Computer Assisted Cataract Identification system from Noisy Images

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Abstract -Identification of cataract from a noisy eye image is still a challenging problem for researchers. To address, this issue we proposed recognition of cataract from a noisy image by applying the non linear robust edge detector to obtain the edge image from a noisy cataract image without using image regularization. Then edge connected components are extracted, for each edge connected component recognition properties are obtained for the test image and compared these properties with the training dataset for recognition process. The recognition rate for the cataract images is obtained from the set of images to measure the performance of a proposed recognition process. The applicability of the proposed method is tested on normal eye images and dataset from MESSIDOR database. It is observed that recognition rate for the proposed method is highly acceptable.

Index Terms: Regularization, Canny edge image, NLRED, Classification, Area, Centroid, Extremal points.

I INTRODUCTION

A cataract is a clouding of the lens inside the eye which causes to a decrease in vision or sight. Visual loss occurs because opacification of the lens obstructs light from passing and being focused on to the retina at the back of the eye. It is most commonly due to biological aging, but there are a wide variety of other causes also. As time passes, the yellow-brown pigment is deposited within the lens and this, together with disruption of the normal architecture of the lens fibres, leads to reduced transmission of light, which in turn leads to visual problems. Detecting cataract from human eye images is a challenging task owing to their variable appearance and the wide range of poses that they can adopt.

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The first need is a robust feature set that allows the human form to be discriminated cleanly, even in cluttered backgrounds under difficult illumination and noise conditions. A number of approaches have been proposed in the literature to match the cataract images by extracting texture information using Local Binary Pattern (LBP) [16], Histogram of Oriented Gradient(HOG) [17], and Scale Invariant Feature Transform (SIFT) [18].

Cataract identification [16] is multi-resolution approach to gray scale and rotation invariant texture classification based on local binary patterns and nonparametric discrimination of sample images. The method is based on recognizing that certain local binary patterns termed 'uniform' are fundamental properties of local image texture, and their occurrence histogram. This method derives a generalized gray scale and rotation invariant operator presentation that allows for detecting the 'uniform' patterns for any quantization of the angular space and for any spatial resolution, and combining multiple operators for multi-resolution analysis. In this method results obtained in true cataract problems of rotation invariance, where the classifier is trained at one particular rotation angle and tested with samples from other rotation angles, demonstrate that good discrimination can be achieved with the occurrence statistics of simple rotation invariant local binary patterns.

Human eye cataract recognition [14], [17] is based on histogram of oriented gradient. This method is based on evaluating well normalized local histograms of image gradient orientations in a dense grid. The basic idea is that local object appearance and shape can often be characterized rather well by the distribution of local intensity gradients or edge directions, even without precise knowledge of the corresponding gradient or edge positions. This method is implemented by dividing the image window into small spatial regions ("cells"), for each cell accumulating a local 1-D histogram of gradient directions or edge orientations over the pixels of the cell. The combined histogram entries form the representation. For better invariance to illumination, shadowing, etc., it is also useful to contrast normalize the local responses before using them. This can be done by accumulating a measure of local histogram "energy" over somewhat larger spatial regions ("blocks") and using the results to normalize all of the cells in the block. This is referred to the normalized descriptor blocks as Histogram of Oriented Gradient (HOG) descriptors.

Object recognition [18] is based on Scale Invariant Feature Transform. This kind of object recognition system uses a new class of local image features. The features are invariant to image scaling, translation, and rotation, and partially invariant to illumination changes and affine or 3D projection. These features share similar properties with neurons in inferior temporal cortex that are used for object recognition in primate vision. Features are efficiently detected through a staged filtering approach that identifies stable points in scale space. Image keys are created that allow for local geometric deformations by representing blurred image gradients in multiple orientation planes and at multiple scales. The keys are used as input to a nearest neighbor indexing method that identifies candidate object matches. Final recognition process is achieved by finding a low residual least squares solution for the unknown model parameters.

In today's world the visual information is transmitted in the form of digital images, but the image obtained after transmission is often degraded with some unwanted pattern or information called noise. The received image needs processing by applying linear or nonlinear filters[1] in order to restore to the original content before using in any applications.

These approaches yield high accuracies when the images are properly registered. If registered images are contaminated with noise then these methods will not exhibit the expected recognition process.

This paper proposes a unique technique for extracting the cataract layer and its surrounding in an accurate manner. The paper is organized as follows. The existing classical edge detectors are explained in section II, The proposed method for recognition of cataract from a noisy images using NLRED method, labelling algorithm and computing regional properties are detailed in section III, the results and discussions are given in section IV and finally conclusion is given in section V.

II EXISTING EDGE DETECTORS

In this research, we propose the use of edge connected components for recognizing the identity of individuals suffering from cataract. In this section we explored various methods available for detection of edge image for the given image.

Edge detection is a challenging task in case of noisy images, since both the noise and the edges contain high frequency content. In literature to detect the edges from the noisy images [1]-[2], [7]-[8] first we need to perform regularization by selecting suitable filters to reduce the appropriate noise. Attempts to reduce the noise results in blurred, distorted edges and sometimes edge pixels may disappear. Operators used on noisy images are typically larger in scope, so they can average enough data to discount localized noisy pixels. Later we need to apply suitable edge detector [1], [3]-[6] to identify the edge from the restored image. Classical methods of edge detection involve convolving the image with two-dimensional filters, which is constructed to be sensitive to large gradients in the image while returning values of zero in uniform regions. There are an

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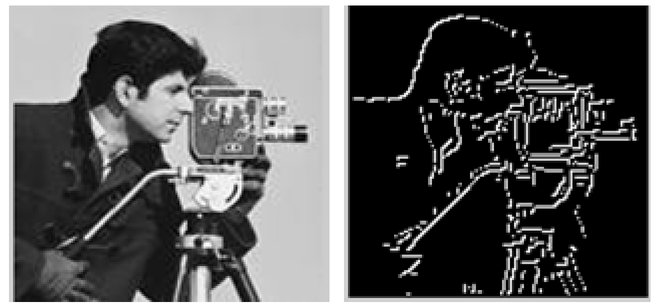
extremely large number of edge detection operators available [1] each designed to be sensitive to certain types of edges. Variables involved in the selection of an edge detection operator include Edge orientation, Noise environment and Edge structure. The geometry of the operator determines a characteristic direction in which it is most sensitive to edges. Operators can be optimized to look for edges in all orientations such as horizontal, vertical, or diagonal. The two step process of obtaining edge pixels from the noisy image can be modified to obtain in a single step without considering regularization. To obtain edge image without image regularization by RRO test [9] identifies detecting edges of all possible orientations in noisy images, locates exactly the edge pixel. The NLFS method [7] obtains both noise reduction and edge detection with a single-stage nonlinear derivative scheme but poor in FOM value. The Nonlinear Noise Suppression Edge Detection (NNSED) scheme [6] for Noisy Images is based on a principle that the gradients are calculated in both directions to compute the slope in X-direction and in Y-direction. The difference of the forward and backward gradient is taken as the actual edge gradient in their respective direction, which is with improved FOM value. Non Linear Robust Edge Detector [15] uses n x n window in order to detect the edges of all possible orientations from noisy images by achieving higher FOM value.

II.1 Canny edge detector – is one of the best methods to obtain the edges from the synthetic and real images. Canny edge detector performs the following four steps to obtain the edge images from the given input image.

1. Smoothing an image with gaussian filter
2. Computation of gradient.
3. Obtaining thin edges by applying non-maximal suppression.
4. Detect the edges by double thresholding.

This method is applicable to the images without noise. If image contains noise, first apply the regularization and then apply edge detector. The Fig.1 shows the obtained canny edge image directly on the cameraman image without noise.

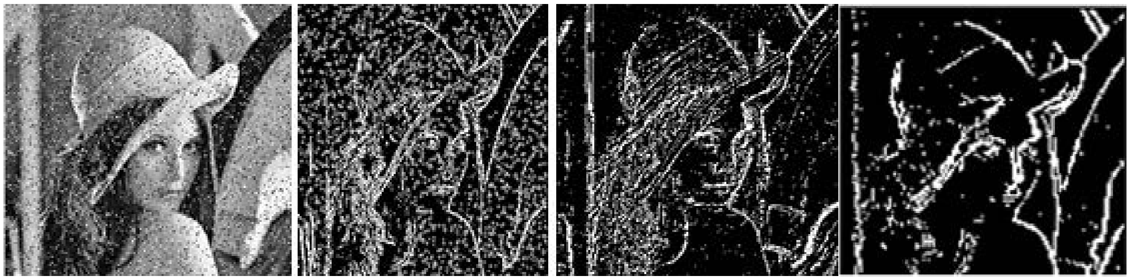


(a) (b)

Fig.1 a) Cameraman image without noise. b) Canny edge image

II.2 Edge detectors without regularization – The Nonlinear Filtering Scheme (NLFS) method and Nonlinear Noise Suppression Edge Detection (NNSED) scheme can obtain the edge images directly even in presence of noise without considering regularization step. The NNSED scheme for Noisy Images is based on a principle that the gradients are calculated in both directions to compute the slope in X-direction and in Y-direction. The difference of the forward and backward gradient is taken as the actual edge gradient in their respective direction. The NLRED method partitions the neighbors of the pixel which is under observation for edge candidature into two sub regions based on differences with the local gray level value. The proposed method calculates test statistic for pixel of each sub region by calculating mean, placement of each member, index of variability and test statistic. The test statistic with maximum value is considered based on two sub regions. These statistics are calculated for eight different orientations. Among these the statistic with minimum value is considered for edge candidature.

The Fig.2 shows the obtained edge images without regularization on lena image corrupted with impulse noise.



(a) (b) (c) (d)

Fig.2. a) Lena image with impulse noise. b) NLFS method edge image. c) NNSED method edge image. d) NLRED Edge Image

III RECOGNITION OF CATARACT FROM NOISY IMAGES

The recognition of the cataract from a noisy test image in the proposed method consists of the following steps. First apply the following steps A to C on the set of images available with the training data set containing eye images with cataract nature and normal(without cataract) nature, store the computed properties into a temporary file. On the given noisy test input image in order to recognize whether it consists cataract nature or normal nature, apply the following steps from A to D. Finally display the identified or recognized nature for the given test image along with the edge image.

A. Apply Non Linear Robust edge detector [15] on the test image containing noise (Impulse noise or Gaussian noise) to extract edge image.

B. Obtain the largest five edge connected components or regions of the edge image by applying iterative labeling algorithm.

C. For each obtained edge connected component, compute the recognition properties Area, Centroid, Mean, Variance, and Extremal points.

D. Perform comparison of the computed regional properties for the test image with the regional properties of the training data set images and finally assign recognized nature.

The Fig.3 shows the block diagram of the recognition process in order to identify cataract from the given test image.

Step III.A : Extract Edge Image by applying NLRED method

By applying NLRED method [15] on the noisy test image obtain the edge image without regularization and submit it as a input to the next step.

Step III.B : Procedure to obtain the edge connected components

Connected components labelling is grouping operation. The objective of the connected components labelling operation is to unit change from pixel to connected component or region or segment. All pixels that have value binary 1 for identified edge pixel from the previous step and are connected or linked to each other by a path of pixels all with value binary 1 are given same identifying label. The label is a unique name or index of the region to which the edge pixels belongs. The label is the identifier for a potential object region. The region is a more complex unit than the pixel. The only properties a pixel has are its position and its gray level or brightness level. A region has a much richer set of properties. A region has shape and position properties as well as statistical properties of the pixel in the region. To each region, therefore, and can construct an N-tuple of its measurement properties. One way to recognize different objects, object defects, or characters is to distinguish between the regions on the basis of their measurement properties. In the second step to obtain the connected components from the edge image we adopted an iterative algorithm [8] and depicted here in brief with algorithm1. It consists of an initialization step plus a sequence of top-down label propagation followed by bottom-up label propagation iterated until no label changes occur.

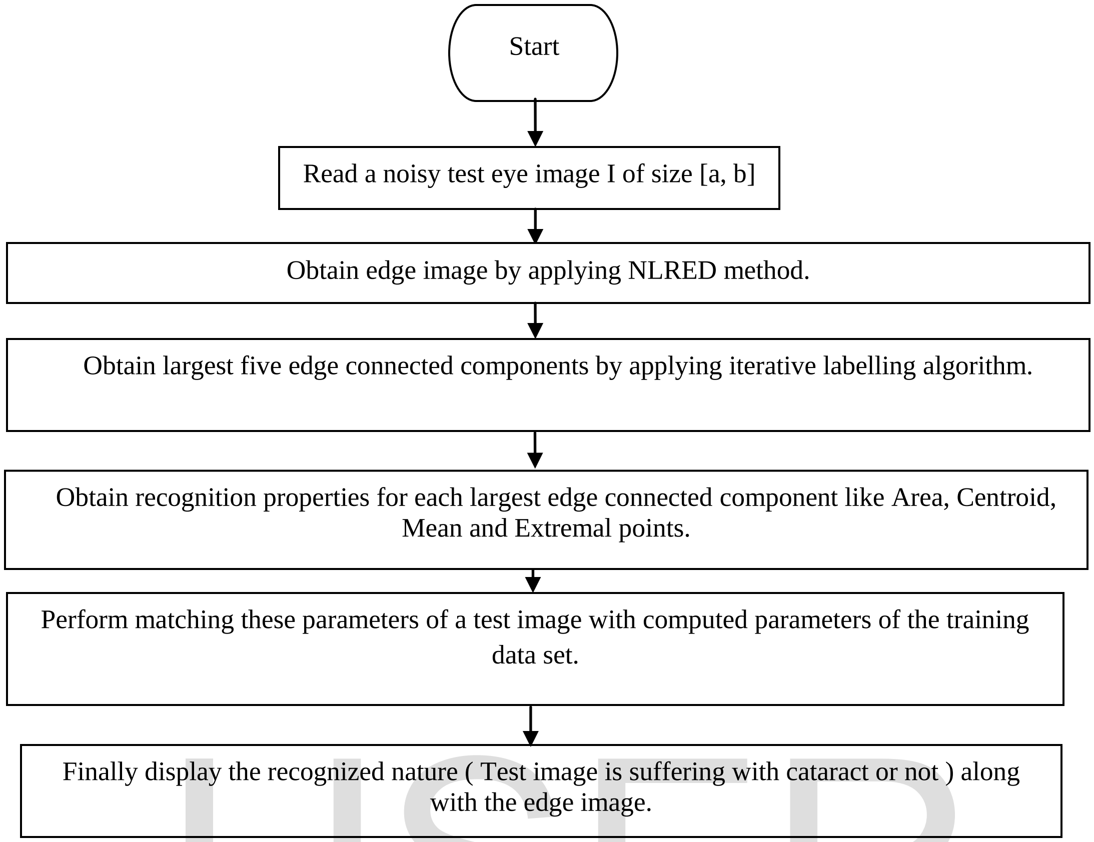


Fig.3 Block diagram for the recognition process.

Algorithm1: Iterative algorithm

Input: Edge image E, obtained by applying NLRED method on the noisy eye image.

Output: Set of connected edge components or edge regions given in ELABEL array.

Method: Iterate ( )

```
[rows, cols] = size(E);
Begin
For L = 1 to rows do
        For P =1 to cols do
If E(L,P) = = 1Then
ELABEL(L,P) = GENERATE_NEWLABEL()
        Else
ELABEL(L,P) = 0
        End for
End for;

Repeat
        CHANGE = false;
For L = 1 to rows do
        For P =1 to cols do
                If ELABEL(L,P) <> 0 then
                Begin
M = MIN(LABELS(NEIGHBOURS((L,P)) U (L,P)));
If M <> ELABEL(L,P)Then
CHANGE = true;
ELABEL(L,P) = M;
End
        End for
End for

For L = rows to 1 by -1 do
For P =cols to 1 by -1 do
        If ELABEL(L,P) <> 0 then
                Begin
M = MIN(LABELS(NEIGHBOURS((L,P)) U (L,P)));
If M <>ELABEL(L,P)Then
CHANGE = true;
ELABEL(L,P) = M;
End
        End for
End for
Until  CHANGE = False
End
```

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Step III.C: Computation of Regional properties from training data set and test input eye image

For each identified connected region of an edge image of the each sample image from the training data set, we can calculate the properties vector [8] which are used for recognition of the objects. A variety of property measurements can be made on each edge region on the basis of the gray level values for those pixels that participate in the edge connected component or region. Here we computed the following properties Area, Centroid, Mean, Variance and length of major axes M1, M2, M3, M4 of each region based on extremal points. Here we represented the set of pixels in a edge region by R. The following Eqs.1–6 are used to compute the region's global properties called

Regions Area is given by

$$A = \sum_{(r,c)\epsilon R} 1 \quad (1)$$

Centroid of each region is given by

$$\bar{r} = \frac{1}{A}\sum_{(r,c)\epsilon R} r \quad (2)$$

$$\bar{c} = \frac{1}{A}\sum_{(r,c)\epsilon R} c$$

Mean Gray level value of each region is given by

$$\mu = \frac{1}{A}\sum_{(r,c)\epsilon R} I(r,c) \quad (3)$$

Gray level variance of each region is given by

$$\sigma^2 = \frac{1}{A}\sum_{(r,c)\epsilon R}[I(r,c) - \mu^2] = \left[\frac{1}{A}\sum_{(r,c)\epsilon R} I(r,c)^2\right] - \mu^2 \quad (4)$$

There are eight distinct extremal points to a region called topmost right, rightmost top, bottommost right, bottommost left, leftmost bottom, leftmost top, and topmost left. Each extremal point has an extremal coordinate value in either it's row or column coordinate position. Each extremal point lies on the normally oriented bounding rectangle of the region as shown in Fig.4.

The coordinates of the extremal points for each region given by Eq.5:

$$r_1 = r_2 = rmin$$
$$r_5 = r_6 = rmax$$
$$c_1 = min\{c|(rmin, c) \in R\}$$
$$c_5 = max\{c|(rmax, c) \in R\}$$
$$c_2 = max\{c|(rmin, c) \in R\}$$
$$c_6 = min\{c|(rmax, c) \in R\}$$
$$r_3 = min\{r|(r, cmax) \in R\}$$
$$r_7 = max\{r|(r, cmin) \in R\}$$
$$r_4 = max\{r|(r, cmax) \in R\}$$
$$r_8 = min\{r|(r, cmin) \in R\}$$
$$c_3 = c_4 = cmax$$
$$c_7 = c_8 = cmin \quad (5)$$

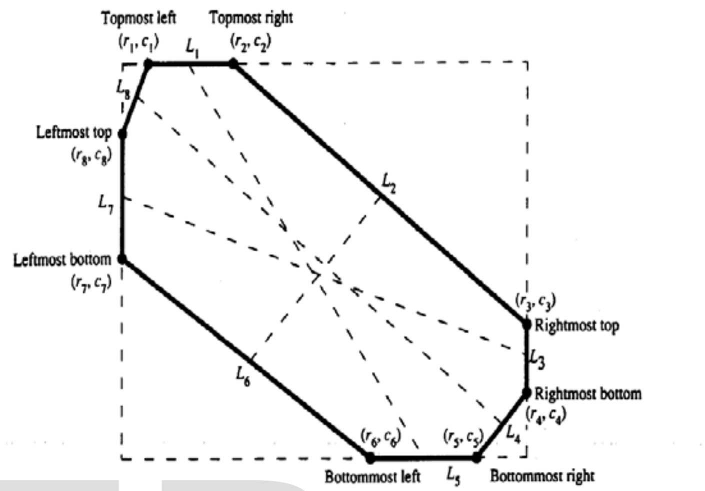

Fig.4 The eight extremal points a region

Then from these extremal points and we find out the axes those are represented by M_1, M_2, M_3, And M_4 where $M_1$is the axis between extremal points $(r_1, c_1)$and (r_5, c_5), $M_2$is the axis between extremal points $(r_2, c_2)$and (r_6, c_6), $M_3$is the axis between extremal points $(r_3, c_3)$and (r_7, c_7), and $M_4$is the axis between extremal points $(r_4, c_4)$and (r_8, c_8) and the length of each axis are computed as given in Eq.6:

$$M_1 = \sqrt{(r_1 - r_5)^2 + (c_1 - c_5)^2} + Q(\emptyset_1)$$
$$M_2 = \sqrt{(r_2 - r_6)^2 + (c_2 - c_6)^2} + Q(\emptyset_2)$$
$$M_3 = \sqrt{(r_2 - r_7)^2 + (c_2 - c_7)^2} + Q(\emptyset_3)$$
$$M_4 = \sqrt{(r_4 - r_8)^2 + (c_4 - c_8)^2} + Q(\emptyset_4) \quad (6)$$

Where $Q(\emptyset)$ is a constant value and set as 1.12 in the proposed emthod.

Step III.D: Recognition of cataract effected nature for the input eye image.

The recognition process includes first calculating the parameters mentioned in Eqs.1-6, for the edge images from the images of training data set, which contains both nature of the images of eye images with cataract nature and normal nature(without cataract). Then calculate the same parameters for the test image to recognize whether it is suffering from cataract or not. The process includes

Initialize the variables count1 and count2.

For images =1 to set of images in the training data set do

For components =1 to 5 largest components do

Obtain the difference1 by calculating sum of absolute value of differences with calculated parameters of eye images from the training data set with cataract nature and parameters of test image.

Obtain the difference2 by calculating sum of absolute value of differences with calculated parameters of eye image from the training data set with normal nature and parameters of test image.

If (diff1<diff2) then increment count1;
Otherwise increment count2;
End;
End;
End;

Higher the value of count variable, which gives the number of images in a training data set matched with the test image and the corresponding nature of eye is assigned and finally display the edge image along with identified nature.

IV RESULTS AND DISCUSSIONS

It is always preferable to have subjective and objective assessment to conclude whether the proposed method achieves or not. In subjective assessment image quality is measured by the subjective evaluations of human observer. The evaluation may be made using an absolute rating scale or by means of side-by-side comparison with output images of different schemes. The objective assessment can be made by using various metrics. The recognition performance depends on how well edge features are retained after applying proposed Nonlinear Robust edge detector on the noisy image without using regularization.

a) Subjective Assessment - Recognition of Cataract From Noisy Images By Using Proposed NLRED Method

TheFig.5 shows the set of sample images from the training data set, which contains set of sample images with cataract nature and normal eye nature(without cataract) for which we calculated the recognition properties after obtaining largest five edge connected components and maintained in a file. Later these are used for recognition process with the given test image to recognize whether it is to be assigned with cataract nature or normal nature.

(a) (b)

Fig.5 (a) Normal eye data set
(b) Cataract eye data set

The Fig.6 and Fig.7 shows the recognition of cataract nature from the given test eye image.

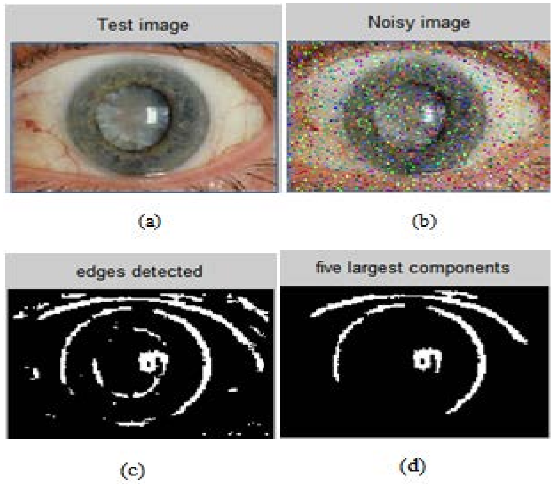

Fig.6 (a) Test image. (b) Test image with noise. (c) edges obtained by applying NLRED detector . (d) Extracted largest five connected componets by applying iterative algorithm.

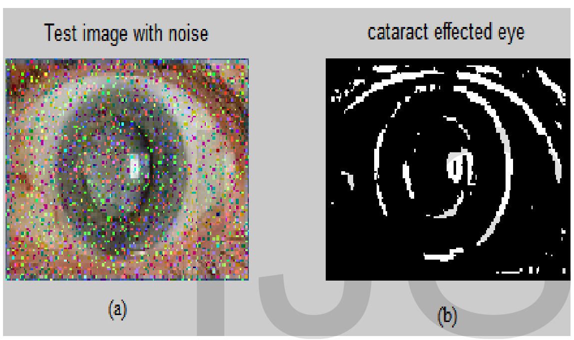

Fig.7 (a) Test image. (b) Recognized and assigned nature for test image

The Fig.8 and Fig.9 shows the recognition of cataract nature from the given test eye image.

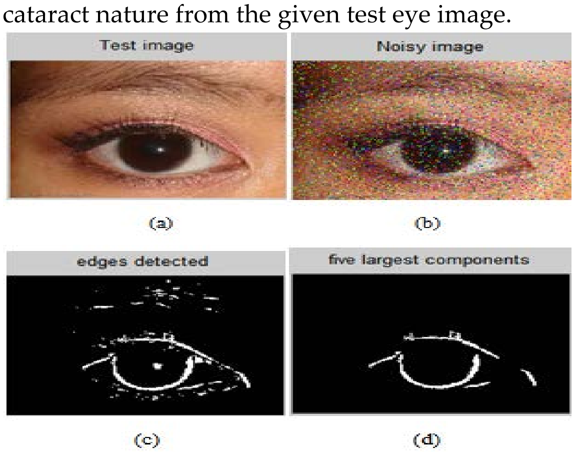

Fig.8 (a) Test image. (b) Test image with noise. (c) edges obtained by applying improved Robust Edge detector. (d) Extracted largest five connected componets by applying iterative algorithm.

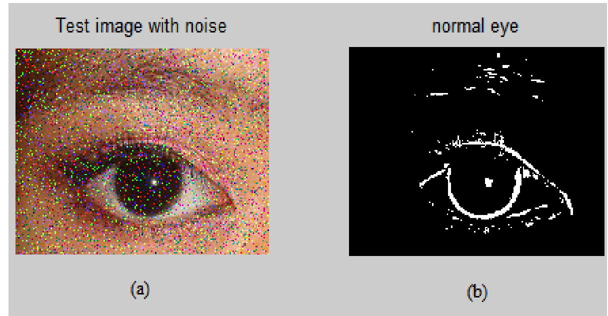

Fig.9 (a) Test image. (b) Recognized and assigned nature for test image.

The results are calculated not only considering the set of eye images by downloading from the google, evaluated on standard data set also. We have tested on retina of eye images with normal eye nature and with cataract nature, which are downloaded freely from MESSIDOR database. MESSIDOR (Methods to evaluate segmentation and indexing techniques in the field of retinal ophthalmology) is a project funded by the French Ministry of Research and Defense with an objective of an issuing and to create large databases of retina images and to use them in order to evaluate the various existing algorithms. And found that the proposed method works well for retina images of eye also exactly. Moreover, we cropped and normalized all images of size 512 X 512 pixels, based on the ground truth position of the retina of an eye. The Fig.10 and Fig.11 shows results obtained by applying on retina of an eye images from MESSIDOR database.

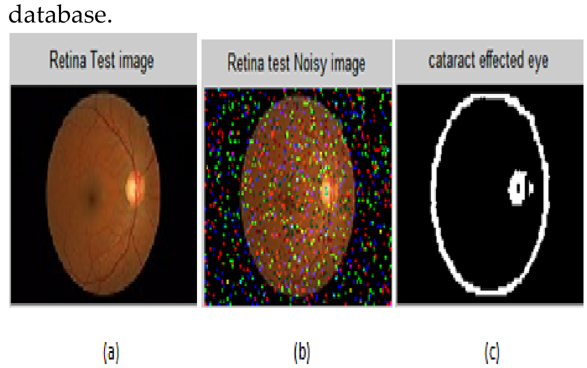

Fig.10. (a) Retina test image. (b) Retina test image with added noise. (c) Recognized and assigned nature for test image.

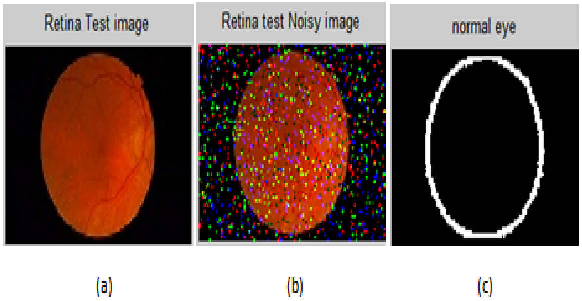

Fig.11. (a) Retina test image. (b) Retina test image with added noise. (c) Recognized and assigned nature for test image.

b) Objective Assesment-

To conclude the performance of the proposed approach we calculated the recognition rate or accuracy also. The recognition rate of a process on a given set is the percentage of test set images that are correctly recognized by the proposed method. For this we applied the proposed method on the set of images containing one hundred positive (normal eye) and eighty negatives (cataract eye) images. Table-I shows the constructed confusion matrix on the set of 180 images with true positives (TP), false positives(FP), true negatives(TN) and false negatives(FN).

Table I : Confusion matrix for the tested images

		Recognized nature	
		Normal nature	cataract nature
Actual nature	Normal nature	92(TP)	08(FN)
	Cataract nature	04(FP)	76(TN)

The recognition rate of the proposed method is calculated using Eqn.(7)-(8)

Recognition rate = Sensitivity(Pos / (Pos+Neg)) + Specificity(Neg/(Pos+Neg)) (7)

Where

Sensitivity = (TP / Pos) and

Specificity = (TN / Neg) (8)

The calculated recognition rate based on the values from the confusion matrix is 0.92 and the error rate is given by (1-recognition rate) and for the proposed approach is obtained as 0.08. Based on these experimental results as FOM value is nearer to 1 by extracting edge image by NLRED method compared to various methods listed in literature, the recognition rate is also more than 90% by yielding minimal error rate, Hence we concluded that the proposed method out performs well.

V CONCLUSION

In this paper we proposed a method for recognition of the cataract for the given test image even it is contaminated in presence of noise. It applies first NLRED method on a given test image to obtain edge image, then obtained largest edge connected components, for which we computed the recognition properties. These properties were used for matching process during cataract recognition with properties of the training dataset. The proposed algorithm acts as a diagnostic tool for the physician for the early detection of cataract. The results produced by the proposed method are highly acceptable. This method works well even images containing high density noise also.

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