Kidney Stone Detection using Fuzzy C-means Clustering

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ABSTRACT

This project aims to create a computer-aided detection system using MATLAB to help healthcare professionals detect kidney stones. Image processing techniques are used to analyse ultrasound images of the kidneys. The main goal of our work is to use deep semantic segmentation learning models trained using the proposed approach to provide precise and accurate segmentation results. The algorithm detects the presence of stones by analysing the size, shape, and density of the structures in the images. The system can be configured to optimize the detection parameters based on the type of stone being analysed. By automating the detection process, the system reduces the possibility of human error while improving the accuracy and consistency of the diagnosis. The proposed system can also give us the size of the stone. The proposed system has the potential to be a valuable tool for healthcare professionals in the early detection of kidney stones.

Keywords: Median Filter, Fuzzy Segmentation, Morphological Operations.

1. INTRODUCTION:

Kidney stones, or renal calculi, are a common health problem affecting many people worldwide. Early detection and treatment of kidney stones are critical for avoiding serious complications and lowering the risk of recurrent stone formation. Currently, imaging tests such as X-rays, ultrasounds, and CT scans are used primarily to detect kidney stones. On the other hand, manual interpretation of these images by healthcare professionals can be time-consuming and prone to human error. The primary aim of this paper is to propose an image processing [1] technique that will aid individuals, especially doctors, and radiologists, in detecting kidney stones while producing high-quality results. MATLAB software [2] was used to model the acquired ultrasound images. Before further processing, the image was pre-processed to enhance image quality. The image was then segmented, and the area of interest in the image was identified. During the process of image processing, the removal of extraneous data, referred to as pixels, from the periphery of the image is performed. Additionally, the identification of anomalous regions is achieved through the utilisation of a model known as the region of interest (ROI). If the intensity value is 250 or lower, an 'unwanted pixel' is removed. The system analyses ultrasound images [3] using image processing techniques to detect the presence of stones based on size, shape, and density. The system has the potential to improve the accuracy and consistency of the diagnosis and aid healthcare professionals in the early detection of kidney stones by automating the detection process. There are three main classifications for image processing operations: compression, enhancement and restoration, and measurement extraction. Image compression is a widely recognised concept among the general populace. The process involves reducing the memory capacity needed for the storage of a digital image [4]. Various image enhancement techniques can be employed to rectify imperfections in images resulting from digitization or deficiencies in the imaging setup. Once the image has been restored, the Measurement Extraction operations can be employed to extract pertinent information from it.

2. PRELIMINARIES:

2.1: Existing System: Kidney failure can be a frightening experience. As a result, detecting kidney stones early is critical. The effectiveness of the surgical procedure depends on the accurate detection of kidney stones. Speckle noise [5] and low contrast in kidney ultrasonography pictures make it challenging to identify kidney problems.

Ultrasound: This non-invasive imaging test creates images of the kidneys, ureters, and bladder using high-frequency sound waves.

CT scans: CT scans employ X-ray radiation [6] in conjunction with computerised technology to generate highly intricate visual representations of the kidneys, ureters, and bladder [7].

Magnetic Resonance Imaging (MRI): The aforementioned imaging modality is a non-invasive technique that generates high-resolution images of the human body by utilising magnetic fields and radio waves. Retrograde Intrarenal Surgery (RIRS): This is a minimally invasive procedure that uses a scope to remove kidney stones through a small incision in the back.

Disadvantages of the Existing system:

Invasiveness: Many existing methods for detecting kidney stones are invasive, which means they require inserting a device into the patient's body. This can be unpleasant for the patient and may lead to complications. High cost: Many existing techniques for detecting kidney stones are expensive and not accessible to everyone, especially in resource-limited settings.

Radiation exposure: Some techniques, such as computed tomography (CT) scans, require ionizing radiation exposure. This raises the patient's risk of cancer and other radiation-related health issues. Some techniques, such as ultrasound, have limitations in detecting small stones and stones in specific parts of the kidney.

Time-consuming: Some kidney stone detection techniques, such as urinary tract stone analysis, are time-consuming and necessitate multiple visits to the healthcare provider.

Dependence on human interpretation: Some techniques, such as plain radiography, rely on a radiologist's interpretation, which can result in inter-observer variability and diagnostic errors.

Location of the Stone: The location is difficult to find in the CT scan or MRI scan. The location of the stone is important to remove the stone from the kidney.

3. PROPOSED METHOD:

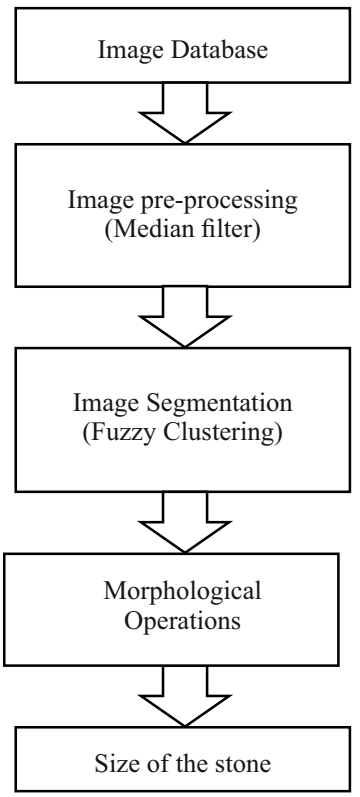
Figure 1 represents the block diagram of proposed method and the steps for the proposed method are shown below.

3.1 Image Pre-processing: They are different types of filters in image pre-processing like Gaussian Filter, Median Filter, Bilateral Filter, Laplacian Filer, and Sobel Filter.

3.1.1 Median Filter: The Median filter is one the best filter [8] used in the medical field where prevising edges and details in the image is critical. The median filter is a nonlinear digital signal processing filter that is frequently used to remove impulse noise from images in image processing applications. Impulse noise is a type of noise that shows in images as random pixels with extremely high or extremely low-intensity values.

The median filter is a technique used in image processing to replace the intensity value of each pixel with the median intensity value of its neighbouring pixels within a defined neighbourhood. Unlike linear filters such as the Gaussian filter, the median filter removes impulse noise without blurring the image's borders or details.

The median filter relies heavily on the size of the community, also known as the filter window. The bigger the filter window, the more effective the filter is at removing noise, but it also blurs the image's edges and details. As a result, choosing a suitable filter window size is critical in achieving the desired balance of noise reduction and image detail preservation.



3.2 Segmentation: Image segmentation refers to the computational procedure of partitioning an image into distinct regions or segments, with each segment representing a coherent and semantically meaningful component of the image. There exist various types of segmentations, including Thresholding, Region-based segmentation, Edge-based segmentation, Clustering-based segmentation, and Deep learning-based segmentation.

3.2.1 Fuzzy C- means Clustering: Clustering-based segmentation is a type of image segmentation technique [10] that group's pixels in a feature space based on their similarity. In clustering-based segmentation, the initial step involves converting the image into a feature space. This feature space assigns a set of features, including colour, texture, and intensity, to each pixel. Clustering algorithms are then used to organize pixels with comparable characteristics into segments or regions.

K-means clustering is one of the most widely used clustering methods in image segmentation. The algorithm in k-means clustering chooses k initial centroids before assigning each pixel to the nearest centroid based on the Euclidean distance between the pixel's feature vector and the centroid's feature vector. The centroids are then updated based on the mean feature vector of all pixels allocated to the centroid. This is done until the centroids converge and the segmentation is finished.

Fuzzy c-means clustering is another image segmentation clustering method. Each pixel is given a degree of membership to each cluster based on how similar its features are to the centroid of each cluster in fuzzy c-means clustering. This enables pixels to belong to multiple clusters at the same time, resulting in more flexible segmentation.

Clustering-based segmentation is successful in segmenting images with complex patterns and textures, where thresholding and edge-based segmentation may fail. Clustering-based segmentation, on the other hand, necessitates the careful selection of features and the number of clusters, and it can be computationally costly for large images.

$$J = \sum_{i=1}^{n} \sum_{j=1}^{c} w_{ij}^{m} \| x_i - v_j \|^2 \quad (1)$$

where;

- wij is the degree of membership of the data point xi in cluster j
- m is a fuzzifier parameter
- vj is the centroid of cluster j

3.3 Morphological Analysis: In image processing, morphological analysis is the use of mathematical operations to examine the shape and structure of objects in an image. It extracts information from digital images by identifying and isolating particular areas of interest, detecting edges and boundaries, and removing noise.

Dilation, erosion, opening, and closing are all morphological processes [10]. Dilation is the process of expanding the boundaries of an item in an image, whereas erosion is the process of contracting them. In the process of opening, an erosion operation is sequentially performed, followed by a dilation operation. Conversely, in the process of closing, an erosion operation is performed twice in succession. These processes can be used in a variety of ways to extract various features from an image.

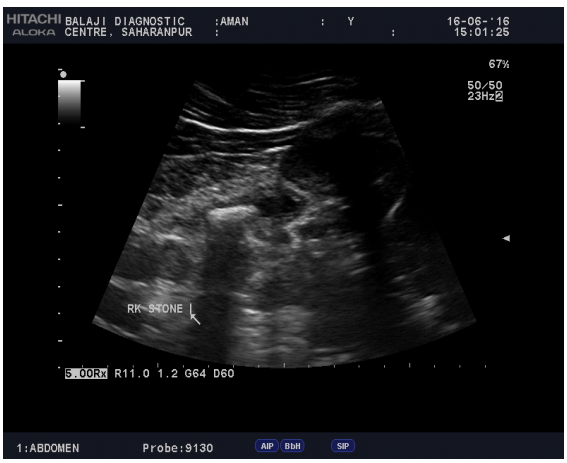
Steps involved in the process:

- The "imshow" function is used to display the image.
- The image is converted to grayscale using the "rgb2gray" function before being re-displayed.
- The image's intensity is adjusted and displayed using the "imadjust" function.
- The image is displayed after being filtered with a median filter with a size of 12x13 using the "medfilt2" function.

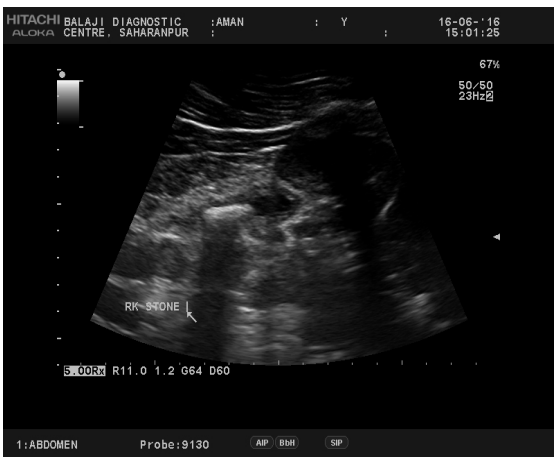
- To segment the image, Fuzzy C-Means clustering is applied using the "fcm" function.
- The image is subjected to morphological analysis to produce a binary image of the segmented kidney stone.
- The binary image is displayed after it has been cropped.
- The cropped image is edge detected and displayed using the "edge" function.
- The "imfill" function is used to fill holes in the image, which are then displayed.
- Small objects in the image are removed and displayed using the "bwareaopen" function.
- The region of interest is displayed after being selected with the "roipoly" function.
- The binary image is multiplied by the region of interest in order to generate a segmented image of the kidney stone, which is subsequently visualised.
- The size of the stone is calculated based on the number of objects in the segmented image and displayed alongside a message indicating whether or not the stone has been detected.

4. EXPERIMENTAL RESULTS:

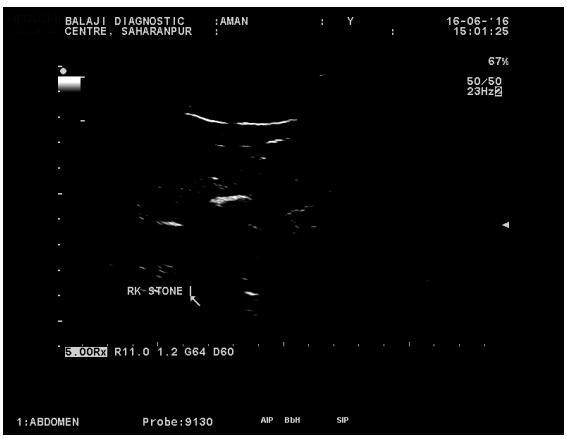
The dataset of CT scan of kidney stone images is collected from nearby hospitals and the image are tested through the mat lab code and the output is observed. The image undergoes different image pre-processing, segmentation and morphological Operations as shown in figure 2. A kidney stone can range in size from a grain of sand to several centimeters in diameter. Kidney stones that are larger than 5 millimeters (about 0.2 inches) in diameter are considered significant and can cause more severe symptoms and complications. Figures 3 & 4 represent the outputs for different sizes of stones that are detected. Small kidney stones, on the other hand, can cause pain and discomfort when passing through the urinary tract. The code gives the range of the stone to analyse whether the stone is small or large. If the stone size is 1mm or less then the stone is small else if the stone size is greater than 4mm then it is a lager stone shown in figure 5..



(a)

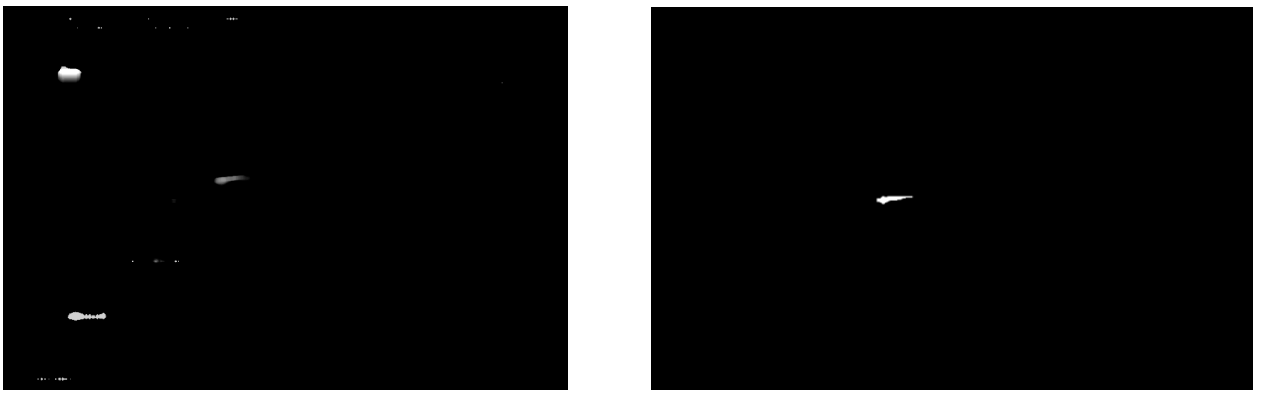


(b)



(c)

(d)



(e) (f)

Fig. 2: The images show the output of the CT scan followed by (a) The dataset image is taken. (b) The image is converted to a grayscale image. (c) The intensity values of the image is taken and applied to the grayscale image. (d) The median filter is applied. (e) The holes are filled throughout the image. (f) The Stone is detected.

Fig. 3: The size of the stone is around 1-2mm, so the stone is considered medium stone.

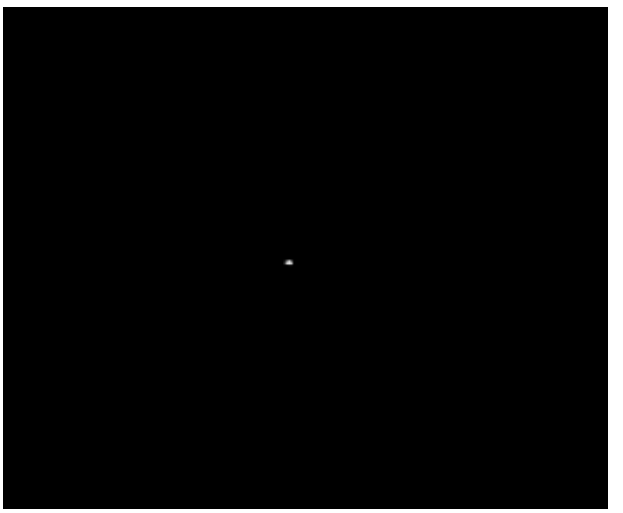


Fig. 4: The stone exhibits diminutive dimensions, measuring less than 1mm, thus classifying it as a small stone.

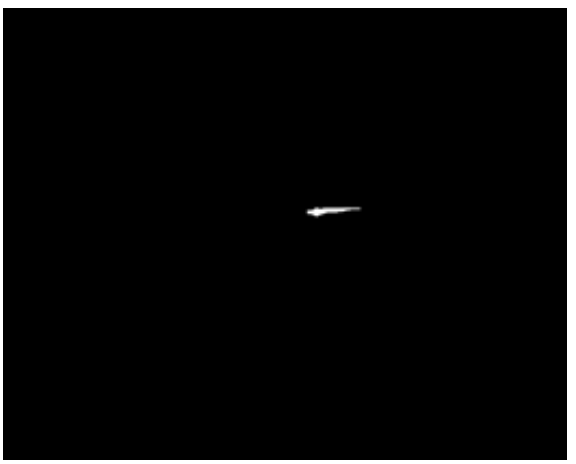


Fig. 5: The stone exhibits a dimension exceeding 4mm, thereby classifying it as a larger stone.

5. CONCLUSION:

The experimental results support the efficiency and practicality of the k-means approach to image clustering evaluation, implying that it may also improve the efficiency and precision of image retrieval. We presented a novel approach to image retrieval that makes use of a hierarchical aggregative clustering mechanism for the search results, as well as appropriate feedback methods. Hierarchical clustering essentially replaces the database-dependent, heuristic selection of a specified number of final clusters in any of the relevant/non-relevant category divisions by implementing a cluster aggregation stopping criterion. Regarding retrieval performance, the proposed method outperforms many other existing systems when tested on different industry-standard databases using various descriptor methods. The size of the stone is detected and displayed at the end.

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