Kidney Stone Detection using Contrast Limited Adaptive Histogram Equalization (CLAHE) on CT Scan Images

L. Prisilla
Department of Computer Science
Periyar University
Salem, India
Prisilla.750@gmail.com

I. Laurance Aroqiaraj
Department of Computer Science
Periyar University
Salem, India
laurence.raj@gmail.com

Abstract- **In modern days need for health services are increasing and the demand for making the Computer-aided medical diagnosis is increasing. The development of imaging techniques, diagnosis using Computed Tomography (CT) images has become widespread because of its low cost, reliable and non-invasive procedure. Feature extraction, analysis, and pattern recognition techniques for these images are used for finding the abnormality like a tumor, cyst, stone etc. Kidney-Urine-Belly Computed Tomography (KUB CT) investigation is an imaging modality that has the potential to improve kidney stone screening and prognosis. This research focuses on efficient computer-aided medical diagnosis from KUB CT kidney images using Contrast Limited Adaptive Histogram Equalization (CLAHE). This image is first removed from Computer-aided medical diagnosis integrates computer science, image processing, pattern recognition and AI techniques and its performance depends on some factors like segmentation, feature selection, reference database size, computational efficiency, etc. Computer-Aided Diagnosis (CAD) is a technique in medicine that helps doctors in the interpretation of medical images. Imaging techniques in mammography, Computerized Tomography (CT), Magnetic Resonance Imaging (MRI), X-ray and Ultrasound (US) diagnostics yields lots of information, which the radiologist has to analyze and evaluate comprehensively in short time. The advance developments made in the field of information technology and medical imaging, there has been a tremendous need for the ability to create speckle noise using Non-Sub sampled CT after which objective diagnosis is made using our proposed technique. The experiment results demonstrated that the work has 87.5% accuracy, which predicts the program's potential is diagnostic effective for kidney stone detection**

Keywords: Pre-Processing, Segmentation, Feature Extraction, CLACHE applying, Stone Detection

1. INTRODUCTION

The development of technology, a lot of computer-aided systems has been evolved for diagnosing the presence of disease with an important emphasis on system accuracy. The chapter brings out various steps in computer-aided medical diagnosis with soft computing skills. The motivation for doing this research, various phases of research and contributions are also discussed artificially intelligent decision support system for detection and diagnosis of diseases. CAD technology aims in developing an image segmentation (F. Grases, A. Costa-Bauza, and R. M. Prieto 2006) tool to automatically detect cyst and incorporate this feature in the knowledge-based artificial intelligent decision support system. Also, telemedicine allows the use of modern telecommunications and information technologies for the provision of clinical care to individuals in remote areas and the transmission of information to provide that care. A Radiologist uses their experience for prognosis. Analysis like has made use of similar images as a denoting aid in disease prognosis. CAD has improved a digital technique that spontaneously selects same images (V. Romero, H. Akpinar, and D. G. Assimos 2010) from the database for detecting the similarity and relationship between and objective characteristics of morbid tissues and stones.

2. IMAGE PREPROCESSING

The aim of pre-processing is to improve the acquired low contrast CT image with speckle noise. Without preprocessing, the CT image quality may not be good for analyzing. For surgical operations, it is essential to identify the location of kidney stone accurately. Pre-processing helps to overcome this issue of low contrast and speckle noise reduction.

a) Image restoration
b) Smoothing and sharpening
c) Contrast enhancement

2.1.Image Restoration

Image restoration is meant to mitigate the degradation of the CT image as shown in the figure 1. Degradation may be due to motion blur, noise, and camera misfocus. The main purpose of image restoration is to reduce the degradations that are caused during acquisition of CT scanning. Thus Merriman and Sethian proposed evolution between max (k, 0) and min (k, 0) as in the equation (1)

$$f(x) = \begin{cases} \max(k, a), & if\ a(x, y)G < (x, y) \\ \min(k, 0), & otherwise \end{cases} \quad (1)$$

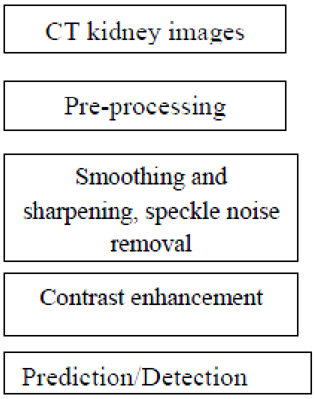

Figure 1. Image Restoration

one based on the mean and one based upon the median (within a given rectangular area of pixels in the image). There are many forms of adaptive speckle filtering,

2.1. 1. Speckle Noise

Speckle noise is a multiplicative noise, and its properties were described by Guru Kalyan et al., 2015. Coherent imaging systems like laser and CT systems have this type of noise (Jyoti Verma, Mahendra Nath, Priyanshu Tripathi, K. K. Saini 2017) Speckle noise is a multiplicative noise and follows a gamma distribution is given in the equation (2)

$$f(x) = \frac{G^{\alpha-1}}{\alpha-1!\alpha^{\alpha}}\, e^{\frac{g}{\alpha}} \quad (2)$$

Where the variance is α^2 and g is the gray level. The gamma distribution of speckle noise shows the speckle noise with variance.

2.2.Smoothing and Sharpening

The restored image is enriched with optimal resolution in both spatial and frequency domains using Gabor filter. This filter acts as a band-pass filter with local spatial frequency distribution (.Gunasundari, K.Viswanath

2015). Image smoothing and removal of noise is performed using convolution operator. The standard deviation of the Gaussian function can be modified to tune the degree of smoothening and its hardware results are shown in Figure 1

A one method involves using adaptive and non-adaptive filters on the signal processing (where adaptive filters adapt their weightings across the image to the speckle level, and non-adaptive filters apply the same weightings uniformly across the entire image). Adaptive speckle filtering is better at preserving edges and detail in high texture areas (such as forests or urban areas). Non-adaptive filtering is simpler to implement and requires less computational power. There are two forms of non-adaptive speckle filtering including the Lee filter, the Frost filter, and the Refined Gamma Maximum-A-Posteriori (RGMAP) filter. Speckle noise in SAR is a multiplicative noise, i.e. it is in direct proportion to the local grey level in any area. The signal and the noise are statistically independent of each other

2.3.Contrast Enhancement

Contrast enhancement plays a crucial role in image processing applications, such as digital photography, medical image analysis, remote sensing, LCD display processing, and scientific visualization. Image enhancement is a technique which reduces image noise, removes artifacts, and preserves details. Its purpose is to amplify certain image features for analysis, diagnosis, and display.

Contrast enhancement increases the total contrast of an image by making light colors lighter and dark colors darker at the same time. It does this by setting all color components below a specified lower bound to zero, and all color components above a specified upper bound to the maximum intensity (that is, 255). Color components between the upper and lower bounds are set to a linear ramp of values between 0 and 255. Because the upper bound must be greater than the lower bound, the lower bound must be between 0 and 254, and the upper bound must be between 1 and 255. Some users describe the enhanced image that if a curtain of fog has been removed from the image (Syed Aathif Hussain, R.Gunasundari, K.Viswanath 2015).

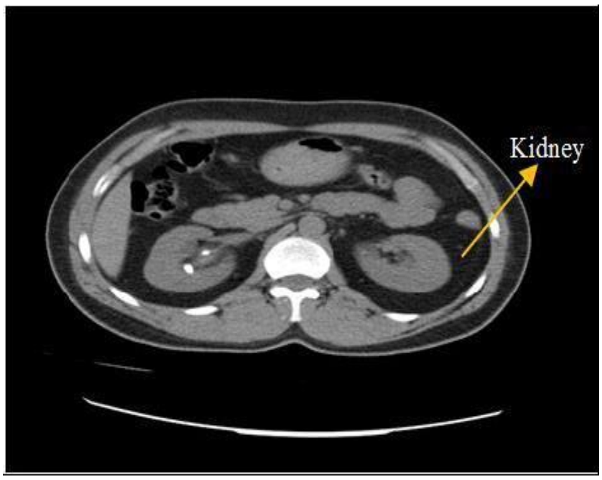

Figure 2. The Sample of a KUB CT scan slice

- The poor quality of the used imaging device
- Lack of expertise of the operator, and
- The adverse external conditions at the time of acquisition.

These effects result in under-utilization of the offered dynamic range. As a result, such images and videos may not reveal all the details in the captured scene and may have washed-out and unnatural look.

2.4.Preprocessing

In this preprocessing phase, principal component analysis with local pixel grouping (Median Filter) based image de-noising algorithm is used to remove the noise from the CT renal calculi images.

2.5.Determining Inner Region Indicator

Let D represents the renal calculi image training dataset, which contains renal calculi images D = {I1,I2 ,…In};n = 1…N, where N is the number of the renal calculi images in the given dataset D. To determine the inner region indicators, Then the whole image is divided into L number of blocks and for every block, an index value, firstly, the regions representing kidney are manually marked in the known training data set CT mages

2.6.Determine Region Parameter

Where is a centroid value of image I1. Then, we determine the region parameters for the extracted regions from R by utilizing MATLAB function. The region parameters determined for each region are (i) Area (ii) Centroids (iii) Orientation and (iv) Bounding Box. This region parameter values are given to the ANFIS system for the training process. In training process, the normal and calculi area are identified by the threshold values t1 and t2. The ANFIS system result value is represented as χ.

CLAHE Algorithm

Step 1: Acquisition process of a CT scan image.

Step 2: Get all input values which is used in enhancement processes like number of regions in a row and Column direction separately, dynamic range (number of bins used in histogram Transform function), image limit, distribution parameter type.

Step 3: Original image divide into some region any preprocess these inputs.

Step 4: Process applied over the tile (contextual region).

Step 5: Generate gray level mapping and imaged histogram. In contextual region numbers of pixels are equally divided in each gray level so, average number of pixels is gray level is described as in the equation (3)

$$N_{avg} = \frac{N_{CR-Xp} \times N_{CR-Yp}}{N_{gray}} \quad (3)$$

Where N_{avg} average number of pixels, N_{gray} number of gray level in the contextual region, N_{CR-Xp} number of pixels in the X direction of the contextual region, N_{CR-Yp} number of pixel in the Y direction of the contextual region

After that calculate the actual image limit as in the equation (4)

$$N_{Image} = N_{image} \times N_{avg} \quad (4)$$

Step 6: Interpolate gray level mapping in order to create the enhanced image. In this process using four-pixel cluster and applied mapping process then each of mapping tiles will partly overlap in the image region after that a single pixel will be extracted and then apply four mapping to that pixel. Interpolate between that results and get enhance pixel, repeat over an image.

2.7.Gamma Adjustment

Gamma correction, or often simply gamma, is a nonlinear operation used to encode and decode luminance or tristimulus values in video or still image systems. (Gunasundari, K.Viswanath 2015) Gamma correction is, in the simplest cases, defined by the following power-law expression as in the equation (5)

$$V_{out} = AV_{in}^{\gamma} \quad (5)$$

where the non-negative real input value is raised to the power γ and multiplied by the constant A, to get the output value V_{out}. In the common case of A = 1, inputs and outputs are typically in the range 0–1.

A gamma value γ < 1 is sometimes called an encoding gamma, and the process of encoding with this compressive power-law nonlinearity is called gamma compression; conversely a gamma value γ > 1 is called a decoding gamma and the application of the expansive power-law nonlinearity is called gamma expansion Generalized gamma.

2.8.Contrast Adjustment (Gamma Adjustment) for Kidney Images

This level is exploratory in nature and was the program's foundation in applying threshold in image processing. It employed the application of gamma adjustment F(x) = X a (1)

As a refining method prior to application of thresholding to allow further image adjustment options. All gamma adjustments were done in the range of 1 to 3.5 by step 0.1 (1.1, 1.2, 1.3… 3.4, 3.5) before application of thresholding in each adjustment. Thresholding established the optimum value for gamma adjustment (gamma = 2.5); values greater than 2.5 results to data loss in some slices, i.e., the objects (stones) tend to disappear after thresholding, while values of less than 2.5 failed to diminish unwanted objects.

Thresholding is applied on the image resulting from gamma adjustment (gamma = 2.5) to allow segmentation of image the foreground (stone and bones) and background. The optimum threshold value for standard KUB CT images such as the ones used in this study intensity 120 When threshold values greater than 120 is applied, it will render the small stones inside the kidney to disappear, while values less than 120 will render some parts of the organs visible in the foreground.

2.8.1. Binary Thresholding Technique:

Image linearization is the process of separation of pixel values into two groups, white as the background and black as foreground. Thresholding plays a major in binarization of images. Thresholding can be categorized into global thresholding and local thresholding. In degraded document images, where considerable background noise or variation.

$$P = \sqrt{\frac{In\,2}{In\frac{i+2p}{2p}}} \tag{6}$$

Where P is the probability of an edge (and 1 P is the probability of an non-edge). In this contest canny ratio is obtained when P = 0.23. This may be a reasonable assumption for typical edge maps.

2.8.2. Binary Connecting Label in Previous Label

Connected component labeling is a fundamental task in several image processing and computer vision applications, e.g., for identifying segmented visual objects or image regions. Thus a fast and efficient algorithm, able to minimize its impact on image analysis tasks, is undoubtedly very advantageous. Some of these particular strategies were focused on taking advantage of the specific hardware architectures by that time, in terms of CPU and memory usage, trying to minimize the number of comparisons, the necessary sorts, the cost of the label management.

2.8.3. Particular Area-Object Detection- Regions

Object detection is a technologically challenging and practically useful problem in the field of image region. Object detection deals with identifying the presence of various individual objects in an image.

The two categories are

- Edge-Based Feature
- Patch-Based Feature

2.9.Program Output and Hospital Record Diagnosis in the Confusion Matrix

TRP (True Positive Rate) = True Positive + All positive sample (7)

Table 1. Confusion Matrix Accuracy

	ACTUAL VALUE (Physician's distinction)	
Prediction Outcome (program distinction)	40 Cases True positive	5 Cases False Positive
	5 Cases False Negative	1 Case True Negative

FPR (False positive Rate) = False positive + All negative sample (8)

ACCURACY = (True Positive + True Negative) + (total samples) (9)

2.9.1. Error rate

Error rate (ERR) is calculated as the number of all incorrect predictions divided by the total number of the dataset. The best error rate is 0.0, whereas the worst is 1.0.

2.9.2. Accuracy

Accuracy is the measure total number of predictions that were correct positive class values correctly classified.

2.9.3. Recall

$$Recall = \frac{TP}{TP+FN} \quad (10)$$

2.9.4. Precision

Precision (PREC) is calculated as the number of correct positive predictions divided by the total number of positive predictions. It is also called positive predictive value (PPV)

$$Precision = \frac{TP}{TP+FP} \quad (11)$$

2.10. Evaluation of Proposed Work

Table 2. Performance evaluation of proposed method

	TP	**FP**	**TN**	**FN**
Normal and Stone image	83%	0.03%	87.5%	0.08%

2.11. Quality Measure

Table 3. Accuracy of Kidney Stone Detection

Quality measure	**Accuracy**
EXISTING (Geometric principals)	83.33
PROPOSED(CLAHE)	87.5

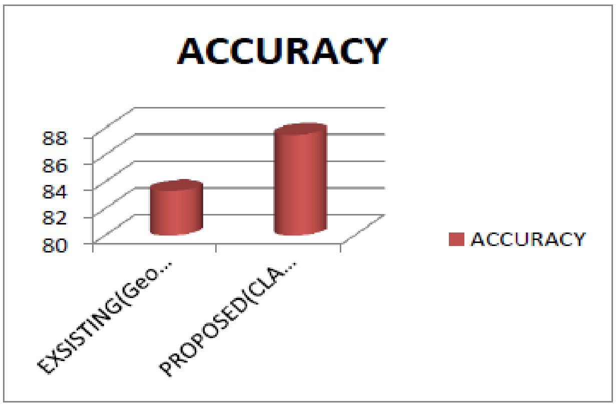

Figure 3. Accuracy of kidney stone detection

3. CONCLUSION

The semi-automated KUB CT image analysis prototype was developed to provide technical support in enhanced kidney stone detection. Its function to pinpoint the kidney area as region of interest and kidney stones as objects of interests provide focused investigation for medical specialists. And the program's capacity to organize by sequence multiple KUB CT slices and combine these based on discernible images of the kidney allows the physician to evaluate an aggregate image from various images that the CT machine took for each patient. This provides cost-effective and timely delivery of diagnosis for both physician and patients. The program's ability to detect and mark kidney stones and to identify stone size and location based on pixel values provide more efficient analysis of cases by using contrast enhancement. Its application in analyzing the cases of 51 kidney patients demonstrated high efficiency and high accuracy (87.41%). It has demonstrated potential usefulness in kidney stone diagnosis and screening, however, the program is only a tool and the opinion of a qualified medical professional is required to validate its output.

3.1. Future Work

In further research, improvement can be made by applying other contrast enhancement techniques, as well as by investigation the morphological operation or artificial neural network approach to make it automated process in finding the optimum values for detecting more accurate kidney stone.

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