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# Lesion Feature Detection of Retinopathy Images

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***Abstract*: In recent years, Diabetic Retinopathy (DR) is fast growing health problem in the society. Ophthalmologists use exudates, microaneurysms and hemorrhages features to diagnose the DR. Detection of these features plays important role in diagnosis and further treatment. This paper proposes automatic lesion detection and analysis methods so as to identify all three features without human intervention. The algorithm developed includes pre-processing as well as post processing, which is very important in DR images. Extraction of minute details in lesions requires highly enhanced images. Contrast enhancement and Morphological operations were applied on green channel DR images. Further, the segmentation is performed on enhanced DR images to capture required region of interest. The Kirsch algorithm has been applied to capture exudates candidate from DR image. Further Top-hat method on preprocessed image extracts microaneurysms and Thresholding technique has been applied for hemorrhage detection. The performance evaluation of algorithms is carried out through the publicly available database. The proposed algorithms depict better results in detection of three major parameters from digital retinopathy images with respect to toolkit evaluation adapted. This automatic detection method helps in reducing screening DR image time as well. The development of proposed algorithm leads to accurate DR detection by helping Ophthalmologists in the diagnosis process.***

***Keywords:*Exudates, Feature Extraction, Hemorrhages Microaneurysms, Retinopathy**

## I. INTRODUCTION

Automated biomedical image analysis is the need of an hour. Now a day's, the automatic analysis of images reduces the burden on experts and enhances health care process. Many researchers focused on the study of automatic image segmentation and diagnosis on biomedical images such as microscopy, retinopathy, MRI etc. out of which very few worked on lesion detection from diabetic retinopathy images. Treatment of several diseases due to abnormalities in retina and the choroid behind it depends on expert diagnosis by observing digital retinal images [1], [2]. Abnormalities in the retina and the choroid are due to effect of mellitus which leads in diabetes complications. According to World Health Organization report the diabetic patients will increase to 350 million until the next 25 years [3].

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According to their report, very few patients know about the health effects of DR disease and perform regular screening to avoid severe late complications. Age of a diseased person and long period of disease are factors causing variation in prognosis of retinopathy. Therefore, early detection of retinopathy is very important in medical perspective. The regular retinopathy screening may reduce the disease severity. The regular screening is costly and hence can be low cost affair using automatic disease detection from retinopathy images. Digital retinal images could be processed automatically using image processing techniques, to detect retinopathy abnormalities and enhance treatment process.

The contribution of this work is introducing automatic algorithms for different retinal lesions extraction. The proposed method includes exudates detection using Kirsch Algorithm, microaneurysms (MA's) using top-hat algorithm and hemorrhage (HA's) detection with multiple thresholding. The results of three retinopathy parameter detection depicts more accurate with respect to available hand labeled database. The DIARETDB1 database and evaluation procedure was used for proposed algorithms. In the literature researchers used sensitivity and specificity parameters for performance analysis; here we have reported Weighted Error Rate and ROC curve for all features using available toolkit [4].

## II. FETURE EXTRACTION METHODS

In literature one can find work on medical image segmentation, identification, classification based on texture based analysis, intuitionistic fuzzy system, FCM approach etc. [5, 6]. Automatic Medical Image analysis reduces the workload of ophthalmologists using image processing techniques. Therefore, one can find many image processing algorithms in literature for automatic detection of DR [7]. Following section discuss several work related to lesion (i.e. exudes, hemorrhages, microaneurysms) detection techniques.

### A. Exudates Detection

Ophthalmologists observe diluted pupil for detection of presence of exudates. The dilution of pupil is performed using chemical solution which may affect the patient's eye and also requires pre- checkup time. Hence, researchers worked on non-diluted pupil observation method using optimally adjusted morphology operators with low contrast image for exudates detection [8].

Gerald Schaefer et. al. presents an automated exudates detection using , neural network [9]. They process images to extract sub-region by using a sliding window approach. Hand labeled database of images with known exudates locations used to train neural networks which classify the central pixels regions into exudates and non-exudates instances.

Akara Sopharak et. al. have proposed automatic exudates detection method on low-contrast images taken from non-dilated pupils [10].

They performed two phase segmentation using Fuzzy C-Means clustering and morphological reconstruction. Because of two phases processing coarse as well as fine image details leads to accurate exudate detection.

Exudates were also classified using a machine learning approach in literature. Here, initially exudates feature selection is performed followed by classification using a naive Bayes classifier [11]. Noise removal is done using filtering and further the image has been enhanced with image contrast. In next step, optic disk (OD) was detected and removed from image to extract local features describing pixels or regions. These features are used to classify DR image using a neural network approach. The naïve Bayes classifier provides better parametric results.

## B. Microaneurysms Detection

Detection of these lesions is very important for effective DR screening. MA's are very small circular dark spots on the region of the retina. Mostly they appear near the tinny blood vessels, but never overlapped on the vessels. These small spots could be easily identified with enhanced digital image. A mathematical morphology technique is used in [12], for preprocessing, contrast enhancement and shade correction steps are recommended. Further, candidate extraction was carried using grayscale diameter closing method.

Researchers proposed automatic MA's detection by using sub-bands of wavelet transformed images with lesion template matching approach [13]. They used three image modalities such as green filtered photographs, color photographs, and angiographs to implement the proposed algorithm.

The MA's detection rate increases using pre-processing methods in combination with candidate extractors [14]. Martins and Charles have proposed method for the detection of Microaneurysms candidates [15]. The vessel segmentation method was based on mathematical morphology and curvature evaluation. The classification of Microaneurysms candidates was accomplished by neural network.

## C. Hemorrhages Detection

With increase in the degree of DR, retinal hemorrhages become clear to identify manually. This indicates an increased ischemia retina. As the number of HA's increases the retinal vessels gets more damaged and leaky. This leads to exudation of fluid, lipid and protein. The severity of diabetic retinopathy is diagnosed using hemorrhage detection criteria. Jang Pyo Bae et. al. have developed hybrid method for the detection of hemorrhages [16]. HA's detected with template matching using normalized cross-correlation technique. Finally, they have applied region growing approach so as to reconstruct the shape of HA's correctly.

In [17], HA's and exudates without fluorescein angiograms were detected automatically. As the pixel values of HA's lower than other regions, they were detected by performing finite difference calculations along with image smoothing.

Yuji Hatanaka et.al.discussed a method of HA's detection using preprocessing and false positive elimination in fundus images [18]. They performed change in brightness of the fundus image with the nonlinear curve and brightness of the HSV color space. In order to highlight brown regions in RGB fundus image, gamma correction was applied on all three planes separately. Subsequently, the individual histograms were extended to detect the HA's candidates.

The research through literature shows that, most of the work on diabetic retinopathy image analysis was evaluated based on parametric analysis. The sensitivity, specificity, accuracy and precision are main parameters considered in literature. The comparative analysis of the evaluation parameters with respect to lesion detection methods is shown in Table I below. Based on this study, the proposed algorithms were also evaluated with respect to these performance parameters. The image database and evaluation toolkit from DIARETDB1 is used in this study so as to compare our algorithm performance with state of art evaluation method.

**Table- I: Performance Measures for lesion detection Methods**

| Author | Method | Performance Measures |
|---|---|---|
| **Exudates Detection Methods** | | |
| Akara Sopharak et al.[8] | Morphological Method | Sensitivity= 86% Specificity=99.4% |
| Gerald Schaefer et. al.[9] | Neural Network | Sensitivity= 94.78% Specificity = 94.29% |
| Akara Sopharak et al. 10] | Fuzzy C-Means Clustering and Morphological Method | Sensitivity= 86% Specificity=99% |
| AkaraSopharak et al. 11] | Naive Bayes classifier | Sensitivity= 93.38% Specificity=98.14% |
| **Microaneurysms Detection Methods** | | |
| Thomas Walter [12] | Grayscale diameter closing | Sensitivity= 88.5% |
| Gwénolé Quellec [13] | Wavelet transform | Sensitivity= 93.74% |
| B´alint Antal [14] | Candidate extractors | Sensitivity= 99% |
| Martins [15] | Mathematical morphology and curvature evaluation. | Not Reported |
| **Hemorrhages Detection Methods** | | |
| Jang PyoBae [16] | Region Growing method | Success Rate= 85% |
| Yuji Hatanaka [17] | Finite Difference Calculations | Sensitivity= 85% Specificity=77% |
| Yuji Hatanaka [18] | Gamma Correction | Sensitivity= 80% Specificity=88% |

# III. EVALUTION METHODS

This research work proposes an innovative system for automatic analysis of different lesions in retinal images. An overview of our proposed method for analysis of different lesions is shown in Fig. 1. Initially, digital images from standard database were preprocessed to enhance low contrast image and avoid illumination effects. Further, feature extraction i.e. lesion parameter extraction is performed. The obtained results need post-processing so as to enhance the detected region in the image. Finally, the retinopathy feature extraction is considered for performance evaluation. Following section describes the detailed process of the proposed method.

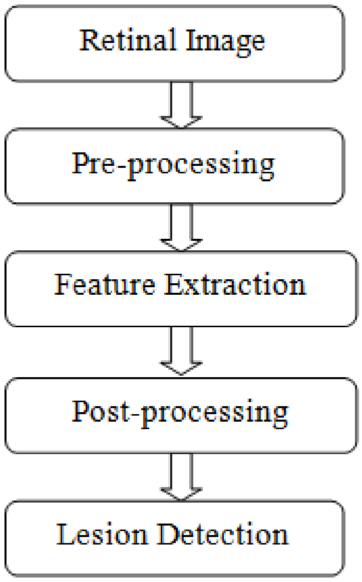



**Fig. 1. Flow Diagram of the Proposed Algorithm**

### A. Exudates Detection Algorithm

Exudates detection method based on three sections like pre-processing, feature extraction and post-processing [19]. In preprocessing algorithm, green channel of color retinal image was considered. Morphological dilation process is applied for thickens objects in binary image [20]. Further morphological operation, contrast-limited adaptive histogram equalization (CLAHE) method enhances the image contrast. Finally, the grayscale image was subtracted from the enhanced image. It gives more contrast in background and lesion.

In color retinal images Optic Disk (OD) and exudate are appear as a bright yellowish region. So because of similar appearance, it is necessary to remove OD for exudates detection. Using histon [21] based method mask is generated for eliminating OD. For exudate feature extraction the Kirsch method is applied on preprocessed image for edge detection. This will produce the maximum value considering as the structuring element for the edge detection. The Kirsch edge detection algorithm identifies both, the presence of an edge and the direction of the edge. All eight directions get identified using proposed algorithm [22]. In post processing, Morphological filling operation, fill holes present in the segmented image, also erosion and dilation operations are applied to the segmented image for removing the false exudate parts.

### B. Microaneurysms Detection Algorithm

In case of retinal images, there is not significant information in blue channel and red channel represents saturation. For preprocessing of MA's detection method only green channel with high contrast was considered. The detection of very small dots having a diameter of 10 to 100 µm i.e MA's is important and unwanted area around it such as vessels, high intensity regions like exudates, optic disk etc need to be removed. To remove vessels, image goes through median filtering then morphological operation. For Micro-aneurysm feature extraction top hat transform method is used in the retinal images [23], [24]. Here original image is subtracted by its area opened image to get final results in post processing.

### C. Hemorrhages Detection Algorithm

MA's and HA's at same intensity level. MAs are small blood dots whereas HA's bigger dots. The images in database have irregular illumination and contrast, which affects the performance of system. Due to this aspect, green channel selection and background normalization is performed as first preprocessing step. Further, morphological filling and OD elimination on the input RGB images is carried out to concentrate on lesion features only. HA's features were detected using Thresholding Approach [25]. Finally, in post processing being on similar intensity level and contrast with blood vessels, cross point of blood vessels are falsely detected as HA's. Hence, thresholding method is applied again to take out complete blood vessels structure from the processed image.

## IV. EXPERIMENTAL RESULTS

This section presents algorithm evaluation using DIARETDB1 database. The database has 89 color fundus images with 84 mild non-proliferative signs of the diabetic retinopathy and 5 normal. Normal images do not show any sign of the diabetic retinopathy. Reproducible results of proposed algorithms described in the above section were computed on this database. Performance measures were analyzed using the tool kit available with database [4].

The proposed algorithm was applied on retinal images from DIARETDB1 database. The hand labeled available with the dataset for each image is considered for evaluation. The different markings made on the hand labeled by different expert at various confidence levels. Fig. 2 below shows the detected exudate features for given input image with hand labeled image. Similarly Fig. 3 and Fig. 4 shows results for MA's detection and HA's detection respectively.

## V. PERFORMANCE MEASURES

Most of the work on retinopathy image analysis evaluates the algorithm performance using sensitivity and specificity values. The literature shows that, evaluation of these parameters is currently used by medical practitioners' and has direct interpretation in the medical terms. Diseased population decides Sensitivity whereas healthy populations depict specificity, which can be calculated using equations (1) & (2). This parametric analysis provides differentiation of diseased and healthy patient's correct diagnosis using proposed method. In comparative analysis of the method proposed, however, these two values are not feasible. This is because of trade-off between the two distributions overlap and the true accuracy values [4].

(a) (b) (c)

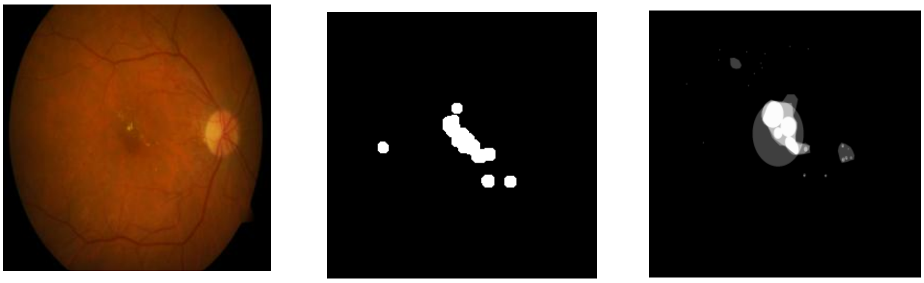


**Fig. 2. Result for Exudate detection Algorithm: a) Original Retinal Image [4], b) Feature Extracted Image, c) Hand labeled Image [4]**

**Fig. 3. Result for Micro-aneurysm Detection Algorithm: a) Original Retinal Image [4], b) Feature Extracted Image, c) Hand labeled Image [4]**

**Fig.4. Results for Hemorrhages Detection Algorithm : a) Original Retinal Image [4], b) Feature Extracted Image, c) Hand labeled Image [4]**

Receiving operating curve (ROC) analysis depicts performance of the feature extraction methods applied in this research. The graphical representation through ROC for True Positive Rate (sensitivity) and False Positive Rate (1-specificity) shows better performance of the proposed algorithm. Although the ROC analysis signifies better results of an algorithm, a single valued performance measure is required for quantitative analysis. Hence, the Equal Error Rates (EER) or a total area under ROC represents single valued measure for algorithm calculated from ROC analysis. In the medical diagnosis system false positives and negatives gives unequal weight, whereas EER measure gives equal weight. The weighted error rate (W) defined using two measures, sensitivity (sn) and specificity (sp) in equation (3) [4].

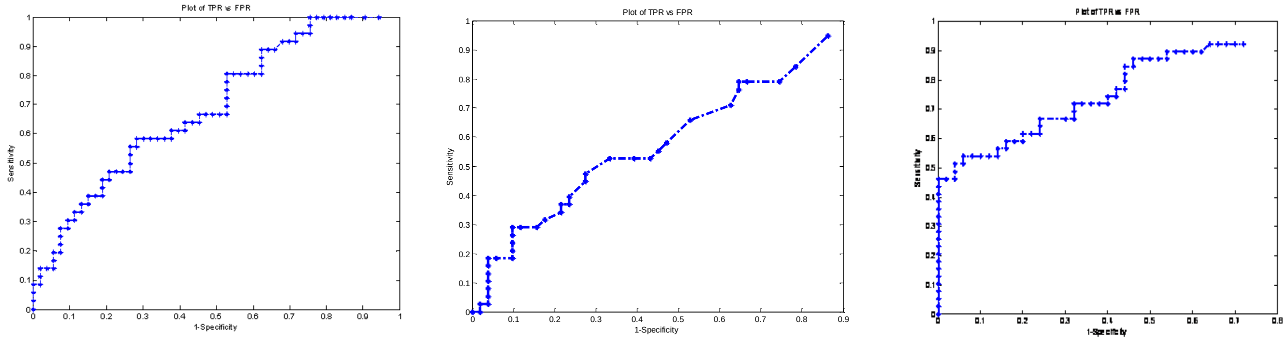
$$sn = \frac{tp}{tp + fn} \quad (1)$$

$$sp = \frac{tn}{tn + fp} \quad (2)$$

$$W(R) = \frac{FPR + R.(FNR)}{1+R} = \frac{(1-sp) + R.(1-sn)}{1+R} \quad (3)$$

Where $R = \frac{C_{FNR}}{C_{FPR}}$ is the ratio between False Positive Rate (FPR) and False Negative Rate (FNR).

The analyses of these quantitative measures are considered as follows: if W=0.1 (less), FNR magnitude is less harmful, when W=1 (moderate), FPR and FNR both are equally harmful and W=10 (High) depicts FNR is more harmful. The nearest true points are taking from ROC without interpolation to compute these measures [4].



(a) (b) (c)

**Fig. 5. ROC curves for a) Exudates; b) Microaneurysms; c) Hemorrhages.**

**Table- II: The Best Performance measures for Exudate detection**

| | FPR | | FNR | | WER | |
|---|---|---|---|---|---|---|
| | Kirsch Method | Baseline Method | Kirsch Method | Baseline Method | Kirsch Method | Baseline Method |
| R=0.1 | 0 | 0.02439 | 0.84211 | 0.45 | 0.07656 | 0.06308 |
| R=1 | 0.28571 | 0.07317 | 0.42105 | 0.25 | 0.35338 | 0.16159 |
| R=10 | 0.83333 | 0.80488 | 0 | 0 | 0.07576 | 0.07317 |

**Table III: The Best Performance measures for Microaneurysms Detection**

| | FPR | | FNR | | WER | |
|---|---|---|---|---|---|---|
| | TOP-HAT Method | Baseline Method | TOP-HAT Method | Baseline Method | TOP-HAT Method | Baseline Method |
| R=0.1 | 0 | 0 | 1 | 0.8000 | 0.090909 | 0.0727 |
| R=1 | 0.27451 | 0.4634 | 0.526316 | 0.1500 | 0.400413 | 0.3067 |
| R=10 | 0.862745 | 0.4634 | 0.052632 | 0.1500 | 0.126278 | 0.1785 |

**Table IV: The Best Performance measures for Hemorrhages Detection**

| | FPR | | FNR | | WER | |
|---|---|---|---|---|---|---|
| | Thresholding Method | Baseline Method | Thresholding Method | Baseline Method | Thresholding Method | Baseline Method |
| R=0.1 | 0 | 0 | 0.5 | 1.0000 | 0.04546 | 0.0909 |
| R=1 | 0.0465 | 0.1628 | 0.4444 | 0.8333 | 0.2455 | 0.4981 |
| R=10 | 0.6512 | 0.8837 | 0.0556 | 0.2222 | 0.1097 | 0.2824 |

The efficiency of the proposed algorithms is evaluated through ROC curve as shown in Fig. 5. It is plotted by using TPR (True Positive Rate) against FPR. Fig.2, Fig. 3 and Fig. 4 shows results obtained from lesion detections algorithms using database. Ground-truth images for evaluation were considered from database. These are obtained through number of experts, where they have marked all regions of interests with different confidence levels.

The obtained results does not resembled with the hand labeled images, due to multiple overlap in hand labeled. The mean area of hand labeled is considered in evaluation of proposed algorithms. The best sensitivity and specificity in detection of lesion are achieved with a confidence level of 0.75, which depicts that better performance of proposed algorithm. Table II, III, IV described the best performance measures for Exudate detection, MA's Detection and HA's detection respectively.

## VI. CONCLUSION

The proposed method includes exudates, microaneurysms and hemorrhage detection from digital retinopathy images. The pixel based image analysis algorithms were presented so as to capture lesions from images to detect abnormality. The proposed morphological pre and post processing operations enhances the results and helps in accurate candidate detection. The segmentation results also represent minute candidate detection along with elimination of unwanted identified regions from DR images. This leads to correct lesion detection and improves algorithm performance. Through DIARETDB1 database and evaluation toolkit, the algorithms were evaluated and the results outperforms in case of detection of lesions. Further, ROC analysis of the algorithms depicts better performance. This automatic detection of lesion features presented in this study could help Ophthalmologists in screening process.

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