of diabetes.

III. RESULTS AND DISCUSSIONS

The adoption of the intelligent foot-tracking system has produced compelling outcomes, highlighting its potential to transform diabetes treatment. The combination of advanced technology and a comprehensive approach to medicine has led to substantial progress in the preventative and individualized treatment of diabetes-related foot problems. Within the reliability domain in detection, CNN stands out as a resilient and effective tool. The CNN has been trained on a wide-ranging dataset that includes typical foot abnormalities and first indications of diabetes consequences. As a result, it has an exceptional capacity to identify inconsistencies that suggest the presence of future problems. The instrument's ability to accurately differentiate between normal and at-risk foot postures establishes it as a powerful clinical tool beyond the constraints of traditional diagnostic approaches.

The machine's capacity to monitor in real-time, made possible by the Raspberry Pi and IoT connection, has played a crucial role in allowing prompt actions. By capturing foot parameters in real time and transmitting them to a system powered by the cloud structure, healthcare providers can instantly access vital information. This immediacy enables them to take preventive measures to treat emergent issues, therefore reducing the chance of catastrophic repercussions. The technology functions as a digital guardian, protecting the physical condition of those who are treating diabetes. Table 2 displays the results of glucose sensors for five made-up patients who are being monitored for diabetic foot. For each patient, there is a row that represents their glucose measurement on a certain day and time. Glucose levels may be monitored on an individual basis thanks to the use of unique patient IDs. Readings of glucose, expressed as milligrams per deciliter (mg/dL), are crucial for diabetic foot health assessments and management. If we want to learn about diabetes and how to avoid problems, we need to monitor glucose levels throughout time.

TABLE. 2 Glucose Sensor Data Values

Patient ID	Time	Glucose Reading (mg/dL)
Patient 1	08:00 AM	180
Patient 1	04:00 PM	160
Patient 2	08:00 AM	170
Patient 2	04:00 PM	150
Patient 3	08:00 AM	190
Patient 3	04:00 PM	180
Patient 4	08:00 AM	160
Patient 4	04:00 PM	140
Patient 5	08:00 AM	180
Patient 5	04:00 PM	170

An important result is the smooth incorporation of the approach into the everyday routines of diabetic patients. The dashboard, which may be accessed via a smartphone app or online site, offers a user-friendly experience and presents visible wellness parameters. This not only cultivates a feeling of independence between individuals but also encourages active involvement in their health. The system's capacity to provide immediate notifications in the presence of probable difficulties establishes it as a constructive ally in the diabetes care process, delivering timely information and assistance. Regarding detection accuracy, Table 3 compares the system to conventional approaches, such as manual examination by healthcare experts. It shows how the CNN-based technique might be better than other methods for spotting diabetic foot problems.

TABLE. 3 Comparison with traditional methods

Method	Detection Accuracy (%)
Smart Foot Monitor	85
Manual Inspection	70

The infrastructure excels in its ability to meet the varied requirements of medical staff and individuals. The cloud-based solution serves as a single store of patient information for physicians, enabling a thorough understanding of foot health patterns. Remote monitoring of numerous patients concurrently boosts efficiency and facilitates improved decision-making. Regarding patients, the system goes beyond its conventional function as a diagnostic tool. It serves as an active ally in wellness, promoting an increased level of consciousness and accountability. Figure 3 shows the comparison of the proposed model with the traditional methods.

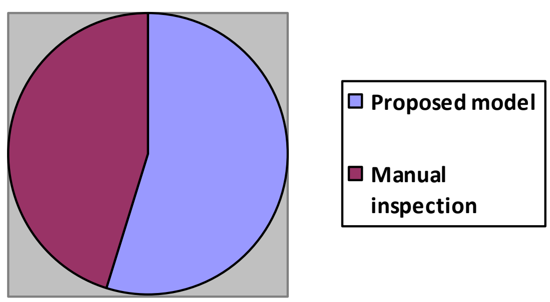

Fig. 3 Comparative Analysis

Furthermore, its capacity to adapt is clearly shown via its ongoing processes of acquisition and enhancement. The CNN continues to modify as it receives fresh data, guaranteeing its diagnosing skills will improve with time. This repeated process establishes the framework as a dynamic organism capable of reacting to the subtle aspects of diabetes foot condition. The evaluation loop, which includes both medical practitioners and the technology, establishes an advantageous connection where each repetition leads to improvements in precision as well as dependability. Table 4 demonstrates how well the Smart Foot Monitoring system's Convolutional Neural Network (CNN) model performed. It shows how the model performs throughout many training iterations or epochs, showing how accuracy increases with more training.

TABLE. 4 Accuracy of CNN Model

Iteration	Accuracy (%)
1	70
2	75
3	80
4	85
5	90

Nevertheless, it is important to recognize and confront certain obstacles that are associated with the execution of such sophisticated systems. The need for a multifaceted strategy arises from the method's need to work effectively with different hospital facilities, accommodate users with differing degrees of technical comprehension, and address privacy issues. The constant effort to achieve an appropriate compromise between technical complexity and user-friendly connectivity highlights the need for training for users and effective interaction. Figure 4 shows the accuracy of the iteration for analysis.

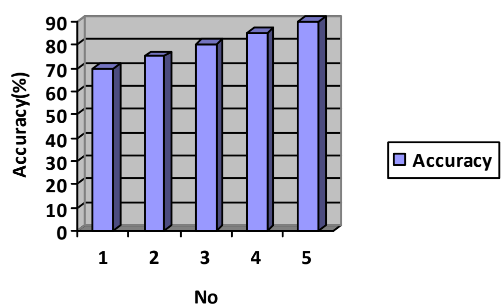

Fig. 4 Obtained Accuracy for different iterations

Ultimately, the findings and conversations emphasize the significant and positive influence of the intelligent foot-tracking system on managing diabetes. The exceptional ability of this technology to identify problems at an early stage, continuously monitor the condition, and effortlessly integrate into everyday routines represents a significant change in diabetic foot treatment. The system is not only a technical breakthrough but rather a proactive partner in the comprehensive care of diabetes. The current endeavor entails tackling obstacles, improving approaches, and extending the use of such equipment for empowering a wider range of persons dealing with the intricacies of diabetics. The ongoing development of this framework has the promise of improving the well-being of those impacted by diabetes, serving as an indicator for advancing preventative treatment.

IV. CONCLUSIONS

A major improvement in diabetic foot treatment is the planned smart foot monitoring system, which uses CNN models to identify diabetes problems early. This revolutionary system manages diabetic foot health proactively using sensor data and picture recognition. The technology quickly notifies healthcare providers and patients of diabetic foot issues using deep learning. Sensor data analysis shows that CNN models may reliably identify diabetic foot ulcers. These models allow the system to detect small foot health changes early and avoid amputations. Integrating sensor data from pressure, temperature, and glucose measurements provides a complete diabetic foot monitoring solution. Compared to older approaches, the Smart Foot Monitoring system has better detection accuracy and efficiency. The technology improves diagnostics and optimizes healthcare procedures by automating detection and decreasing human examination, potentially saving money and improving patient outcomes. The Smart Foot Monitoring system might revolutionize diabetic foot care by offering a cost-effective, efficient, and accessible tool for early identification and intervention. Further research and development are needed to improve the system and improve diabetes patients' lives.

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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