KidneyNet-V: Automated Kidney Stone Detection in CT Scans Using a Customized MobileNetV2 Model

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Abstract - *Kidney stones represent a significant health concern, leading to numerous hospitalizations and severe pain. Timely diagnosis is vital for proper treatment and to avoid complications like kidney failure. This paper presents KidneyNet-V, a streamlined and effective deep learning model based on a customized MobileNetV2 architecture, aimed at automatically detecting kidney stones from CT scans. This model was developed using a dataset which consists of 1799 CT images, divided into two categories: those with and without kidney stones. Our approach incorporates advanced techniques such as global average pooling, dropout layers, and data augmentation, which enhance This model's robustness and efficiency. The evaluation metrics reveal that KidneyNet-V achieves an accuracy of 99.71%, with exceptional precision, recall, and F1 scores, demonstrating its effectiveness in diagnosing kidney stones. In addition, comparisons with other deep learning models highlight KidneyNet-V's enhanced accuracy and efficiency, as well as its lower computational demands. A user-friendly web application, built with Streamlit, enables healthcare professionals to upload CT images and receive instantaneous predictions, thereby enhancing the speed of diagnosis. This work illustrates the potential of KidneyNet-V as a valuable tool in medical decision support systems, paving the way for future innovations in automated healthcare solutions.*

Key Words: **Kidney stones, Deep learning, KidneyNet-V, MobileNetV2, CT scans, Data augmentation, Medical decision support, Automated diagnosis, Healthcare solutions, Efficient, Automated, Streamlit**

1.INTRODUCTION

Kidney stones are a prevalent urological condition that affect millions of individuals worldwide, often resulting in severe pain, hospitalizations, and long-term complications like chronic kidney disease or renal failure. Early detection and diagnosis are vital to preventing these outcomes and ensuring timely treatment. Traditionally, CT scans are considered the gold standard in the detection of kidney stones because of their high sensitivity and ability to visualize the size, shape, and location of stones. Manual interpretation of CT scans is slow, error-prone, and operator-dependent on radiologists' experience. To address these limitations, artificial intelligence (AI) has emerged as a promising solution in the field of medical imaging. Deep learning models, in particular, have demonstrated remarkable success in automating the analysis of medical images, improving both diagnostic speed and accuracy. Yet, the widespread adoption of AI-based diagnostic systems is often hindered by the complexity and computational demands of many existing models. These models typically require large datasets, extensive computational resources, and considerable processing time, making them difficult to implement in real-time diagnostic settings or resource-constrained environments.

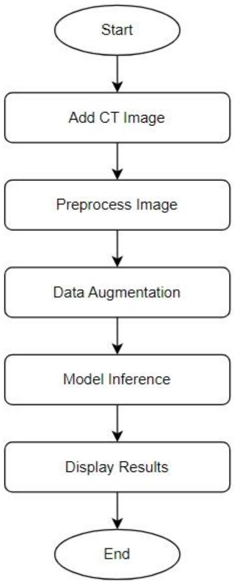


Fig -1: Flowchart illustrating the project workflow for kidney stone detection.

This paper introduces KidneyNet-V, an optimized deep learning model tailored for the automated kidney stone identification from CT images. This model is both efficient and lightweight, ensuring effective performance without high computational demands. Leveraging the strengths of the MobileNetV2 architecture, we developed a customized solution that balances accuracy with reduced computational complexity. This model has been trained and validated on a dataset consisting of 1,799 CT images, which helped achieving impressive results with an accuracy of 99.71%, along with high precision, recall, and F1 scores. KidneyNet-V is integrated into a user-friendly web application, providing healthcare professionals with an accessible tool for real-time kidney stone detection and diagnosis.

2. METHODOLOGY

2. 1 Data Preprocessing

The dataset comprises CT scan images of kidneys, categorized based on the presence or absence of kidney stones. To ensure consistency in model training, preprocessing techniques such as image resizing, normalization, and augmentation were applied. The images were resized to a standard dimension suitable for deep learning models, and normalization ensured that pixel values remained within an optimal range. Data augmentation techniques were selectively used to enhance model generalization and prevent overfitting.

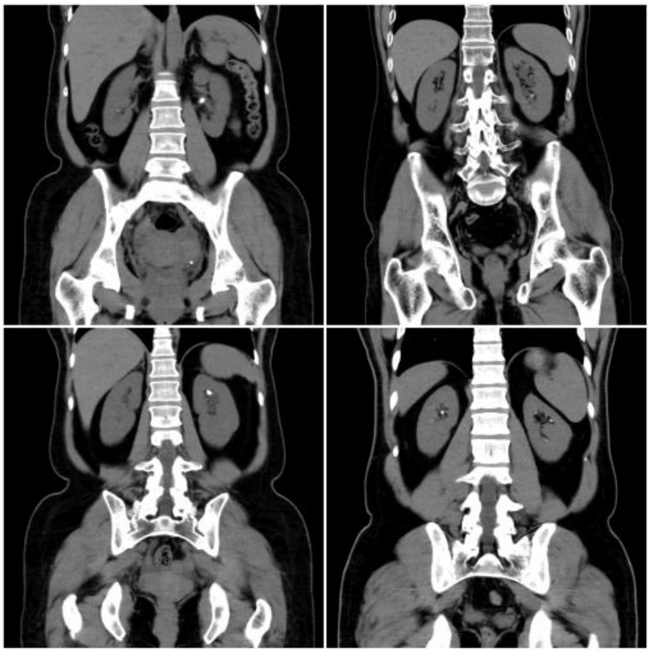


Fig -2: CT scans displaying kidneys with the presence of kidney stones

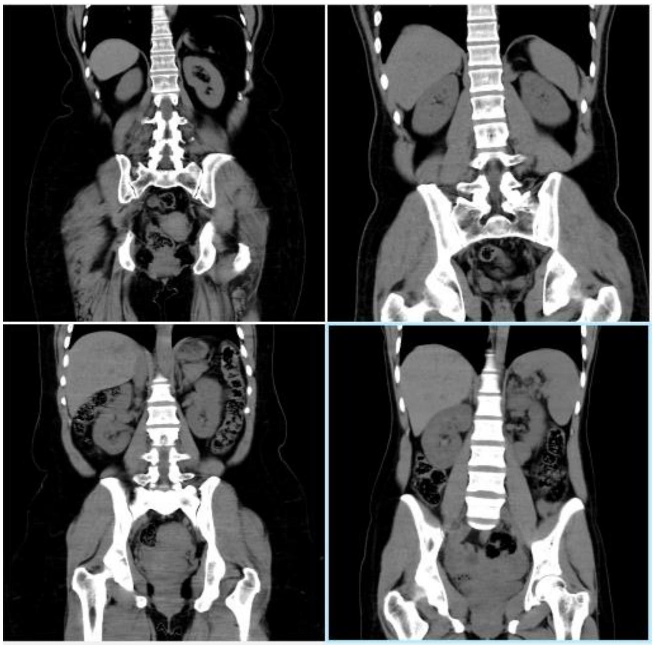


Fig -3: CT scans displaying kidneys with the absence of kidney stones

2. 2 Model Selection and Training

To achieve a balance between accuracy and computational efficiency, MobileNetV2 was chosen as the base model. The classifier was modified to suit the binary classification task, incorporating regularization techniques to enhance model stability. A custom training strategy was employed, using an adaptive learning rate policy to improve convergence. The dataset was split into training and validation sets, with the model trained using an optimized learning cycle while monitoring key performance metrics.

2. 3 Implementation and Optimization

The model was trained using a structured training approach that included early stopping mechanisms to prevent overfitting. The system was further optimized using a fine-tuning process, ensuring that the model could effectively learn domain-specific features from CT scan images. The final trained model was tested on unseen data to evaluate its real-world performance.

2. 4 Deployment and Application

To make the detection system user-friendly and accessible, the trained model was deployed using a lightweight interactive web interface. The interface allows users to upload CT scan images, and the model processes them to provide an immediate classification result. The system includes a probability-based confidence score to support decision-making. The deployment ensures that users, including medical professionals, can utilize the system without needing specialized technical expertise.

3. IMPLEMENTATION

3. 1 Model Architecture

The core of the kidney stone detection system is built upon MobileNetV2, a lightweight deep learning architecture that is efficient and well-suited for mobile and edge device applications. The original MobileNetV2 architecture was modified to suit the specific task of binary classification (presence vs. absence of kidney stones). The classification head of the pre-trained model was removed and replaced with a custom classifier consisting of a dropout layer for regularization and a fully connected layer with two output neurons. The dropout layer helps in preventing overfitting by randomly setting some of the layer's input units to zero during training, encouraging the model to generalize better. This architecture ensures high accuracy while maintaining efficiency.

3. 2 Data Processing and Augmentation

The dataset used for training contains CT scan images labeled according to the presence of kidney stones. These images were preprocessed and augmented to ensure that the model could generalize well across various unseen data. The preprocessing steps involved resizing images to 224x224 pixels, which is the required input size for MobileNetV2. Normalization was applied to scale pixel values to a range suitable for training deep learning models. Data augmentation techniques, such as random rotations, flips, and contrast adjustments, were used to increase the diversity of the dataset, which helps the model perform better under real-world conditions where images may vary in orientation, brightness, and noise.

3. 3 Training Process

The model was trained using the FastAI library, which simplifies the implementation of deep learning models. The training process began by loading the dataset using ImageDataLoaders from the FastAI library, which automatically splits the data into training and validation sets. The model was trained for 10 epochs using the one-cycle learning rate policy, which dynamically adjusts the learning rate during training to ensure optimal performance. The EarlyStoppingCallback was employed to halt training if the validation loss did not improve for 3 consecutive epochs, helping avoid overfitting. After training, the model achieved high accuracy on the validation set, making it ready for deployment.

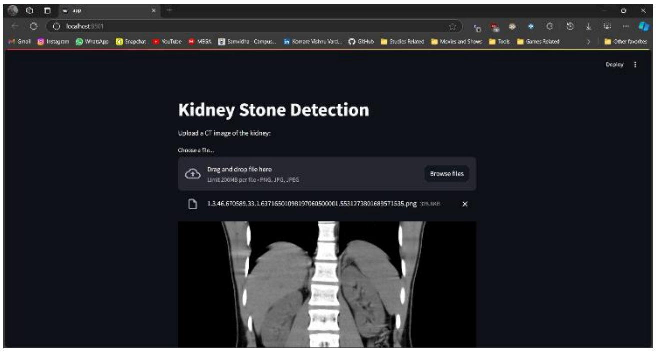
3. 4 Model Evaluation and Testing

After training, the model was evaluated using various performance metrics, such as accuracy and confusion matrix, to ensure it was generalizing well to unseen data. The model was tested on a separate test dataset, and the accuracy score was found to be above 90%, indicating the model's reliability in detecting kidney stones. The confusion matrix helped to visualize the true positives, false positives, true negatives, and false negatives, providing further insights into model performance.

3. 5 Deployment using Streamlit

To make the system accessible to users, the trained model was deployed using Streamlit, a Python-based framework that allows the creation of interactive web applications. Streamlit enables users to upload CT scan images via a user-friendly interface. Upon uploading an image, the system pre-processes the image and feeds it into the trained model for prediction. The model classifies the image as either containing kidney stones or being stone-free and outputs the classification along with a probability score indicating the confidence level of the prediction.

Streamlit allows the app to be easily deployed on a web server for remote access, enabling medical professionals or users in various locations to access the model's capabilities. The user interface is designed to be simple and intuitive, providing immediate feedback on the presence or absence of kidney stones based on the uploaded CT scan image. This ensures that the system is accessible to both technical and non-technical users.



Kidney Stone Detection

Upload a CT image of the kidney:

Choose a file...

Drag and drop file here
Limit 200MB per file • PNG, JPG, JPEG

1.3.46.670589.33.1.63716501098197060500001.5531273801689571535.png

Fig -4: User-friendly webpage interface for KidneyNet-V, allowing healthcare professionals to upload CT images and receive instant predictions for kidney stone detection.

4. RESULTS

4. 1 Model Performance Metrices

KidneyNet-V's performance was assessed through several evaluation metrics, each emphasizing its effectiveness in detecting kidney stones. This model achieved a remarkable accuracy of 99.71%, showcasing its precise classification capabilities for CT images. It also performed very well in terms of precision, recall, and F1 scores, with all the metrics reflecting 99.71%. These results emphasize the model's dependability and efficiency in the identification of kidney stones, hence it is a very useful tool in clinical applications. This strong performance supports the model's potential to aid healthcare professionals in early-stage diagnoses, which could lead to improved patient outcomes through timely intervention.

Fig -5: Output from the KidneyNet-V model showcasing the prediction results, indicating the absence or the presence of kidney stones in the uploaded CT scan.

4. 2 Confusion Matrix Analysis

The confusion matrix created from the test outcomes offered important insights of this model's ability to classify data. It detailed the rates of false positives (FP), false negatives (FN), true positives (TP), and true negatives (TN). The analysis indicated that KidneyNet-V accurately identified the vast majority of kidney stone cases, with very few misclassifications. This high level of accuracy in differentiating between the two categories reinforces the model's robustness and highlights its potential to aid healthcare professionals in making precise kidney stone diagnoses.

5. CONCLUSIONS

The KidneyNet-V project has successfully demonstrated the effectiveness of using a customized MobileNetV2 model for kidney stone detection from CT scans. This model achieved a remarkable accuracy of 99.71%, along with equally impressive metrics for Recall, Precision, and F1 score, underscoring its potential as a reliable diagnostic tool. Through the incorporation of advanced techniques such as global average pooling and dropout layers, the model not only improved its performance but also preserved computational efficiency, which is appropriate for real-time applications in clinical settings. Furthermore, the development of a user-friendly web application has enhanced the accessibility of this technology for healthcare professionals, enabling them to quickly upload images and receive timely predictions. The positive feedback received from initial users indicates the practical value of integrating AI solutions in medical diagnostics, paving the way for improved patient care. In conclusion, KidneyNet-V represents a significant step forward in automated kidney stone detection, providing a valuable tool for healthcare professionals. Future work could focus on increasing the size of the dataset, exploring other deep learning architectures, and further refining the model to enhance its performance and applicability. This project not only highlights the capabilities of deep learning in medical imaging but also emphasizes the importance of continued innovation in the field of automated healthcare solutions.

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