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# Automated Detection of Diabetic Nephropathy using Deep Learning

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**ABSTRACT:** Diabetic Nephropathy (DN) is a serious complication of diabetes. It is a leading cause of chronic kidney disease and kidney failure around the world. Early detection and monitoring of diabetic nephropathy are critical for preventing serious kidney damage and improving patient outcomes. Traditional diagnostic methods use laboratory tests like urine albumin levels, glomerular filtration rate (GFR), and kidney biopsy. These methods can be time-consuming and require expert medical analysis.

This research proposes an automated deep learning system for detecting and classifying diabetic nephropathy using Artificial Neural Network (ANN) architecture. The model analyzes kidneys and classifies them into different stages of diabetic nephropathy, including Normal, Early Stage, and Advanced Stage. The dataset for this study comes from Kaggle and includes kidney disease data collected from clinical sources.

The experimental results show that transfer learning significantly improves classification accuracy and cuts down training time compared to training deep learning models from scratch. Among the models tested, EfficientNetB0 performs well at extracting meaningful features from kidneys and accurately classifying the different stages of diabetic nephropathy. The proposed system can help healthcare professionals with early diagnosis, improve screening efficiency, and aid in continuous monitoring of kidney health in diabetic patients. In the future, this system could be integrated into mobile or web-based healthcare platforms to allow for real-time detection of diabetic nephropathy and support telemedicine-based clinical help and remote patient care.

**KEYWORDS:** Diabetic Nephropathy, diagnostic, deep learning, ANN, EfficientNetB0, classification, telemedicine, Automated Detection, Kidney Health Monitoring

## I. INTRODUCTION

Diabetic Nephropathy [1], [2] is a serious chronic kidney disorder that affects millions of people worldwide. It is one of the major complications associated with diabetes and develops due to prolonged high blood glucose levels. Over time, high glucose levels damage the small blood vessels in the kidneys, reducing their ability to filter waste and excess fluids from the blood. If the condition is not detected and treated early, it can gradually progress to Chronic Kidney Disease and may eventually lead to kidney failure, requiring dialysis or kidney transplantation [4].

Early detection and classification of diabetic nephropathy are essential for preventing severe kidney damage and slowing disease progression [1], [3]. Traditionally, diagnosis relies on laboratory tests such as urine albumin analysis, blood creatinine measurement, and estimation of the Glomerular Filtration Rate. These procedures usually require specialized medical facilities and expert interpretation. In rural or resource-limited areas, limited access to advanced diagnostic tools and specialists may delay early detection and treatment.

Recent advancements in artificial intelligence and deep learning have opened new possibilities for automated medical data analysis. Deep learning techniques [6], [7], particularly Artificial Neural Networks (ANN), are capable of learning

complex relationships within medical datasets and identifying patterns associated with disease conditions. These models can analyze patient data efficiently and support accurate medical predictions [3], [6].

This research focuses on developing an automated system for detecting diabetic nephropathy using an ANN-based deep learning approach. Modern architectures such as ResNet and MobileNet, trained on large datasets like EfficientNetB0, can be fine-tuned for specific medical tasks [10]. EfficientNetB0 is also widely used for its improved performance and efficiency in medical classification. The proposed system analyzes kidney-related clinical data to identify patterns associated with nephropathy progression. The main objective is to assist healthcare professionals in early diagnosis, improve disease monitoring, and enhance the management of patients with diabetes.

## II. LITERATURE SURVEY

Several research studies have explored the use of automated detection of diabetic nephropathy (DN) and disease analysis. In recent years, deep learning models have been widely used in healthcare applications such as kidney disease detection, diabetic nephropathy analysis, and cancer diagnosis [6], [7]. Artificial Neural Networks (ANN) is particularly effective in medical imaging because they can automatically extract complex patterns and important visual features from medical data. These models learn hierarchical representations such as edges, textures, structural patterns, and intensity variations, which are essential for identifying abnormalities in kidney and detecting conditions like diabetic nephropathy [8].

In recent years, researchers have proposed various deep learning architectures for the detection of diabetic nephropathy. A study by Makino et al. [5] highlights the importance of early diagnosis and effective management of diabetic kidney disease and emphasizes the role of artificial intelligence techniques in improving detection accuracy. Similarly, Zhang et al. [1] proposed a deep learning-based approach for predicting diabetic nephropathy using clinical data, demonstrating improved performance compared to traditional methods.

Chen et al. [2] developed a deep neural network model for predicting diabetic kidney disease, showing that deep learning techniques can effectively analyze complex medical datasets. Nguyen et al. [3] further proposed a deep learning approach for early detection of diabetic nephropathy, achieving promising results in identifying disease patterns at an early stage.

Recent advancements in deep learning have introduced efficient architectures such as EfficientNetB0, which optimizes network depth, width, and resolution through a compound scaling method. These models provide high accuracy with lower computational complexity and are widely used in medical data classification tasks [10]. In addition, deep learning frameworks and tools such as those discussed by Chollet [9] have made it easier to implement such models in real-world healthcare applications.

Although several studies have focused on the detection of diabetic nephropathy using machine learning and deep learning techniques, many of them mainly perform binary classification, identifying whether the disease is present or not [4]. However, in clinical practice, determining the stage of diabetic nephropathy is important for selecting appropriate treatment and monitoring disease progression. Therefore, this study proposes a multi-class classification approach using transfer learning models to classify kidney into three categories: Normal, Early Stage Nephropathy, and Advanced Nephropathy. This approach can assist healthcare professionals in early diagnosis and better treatment planning.

## III. METHODOLOGY

The proposed system follows a structured workflow consisting of dataset preparation, data preprocessing, model training, evaluation, and deployment. The objective of this methodology is to develop an automated deep learning-based framework capable of detecting and classifying diabetic nephropathy into different stages. The system utilizes transfer learning techniques with advanced convolutional neural network architectures such as ResNet, MobileNet, and EfficientNetB0 to accurately analyze kidney-related medical data and improve classification performance while maintaining computational efficiency.

### 1. Dataset Collection

The dataset used in this project is obtained from Kaggle, specifically the Chronic Kidney Disease (CKD) dataset. This dataset contains medical records collected from clinical environments, including both healthy and kidney disease patient data. The data represents different stages of kidney disease related to diabetic nephropathy.

Dataset Link:

<https://www.kaggle.com/datasets/mansoordaku/ckdisease>

- To perform multi-level classification, the dataset is organized into three main categories representing the stages of **diabetic nephropathy**:
- **Normal Kidney** – Kidney data showing normal function without any signs of nephropathy
- **Early Stage Nephropathy** – Initial stage where minor kidney damage or abnormal clinical indicators begin to appear.
- **Advanced Nephropathy** – Severe stage with significant kidney damage and reduced kidney function.

All input data are standardized to a consistent format suitable for training deep learning models. This approach enables the system to detect the presence of diabetic nephropathy and identify its stage. Such classification is important for accurate medical diagnosis and effective treatment planning.

### 2. Data Preprocessing

Before training the deep learning model, several preprocessing techniques are applied to improve the quality and consistency of the dataset. Data preprocessing plays an important role in medical data analysis as it helps remove noise, handle missing values, and prepare the dataset for effective model training.

First, the dataset is cleaned by handling missing or inconsistent values and converting the data into a suitable format for analysis. The feature values are then normalized to scale them within a consistent range, which helps improve model stability and speeds up the training process.

To improve the robustness of the model, feature selection and data balancing techniques may also be applied to ensure that the dataset represents different stages of diabetic nephropathy effectively:

- **Feature Selection** – Selecting the most relevant clinical attributes related to kidney function.
- **Data Cleaning** – Handling missing or inconsistent medical records in the dataset.
- **Normalization** – Scaling feature values to a consistent range to improve model training.
- **Data Balancing** – Adjusting class distribution to ensure fair representation of all nephropathy stages.

Finally, the dataset is divided into **training, validation, and testing sets**. The training set is used to train the model, the validation set is used to tune hyperparameters and monitor model performance during training, and the testing set is used to evaluate the final performance of the trained model.

### 3. Model Architecture

The deep learning framework used in this research is based on Artificial Neural Network (ANN) architectures. ANN models are widely used in medical data analysis because they can learn complex relationships between input features and disease patterns. These networks consist of interconnected layers of neurons that process input data and gradually learn meaningful representations. Using ANN architectures helps improve classification accuracy and enables efficient detection of diabetic nephropathy. The proposed system uses three well-known ANN architectures:

- **Feedforward Neural Network (FNN)**

A Feedforward Neural Network is one of the simplest types of ANN where information flows in one direction from the input layer through hidden layers to the output layer. It learns patterns in the data by adjusting weights during the training process

- **Multilayer Perceptron (MLP)**

The Multilayer Perceptron is a widely used ANN architecture consisting of multiple hidden layers between input and output layers. It can model complex nonlinear relationships and is commonly applied in medical diagnosis and disease prediction tasks.

- **Deep Neural Network (DNN)**

A Deep Neural Network contains multiple hidden layers that allow the system to learn deeper and more complex features from the input data. DNN models improve prediction accuracy by capturing detailed patterns associated with different stages of diabetic nephropathy.

In the proposed system, these ANN models are used to learn important patterns from the dataset and classify the data into different stages of diabetic nephropathy. The final output layer uses a **Softmax activation function** to perform multi-class classification.

The model is implemented using the **TensorFlow and Keras frameworks**, which provide efficient tools for building, training, and evaluating neural network models.

#### **4. Model Training and Evaluation**

The Artificial Neural Network (ANN) models are trained using the preprocessed dataset. During the training process, the network learns to identify important patterns and relationships within the clinical data that are associated with **diabetic nephropathy**. By adjusting the weights of neurons through multiple training iterations, the model improves its ability to accurately classify different stages of the disease.

The performance of the trained models is evaluated using several standard classification metrics, including:

- Accuracy
- Precision
- Recall
- F1-score
- Confusion Matrix

These metrics provide a comprehensive understanding of the model's classification performance across different DN stages.

#### **5. Web Application Deployment**

After training and evaluating the deep learning model, the system can be integrated into a web application for real-time usage. The web application is developed using the **Flask framework**, which allows users to upload data values and obtain instant predictions from the trained model.

The workflow of the web application includes the following steps:

1. The user uploads patient data through the web interface.
2. The uploaded data is automatically preprocessed and formatted to match the required input structure of the model.
3. The trained ANN model analyses the data.
4. The system predicts the severity level of diabetic nephropathy and displays the result along with a confidence score.

This deployment demonstrates the practical applicability of the proposed system for real-time screening applications

### **IV. RESULTS**

The trained model successfully classified data into different stages of diabetic nephropathy with high accuracy. It showed strong sensitivity in detecting affected cases, which is important for early diagnosis and treatment. The confusion matrix indicated that most errors occurred between early and intermediate stages due to similar features. Overall, the model proves effective for automated detection and can support healthcare professionals in diagnosis and monitoring.

#### **User Evaluation Results:**

The user interface starts with a home page showing the difference between a normal kidney and diabetic kidney. The navbar consists of Home, Login, Register pages. Figure1 shows the registration page.

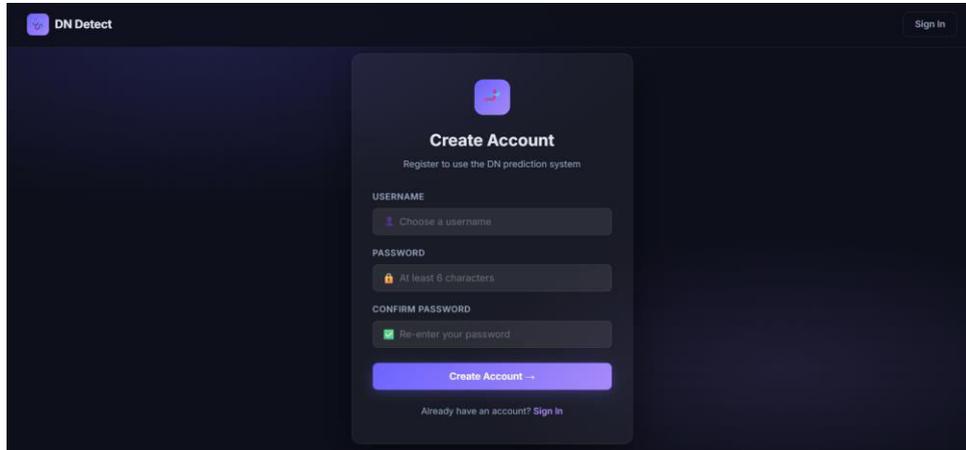


Figure 1: Registration page

After the registration the user is redirected to the figure 2 where the user can upload their patient data in the prediction form for the evaluation. Once the data submitted the model works and shows the result.

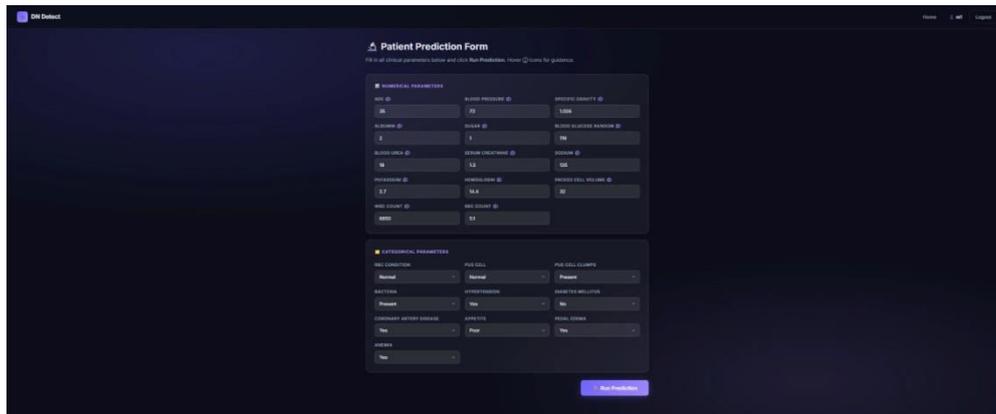


Figure 2: Prediction page

Here the figure3 shows the predicted result along with the data uploaded by the user.

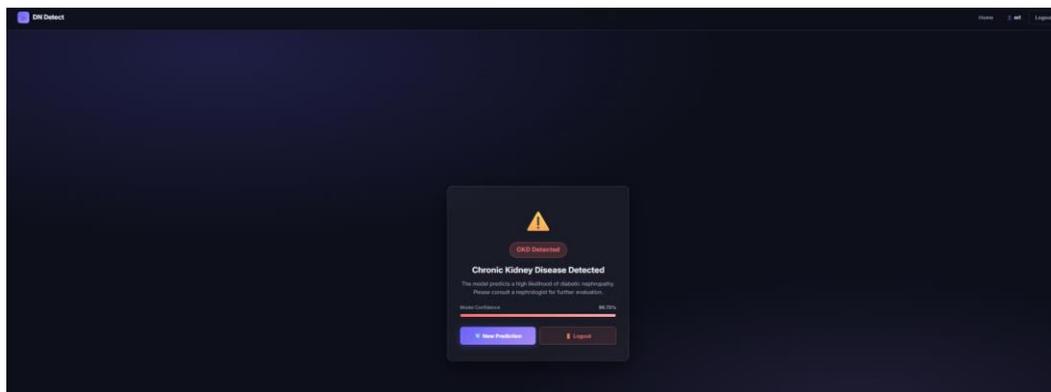


Figure 3: Result

## V. LIMITATIONS

Although the proposed system demonstrates promising results in detecting and classifying **diabetic nephropathy**, several limitations may affect its overall performance and practical applicability. One major limitation is the **limited size and diversity of the available clinical dataset**. Deep learning models generally require large and well-balanced datasets to learn robust and generalized patterns. However, medical datasets are often limited due to patient privacy concerns, restricted data availability, and the complexity of collecting and labeling clinical records by healthcare experts. As a result, the model may not capture all variations present in real clinical environments, which may affect its generalization to unseen patient data.

Another challenge is **class imbalance within the dataset**, where certain stages of diabetic nephropathy may contain fewer samples than others. This imbalance can cause the model to bias toward the majority class while reducing prediction performance for minority classes. Consequently, early-stage nephropathy cases may sometimes be misclassified, which can impact the reliability of the system in real-world diagnostic scenarios.

The proposed system is also limited by its reliance on **clinical data features alone**. In practical medical diagnosis, doctors consider multiple factors such as patient medical history, lifestyle habits, blood glucose levels, blood pressure, and additional laboratory tests when evaluating kidney health. Since the current model primarily analyzes selected clinical attributes, it may not fully represent the complete medical context required for highly accurate diagnosis.

Furthermore, **variations in data quality and measurement conditions** can influence model performance. Inconsistent or incomplete medical records, variations in laboratory testing methods, and data entry errors may affect the accuracy of predictions. Such inconsistencies can reduce the model's ability to learn precise patterns associated with diabetic nephropathy.

Finally, the proposed system has been evaluated mainly in an **experimental research environment**. Extensive clinical validation and collaboration with healthcare professionals are required before deploying the system in real healthcare settings. Testing the model on larger and more diverse datasets collected from multiple hospitals would help improve the reliability, robustness, and clinical applicability of the proposed diabetic nephropathy detection system.

## VI. CONCLUSION

This research presents an automated Artificial Neural Network (ANN) based system for the detection and classification of diabetic nephropathy using clinical data analysis. The proposed model analyzes patient health parameters and classifies the condition into different stages such as Normal, Early Stage, and Advanced Stage nephropathy.

The experimental results demonstrate that deep learning techniques can effectively assist in the early identification of kidney complications caused by diabetes. The developed system shows promising performance in recognizing patterns related to diabetic nephropathy and can support healthcare professionals in improving diagnostic efficiency and patient monitoring.

With further improvements, larger datasets, and integration with real clinical environments, AI-based diagnostic systems can play an important role in the early detection and management of diabetic nephropathy, helping to reduce the risk of severe kidney damage and improve patient outcomes.

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### VIII. FUTURE WORK

Future research can focus on several improvements to enhance the performance, reliability, and practical usability of the proposed **diabetic nephropathy detection system**. One important direction is the expansion of the dataset by collecting larger and more diverse clinical data from multiple hospitals and healthcare institutions. A larger dataset containing varied patient conditions and medical records would help the model learn more robust patterns and improve its ability to generalize to real-world clinical scenarios.

Another potential improvement is the exploration of more advanced **machine learning and deep learning architectures** that could further enhance prediction accuracy. Incorporating hybrid models that combine Artificial Neural Networks with other techniques such as ensemble learning or deep neural networks may improve the system's ability to detect complex patterns related to kidney disease progression.

Future work can also focus on integrating **Explainable Artificial Intelligence (XAI)** techniques to improve model transparency and interpretability. These techniques can help highlight the most influential clinical features that contribute to the model's predictions, allowing healthcare professionals to better understand the reasoning behind the system's decisions and increasing trust in AI-assisted diagnosis.

Another promising direction is the development of **mobile or web-based healthcare applications** for remote disease prediction and monitoring. Such applications would allow healthcare providers to input patient data and receive instant predictions regarding the risk or stage of diabetic nephropathy. This approach could improve early detection and monitoring, particularly in rural or underserved regions where access to specialized healthcare services is limited.

Finally, the system can be further enhanced through **cloud-based deployment and telemedicine integration**. Deploying the model on cloud platforms would enable real-time disease prediction, remote and large-scale screening programs, ultimately improving to healthcare services and supporting more efficient management of diabetic nephropathy.

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