

A Survey on Deep Learning Approaches for Early Diabetes Detection

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Abstract: Diabetes mellitus is a chronic metabolic disorder that poses significant health risks if not detected and managed in its early stages. Early diagnosis is crucial to prevent severe complications and improve patient outcomes. With the rise of artificial intelligence in healthcare, deep learning has emerged as a powerful tool for the early detection of diabetes due to its ability to learn complex patterns from large datasets. This survey provides a comprehensive overview of recent deep learning approaches applied to early diabetes detection. We explore various architectures, including Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Autoencoders, and hybrid models, analyzing their performance across diverse datasets and diagnostic scenarios. The paper highlights key methodologies, comparative analyses, strengths, limitations, and potential improvements. Moreover, it discusses challenges such as data quality, interpretability, and real-world applicability. This survey aims to guide future research by identifying promising directions and encouraging the development of more accurate, reliable, and interpretable diagnostic systems.

Keywords— Deep Learning, diabetes prediction, early detection, Heart rate variability, ECG, CNN, LSTM

I. INTRODUCTION

Diabetes mellitus is a chronic, life-threatening metabolic disorder characterized by elevated blood glucose levels resulting from the body's inability to produce or effectively use insulin. According to the International Diabetes Federation, over 530 million adults were living with diabetes in 2021, and this number is projected to rise significantly in the coming decades. The early stages of diabetes often present with mild or no symptoms, making timely diagnosis challenging. Undetected or poorly managed diabetes can lead to severe complications, including cardiovascular diseases, kidney failure, blindness, and neuropathy. Therefore, early detection and

intervention are crucial to improving patient outcomes and reducing the global healthcare burden. Traditional diagnostic methods, such as fasting blood sugar tests and oral glucose tolerance tests, are effective but often require clinical visits and can be time-consuming. With advancements in artificial intelligence and the increasing availability of health-related data, machine learning and, more recently, deep learning techniques have shown promising results in automating and improving the accuracy of diabetes diagnosis. Deep learning models, particularly those based on neural networks, can automatically extract and learn complex patterns from large and diverse datasets without the need for extensive manual feature engineering. This paper presents a comprehensive survey of deep learning approaches used for early detection of diabetes. It explores various deep learning architectures such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Deep Belief Networks (DBNs), Autoencoders, and hybrid models. The study evaluates these methods in terms of performance, data requirements, interpretability, and practical deployment. It also identifies existing challenges and potential future directions to enhance the reliability and efficiency of such systems. By consolidating the current research landscape, this survey aims to support the development of advanced, data-driven solutions for early diabetes detection and contribute to more effective healthcare delivery.

The primary aim of this review paper is to provide a structured and comprehensive overview of deep learning methodologies applied to the early detection of diabetes. By systematically analyzing various models and techniques, the paper seeks to identify the most effective architectures, highlight current trends, and pinpoint gaps that require further research. Additionally, it aims to assist researchers, data scientists, and healthcare professionals in

understanding how deep learning can be leveraged to improve diagnostic accuracy and enable timely interventions. This review also examines the datasets commonly used in diabetes prediction studies, such as the Pima Indian Diabetes Dataset (PIDDD), UCI Diabetes datasets, and electronic health records (EHRs) from clinical sources. These datasets vary in size, features, and quality, which significantly influence model performance. A critical comparison of these datasets is included to understand their role in training robust and generalizable deep learning models for early diabetes detection.

II. LITRETURE REVIEW

The literature on diabetes detection highlights the growing use of deep learning models due to their superior ability to learn complex patterns from medical data. Early studies focused on traditional machine learning, but recent research has shifted toward deep architectures like CNNs, RNNs, and hybrid models. These approaches have shown improved accuracy in diagnosis using clinical, demographic, and lifestyle data. The literature also addresses challenges such as data imbalance, model interpretability, and the need for clinically validated systems.

Authors [1] proposed a blending model named HiTCLe using Highway, LeNet, and a Temporal Convolutional Network (TCN) to detect and predict diabetes at an early stage. HiTCLe performs best, beats its individual models, highway, TCN and LeNet, and achieves an accuracy score of 94% and a F1-Score of 94%, whereas individual models achieve an accuracy score between 89% and 91% on 10 epochs. To overcome the class imbalance problem, a Proximity-Weighted Synthetic Oversampling (ProWSyn) technique is implemented.

Author's [2] applied an ensemble feature selection approach to identify critical predictors. To address the class imbalance, Generative Adversarial Networks (GANs) were used to generate synthetic data, ensuring the model's robustness in identifying underrepresented cases. Additionally, a hybrid loss function combining cross-entropy and focal loss was implemented to improve classification, especially for hard-to-detect instances. Our results show that the attention-based DBN model, augmented with

synthetic data from GANs and optimized with a hybrid loss function, achieves an AUC of 1.00, F1-score of 0.97, precision of 0.98, and recall of 0.95, outperforming several baseline models. This research offers a novel and effective approach for early diabetes detection, demonstrating potential for use as a clinical tool in preventive healthcare settings.

Author's [3] investigates and discusses the impacts of the latest machine learning and deep learning approaches in diabetes identification/classifications. It is observed that diabetes data are limited in availability. Available databases comprise lab-based and invasive test measurements. Investigating anthropometric measurements and non-invasive tests must be performed to create a cost-effective yet high-performance solution. Several findings showed the possibility of reconstructing the detection models based on anthropometric measurements and non-invasive medical indicators. This study investigated the consequences of oversampling techniques and data dimensionality reduction through feature selection approaches. The future direction is highlighted in the research of feature selection approaches to improve the accuracy and reliability of diabetes identifications.

Author [4] explores the deep learning model for diagnosis the disease. This work used the PIMA Indians diabetes database. Used strong CNN model for diagnosis. This model achieves 97.19% accuracy.

Author's [5] proposed a method can help not only to predict the occurrence of diabetes in the future but also to determine the type of the disease that a person experiences. Considering that type 1 diabetes and type 2 diabetes have many differences in their treatment methods, this method will help to provide the right treatment for the patient. By transforming the task into a classification problem, our model is mainly built using the hidden layers of a deep neural network and uses dropout regularization to prevent over-fitting. Authors tuned a number of parameters and used the binary cross-entropy loss function, which obtained a deep neural network prediction model with high accuracy. The experimental results show the effectiveness and adequacy of the proposed DLPD (Deep Learning for Predicting Diabetes) model. The best training accuracy of the diabetes type data set is 94.02174%, and the training accuracy of the Pima

Indians diabetes data set is 99.4112%. Extensive experiments have been conducted on the Pima Indians diabetes and diabetic type datasets. The experimental results show the improvements of our proposed model over the state-of-the-art methods.

Authors [6] propose a hybrid model that joins the qualities of convolutional brain organizations (CNNs) and repetitive brain organizations (RNNs) to further develop DR discovery exactness. The proposed crossover profound learning model involves three principal stages. A pre-handling, first and foremost, step is applied to upgrade the quality and differentiation of fundus pictures, in this manner working on the model's capacity to remove basic highlights. After that, a Residual CNN is used to extract features from the images that have already been processed. Residual CNNs are adroit at catching various leveled highlights, and this stage empowers the model to successfully gain discriminative elements from the information pictures. The subsequent stage includes incorporating RNNs into the model. RNNs are ideal for analysing sequential patterns in medical images because they are well-suited to handling sequential data and capturing temporal dependencies. The model's ability to extract temporal information from fundus image sequences thanks to the inclusion of RNNs improves its ability to identify early DR progression signs. The third and last stage centers around the characterization task, where a completely associated brain network is utilized to decipher the highlights separated by the past stages and order the pictures into various DR seriousness levels. The hybrid model's architecture facilitates the fusion of spatial and temporal information, resulting in a more comprehensive and accurate DR diagnosis.

III. FINDINGS OF THE SURVEY

This survey reveals several important findings regarding the use of deep learning approaches for early diabetes detection. First, deep learning models consistently outperform traditional machine learning techniques in terms of prediction accuracy and feature extraction, especially when large and diverse datasets are available. Convolutional Neural Networks (CNNs) have shown strong performance in analyzing structured and image-based data, while Recurrent

Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks are effective in handling temporal or sequential medical data.

Hybrid models that combine CNNs with RNNs or use ensemble methods tend to yield higher accuracy and robustness compared to standalone models. Autoencoders have been widely used for unsupervised feature learning, especially when labeled data is limited. Transfer learning and data augmentation have also proven useful in improving model performance when data availability is a constraint. The survey also finds that the Pima Indian Diabetes Dataset (PIDD) is the most commonly used dataset across studies, although its limited size and demographic focus raise concerns about generalizability. Real-world datasets like electronic health records (EHRs) offer richer insights but introduce challenges related to data privacy, noise, and preprocessing.

Another significant finding is the trade-off between model accuracy and interpretability. Many deep learning models function as black boxes, limiting their transparency in clinical applications. Interpretability tools such as SHAP and LIME are increasingly being integrated to address this concern. Overall, the survey concludes that while deep learning models offer promising results for early diabetes detection, there remains a critical need for better-quality data, model interpretability, and real-world validation before clinical deployment can be fully realized.

IV. CONCLUSION

Early detection of diabetes is vital for effective disease management and prevention of long-term complications. This survey has explored the growing role of deep learning in enhancing diagnostic accuracy and reliability for early diabetes detection. Various deep learning architectures, including CNNs, RNNs, Auto encoders, and hybrid models, have demonstrated significant potential in extracting meaningful patterns from structured and unstructured medical data. Among these, hybrid and ensemble models often achieve superior performance due to their ability to integrate diverse data features.

The widespread use of datasets like the Pima Indian Diabetes Dataset underscores the importance of

accessible, high-quality data; however, limitations in dataset size and diversity highlight the need for broader, real-world datasets. While deep learning models offer notable improvements in predictive capabilities, challenges remain in terms of model interpretability, data privacy, and clinical applicability. To move forward, future research should focus on improving model transparency, developing robust models that generalize across populations, and incorporating domain knowledge to enhance clinical relevance. Additionally, collaboration between healthcare professionals and AI researchers is essential for designing solutions that are both technically sound and practically implementable. This survey serves as a foundation for guiding future innovations in AI-driven, data-centric approaches for early diabetes detection.

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