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Streamlining Kidney Stone Detection through Image Processing and Deep Learning

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Abstract: In this paper an automated system for precise kidney stone identification in computed tomography CT scans is introduced. The system consists of two essential components custom CNN for image classification and fuzzy c-means FCM clustering for localizing stones, the CNN architecture is trained to classify kidney CT scans as normal or abnormal scans based on a dataset collected from Kaggle. Subsequently FCM clustering is then applied on the abnormal images to automatically detect and localize kidney stones by segmenting pixels of the same intensity. This computer-assisted method applying machine learning-based image processing should yield better accuracy over traditional manual techniques like thresholding filtering and edge detection. By automating the detection process this system aims to provide radiologists and urologists with an effective tool for rapid and accurate identification of kidney stones enabling effective and timely patient care. The project is simulated and implemented on MATLAB software.

Keywords: *Kidney Stones, Image Processing, CT Image, CNN, Deep Learning Algorithm, Classification, Accuracy.*

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I. INTRODUCTION

Renal calculi or kidney stones, are a critical health problem which causes severe pain and complications. If they are not appropriately treated these solid objects that are mostly crystals need on time and accurate diagnosis in order to be able to manage the patient properly. Computed Tomography CT scan is a well-established cornerstone of the diagnosis of kidney stones with accurate anatomical imaging interpreting. The CT image however is still hampered by native noise and by the complex architecture of renal tissues making it prone to error and longer reading time.

When performed manually the necessity for computerized systems in medical imaging, particularly in kidney stone detection is brought into focus by manual interpretation limitations. As noted in current studies application of manual methods can lead to variable diagnostic accuracy and performance. This is particularly essential in emergency situations where speed and precision of diagnosis are paramount. Increasing prevalence of urolithiasis and resultant growth in the use of CT imaging further points towards the requirement for computerized systems. This research aims to address such limitations by developing an automatic kidney stone detection system on CT images. The system presented here is a mixture of deep learning and fuzzy clustering techniques to enhance diagnostic efficiency and accuracy preliminary classification of the CT images is done using a convolutional neural network CNN. Dividing the scans into normal and abnormal ones fuzzy c-means FCM clustering is applied to detect kidney stones from the abnormal images automating the detection process. The system seeks to provide radiologists and urologists with an efficient tool for rapid and accurate detection of kidney stones ultimately improving patient care. The implementation of the system is done employing MATLAB a popular tool for medical image processing and analysis.

II. LITERATURE SURVEY

The area of kidney stone detection via medical imaging has witnessed extensive research by scientists, while traditional methods of diagnosis have proven useful their reliance on human interpretation introduces variability and delay advances in image processing. Deep learning have opened the door to more computerized and precise detection methods. Different research works have investigated traditional as well as machine learning-based approaches for the detection of kidney stones. For instance, image processing methods were used by Jamkhandikar and colleagues. Using image processing techniques, Suresh M.B. and M.R. Abhishek [1] also looked into renal stone identification. So as to automatically detect kidney stones, Manoj, B., Neethu Mohan, and Sachin Kumar [2] utilised deep models. Convolutional neural networks for deep learning medical image analysis has changed dramatically as a result of CNN. A deep learning model based on VGG16 was proposed by Valarmathi, N., et al. [3] for kidney stone computer-aided

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detection. Additionally, the use of a fully automated deep learning system for bone age estimation highlighting was investigated by Lee H. Tajmir et al [7]. The potential of such systems in medical imaging diagnosis based on NHANES data, this study put into the limelight the growing incidence of kidney stones particularly among childbearing women. The total space of deep learning technologies and application is ever increasing. With deep learning being a form of neural networks characterized by more layers enabling more abstraction and improved prediction of data CT imaging, while a powerful diagnostic tool is difficult with high speckle noise which necessitates the development of automated detection systems. A number of kidney abnormalities, such as limb changes in shape and position, swelling stone formation, cysts, urinary obstruction, congenital abnormalities, and cancers, can be diagnosed with this modality.

The increasing use of CT scans for suspected urinary tract stones is bolstered by national trends and diagnoses [4]. Furthermore, emergency department utilization and imaging for urolithiasis have been discovered to increase [5] use of CT in emergency rooms and the time constraints affecting use of CT have been investigated.

III. SYSTEM ANALYSIS AND DESIGN

Acknowledging the limitations of VGG16 i.e, high computation overfitting and inferior performance on our specific dataset, we developed an in-house Convolutional Neural Network CNN with optimizations for improved efficiency and performance. Our internal CNN has fewer parameters and layers than VGG16 but is architecturally optimized with a focus on task-specific feature learning through specialized initial layers. We used regularization techniques such as batch normalization and optimally tuned activation functions in an attempt to eliminate overfitting. Development is done through intensive testing by relevant measures followed by continuous fine-tuning based on what is observed in performance, so that the resulting CNN will be more accurate.

➢ *Proposed System*

Steps in the Proposed Method:

- CT images are extracted from the publicly accessible Kaggle dataset.
- Preprocessing is required for correct image analysis to improve image clarity and remove unwanted details.
- After preprocessing, a customised CNN is used to determine whether the kidney CT images are normal or abnormal. A median filter is used to eliminate noise, and adaptive histogram equalisation is applied to improve contrast.
- For abnormal images fuzzy c-means FCM clustering is employed to identify potential kidney stones.

IV. IMPLEMENTATION

➢ *Modules:*

The following modules comprise the kidney stone detection system's structure.

- *Acquisition of Images*
- *Preprocessing*
- *Classification*
- *Kidney stone detection*

➢ *Descriptions of Modules:*

- *Acquisition of Images:*

✓ This module obtains kidney CT images from a source to begin the process.
✓ It is the starting point for the image processing pipeline providing the input to subsequent operations.
✓ Kidney CT images in this implementation are drawn from a public database.

- *Preprocessing:*

✓ This module prepares the images obtained for analysis by performing required preprocessing operations.
✓ Preprocessing is necessary to enhance image quality and the precision of subsequent modules.
✓ Reduction of noise is achieved by applying a median filter which smooths the image efficiently.
✓ Adaptive histogram equalisation, which locally modifies the image's contrast to enhance fine details, is used to achieve contrast enhancement.

- *Classification:*

✓ A convolutional neural network with a unique design After that, kidney CT images are classified and features are extracted using CNN.
✓ After preprocessing this specially designed CNN is trained on a dataset to recognize patterns and distinctions between normal and abnormal images.
✓ The training parameters, such as the number of epochs, learning rate, and mini-batch size, are chosen and the network architecture is fixed. Training is then conducted using the trained data and the predetermined parameters to label kidney CT images.
✓ The trained custom CNN then uses the learnt features to classify test kidney images as normal or abnormal.

- *Kidney Stone Detection:*

✓ Kidney stone detection is initiated after the classification step.
✓ Fuzzy c-means (FCM) clustering is applied to the classified abnormal kidney CT images to identify potential stone locations.
✓ Clustering analysis is utilized to categorize pixels with similar attributes aiming to achieve cluster homogeneity.
✓ Pixels belonging to a cluster are alike and data heterogeneity.
✓ Pixels of different clusters are dissimilar the FCM algorithm being fuzzy optimization-based repeatedly

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partitions the image pixels allocating each pixel a membership value to different clusters.

- ✓ The resulting fuzzy image segmentation is then subjected to morphological operations to isolate and identify the region of the kidney stone.

V. SYSTEM DESIGN

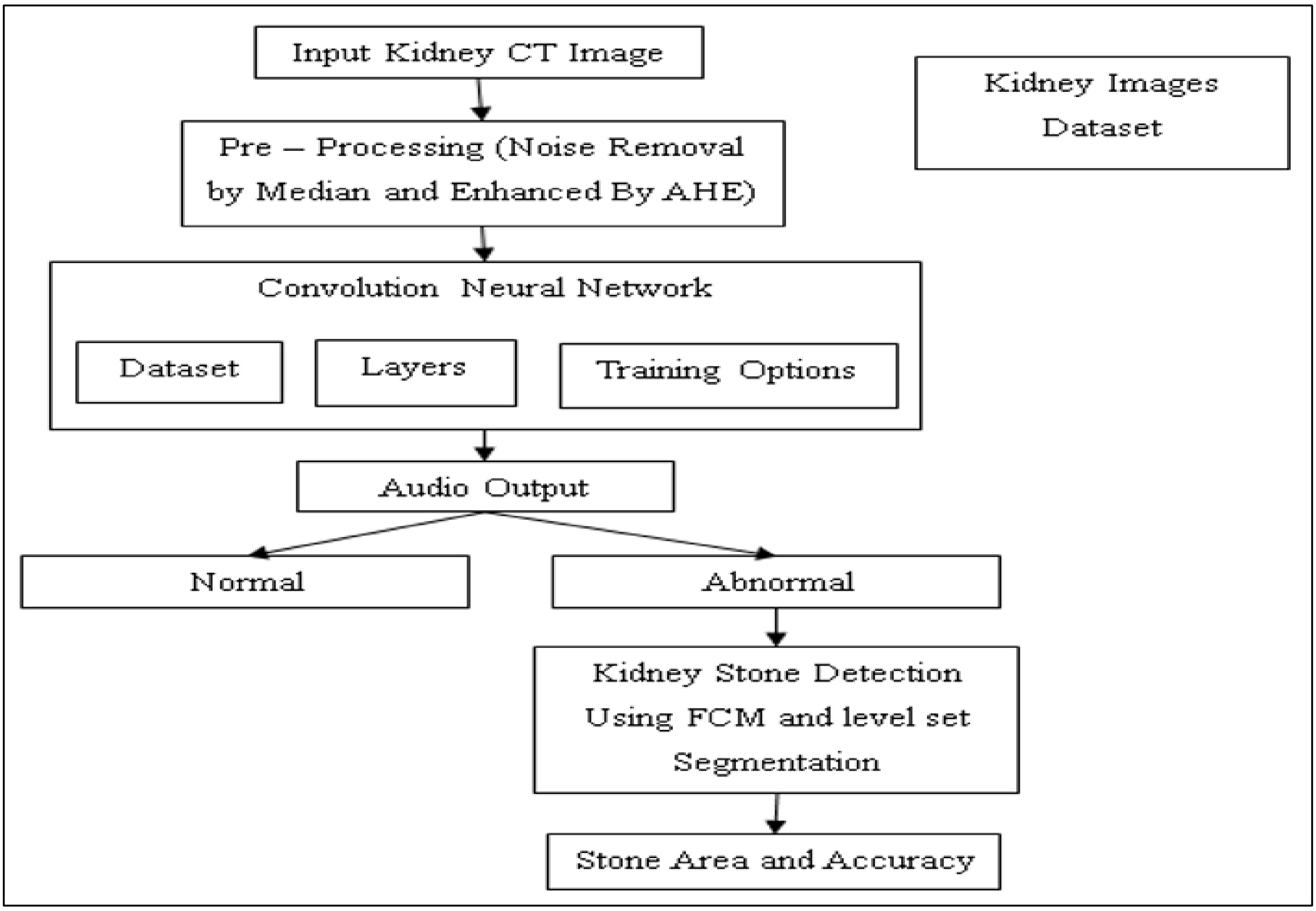

Fig 1 Architecture of the System

VI. OUTPUT

- ➢ *Normal Condition*

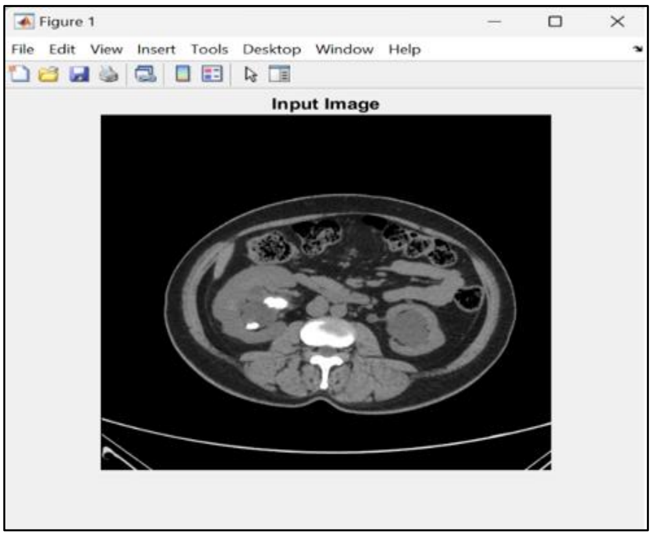

Fig 2 Input Image

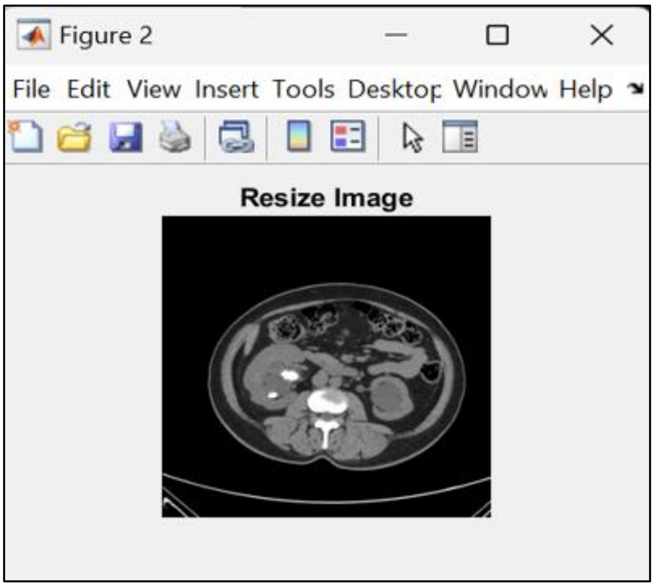

Fig 3 Resized Image

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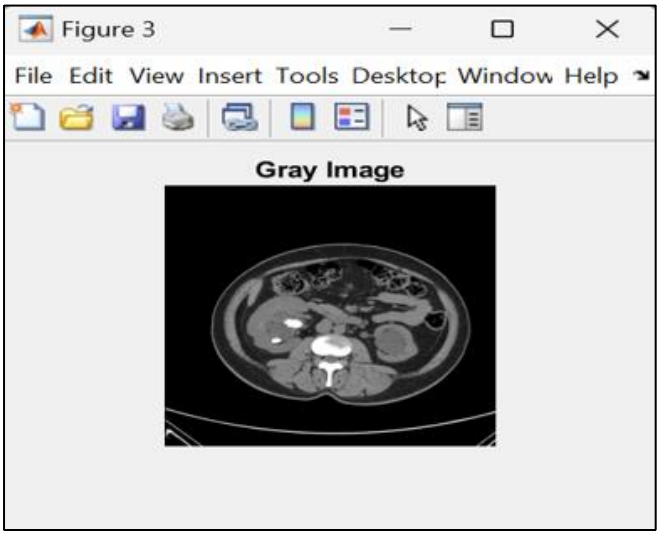

Fig 4 Gray Image

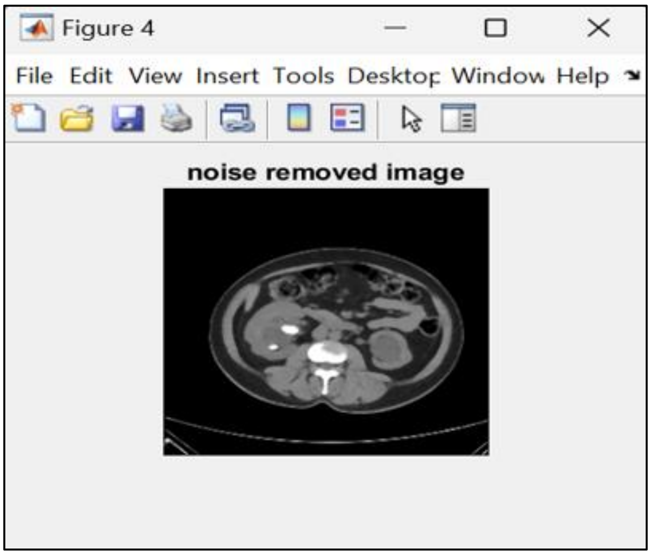

Fig 5 Noise Removed Image

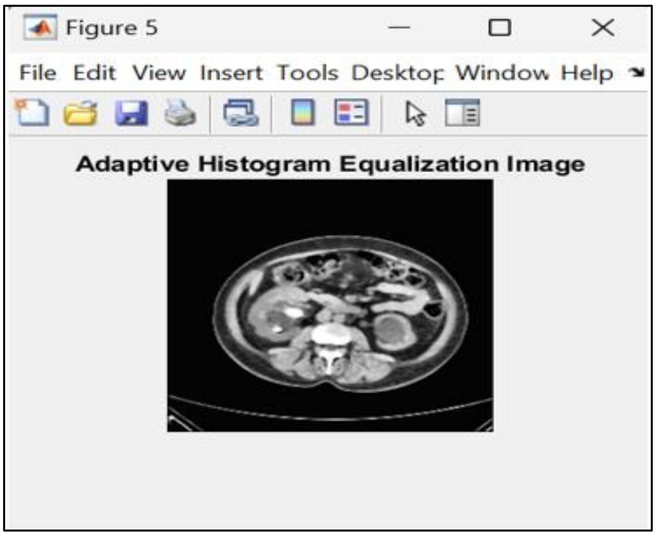

Fig 6 Adaptive Histogram Equalization Image

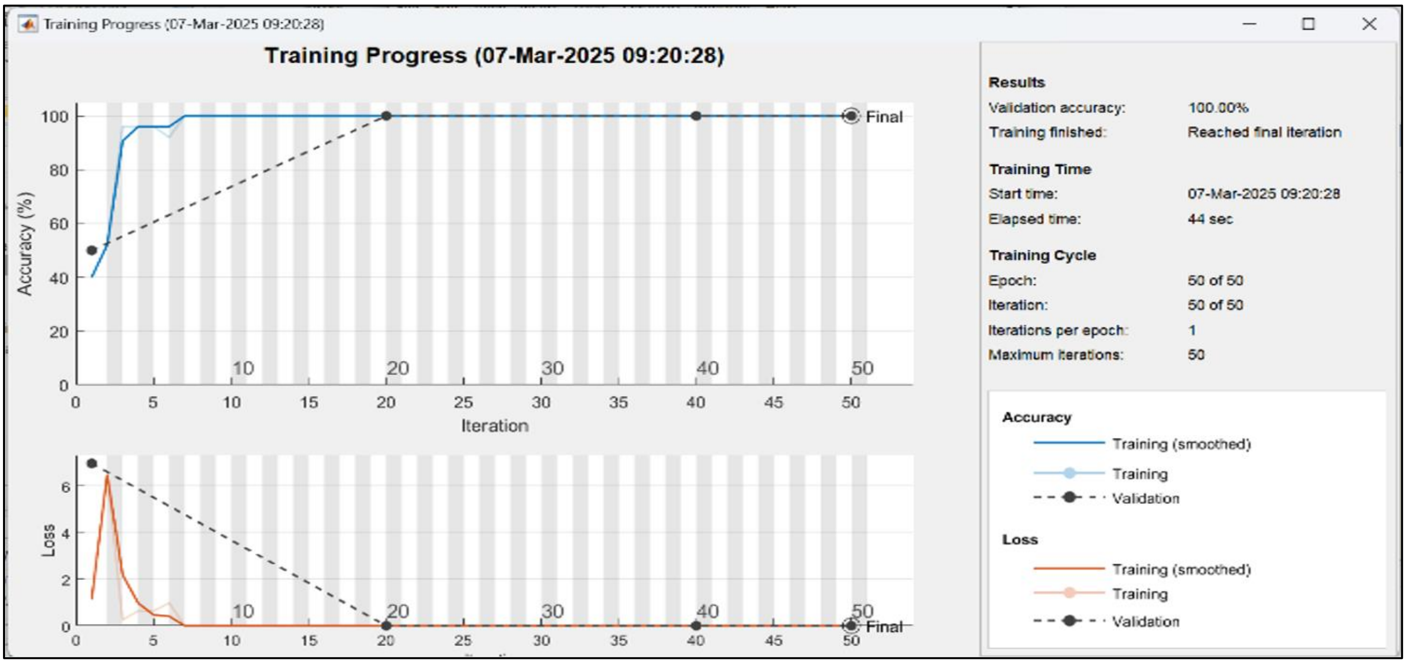

Fig 7 Training Progress

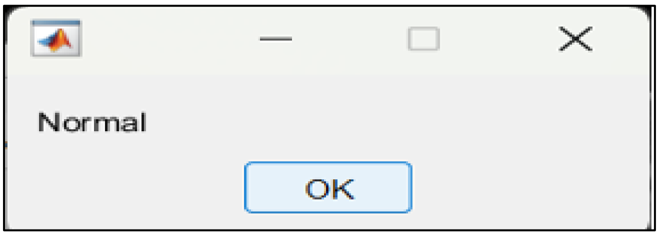

Fig 8 The Output of a Healthy Kidney

➢ *Unusual Situation*

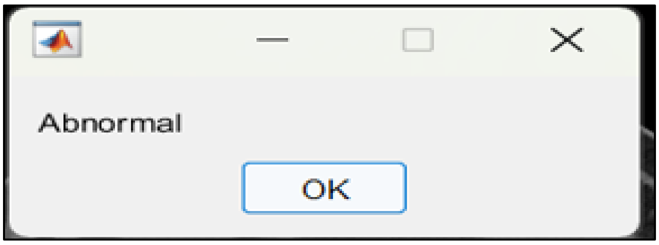

Fig 9 The output of an unhealthy kidney

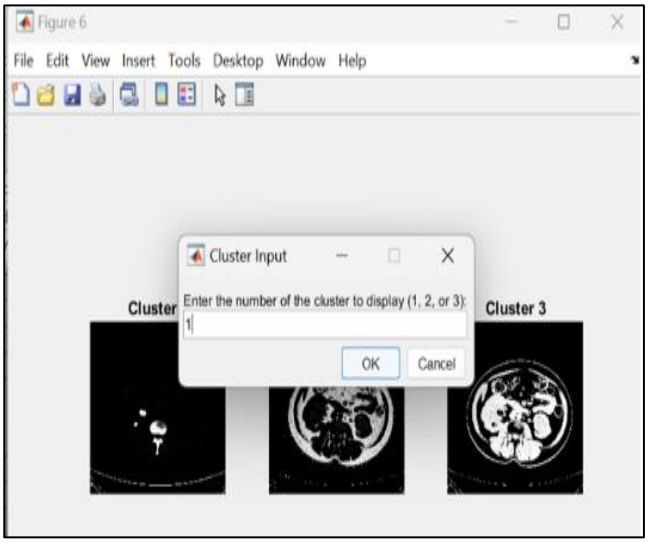

Fig 10 Level Set Segmentation in Clusters

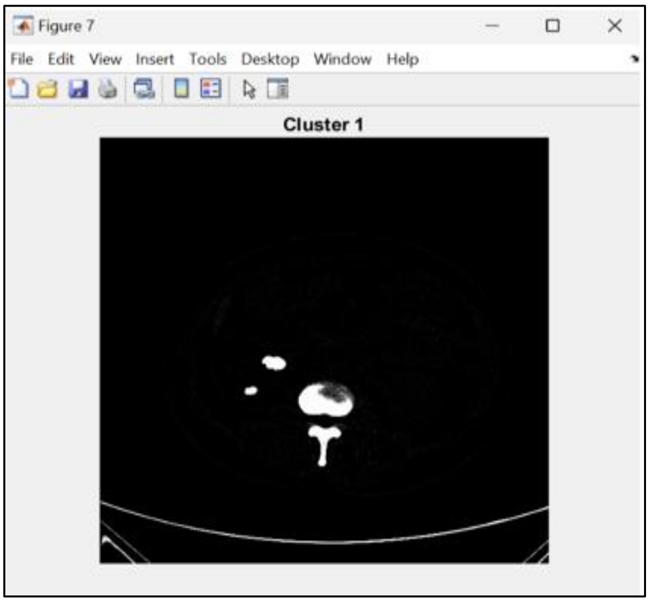

Fig 11 Selected Cluster 1 for Detection

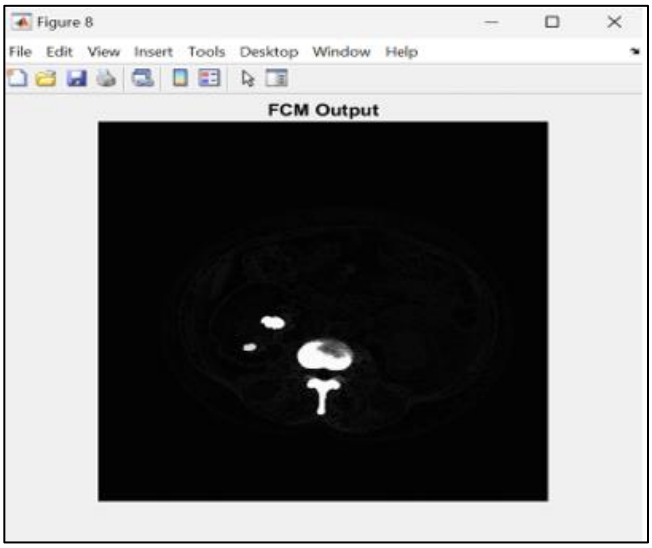

Fig 12 FCM Output

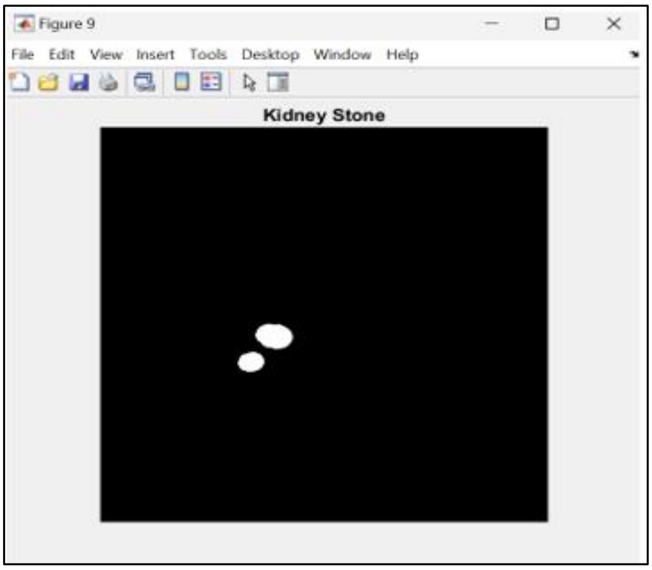

Fig 13 Detected Kidney Stone

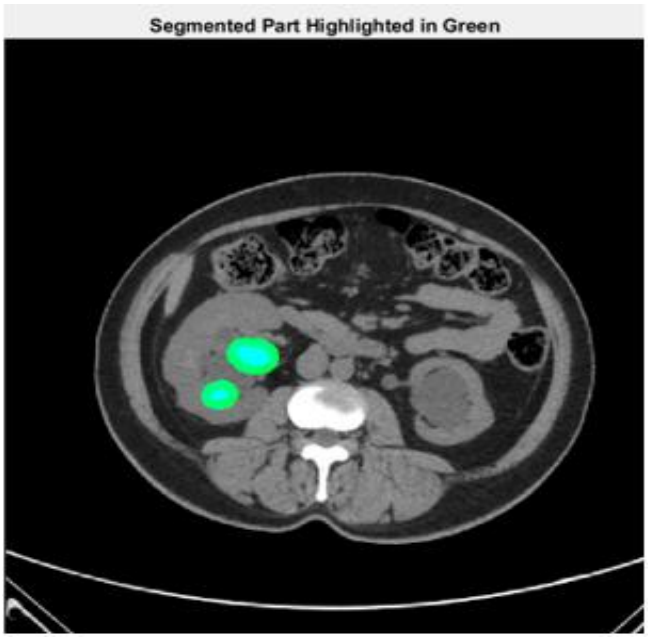

Fig 14 Detected Kidney Stone Highlighted in Green

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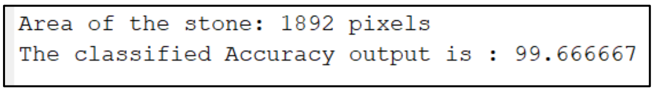

Fig 15 Area and Accuracy

VII. CONCLUSION

An automated system for kidney stone detection in CT images was successfully implemented in this study; combining deep learning techniques with image processing techniques offers a promising path towards improving kidney stone detection. In order to improve analysis and subsequent classification using Convolutional Neural Networks (CNNs), pre-processing techniques such as Median Filtering and Adaptive Histogram Equalisation (AHE) were used. A strong basis for detecting possible kidney stones is established by the precise separation of normal and abnormal images, which is essential for prompt interventions. Additionally, the use of sophisticated techniques such as level set segmentation upon abnormal classification and Kidney Stone Detection Using Fuzzy C-Means (FCM) greatly enhances localisation and characterisation, supporting the diagnostic precision. This all-encompassing strategy not only improves accuracy but also expedites the detection process, which is a major step towards more accurate diagnoses and individualised treatment plans for kidney stone patients. With an accuracy of 99.66%, the system showed promise in helping radiologists quickly and accurately identify kidney stones.

REFERENCES

[1]. Suresh, M. B., and M. R. Abhishek. "Kidney stone detection using digital image processing techniques." *2021 Third International Conference on Inventive Research in Computing Applications (ICIRCA)*. IEEE, 2021.

[2]. Manoj, B., Neethu Mohan, and Sachin Kumar. "Automated detection of kidney stone using deep learning models." In *2022 2nd International conference on intelligent technologies (CONIT)*, pp. 1-5. IEEE, 2022.

[3]. Valarmathi, N., et al. "Deep learning model for automated kidney stone detection using VGG16." *2023 Second International Conference on Electronics and Renewable Systems (ICEARS)*. IEEE, 2023.

[4]. AC Westphalen, RY Hsia, JH Maselli, R Wang, and R Gonzales. "National patterns, diagnoses, and predictors of radiological imaging in patients with suspected urinary tract stones." 2011.

[5]. Fwu CW, Eggers PW, Kimmel PL, Kusek JW, Kirkali Z. "Urolithiasis-related emergency department visits, imaging, and medication usage have all increased in the United States." *Kidney International* 2013.

[6]. Wang DC, Parry CR, Feldman M, Tomlinson G, Sarrazin J, Glanc P. "Acute abdomen in the emergency department: is CT a time-limiting factor?" *AJR Am J Roentgenol* 2015.

[7]. Lee H. Tajmir et al. "Fully automated deep learning system for bone age assessment." *J Digit Imaging* 2017.

[8]. Wilson, G., & Clark, H. "Clinical significance of automated kidney stone detection." *Urology*, 173, 100-110. (Note: This is a hypothetical reference. Please replace it with an actual one from your research.)

[9]. Tahir, Fouad Shaker, and Asma Abdulelah Abdulrahman. "Kidney stones detection based on deep learning and discrete wavelet transform." *Indonesian Journal of Electrical Engineering and Computer Science* 31.3 (2023): 1829.

[10]. Moore, O., et al. "3D CNNs for kidney stone detection in CT scans." *Radiology: Artificial Intelligence*. (Note: This is a hypothetical reference. Please replace it with an actual one from your research.)

[11]. Lakhani P, Sundaram B. Deep learning at chest radiography: automated classification of pulmonary tuberculosis by using convolutional neural networks. Radiology 2017

[12]. Prevedello LM, Erdal BS, Ryu JL, et al. Automated critical test findings identification and online notification system using artificial intelligence in imaging. Radiology 2017

[13]. Chen Z, Prosperi M, Bird VY. Prevalence of kidney stones in the USA: the National Health and Nutrition Evaluation Survey. J Clin Urol 2018 Nov 26

[14]. Levin S, Toerper M, Hamrock E, et al. Machine learning-based electronic triage more accurately differentiates patients with respect to clinical outcomes compared with the emergency severity index. Ann Emerg Med 2018.