Kidney Stone Recognition and Extraction using Directional Emboss & SVM from Computed Tomography Images

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Kidney Stone Recognition and Extraction using Directional Emboss & SVM from Computed Tomography Images

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***Abstract*—The kidneys are a pair of fist-structured organs placed beneath the rib cage. Kidneys function is indispensable to having a healthful body. Kidney disorder happens when it cannot execute its role and can lead to other health predicaments, including puny bones, nerve damage, and malnutrition. If the disease gets worse then kidneys may stop functioning totally and it may cause lethal if left untreated. Kidney disorder may also occur because of stone formation, malignancy, congenital anomalies, blockage of the urinary system, etc. The existence of stone in the kidney called Nephrolithiasis and it is a tremendously painful disorder. For surgical operations, it is incredibly essential to foresee the exact place of tumors in the kidney. The CT scan pictures have poor contrast and also contain noise; this creates complications for recognizing kidney abnormalities manually. So, there is a must wanted an accurate and intelligent system to foresee the stone automatically; it will be really advantageous for necessary treatment. The prime intention of this effort is to develop an automatic stone detection system from the CT picture. A learning model- Support Vector Machine is a proficient algorithm for classifying stone. It classifies the vector space of stone affected & normal kidneys into two separate districts. Before classifying the stone, the image may refer to some kind of improvements such as histogram equalization and Emboss that directionally calculates the differences in colors. Generally, existing approaches may deform the genuine information that degrades the accurateness of the system. The System obtained 98.71% accuracy by testing 156 CT samples that have a stone or tumor as well as a healthful kidney.**

Keywords*—*CT scan image, Digital Image Processing, Kidney stone, Histogram Equalization (HE), SVM, Embossing.

I. Introduction

Kidneys are bean structured organs. They are placed in the back on both side of the spine. Healthy kidneys are helpful for purifying waste materials from the blood by making urine and also balance the number of certain elements. Kidneys function is awfully indispensable to having a healthful body. The kidneys are also proficient in adjusting PH, salt, and potassium ranks. Kidney disorder happens when it cannot execute their duty. The disease may be occurring by diabetes, high BP, and other chronic conditions and also answerable for other health predicaments, including puny bones, nerve damage, and malnutrition. If the disease gets worse then kidneys may stop responding entirely. This means dialysis will be required to perform the function of the kidneys. But dialysis can't cure kidney disorder; it only prolongs your life. Kidney stone treatment is exorbitant costly for penniless people. Early prediction and treatment of kidney stones are very crucial for enhancing the chance of patient's survival.

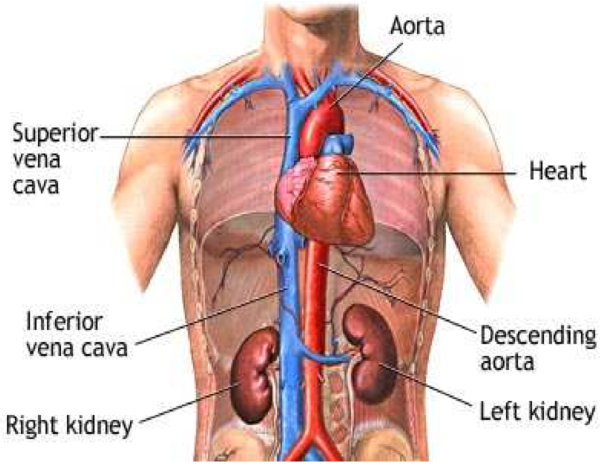
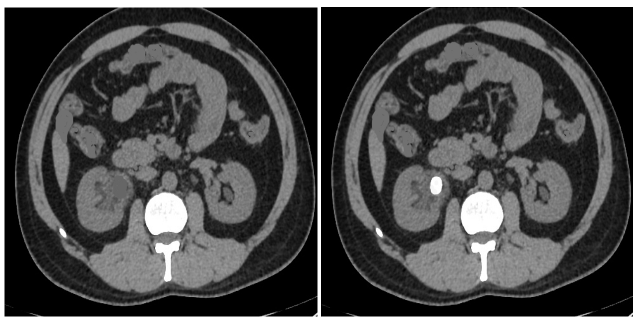


Fig .1. Human body structure [1]

In this framework, we develop a novel approach for automatic recognizing kidney stones in an early period which is very accurate, economical, and convenient. The primary aspire is to inspect the CT scan to recognize whether kidneys are free from sickness or influenced by a stone. The developed system is based on an embossing differential filter as well as SVM. System process with kidney CT scan pictures and upgrade the contrast via HE technique that amended the brightness efficiently. Altered image is later processed through embossing operation for better visibility of low disproportion. It is also known as a directional difference filter. The visibility of kidney stone gets enhanced after applying embossing. Once it expressed, SVM is applied for better classification. SVM is advantageous for classifying the two different classes of data in two particular shells and construct a hyperplane that can be valuable for regression.



(a) (b)

Fig.2. (a) healthy kidney[12], (b) stone influenced kidney[12]

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II. Related Works

A. Related Works

Nilar Theinet et al. [2] proposed an approach that depends on accurate segmentation techniques for automated kidney stone identification. The research intention is to conduct a comparative study of the three different preprocessing methods for the noise deduction from the CT pictures. Three noise deduction techniques are calculated based on the size-based thresholding (method I), shape-based thresholding (method II), and hybrid thresholding (method III). The methods aim to boost their readability and to help out the segmentation process in the kidney stone diagnosis system.
Shahina M K et al. [3] proposed a framework that depends upon adaptive histogram, GAC segmentation, feature extraction, and morphological operations. The research aim is to recognize and extract kidney stone in the ultrasound kidney image. Ishrat Nazeer et al. [4] introduce a system that is useful for chronic kidney disease and renal cell malignancy identification. Identification is done by analyzing the ultrasound illustration of patients. For CKD feature masking, apply contour finding on the kidney's area of concentration, and RCC recognition is utilized for object segmentation. Afterward, the dataset is deployed on the cloud. These studies will proficient for direct communication via the internet and access medical repositories on cloud systems.

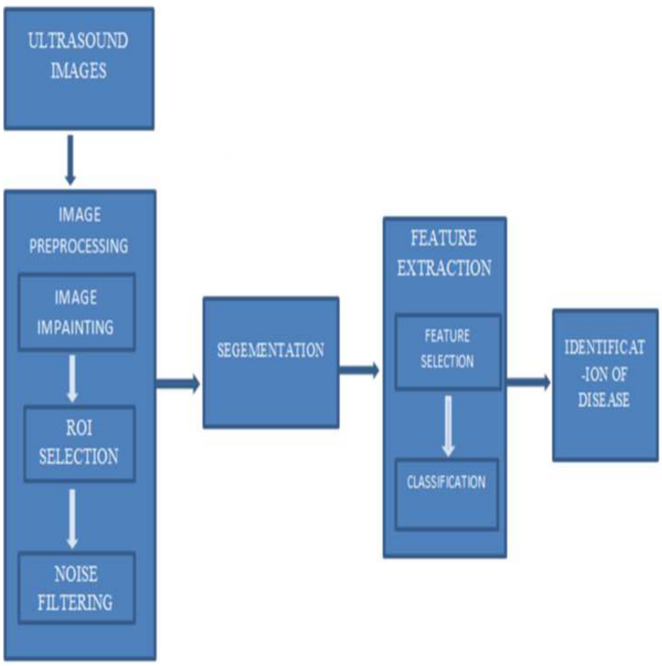


Fig.3. Block diagram of disease detection from images [4]

Nuhad A. Malallaet al. [5] the objective of proposed project is to locate the lump in the kidney; a C-arm tomography process was examined in this effort to create three-dimensional kidney structural details. The consequences of the experiment were achieved by a kidney phantom with a low radiation dosage. Reconstruction algorithms based on distance driven (DD) method were developed for the C-arm tomographic approach.

III. Problem Identification

M.Edhayadharshini et al. [6] proposed system has been trained only with 28 abdominal CT scans. Out of which 6 as healthy and the remaining 22 are abnormal imagesthis means that these 22 images are influenced by kidney lump. The algorithm acquired 93.65% accuracy rate which is not acceptable in the medical field because false recognition may lethal for patients. The kidney is a fist-shaped internal organ that is made up of numerous cells, blood vessels, and veins. Where no. of veins or blood vessel meets in one place then the system may be confused and this compilation of veins may recognize as stone or tumor, so system accuracy may jounce towards low due to false recognition. Here the major problem with the accuracy parameter which is not satisfactory.

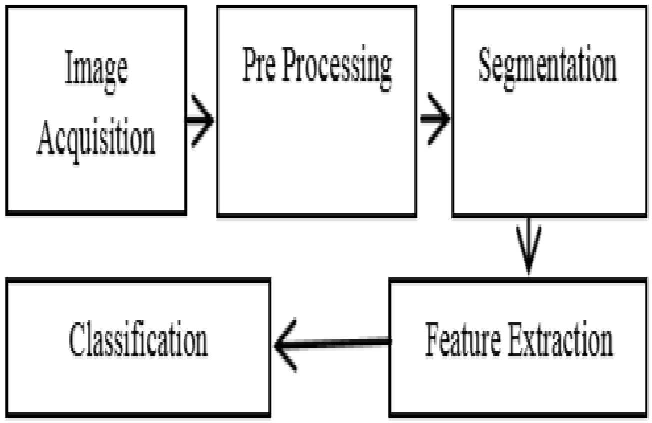


Fig.4. Detection of abnormalities in CT kidney image [6]

IV. Proposed Work & Implementation

The developed system is based on embossing differential filter as well as SVM. The scheme is proficient enough for recognizing the kidney's stone effectively. System process with kidney CT scan pictures and upgrade the contrast via HE technique that amended the brightness efficiently. Altered image is later processed through embossing operation for better visibility of low disproportion. It is also known as a directional difference filter that improves edges directionally with convolution kernel.

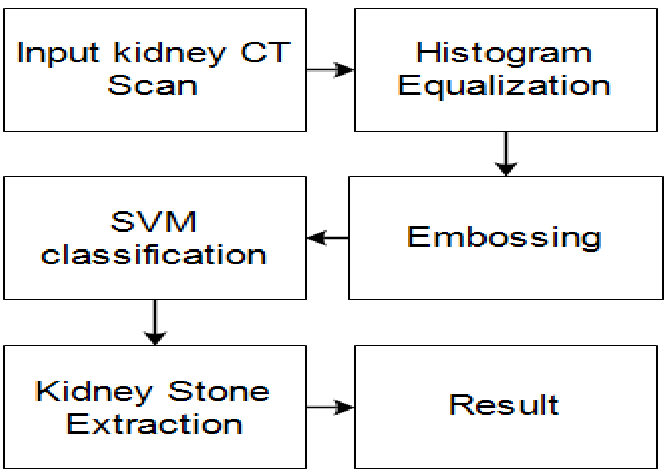


Fig.5. Block diagram of proposed system

Embossing uses a horizontal and vertical kernel for edge detection operations. As an effect, the mask is slide over the picture, alter that pixel and then shifts one pixel to the right and carry on the end point of a row, and further starts at the beginning of the new row**.**

$$\begin{vmatrix} 0 & +1 & 0 \\ 0 & 0 & 0 \\ 0 & -1 & 0 \end{vmatrix} \begin{vmatrix} +1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{vmatrix} \begin{vmatrix} 0 & 0 & 0 \\ +1 & 0 & -1 \\ 0 & 0 & 0 \end{vmatrix} \begin{vmatrix} 0 & 0 & +1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{vmatrix}$$

Emboss can be applied either horizontally as well as vertical or composition of both. 128 value of brightness (half the 0-255 color range) to each pixel that creates the final image with grey-toned background [7].

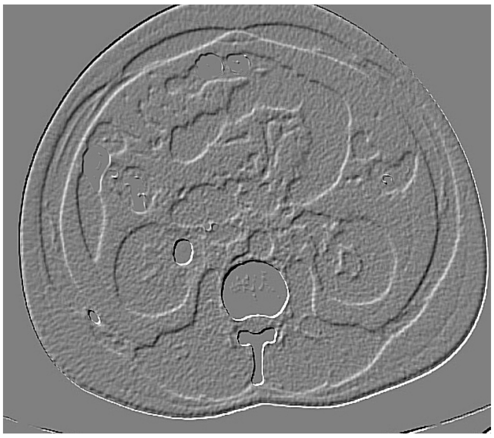


Fig.6. Emboss filtered CT kidney image

The visibility of kidney stone gets enhanced after applying embossing in the scene. Once it expressed, SVM is applied for better classification. SVM is advantageous for classifying the two different classes of data in two particular shells and construct a hyperplane that can be valuable for regression. Mostly, a good classification can be achieved by the hyperplane and has the volumetric distance to the proximate training-data point, since in general the abundant margin; minimize the generalization error of the classifier [8]. To divide the two classes of data points, there are various possible hyperplanes that can be elected. The intention of the system is to locate a hyperplane with maximum margin, i.e. the highest distance between data points of both the classes. The mensuration of the hyperplane is depending upon the no. of features [9]. It is an easy trick to divide the data if data is linearly separable. But there is no linear separation; due to that, it cannot be applied to the data. It pertains to non-linear data classification where there is a distinct data point available in a kidney CT scan picture. Calculating φ and φ(x) is worth for linear separable but it is not effectual for non linear separable data. In that case, it is needed to move forward it to the kernel that will convert low-frequency data dimensions to high-frequency data dimensions.

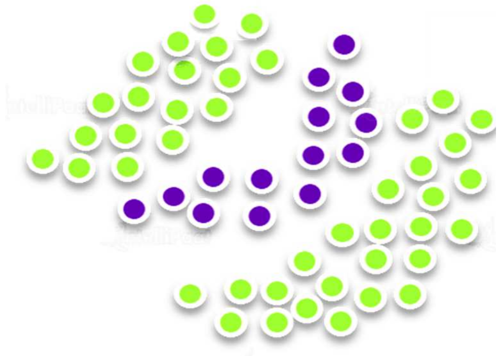


Fig.7. Non-Linear separation [10]

Kernel trick is a method of building a linear classifier to categorize the non-linear data points. It alters non-linear data points to a higher frequency data dimension where it can be linearly separable. The kernel is a function that truly performs the conversion. There are various kinds of kernels like linear, polynomial, redial, and many more. Selecting an optimized kernel that can best suit on data can be obtained through cross-validation.

SVM Non-linear separable (Kernel Trick)

Step 1: Describe data points

x= $(x_1, x_2, x_3)^T$

y=$(y_1, y_2, y_3)^T$

Here, x& y are two data points

Step 2: Calculate dimensional space

$$\varphi(x) = (x_1^2, x_1x_2, x_1x_3, x_2x_1, x_2^2, x_2x_3, x_3x_1, x_3x_2, x_3^2)\text{^}T$$

$$\varphi(y) = (y_1^2, y_1y_2, y_1y_3, y_2y_1, y_2^2, y_2y_3, y_3y_1, y_3y_2, y_3^2)\text{^}T$$

$K(x, y) = (x^T\, y)\text{^}2$

$= (x_1y_1 + x_2y_2 + x_3y_3)\text{^}2$

$= \sum_{i,j=1}^{3} x_ix_jy_iy_j$

$K(x, y) = \varphi(x)\text{^}T\varphi(y)$

Step 3: Kernels are resemblance functions between vectors of data points in an image

K: X*X→ R

Step 4: let K is equal toφ,with n features and d degree of polynomial

K(x, y) =($x^T\, y + 1$*)^d*

Step 5: calculate kernel matrix to find decision boundary

$$C^TK_c = \sum_i \sum_j C_iC_jK_{i,j}$$

$$= (\textstyle\sum_i c_i\, \varphi(x_i))\, (\sum_i c_i\, \varphi(x_j))$$

$$= \left\| \left(\textstyle\sum_j c_j\, \varphi(x_j) \right) \right\|^2 \geq 0$$

Step 6: Designing new data

Step 7: Calculating the unknown

Step 8: Outcome

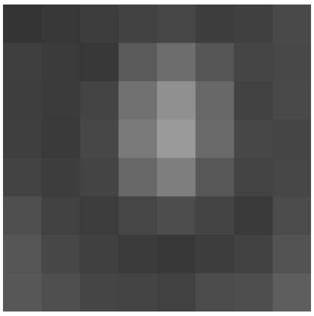
A. Histogram Equalization

HE is a trendy approach due to its high efficiency and amenities. HE is advantageous for improving image contrast and it is obtained by normalizing the intensity distribution with its cumulative distribution function so that the consequential picture may have a consistent distribution of intensity.

Grayscale image - {x}; n_i is the no. of incidence of gray levels.

$$p_x = p(x=i) = \frac{n_i}{n}, 0 \le i < L \quad (1)$$

Where, L is the total no. of gray levels, n is the total no. of pixels, p_x(i) is the image histogram.



52	55	61	59	79	61	76	61
62	59	55	104	94	85	59	71
63	65	66	113	144	104	63	72
64	70	70	126	154	109	71	69
67	73	68	106	122	88	68	68
68	79	60	70	77	66	58	75
69	85	64	58	55	61	65	83
70	87	69	68	65	73	78	90

Fig.8. 8 Bit grayscale image & gray levels [11]

B. Embossing

The embossing is a filter for taking a relief effect of images. Normally, the embossed picture is showed by the flat and slope vicinity. That is, the sharp area of an original picture is showed by higher or lower intensity according to the mask degree and the smooth region in the original picture is showed by the flat intensity in the embossed representation. The emboss operator is also called a directional difference filter because it is a subsidiary for improving the edges directionally as convolution mask. When emboss is applied the filter matrix is calculated, so it has a huge amount of calculations when an emboss filter mask dimension is large. The emboss filter encore the calculations that have been encoded in a filter matrix at each pixel in a picture; the method itself compares neighboring pixels and leaving a spot over there when a sharp alteration is recognized.

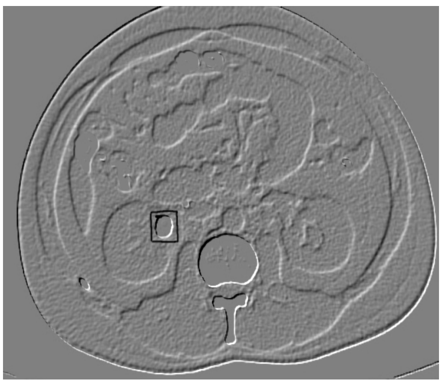


Fig.9. Stone affected kidney embossing

C. Segmentation

Segmentation is a great expedient for analyzing a region of concern. It is necessarily required to attain the influenced region that has been affected by stone. Segmentation can categorize the veins, blood vessels effectively. It can be executed through thresholding operation by replacing low-intensity pixels with nonactive pixels i.e. 0 and high-intensity pixels can be replaced with active pixels i.e.1. The replacement of pixels intensity can be done by threshold value.

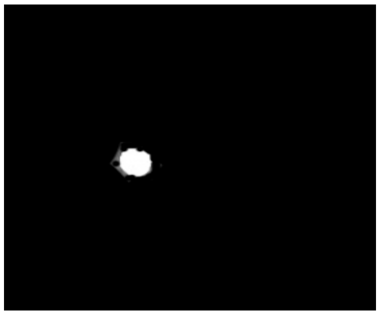


Fig.10. Kidney stone extracted

E. Flow Chart

Flow chart illustrates the process model for kidney stone recognition. First of all; a kidney CT picture is to be acquired for implementation and once the picture has been imported it is needed to pre-process that data with HE operation, embossing and segmentation. Once the pre-processing has been completed; SVM classification is applied for clustering analogous types of data in a particular class. After that computing entropy and if it is superior to the threshold value that means selected kidney picture may have stone or lump otherwise system declared it as a healthful kidney.

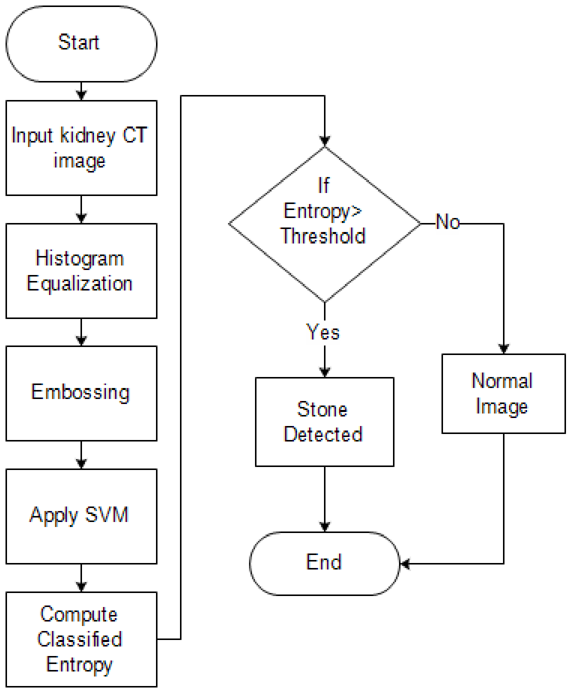


Fig.11. Flowchart

V. Result Analysis

The system has been trained with 156 kidneys CT scan pictures where 78 images affected with stone and the remaining 78 images are healthy. The system recorded 154 images as correct detection and 2 as false recognitions out of 156. By observing the data sets; the resulting accuracy is 98.71%. There are 2 false-positive cases and zero false acceptances.

Table No. I Result Analysis

Terms	Proposed
Total Testing Class	156
True Positive	76
True Negative	78
False Positive	2
False Negative	0

Here, the system attained 76 true positive that means; these 76 images are truly affected by stone and the system positively identified as malignant but 2 of them are ignored by the system by considered as influenced kidney but they actually don't have stone i.e. false positive. There are 78 True negative that means the system predicted no, and they don't have any stone. So, as per the total no. of correct predictions; the accuracy is calculated as 98.71% which is a bit superior to the existing systems.

$$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+FP+TN+FN}}\,\% \quad (2)$$

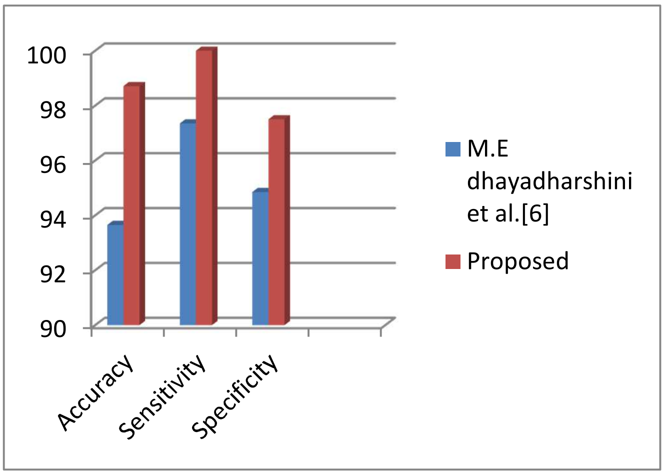
$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP+FN}}\,\% \quad (3)$$

$$\text{Specificity} = \frac{\text{TN}}{\text{TN+FP}}\,\% \quad (4)$$

Table No. II. Result Comparison

Terms	M.Edhayadharshini[6]	Proposed
Accuracy	93.65%	98.71%
Sensitivity	97.35%	100%
Specificity	94.85%	97.5%

Graph No. I result comparision graph



VI. Conclusion & Future Scope

The proposed work is advantageous for recognizing kidney stones from CT scan pictures with less processing instant and achieves great accuracy. Firstly, the input image is enhanced by the histogram equalization approach and then applies the Embossing technique for better visibility of low disproportion and also improves edges directionally with convolution kernel after that we apply SVM for better classification. Finally, the system achieved the desired consequences successfully. The System obtained 98.71% accuracy by system trained with 156 CT scan samples that affected by stone as well as healthful kidney. The system accuracy has been calculated on the basis of TP, TN, FP, FN parameters. Automatic identification is now trending in medical science which legitimately helpful for saving human health and wealth also. Accuracy is a tremendously crucial parameter in the medical field so in the future other techniques and filter may helpful for accuracy enhancement and detecting multiple stone in kidney.

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