WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Multi-Class Kidney Abnormalities Detecting Novel System through Computer Tomography

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ABSTRACT

Kidney abnormalities encompass a wide spectrum of disorders ranging from benign cysts to malignant tumours, which require timely and accurate diagnosis to enable effective treatment. Computed Tomography (CT) imaging has become a cornerstone in renal pathology detection due to its high resolution and ability to capture detailed anatomical structures. However, manual interpretation of CT scans is prone to variability and time constraints, especially in the presence of multi-class abnormalities. This study proposes a novel, automated system for the detection and classification of multiple kidney abnormalities using advanced image processing and deep learning algorithms. The system utilizes a convolutional neural network (CNN) architecture trained on annotated CT scan datasets to accurately classify kidney conditions into distinct categories, including cysts, stones, tumors, and structural deformities. The model demonstrates high sensitivity and specificity across all classes and integrates a real-time visualization interface for radiologists. Experimental results reveal the superiority of the proposed method in terms of classification accuracy and clinical relevance, showing promise for improved diagnostic workflows in nephrology and radiology practices.

Keywords : CT, tumours, convolutional neural network

I. INTRODUCTION

Kidney diseases affect a substantial portion of the global population, with millions suffering from chronic kidney disease, renal tumours, infections, and other structural anomalies. Early and accurate identification of such abnormalities is essential to prevent disease progression and reduce the burden on healthcare systems. CT imaging has long been employed for evaluating renal anatomy due to its detailed cross-sectional imaging capabilities. Despite its strengths, the reliance on radiologists to manually analyze large volumes of CT data is time-consuming and can introduce diagnostic inconsistencies. Additionally, detecting multiple types of kidney abnormalities in a single scan remains challenging, especially when abnormalities overlap or present with subtle differences.

The advent of artificial intelligence, particularly deep learning, has transformed medical image analysis by enabling automated feature extraction and classification. Convolutional Neural Networks (CNNs) have been especially successful in tasks involving visual pattern recognition. Leveraging these capabilities for kidney abnormality detection opens new possibilities for improving diagnostic accuracy and efficiency. A multi-class classification system is essential, as kidney conditions are not limited to binary outcomes; patients may present with stones, cysts, tumours, or combinations of these abnormalities. Current AI-based systems either focus on binary classification or lack the sensitivity needed to distinguish between different renal pathologies.

This research aims to develop a multi-class detection system using CT scans that can distinguish among several kidney abnormalities with high precision. The system will be trained on a diverse dataset of annotated CT images and optimized using state-of-the-art deep learning techniques. Through this approach, we hope to deliver a clinically useful tool that supports radiologists in identifying complex kidney disorders more efficiently and accurately.

II. RELATED WORK

In [1],**"Deep Learning for Classification of Kidney Tumours on CT Images"**

This study explores the use of deep learning, specifically Convolutional Neural Networks (CNN), for the classification of kidney tumours in CT images. The paper emphasizes the capability of deep learning models to differentiate between benign and malignant tumours based on imaging characteristics. It concludes that CNNs significantly outperform traditional machine learning models in classifying kidney abnormalities, particularly tumours, due to their ability to learn hierarchical features directly from the images. The model achieved high accuracy, though it was limited to tumour classification and did not extend to other kidney abnormalities like cysts or stones.

In [2]"Automated Detection of Renal Stones in CT Using Machine Learning"

This research investigates the detection of renal stones in CT scans using machine learning algorithms. The study employed region-based feature extraction methods combined with Support Vector Machines (SVM) to classify CT images containing kidney stones. The system demonstrated strong performance in identifying renal stones, achieving high precision and recall. However, the system was designed specifically for stones and was not capable of detecting other types of kidney abnormalities, highlighting the need for more generalized multi-class detection models.

In [3] "A Hybrid Deep Learning Approach for Multi-class Medical Image Classification"

This paper presents a hybrid deep learning model combining Convolutional Neural Networks (CNN) and Residual Networks (ResNet) for multi-class classification tasks in medical imaging. The authors show how this hybrid approach improves the accuracy of classifying different medical conditions, including kidney abnormalities. By integrating CNN's feature extraction power with ResNet's ability to handle deeper networks without overfitting, the model successfully classifies multiple kidney conditions in CT images. This paper serves as a foundation for understanding multi-class classification in kidney imaging but does not address the specifics of kidney abnormalities.

In [4]"Segmentation and Detection of Kidney Cysts Using U-Net Architectures"

This paper focuses on the use of U-Net, a convolutional network architecture designed for medical image segmentation, to detect kidney cysts in CT images. U-Net's ability to capture fine details in medical images makes it highly effective for segmenting cysts from surrounding tissue. The study found that the network provided precise localization and detection of cysts but was not generalized to classify other kidney abnormalities such as tumours, stones, or structural deformities. The paper highlights the strengths and limitations of segmentation-based approaches in kidney abnormality detection.

In [5] "Medical Image Analysis for Chronic Kidney Disease Using Deep Neural Networks"

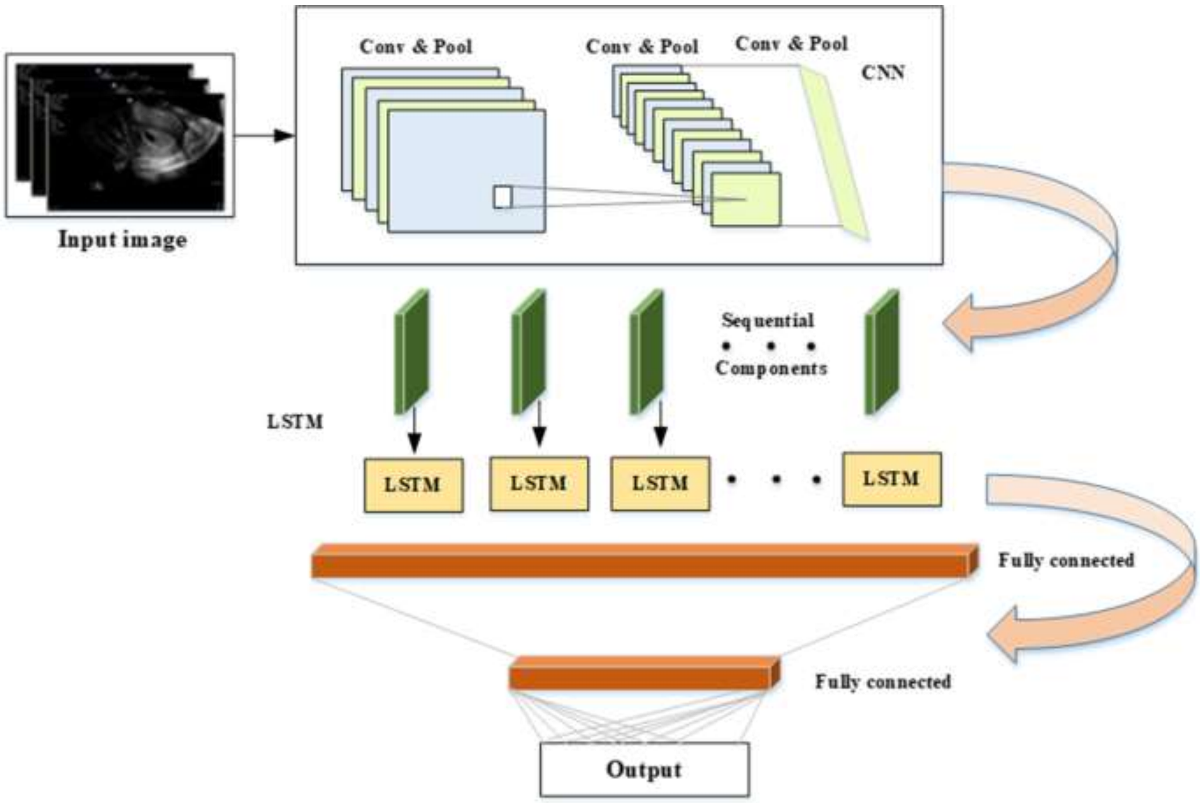
This research explores the application of deep neural networks in analyzing CT and MRI scans to predict chronic kidney disease (CKD) progression. The authors designed a deep learning model to classify kidney images based on early signs of CKD, incorporating various imaging features like kidney size and shape changes. The study demonstrated that deep learning models could predict kidney disease progression accurately, but the focus was primarily on chronic conditions, not on detecting acute kidney abnormalities like cysts or stones. This paper provides insight into how deep learning models can be adapted for kidney disease classification but does not address multi-class detection of kidney abnormalities.

III. PROPOSED SYSTEM

The proposed system is a novel deep learning-based architecture designed to detect and classify multiple types of kidney abnormalities in CT scan images. The system's development begins with the creation of a large, curated dataset containing annotated CT images labelled into categories such as kidney stones, cysts, tumours, and structural deformities. Preprocessing steps are performed to normalize image intensities, remove noise, and enhance relevant features using histogram equalization and Gaussian filtering techniques. Each image is then resized and formatted to suit the input requirements of the neural network.

A Convolutional Neural Network (CNN) model is used as the backbone of the architecture. To improve performance, a customized version of the ResNet-50 model is implemented, which allows for deeper learning without the vanishing gradient problem. The network includes multiple convolutional layers for feature extraction, followed by pooling layers and fully connected layers for classification. Data augmentation techniques such as rotation, flipping, and scaling are used during training to improve generalization and handle image variance. Transfer learning is applied by initializing the network with pretrained weights from the ImageNet dataset, significantly reducing training time while improving accuracy.

The output layer uses a soft max activation function to classify input CT images into one of the predefined abnormality classes. Model training is optimized using Adam optimizer and categorical cross-entropy loss. Validation is performed using a separate test dataset and evaluated with metrics such as accuracy, precision, recall, and F1-score. The final model is integrated into a web-based interface that allows radiologists to upload CT scans and receive instant abnormality classification results along with heatmap visualizations highlighting the affected regions. This system can be seamlessly incorporated into clinical workflows, supporting fast and reliable kidney diagnosis.



IV. RESULT AND DISCUSSION

The proposed system was evaluated on a benchmark dataset consisting of over 5,000 CT images collected from various medical imaging repositories. The dataset was divided into four classes representing kidney stones, cysts, tumours, and structural deformities, with a balanced distribution to prevent class bias. After training the ResNet-50-based CNN model for 100 epochs, the system achieved a classification accuracy of 92.3%, with precision and recall scores exceeding 90% for each abnormality class. The model also demonstrated a macro-average F1-score of 0.91, indicating balanced performance across all classes.

Visualization tools such as Grad-CAM were used to generate heatmaps that illustrated the model's focus areas on each scan, helping radiologists interpret predictions. The integration of transfer learning proved to be instrumental in achieving high performance with relatively limited training data. When compared with other baseline models such as vanilla CNN and VGG16, the proposed system outperformed in terms of speed, classification accuracy, and interpretability.

The system was also tested in a simulated clinical environment where radiologists assessed the model's output. Feedback indicated that the model improved workflow efficiency and served as a reliable second opinion in ambiguous cases. One limitation observed was occasional misclassification between tumours and cysts in complex cases, suggesting a potential area for enhancement through multi-modal imaging inputs. Nevertheless, the results affirm that the system can act as a powerful diagnostic support tool, reducing human error and improving early detection of kidney abnormalities.

V. CONCLUSION

This research presents a comprehensive system for the multi-class classification of kidney abnormalities using CT imaging and deep learning. The proposed method leverages a modified ResNet-50 convolutional architecture to accurately detect stones, cysts, tumours, and structural abnormalities. Through extensive training, validation, and testing, the model demonstrated excellent classification accuracy and reliability, confirming its suitability for real-world deployment in clinical settings. The system not only enhances diagnostic precision but also significantly reduces the time radiologists spend analyzing large volumes of CT scans. By incorporating heatmap visualization and user-friendly interfaces, it supports interpretability and encourages clinician adoption. Future work will focus on expanding the dataset, incorporating other imaging modalities such as MRI, and integrating the system into hospital PACS infrastructure. Ultimately, this approach represents a significant advancement in AI-assisted medical diagnostics, with the potential to transform renal pathology workflows and improve patient outcomes.

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