Prediction of Chronic Kidney Diseases with Neural Network-Based Classification Methods

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***Abstract*—**Early detection and diagnosis of kidney-related issues are essential for improving patient results. However, traditional diagnostic methods often fail to detect early signs of kidney disease. Machine learning and computer science advancements have shown that neural networks can be effective in early disease prediction. In this study, we focused on Convolutional neural networks (CNNs) based algorithms for the classification of kidney diseases using CT images. Our research model implemented a dataset from Kaggle named CT kidney Dataset, consisting of four image classes that are Normal, Cyst, Tumor, and stone. The dataset consisting of around 12,446 images as our primary source. We employed various preprocessing and augmentation techniques to enhance the dataset's quality and diversity. We trained our research with three neural network models: VGG16, MobileNet, and Customized CNN. These models are executed for 20 epochs. The VGG16 gained the average accuracy of 89% and MobileNet 91% of accuracy. Our proposed Customized CNN 96% of accurcy and that was constant for 20 epochs.

Keywords:**Deep learning, MFCC, CNN, Bird Species.**

I. Introduction

The prevalence of chronic kidney disease (CKD) is rapidly rising worldwide, affecting approximately 10% of the global population [1],[2]. CKD ranks as the 16th leading cause of death globally. Cysts and kidney stones are major contributors to kidney malfunction and can lead to a painful death. A kidney cyst is a fluid-filled pocket on the kidney's surface, enclosed by a thin wall. CT scans are frequently employed to image the kidneys and detect such abnormalities [3],[4],[5]. Conversely kidney stones are crystalline deposits in the kidneys, affecting approximately 12% of the global population [6],[7]. Kidney stones are a high-risk factor for kidney failure problems. Sometimes, the increased size of the stone led the patient to transplantations or removal of the kidney to the patient. Research into the diagnosis of this disease has the possibility to enhance patients' quality of life and reduce the risk of kidney failure.

Renal cell carcinoma (RCC), also known as kidney tumor, ranks among the top 10 most prevalent tumors globally. [8],[9] Therefore, one of the aims of this study was to precisely identify kidney related diseases at an early stage. Early diagnosis of chronic kidney disease can helped to reduce the risk. Pathology tests and imaging processing techniques such as X-rays, CT scans, ultrasound, and MRI are commonly used to detect Kidney issues[10],[11],[12]. These methods allow healthcare to identify and diagnose conditions at an early stage, which is essential for sufficient treatment and management. Failure to identify and treat kidney problems such as cysts, stones, and tumors can lead to many health issues for patient [13],[14].

In order to properly figure out the chronic kidney disease linked with image processing, advanced and context-aware systems are still required, notwithstanding the progress made in deep learning and neuro rehabilitation.

The overall effectiveness of these programs is restricted by the fact that current methods frequently lack the precision needed to customize rehabilitation interventions to the particular needs of each individual [15].Several researchers conducted an investigation to diagnose chronic kidney disease (CKD) using SVM, DT, NB, and KNN .They changed a number of computing characterizations, such as back-propagation networks (BPN), random subspace, LDA classifiers, KNN, and DT[16],[17]. An initial CNN model for the diagnosis of kidney tumors was unable to bridge the gap with this test, which uses radiological imaging scans for kidney tumor detection. Existing approaches frequently involved feature extraction techniques, including texture analysis, edge detection, and region-based segmentation. Many existing solutions focused on a single modality of medical imaging, such as ultrasound or MRI scans [18],[19],[20].

In our research, we analyzed neural network-based algorithms for classifying kidney diseases using CT images. We used the CT Kidney Dataset from Kaggle, which included four image types: Normal, Cyst, Tumor, and Stone. Our model-adapted dataset contained 12,446 image samples, and these are our primary data sources. We applied various preprocessing and augmentation techniques to improve the dataset's quality, including image normalization, rotation, scaling, and flipping. We trained our models using three neural network architectures that are VGG16, MobileNet, and Customized CNN model. Each model evaluated the training process for 20 epochs. The VGG16 model achieved an average accuracy of 89%, while the MobileNet model gained an average accuracy of 91%.
Our Proposed custom CNN model gained an accuracy of 96%.The reaming of the paper arranged as follows: The section presented the various existing models of CKD literature; section 3 provided the main methodology of our model and section 4 comparatively exampled the result of our research.

II. Related work

M. S. Hossain [1] has conducted various neural network approaches to classify and detect kidney diseases based on MRI, ultrasound, and CT scans. They analyzed the diseases of the kidney by summarizing the various medical imaging techniques employed in CKD detection. Subsequently, in this research, the authors focused on the role of machine learning and other advanced technology important in classifying kidney diseases. This study illustrated the utilization of various DeepMedic, ScaleNet, VNet, and HighRes3dNet to enhance CKD prediction. Mehedi et al [2] evaluated kidney-related disease classification using a Deep neural network model. For this, they considered the input dataset samples from MRI and CT scanned images. In this dataset, the total number of images is the 500 NCTT images gathered from Elazing Fethi Sekin City Hospital. In this research, to classify the input data to predict the disease of the kidney, they used a cross-residual network (X-ResNet-50). This model was cloned from the CNN structure and achieved an accuracy of 96.82%.

Chaitanya et al.[3] explored an approach to predict the kidney disease using deep learning models. The dataset used in this study was gathered from Changhua Christian Hospital in Taichung, Taiwan, containing a total of 5617 records. The research introduced a novel system involving a Fuzzy Deep Neural Network combined with deep learning techniques for the recognition and prediction of kidney disease, achieving an accuracy rate of 99.23%.

Almasoud et al.[4] presented a novel deep learning model detection of CKD using neural networks.

In order to determine which traits are more crucial for prediction, the researchers also examined the Recursive Feature Elimination technique. Features are input into classification algorithms. With 90% accuracy, the proposed DNN exceeded the other classifiers, such as SVM and KNN classifier. This study's primary flaw is that it was conducted using small data sets for testing.

Mondol et al. [5] proposed a model to the diagnosis of chronic kidney disease based on CNN and LSTM .This study suggested a hybrid model that automatically classifies chronic kidney disease (CKD) using a two-class data set using CNN and LSTM. Thirteen features made up the data set, and one result was displayed for each feature. Based on the accuracy produced by classifiers such as KNN, SVM, etc., CKD was diagnosed, and the best classifier was chosen for the model. The accuracy of the proposed CNN-LSTM based model was 99.17%. Sarada et al.[6]In order to predict and classify CKD, this study used a variety of clinical parameters associated with the disease and seven cutting-edge deep learning algorithms (ANN, LSTM, GRU, Bidirectional LSTM, Bidirectional GRU, MLP, and Simple RNN). The suggested techniques were used in an artificial intelligence-based manner. This study looked at how well seven DL algorithms predicted CKD. ANN, MLP, and Simple RNN outperformed the other models in terms of accuracy, predicting the disease with a 97% prediction rate.

III. METHODOLOGY

This research aimed to enhance the early detection and accurate diagnosis of chronic kidney disease using advanced neural network algorithms. Our methodology used CT image dataset. The data set consisting of around 12,446 images as our primary source. To enhance the dataset's quality and diversity, we employed various preprocessing and augmentation techniques. Initially, we gathered our dataset from Kaggle termed as follows CT Kidney Dataset .The dataset linked above contains CT scan images. After gathering the necessary CT kidney images, we converted them into JPG format. Following this, we divided the data into two sets: a training set comprising 70% of the images and a test set containing the remaining 30%. This study used various clinical parameters associated with the disease and classification algorithms to predict and classify CKD. We have implemented the VGG16 ,MobileNet and Customized CNN model to classify the disease type of kidney.

A. *Dataset and Preprocessing*

The dataset for our project was sourced from Kaggle and is publicly available. This dataset is split into test and train directories, which are further validated. In total, there are 12,446 CT kidney images in the dataset. The dataset is categorized into four various classes. The distribution of the 12,446 images across the classes is as follows: 3,709 images in the Cyst class, 5,077 in the Normal class, 1,377 in the Stone class, and 2,283 in the Tumor class. The dataset was divided into two sets: a training set comprising 70% of the images and a test set containing the remaining 30%. Subsequently, the training set is further divided into two portions: 90% for actual training and 10% for validation purposes.

Data augmentation involves artificially creating new data from existing data. Following the steps of image resizing and segmentation, we applied data augmentation techniques. We employed the Keras `Image Data Generator` function to create training and validation group of image samples that incorporating various augmentation techniques to enhance the data. By employing these augmentation techniques, we aim to enrich our training dataset, improving the robustness and generalization capability of our model.
Figure 1 shows the sample images of the selected images.

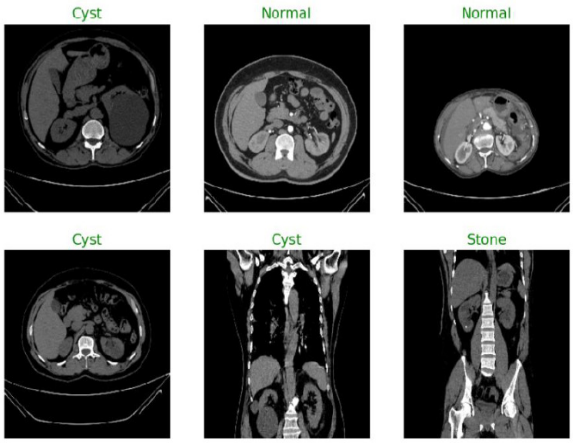

Fig.1. Dataset samples

B. Implementation

VGG16 is a substantial Convolution Network design distinguished for its 19 tiers—16 filtering. Originating from the Visual Geometry Group at the University of Oxford, VGG19 excelled on the ImageNet dataset, comprising numerous labeled images spanning thousands of categories. A defining aspect of VGG19 is its straightforward, consistent architecture. It relies on 3x3 convolutional filters across the network, integrating max-pooling layers to condense spatial dimensions. The network culminates in three thoroughly joined layers, succeeded by a normalized exponential stages for organization. Despite its effectiveness, VGG19 is notably large and computationally demanding.

We have trained the model using Keras by using Batch normalization technique and adam as an optimizer model with no of epochs 10. The graph shows the training and validation loss for a model using VGG16 architecture. The learning divergence is 0.45, and the verification error is 0.15. Next model that we have implemented, Mobile Net lies in its utilization of independent convolutions, which disentangle the spatial convolution kernel from the depth wise convolution.

This approach significantly decreases the computational burden compared to traditional convolutions, where each kernel convolves the input across all channels.

Through this separation, Mobile Net achieves a desirable balance between model size, speed, and accuracy. The Mobile Net algorithm uses adam as an optimizer no of epochs as 15 and a framework of Keras and tensor flow.

Customized Convolutional Neural Network has to locate and detect the kidney disease with maximum accuracy. The Customized CNN prototype comprised a total of 16 layers, including 4 filtering layers with 3x3 filters and and four 2x2 subsampling stages with a progress of 2. Additionally, there is one flattened layer after the last down sampling layer, four Dense layers, and three omission tiers. The first three intense levels consist of 512 nodes 256, 15 nodes, and 128 nodes, respectively, with ReLU activation function. The elimination ratio is 30% for all randomized regularization. The specified images provide information about the loss incurred by the CNN model and the resulting confusion matrix. The implementation of our kidney disease detection website is outlined as follows which was created using Keras,Tensorflow, Flask.

IV. RESULT AND DISCUSSION

The results obtained using CNN are satisfying, and it produced more accuracy than other methods. In our investigation, we used three unique cognitive computing techniques: Vgg16, MobileNet, and Customized CNN. Table -1 in the categorization summary demonstrates that the vgg16 model employed an accuracy of 89%, whereas Mobile Net produced an accuracy of 91%. The proposed Customized CNN model achieved the maximum precision, with an overall accuracy of approximately 96%. Likewise, the precision values for all classes are highest in our proposed CNN model compared to Mobile Net and Vgg16. The Customized CNN model was trained for 20 epochs at a drop-out of 0.4.
To prevent overfitting, it employed a learning rate of 0.001 and utilized ReLU and Softmax activation functions to enhance performance.

The Adam optimizer was used to improve intersection and training efficiency. Figure 2 illustrate the VGG16 model loss and accuracy graphs. Figure 3 shows the MobileNet model loss and accuracy graphs. Figure 4 presented the Custom CNN model loss and accuracy graphs. Figure 5, Figure 6 and Figure 7 are confusion matrixes of VGG6,MobileNet and Custom CNN model respectively. Table 1 presents the various models accuracy and loss results.

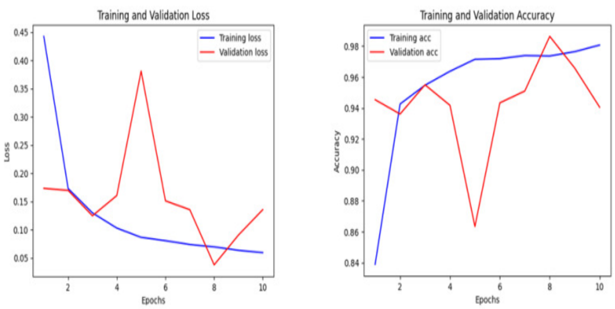

Fig.2. VGG16 model loss and accuracy graphs

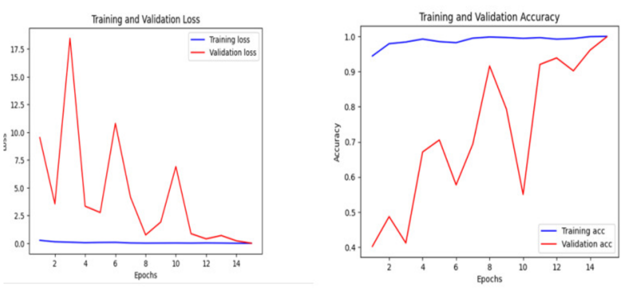

Fig.3. MobileNet model loss and accuracy graphs

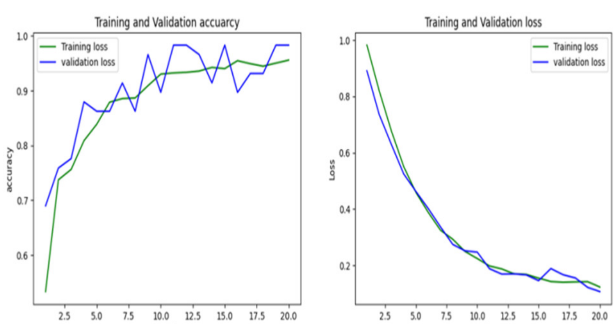

Fig.4. Customized model loss and accuracy

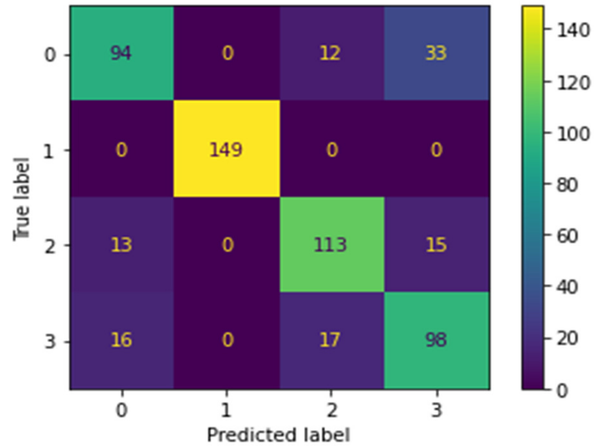

Fig.5. Confusion matrix of VGG16.

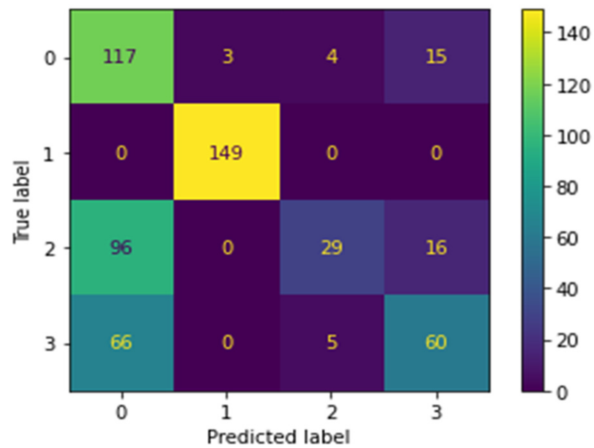

Fig.5. Confusion matrix of MobileNet.

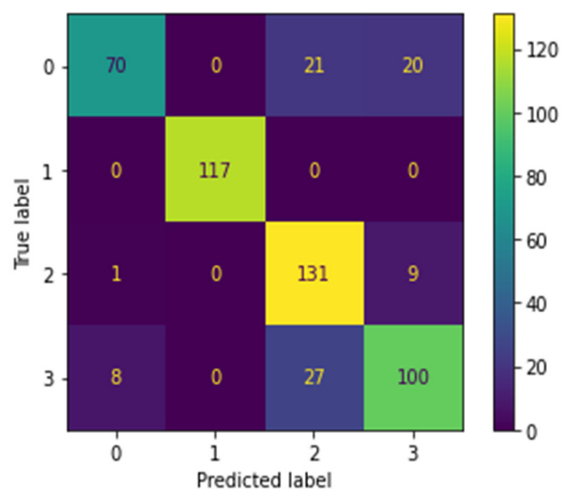

Fig.6. Confusion Matrix of Customized CNN

Table.1. Accuracy and loss values of implemented models.

Model	Loss	Accuracy
VGG16	0.45	89%
MobileNet	0.25	91%
Customized CNN	0.70	96%

V.CONCLUSION

This research exhibited the possibility of advanced neural network methods to improve the early detection and accurate diagnosis of chronic kidney disease by analyzing kidney CT images. Using the publicly available CT Scan dataset from Kaggle, our model classified the Normal,Cyst, Tumor, and Stone-related information of the kidney. In the classification phase VGG16 achieved 89% accuracy, and MobileNet achieved 91%, respectively. However, the customized CNN model achieved an accuracy of 96%.Our future work should further enrich these models, incorporate additional data, and conduct clinical verifications to ensure practical applicability in real-world healthcare.

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