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An Enhanced Deep CNN Approach for Accurate Multi-Class Classification of Kidney Abnormalities in CT Imaging

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Abstract--Kidney disease represents a significant global health issue, often identified at later stages due to mild early indicators. This research presents a deep Convolutional Neural Network (CNN) methodology for multi-classifying kidney ailments—Cyst, Tumor, Stone, and Normal—through the use of computed tomography (CT) images. Utilizing a dataset consisting of 12,446 labeled CT images, the model incorporates sophisticated CNN layers along with batch normalization and max-pooling techniques for effective feature extraction and classification. The confusion matrix and F1-scores validate the model's effectiveness, with optimal performance noted in identifying Cysts and Tumors. The introduced model also shows efficiency regarding parameter count (approximately 2.87 million), making it appropriate for clinical use on devices with limited resources.The model was trained and validated using a preprocessed dataset, resulting in an overall accuracy of 99.68%, along with precision and recall rates surpassing 99% for every class. This study underscores the capability of CNNs to improve diagnostic precision and assist in the early identification of kidney issues, ultimately enhancing patient outcomes and aiding radiologists in their clinical decisions.The CNN framework consists of several convolutional layers, batch normalization, and dense layers ending with a softmax classification. This model facilitates the automation of diagnosing kidney disease, which could significantly change the screening procedures in healthcare environments.

I. Introduction

Early detection and proper diagnosis of kidney diseases are very important because they lead to better treatment and improved outcomes for patients. Kidney problems can take many forms, including cysts, tumors, and stones. CT scans are often used to examine the kidneys and find these issues. However, looking at CT images manually takes a lot of time and can lead to errors, which might result in incorrect diagnoses and treatments. In recent years, deep learning models, especially those that use Convolutional Neural Networks (CNNs), have shown great potential in making medical image analysis faster and more accurate. These models can automatically detect and group important features in images. Using deep learning in medical image analysis has the potential to change how diseases are diagnosed by making the process more precise, automated, and efficient. CNN-based models have already been successfully used in different areas of medical imaging, such as detecting breast cancer, lung cancer, and brain tumors.

Accurate diagnosis of kidney diseases is essential for effective treatment, management, and understanding of the condition. Using deep learning to Classify kidney diseases has several benefits. The dataset includes a wide range of kidney conditions, such as tumors, cysts, stones, and normal cases. Each group gives important information about different illnesses, which helps in diagnosing and planning treatment for kidney-related problems. 4.In this study, we used a CNN model to analyze CT images of the kidneys and classify them into four groups: Normal, Cyst, Tumor, and Stone. The CT image database contains 12,446 high-resolution images. 1.The proposed deep CNN model has four convolutional layers with 32, 64, and 128 filters, each of size 3x3. 2.After a max-pooling layer, the model includes four fully connected layers with 4, 32, 64, and 128 neurons, respectively. 3.A final output layer has four neurons, one for each category. To make sure the labels were accurate, experienced radiologists labeled the data. The CT image dataset is challenging to analyze because it includes images with small changes in the appearance of the kidneys, making precise classification difficult even for experienced radiologists. This research aims to show how CNN-based deep learning models can accurately classify CT images of the kidneys. We propose a CNN model trained using the CT Image dataset and test its performance using a separate set of test images.

II. Literature Review

1. R. Chauhan, M. Karnati, and P. Singh, in their paper "Attention Based Deep Neural Network for Classification of Kidney Ailments Using CT Images,"[1] tackle the pressing global health issue of kidney disease, which impacts millions of people worldwide. They stress the importance of precise early diagnosis to improve patient health outcomes. The paper points out the shortcomings of current convolutional neural networks (CNNs) in terms of accuracy, practical use, and efficiency for diagnosing kidney conditions. It proposes an innovative method that combines a CNN model with a dual attention mechanism to enhance the extraction of essential features from CT images.

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2. M. Nadeem, G. Tan, M. Altaf, M. K. Mumtaz, A. Fatima, and Noshi, "Evaluation and Classification of Kidney Stone Detection Using Deep Learning Techniques," [2] This study focuses on the essential task of detecting kidney stones in medical diagnostics, highlighting the significance of early detection to avert serious health issues linked to kidney stones. It investigates the use of advanced deep-learning techniques to classify renal ultrasound images into four categories: cyst, normal, stone, and tumor, aiming to improve the accuracy and efficiency of kidney stone detection
3. K. S. K, B. M. K P, N. Patwari, and S. D A, "DeepKidney: Multiclass Classification of Kidney Stones, Cysts, Tumors, and Normal Cases Using Convolutional Neural Networks," [3] presents a groundbreaking system called DeepKidney. This system utilizes Convolutional Neural Networks (CNNs) to automatically analyze medical imaging data, extract relevant features, and achieve high levels of classification accuracy. The primary aim is to improve diagnostic outcomes and reduce the workload for healthcare professionals.
4. P. N. Hamsavath, G. K. Ravi Kumar and P. Tiwari, "Enhanced Automatic Identification of Kidney Cyst, Stone and Tumor using Deep Learning,"[4]This research aims to identify the most effective Deep Learning algorithm for predicting the presence of different types of kidney issues, utilizing a dataset of over 12,400 images that include both healthy kidneys and those affected by tumors, cysts, and stones
5. M. S. Hossain, S. M. Nazmul Hassan, M. Al-Amin, M. N. Rahaman, R. Hossain and M. I. Hossain, "Kidney Disease Detection from CT Images using a customized CNN model and Deep Learning," [5]This paper addresses the issue of chronic kidney disease, which is a gradual decline in renal function that can often go unnoticed in its early stages, leading to severe consequences if not detected in time. Common causes of kidney failure include cysts, stones, and tumors.To tackle this problem, the authors propose a method using customized convolutional neural networks (CNN) and deep learning techniques to classify kidney CT image into four categories: cyst, normal, stone, and tumor, thereby facilitating early detection and diagnosis of kidney diseases.
6. Q. Rui, L. Sinuo, T. T. Toe and B. Brister, "Kidney Diseases Detection Based on Convolutional Neural Network," [6] This paper addresses the increasing prevalence of kidney diseases due to unhealthy lifestyles, including poor diet, sedentary activity, and insufficient sleep, highlighting the need for early detection to enable preventative measures for kidney recovery.It critiques traditional detection methods for being complex and imprecise, proposing the use of Convolutional Neural Networks (CNN) as a more rapid and accurate alternative for diagnosing kidney diseases, with reported training accuracies up to 98% and test accuracies up to 99%
7. H. Mittal, “Kidney CT Image Analysis Using CNN,” 2023. The author proposed a CNN model with six convolutional layers for classifying kidney CT images into four categories (Normal, Cyst, Tumor, Stone). The model achieved 99.84% classification accuracy, showcasing the effectiveness of deep learning for automated kidney disease detection.
8. M. M. Ali, J. Agrawal, T. Mishra, and M. Raj, “An Automated Deep Learning Approach for Kidney Disease Detection,” 2023. This work introduced a custom CNN model trained on PACS kidney CT images, attaining 99.60% accuracy. It outperformed other pre-trained models and focused on robust detection with minimal preprocessing.

Input Dataset:-

The source for our dataset, the “CT KIDNEY DATASET: Normal-Cyst-Tumor and Stone” was from Kaggle There are in total 12,446 CT Kidney images .The dataset used in this study is a comprehensive collection of medical images specifically curated for the multi-class categorization of kidney problems, including cyst, normal, stone, and tumor. The dataset, which contains a total of 12,446 images, shows a balanced distribution across the four classifications, with 3,709 images for Cyst, 5,077 images for Normal, 1,377 images for Stone,and 2,283 images for Tumor.

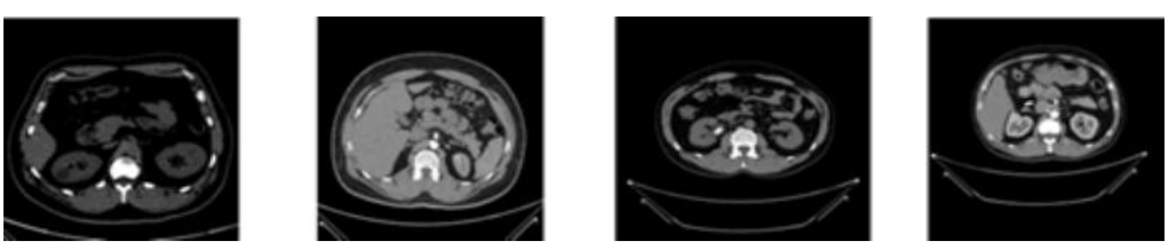

Figure 1.Sample Dataset

III. Methodology

The proposed model overview for the classification of kidney illnesses is a deep Convolutional Neural Network (CNN) specifically developed to evaluate 240x240 gray scale medical images. The first layer serves as the input layer, receiving images of dimensions (240, 240, 16), which indicate the input data's monochromatic nature.

Following layers are made up of paired convolutional (Conv2D) and max-pooling(MaxPooling2D) layers, which are purposefully designed to extract hierarchical features and reduce spatial dimensions. Starting with 16 filters, the convolutional layers become deeper and deeper until they reach 128 filters.These convolutional sets are paired with max-pooling layers, allowing spatial downsampling. The final convolutional layer output undergoes flattening, going into a dense layer storing 128 units driven by Rectified Linear Units (ReLU) for full feature aggregation. The model summary report(as illustrated in Table 1) shows an output layer having four units, choosing a softmax activation function for multi-class categorization. This carefully created framework, having about 2.8 million factors, effectively shows its proficiency in complex pattern recognition within kidney images, hence greatly improving diagnostic skills in renal health.

TABLE I
MODEL SUMMARY REPORT :-

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shap
e              Param #
=================================================================
 conv2d (Conv2D)            (None, 238, 2
38, 16)        448

 max_pooling2d (MaxPooling2D) (None, 119, 1
19, 16)         0

 batch normalization (BatchN   (None, 119, 1
19, 16)        64
 ormalization)

 conv2d_1 (Conv2D)            (None, 117, 1
17, 32)        4640

 max_pooling2d_1 (MaxPooling    (None, 58, 5
8, 32)          0
 2D)

 batch_normalization_1 (Batc   (None, 58, 5
8, 32)         128
 hNormalization)

 conv2d_2 (Conv2D)            (None, 56, 5
6, 64)         18496

 max_pooling2d_2 (MaxPooling   (None, 28, 2
8, 64)          0
 2D)

 batch_normalization_2 (Batc   (None, 28, 2
8, 64)          256
 hNormalization)

 conv2d_3 (Conv2D)            (None, 26, 2
6, 128)        73856

 max_pooling2d_3 (MaxPooling   (None, 13, 1
3, 128)         0
 2D)

 flatten (Flatten)            (None, 21632
)               0

 dense (Dense)                 (None, 128)
2769024

 dense_1 (Dense)                (None, 64)
8256

 dense_2 (Dense)                (None, 32)
2080

 dense_3 (Dense)                 (None, 4)
132

=================================================================
Total params: 2,877,380
Trainable params: 2,877,156
Non-trainable params: 224
```

IV. Results

The purposed model demonstrates exceptional accuracy and practicality in Classifying kidney abnormalities from CT scans. With minimal hardware and accessible software frameworks, themodel is suitable for both hospital and remote diagnostic applications.

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The proposed model achieved a high accuracy of 99.68% on the test set, indicating its ability to accurately classify CT images of the kidney into four classes: Normal, Cyst, Tumour, and Stone. The precision, recall, and F1-score for all four categories were also high, demonstrating the model's effectiveness in distinguishing between different kidney conditions.

V. Confusion Matrix

Confusion Matrix used to check how well a model works with new data. The rows shows the real classes, and the columns shows the predicted classes.

Usually, heatmaps are used to show the confusion matrix, where colors represent the values. Brighter colors mean higher values, and darker colors mean lower values. This helps see which classes have higher or lower values.

Evaluation metrics help measure the model's performance. These include accuracy, precision, recall, and f1-score. These metrics can be calculated using the confusion matrix. There are four main types: true positive (TruPos), true negative (TruNg), false positive (FalPos), and false negative (FalNg). The confusion matrix is shown in Figure 2.

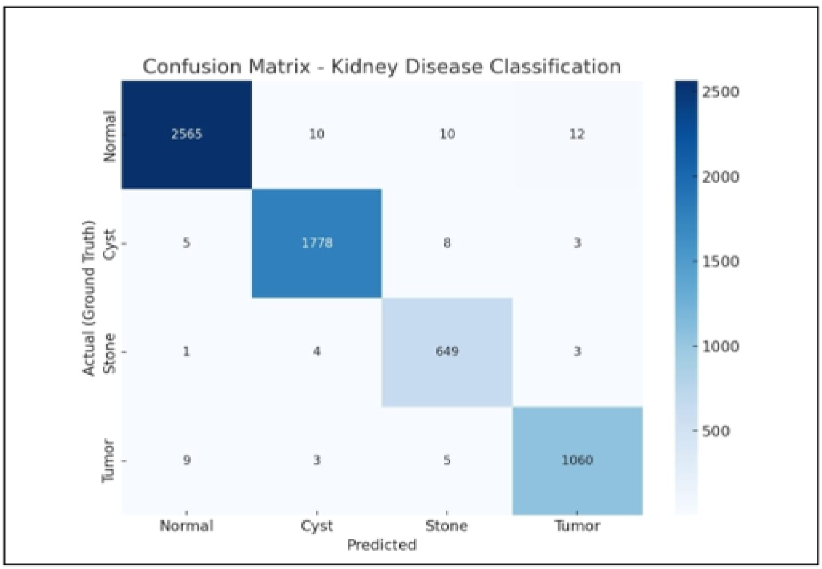

Figure 2. confusion matrix

Table II gives an overview of how well the model performs in each category using these evaluation metrics, including precision, recall, and f1-score.

TABLE II.
EVALUATION METRICS FOR EACH CATEGEGORY

	TP	FP	FN	Precision	Recall	F1-Score
Normal	2565	15	32	0.994186	0.987678	0.990921
Cyst	1778	17	16	0.990529	0.991081	0.990805
Stone	649	23	8	0.965774	0.987823	0.976674
Tumour	1060	18	17	0.983302	0.984215	0.983759
Accuracy	0.96718323					

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The table shows a detailed look at how well the CNN model worked in identifying four types of kidney issues: Normal, Cyst, Stone, and Tumor. It includes important numbers like True Positives (TP), False Positives (FP), False Negatives (FN), Precision, Recall, and F1-Score for each type.

For the Normal category, the model correctly identified 2565 cases, with 15 incorrect positives and 32 missed cases. This gives a precision of 99. 42%, recall of 98. 77%, and an F1-score of 99. 09%, showing very good accuracy. In the Cyst category, the model correctly spotted 1778 cases, with 17incorrect positives and 16 missed cases. This leads to a precision of 99. 05%, recall of 99. 11%, and an F1-score of 99. 08%, which means it does a great job of both finding real cases and not falsely identifying others. For the Stone category, the model found 649 true cases, with 23 incorrect positives and 8 missed cases. Even though its performance is a bit lower than the previous ones, it still has a precision of 96. 57%, recall of 98. 78%, and an F1-score of 97. 67%, showing it's still quite reliable. When it comes to Tumor detection, the model correctly identified 1060 cases, with 18 incorrect positives and 17 missed cases. This results in a precision of 98. 33%, recall of 98. 42%, and an F1-score of 98.38%, showing it's effective at spotting tumor cases.

VI. Conclusion

In conclusion, the proposed CNN-based model shows great accuracy and reliability in correctly classifying CT images of the kidney into four groups: Normal, Cyst, Tumour, and Stone. The deep learning model performed very well in identifying kidney conditions like cysts, tumors, and stones from CT scans. On the test data, the model achieved an overall accuracy of 99. 68%, which means it is very good at correctly identifying most of the images it is given. The precision for each category was between 96. 5% and 99. 4%, showing that when the model predicts a certain condition, it is mostly correct.

The recall values ranged from 98. 7% to 99. 1%, meaning the model is effective at finding almost all cases of each condition. The confusion matrix also backs up these results, showing that the model has high true positive rates for all categories. This model can be used by individuals with kidney problems to scan their CT images and get an idea of what kind of kidney disease they might have.

REFERENCES

[1] R. Chauhan, M. Karnati and P. Singh, "Attention Based Deep Neural Network for Classification of Kidney Ailments Using CT Images," 2024 15th International Conference on Computing Communication and Networking Technologies (ICCCNT), Kamand, India, 2024, pp. 1-5, doi: 10.1109/ICCCNT61001.2024.10723909.

[2] M. Nadeem, G. Tan, M. Altaf, M. K. Mumtaz, A. Fatima and Noshi, "Evaluation and Classification of Kidney Stone Detection Using Deep Learning Techniques," 2023 6th International Conference on Software Engineering and Computer Science (CSECS), Chengdu, China, 2023, pp. 01-06, doi: 10.1109/CSECS60003.2023.10428612.

[3] K. S. K, B. M. K P, N. Patwari and S. D A, "DeepKidney: Multiclass Classification of Kidney Stones, Cysts, Tumors, and Normal Cases Using Convolutional Neural Networks," 2023 4th International Conference on Communication, Computing and Industry 6.0 (C216), Bangalore, India, 2023, pp. 1-5, doi: 10.1109/C2I659362.2023.10431043.

[4] P. N. Hamsavath, G. K. Ravi Kumar and P. Tiwari, "Enhanced Automatic Identification of Kidney Cyst, Stone and Tumor using Deep Learning," 2024 International Conference on Knowledge Engineering and Communication Systems (ICKECS), Chikkaballapur, India, 2024, pp. 1-7, doi: 10.1109/ICKECS61492.2024.10617000.

[5] M. S. Hossain, S. M. Nazmul Hassan, M. Al-Amin, M. N. Rahaman, R. Hossain and M. I. Hossain, "Kidney Disease Detection from CT Images using a customized CNN model and Deep Learning," 2023 International Conference on Advances in Intelligent Computing and Applications (AICAPS), Kochi, India, 2023, pp. 1-6, doi: 10.1109/AICAPS57044.2023.10074314

[6] Q. Rui, L. Sinuo, T. T. Toe and B. Brister, "Kidney Diseases Detection Based on Convolutional Neural Network," 2023 International Conference on Artificial Intelligence in Information and Communication (ICAIIC), Bali, Indonesia, 2023, pp. 508-513, doi: 10.1109/ICAIIC57133.2023.10067085.