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Hard Limiting and Soft Computing Techniques for Detection of Exudates in Retinal Images: A Futuristic Review

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Authors' contributions

This work was carried out in collaboration between all authors. Author HSVK made a detailed referential work. Author MAJ guided in preparing the first draft of the manuscript and managed citation accuracy. Author AGK fine tuned the article. All authors read and approved the final manuscript.

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ABSTRACT

Retinopathy in general, diabetic retinopathy in particular is the major concerns of blindness and appearance of hard exudates is one of its early symptoms. Since almost two decades, researchers are striving to develop automated algorithms and systems either to detect or to grade the severity of hard exudates. In this direction, this paper is a sincere effort to present the research carried out in this field. This paper has three specific intents i) to update the state- of-the-art techniques by bringing to the fore research that is being carried out, ii) to encourage prospective researchers in this area to explore various computational methodologies for the future development of detection techniques, and iii) to provide insights into some unsolved recognition problems.

Keywords: Diabetic retinopathy; exudates; image processing; hard limiting; soft computing.

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1. INTRODUCTION

Diabetic Retinopathy (DR) is an ailment of retina caused by complications of diabetes mellitus, which can eventually lead to blindness in both middle and advanced age groups [1]. Diabetes can cause weakening in the retina's blood vessels. The blood vessels in the retina are very susceptible to this weakening and can go through a series of changes. Recent research has given a better understanding of the disease processes and is opening up new avenues for prevention and treatment. Very effective treatments are available and are optimally used when retinopathy is detected early, well before the patient is aware of the symptoms. For this reason screening programs for early detection of retinopathy are an essential part of diabetes care and are in widespread use [2]. As per the National Institute of Health (NIH 2009), diabetic retinopathy is the most common diabetic eye disease that is caused by changes in the blood vessels of the retina, where in blood vessels may swell and leak fluid, abnormal new blood vessels may grow on the surface of the retina. It is well known that the complications grow incrementally marked by the four stages. The first stage consists of blood clots which appear as small red dots typically called micro aneurysms. The second stage involves exudates which are bright yellow spots which are basically concentrate fat deposits, third stage is little severe with hemorrhages that create blood stains regions relatively over a wide area. The final stage is marked with cotton wool whitish yellow regions that are caused by the damage of nerve fiber [3,4]. Researchers have made attempts to localize and mask the blood vessel network and optic disk for detection of exudates, hemorrhages and micro aneurysm. In this direction several computational strategies have been proposed and documented with the intent of automated detection of retinopathy. It is cited in the literature that the most of the research work have been carried out on publicly available data sets which are STARE (STructured Analysis of the Retina), DRIVE (Digital Retinal Images for Vessel), DIARETDB (Diabetic Retinopathy Database)1, DIARETDB0, MESSIDOR (Methods for Evaluating Segmentation and Indexing techniques Dedicated to Retinal Ophthalmology), Retinopathy online Challenge, CMIF(Collection of multispectral images of the fundus) , REVIEW (Retinal veseel image set for estimation of width), JRD (Junction resolution data set, ONHSEG (Optic nerve head segmentation data set), RIM-ONE (Retinal Image database for Optic Nerve Evaluation), ARIA (Automated Retinal Image Analysis), INSPIRE (Iowa Normative Set for Processing Images of the Retina*)*. This paper is an attempt to make an elaborate survey of research in this domain. The rest of the paper is organized as follows: Section II elaborates the detection of exudates by sheer Image processing techniques adopted in automated detection of exudates, section III presents some of the hard limiting computation techniques adopted in automated detection of exudates, applications of soft computing techniques in detecting exudates is the matter presented in section IV. Section V brings out the futuristic view point of the authors and section VI concludes the paper.

2. IMAGE PROCESSING TECHNIQUES FOR DETECTING EXUDATES

Prior to the application of various computational strategies, extensive work has already been carried out in the direction of automated exudates detection, by augmenting traditional image processing techniques. This is driven the fact that the processing of color images of retina has the potential to play a major role in diagnosis of diabetic retinopathy. There are three different ways in which it can contribute towards the image enhancement, mass screening (it includes detection of pathologies and also retinal features), and monitoring which includes feature detection and registration of retinal images. Efficient algorithms for the detection of the optic disc and microaneurysm, hard and soft exudates have been used.

Clara Sanchez et al. [5] presented a novel automatic image processing algorithm for detection of hard exudates in retinal images. The algorithm is based on Fishers Linear discriminant analysis and makes use of color information to prefer the classification of retinal exudates. HE (Hard exudates) is composed of preprocessing steps consisting of RGB color space transformed to YIQ color space, color normalization and contrast enhancement is applied. The three dimensional RGB model is the feature vector considered. The exudates training set is obtained by carrying out a Coarse Segmentation of the image. Exudates edges are enhanced by applying Frei-chen operator which highlights the edges, and sharpness of the edges is found by using Kirsch operator. This method detects HE lesions based on color, using statistical classification. Fishers Linear discriminant is used for classification which takes the shape of the clusters in the feature space into consideration.

OD (Optic Disk) is detected using Hough transform and candidate selection is done by using mathematical morphology. The performance achieved a sensitivity of 88% with a mean number of 4.84 +-4.64 false positives for lesion-based evaluation and achieved a sensitivity of 100%, specificity of 100% and accuracy of 100%.

An analytical approach with the focus on direct identification of exudates using accurate geometric models has been investigated [6]. In this work two separate algorithms are developed to detect exudates and dot hemorrhages information from the color information. Morphology technique and intensity gradients of the fundus photographs provides a means to detect number of exudates and dot hemorrhages and thus determine the presence of diabetic retinopathy. OD is identified as the largest connected region of dots on green color channel as the boundary circle is created to eliminate the OD. Exudates are found using pixel median filter along all vertical and horizontal lines. Adding of the selected pixels to the potential exudates is done by checking if they are connected to the exudates pixel. Dot hemorrhages are identified by the binary image and checked if potential DHs are blood vessels by removing the false DHs. Hard exudates identification results in specificity of 96.7% and sensitivity of 94.9%. Dataset used is DIARETDB0 database. Usage of fixed and variable threshold for automatic tracing of optic disk and exudates has been attempted by Ahmed Wasif Reza et al. [7]. The preprocessing steps include green channel extraction from RGB image, average filtering is used to reduce noise, contrast adjustment and threshold is performed. Morphological opening is applied on the threshold resulting image, the image complement is performed followed by extended maxima operator, minima imposition and watershed transformation is applied to detect Optic Disc and exudates. In the post processing method the image is converted back to RGB image. The present method yields a sensitivity value of 96.7%. STRIVE and DRIVE dataset are used for evaluation.

Vijayakumari et al. [8] has developed a method for exudates detection using image processing techniques. Pre -requisite stage of exudates detection is the detection and elimination of Optic Disc. Principal component analysis between clusters and propagation through radii are used to detect optic disk. Three algorithms are presented and compared for detection of exudates. Template matching, minimum distance discriminant classifier and enhanced minimum distance discriminant classifier methods are used to detect the presence of exudates. The basic requirement of template matching is that both normal and abnormal images are required. The orientation, angle, lighting of both reference and the abnormal image should be same otherwise it would give wrong identification of the presence of exudates. Minimum distance discriminant classifier is based on statistical recognition technique and this gives better result. This works on spherical coordinates and the center are found using a training set and hence remain fixed. This causes problem and employed such that the center of class varies dynamically, depending on the image. Enhanced minimum distance discriminant classifier uses RGB values of the image and the abnormality is characterized by the features yellowish color and sharp edges. Dataset used is local dataset. Application of split and merge algorithm has been made for detecting exudates. In this work the green component from RGB image is extracted with uneven illumination of the image. The typically of the work lies in the use of morphological top-hat operator with disk-shaped structuring element of a fixed radius of 25 pixels. Hough transform is used to detect circular region of interest [9]. By coarse exudates detection method, blood vessels are being eliminated using local variation operator. Morphological closing operator is applied to the preprocessed image. Automatic threshold is applied using Otsu's algorithm. Finally a clear border operator is applied to suppress structures that are lighter than their surrounding and connected image border. Fine exudates detection consists of two steps: The first step is to investigate the optimal number and directions of image partitioning using split-and-merge algorithm. The second stage is to apply global threshold on each individual sub-image separately with appropriate threshold value using a histogram-based threshold. The performance is achieved with a sensitivity of 89.3%, specificity of 99.3% and accuracy of 99.4%.The publicly available database DIARETDB1 has been used in evaluation process.

Guoliang Fang et al. [10] has proposed a frame work to automatically segment the hard exudates. Soft segmentation approach by Fisher discriminant is used to segment the pixels in the region into foreground and background. Ada boost method in BSS algorithm is used in classification. Based on the confidence map, from boosted soft segmentation algorithm, candidate the HEs by background subtraction. Multi-scale median filter is chosen to subtract background from the confidence map. After background subtraction, a fixed threshold is used to achieve coarse segmentation. In Fine segmentation technique OD are detected using vessels direction matched filtering which are used to segment the vessels using Gabor wavelet filters. The double-ring filter is used to adjust the OD center and the size. The features extracted in this work are the subtracted background values of mean, standard deviation for both outside and inside the region of interest. Further background substation values at the centroid and region edge strength. The performance achieved a sensitivity of 88.54% and positive predictive value of 85.61% for lesion-based. The performance achieved a sensitivity of 100%, specificity of 88.57% and accuracy of 91.38% for image-based results. Hussain et al. [11] proposed a method of grading hard exudates from retinal fundus images. Preprocessing steps involves, green channel component is smoothed using two filter stages, first by median filter and then by a Gaussian filter. The shade correction is carried out using morphological operations. The shade corrected image is generated by subtracting the estimated background from the smoothed image. CLAHE (Contrast-Limited Adaptive Histogram Equalization) is applied to the result of the shade correction for contrast enhancement. Two operations are carried out to detect HEs, namely adaptive threshold and classification. The adaptive threshold includes two steps: Image partitioning into homogeneous and then segmenting candidates of HEs from background of these regions. Edges in each region are detected using canny edge detector. To remove contrasted blood vessels from resulting sub-image, a morphological closing operator with disk-shaped structuring element and fixed radius of 6 pixels was used. Hard exudates (HE) can be discriminated using shape features such as length, width, aspect ratio, area, perimeter, circularity, solidity and eccentricity. A classification process is carried out to classify HEs from non-HEs using a rule-based classifier. The performance measures in image basis is found with a sensitivity and specificity of 98.4% and 90.5%, while in the pixel level sensitivity of 93.2% is achieved.

S.Kavitha et al. [12] has reported a method to detect exudates and macula in fundus images. The technique involves three stages namely, detection of exudates, macula detection and severity estimation of DR. In the first step of detection of exudates, the usual preprocess followed by circular Hough transform for OD elimination and the blood vessels are eliminated using the morphological closing operator. Exudates are detected using split and merge technique based on the variation of the whole image. In the second step, macula is detected, it consists of preprocessing step where RGB converted to Lab space- L channel is used, and CLAHE is applied for contrast enhancement. OD Diameter is calculated to locate the macula region. ROI is taken over the OD boundary. Top hat filtering technique is applied with disc shaped structuring element. ROI is taken over the macula and is converted to binary image. Inverse binary is performed to detect macula. Image is smoothened using morphological operation to detect macula exactly. Jack Lee et al. [13] developed a novel method to detect exudates that based on interactions between texture analysis and segmentation with mathematical morphological technique by using multimodel inference. The texture analysis involves three components: They are statistical texture analysis, high order spectra analysis, and fractal analysis. The performance of the proposed method is assessed by the sensitivity, specificity and accuracy using the public data DIARETDB1. Many experiments have been performed on normal and abnormal retinal images based on presenting of exudates. To test and validate the proposed method, the following 89 images from the DIARETDB1 database of resolution 1500 × 1152 with their clinician marked images were used to validate the method at the pixel level. 47 of these images contain exudates while the remaining 42 either contain other type of lesions or are normal. They used this database to measure the accuracy of the proposed method based on its ability to distinguish between normal and abnormal images. The performance of the proposed approach for exudates detection was assessed quantitatively by comparing the results of extractions with the ophthalmologist's ground-truth images. Results show that the sensitivity, specificity and accuracy are 95.7%, 97.6% and 98.7% (SE = 0.01), respectively. It is shown that the proposed method can be run automatically and also improve the accuracy of exudates detection significantly over most of the previous methods.

Morium A kter et al. have reported an improved method [14] of automatic exudates detection in retinal images using nonlinear background elimination. This method used forty - six color fundus images from Bangladesh Eye Hospital, Dhaka, Bangladesh and evaluate the performance of the method. The result is compared with ophthalmologist hand drawn ground truth and the proposed method gives good predominance. The experimental results for sensitivity, specificity, accuracy, and positive predictive value (PPV) are calculated for images those contain exudates. It is reported that the PPV of the method resulted in a substantial improvement up to 94.9% when compared to 92.8 of the existing method. Jaskirat Kaur et al. [15] have proposed a simple automated method to diagnose retinal disease. The technique initially separates the healthy regions like blood vessels and optic disc from the retinal images and classifies as non exudates. Further the dynamic region growing method is employed for the segmentation of exudates in the images containing retinal disease. The technique developed is examined on various retinal images and the outcomes confirm that the presented technique performs better than the previous proposed methods for the segmentation of exudates. In order to segment the exudates dynamic region growing method is used. The developed technique, tested on 128 retinal images, showed higher precision in segmentation than the other techniques. The entire interpretation of a particular retinal fundus image was carried out in 7 seconds without any expert involvement. This method locates and detects approximately 96.1% of the ODs and segments approximately 98.65% of exudates correctly. Thus, this technique provides a better segmentation and quantification precision. The complexity, cost and time of the system is reduced at the much comparable results. The proposed method also has the ability to eliminate blood vessels in the retinal fundus images, and it also discards the optic disc region to quantify exudates area precisely. Vesna Zeljkovic et al. [16] have proposed two algorithms for exudates detection and optic disk elimination for retinal images classification and diagnosis assistance. They represent the effort made to offer a cost-effective algorithm for optic disk identification and elimination which will enable for easier exudates detection and extraction, detection of excaudate and retinal images classification aimed to assist ophthalmologists while doing diagnoses. The algorithm proposed is robust to various appearance changes of retinal fundus images and show very promising results. The obtained results indicate that the proposed algorithm successfully and correctly classifies more than 98% of the observed retinal images because of the changes in the appearance of retinal fundus images typically encountered in clinical environments. Manpreet Kaur et al. [17] have developed a hybrid approach for automatic detection of exudates from eye fundus images. In this approach, unsharp masking is used for preprocessing, region based segmentation is used for candidate detection and pixel based classification is used to determine the severity level of the disease. The proposed method is tested at the image-level as well as at pixel -level on publically available database DIARETDB1. The results showed 98.12 % specificity and 90.83% sensitivity considering the pixel- level evaluation, while it is 86.04% and 91.06% respectively on image-level evaluation. The summary of the research is presented in Table 1.

Table 1. Exudates detection methods using sheer image processing techniques

Sl	Year	Author / Researcher	Methods used
1	2015	Manpreet Kaur et al.	Region Based segmentation, Pixel based classification
2	2015	Vesna Zeljkovic et al.	Mathematical Modelling, Varying levels of intensity
3	2014	Jaskirat Kaur et al.	dynamic region growing method
4	2014	Morium A kter et al.	Nonlinear background elimination
5	2013	Jack Lee et al.	mathematical morphological technique by using multimodel inference,Texture Analysis
6	2012	S.kavitha et al.	Split and merge technique based on variation of whole image
7	2011	Hussain F.Jaafar et al.	Median filter, Gaussian filter, morphological operation, adaptive thresholding
8	2010	Guoliang Fang et al.	Coarse segmentation, Fisher discreminant, Ada boost method, background subtraction
9	2010	Hussain F.Jaafar et al.	Image Partitioning using Split and Merge Algorithms, Apply Global thresholding

Sl	Year	Author / Researcher	Methods used
			Histogram-based thresholding
10	2010	V.Vijayakumari et al.	Template matching, Minimum Distance Discriminant classifier and Enhanced Minimum Distance Discriminant classifier
11	2010	Ahmed Wasif Reza ET AL. et al.	Contrast adjustment and thresholding, Morphological opening, watershed transformation
12	2009	Christopher et al.	Morphology technique and intensity gradients
13	2008	C.I. Sánchez et al.	Fishers Linear discriminant analysis, coarse segmentation and Kirsch operator

3. HARD LIMITING COMPUTATIONAL TECHNIQUES

Hard limiting computational Techniques have been used to solve different problems in multiple domains since a long time. They are basically traditional in nature and founded on principles of precision, certainty, and inflexibility inherent in white and black logic. It has been noticed that hard computing techniques such as K-Nearest Neighbor (KNN), the variants of KNN, support vector machine (SVM), Binary trees linear discrete analysis, polynomial curve fitting, symbolic logic and reasoning etc, are efficient to solve real life problems. In this section, applications of such hard limiting techniques in acceleralated exudates detection methods have been disused. Niemeijer et al. [18] have used machine learning based computer algorithm to evaluate and detect exudates and cotton-wool spots and to differentiate them from drusen. K-Nearest Neighbor was used to classify the pixels on the basis of filter response together with a linear discriminant function. In this work each pixel is classified and a probability map that indicate the probability of each pixel to be a part of bright lesion has been developed. Differentiation of types of pixels or clusters are based on features such as pixel color, cluster area etc. The algorithm so developed resulted in two outputs where bright lesion are present or not and which class each lesion as a part of exudates, cotton wool spots or drusen. The algorithm showed a performance of 95% and 86% with respect to sensitivity and specificity in detecting exudates. Wei Lin et al. [19] have merged the image region by KNN graph. The detection of OD and blood vessels are done by the combination of Gaussian filter matching and iterative threshold tracking. The extracted result is taken as input to fuzzy convergence algorithm to detect the OD center by determining the origination of blood vessels network. An edge image is drawn using Kirsch's mask. Segmentation of retinal images are done by a fast agglomerative clustering method using a K-NN graph. Regions are merged together to form a segmentation of the image according to their homogeneity. Merging is started with little regions and K-NN graph is used for searching regions that should be merged. A stack is used to predefine a threshold, namely a color deviation. Mean intensity of the current region is updated to the stack. After all the pixels are assigned a region the algorithm is terminated. The performance achieves an average specificity of 95.42% and average sensitivity of 91.08% in detection of exudates.

Giri Babu Kande et al. [20] have presented a method of feature extraction in digital fundus images. Optic disc boundary detection done by the use of color morphology in Lab space to get homogenous optic disc region and geometric active contour model with variation to extract the boundary of the optic disc. The exudates segmentation algorithm consists of three steps. First step is preprocessing, Second is optic disc is detection by using entropy feature on contrast image. A flat disc shaped element with a fixed radius is used to eliminate the optic disc. In the third step, exudates segmentation is based on feature gray level. Spatially weighted fuzzy C-means clustering (SWFCM) is used for exudates segmentation. The features extracted for classification are region edge strength, gray level difference between inside region area and surrounding area. The sensitivity and specificity of exudates detection are 100% and 89% correspondingly. The dataset used are STARE, DRIVE, DIARETDB0, and DIARETDB1 database. SVM was applied in diagnosis of retinal images [21] to do so the statistical features extracted are obtained from co occurrence matrix such as energy, entropy, correlation, inertia and local homogeneity. The image with morphological structuring element is binarized using thresholding to differentiate between images with and without exudates. The SVM classifier with the above mentioned inputs has a sensitivity of 97.5% and specificity of 100%. The dataset used is MESSIDOR database.

An entropy based feature selection using Otsu algorithm has been reported by Akara et al. [22]. In this work Image vessel edge pixels were detected using decorrelation stretch on red band together with Contrast exaggeration to expand the range of intensities of highly correlated images and the resulting image is thresholded for detecting blood vessels. In total 15 features are being involved while classifying exudates using naive bayes and support vector machine classifiers. It has been reported that both the algorithms have shown 92.28% sensitivity 98.52%, specificity 53.50 % precision followed by accuracy of 98.41%. KNNFP (K-Nearest Neighbor Classification on Feature Projections) and WKNNFP (Weighted-KNNFP) are conjointly used for exudates detection [23]. The features extracted are Hue, intensity, mean intensity, standard deviation intensity and distance between OD and intensity. Euclidean distance and Manhattan distance measures are used for KNNFP and WKNNFP respectively. The performance of KNNFP is achieved with a sensitivity of 100% and 86.84%, specificity of 92.59% and 90.90%, accuracy of 96.67% and 88.33% for both distances correspondingly. The performance measure for WKNNFP is achieved with a sensitivity of 100% and 100%, specificity of 92.59% and 92.59%, accuracy of 96.67% and 96.67% for both distances correspondingly. Clustering algorithm has been used by Annie et al. [24]. The work involves segmentation of effected regions into 5 clusters using k-means algorithm. The features extracted are contrast, homogeneity, entropy, variance, shade, and PROM. The selected features are used to classify the clusters into exudates and Non exudates using SVM. With this approach a detection rate of 96% has been claimed by the researchers. In yet another attempt has made for detection of exudates using SVM [25] assisted segmentation with features such as area of exudates, area of blood vessels, area of MA, contrast, homogeneity, correlation and energy. The classification was done. The classification of the work has showed a classification accuracy of 93% over DRIVE, DIARETDB1 and MESSIDOR database.

In a Medical decision support system meant for grading retinopathy image regeneration technique is used to calculate the bright lesions which are divided by the whole image of the retina. The system works on the features selected based on the pixel values for cotton wool spot, Large Plaque Hard exudates, and hard exudates. Rule-based classification is developed for the categorizing non-proliferative diabetic retinopathy and proliferative diabetic retinopathy. SVM is used for classification of normal and abnormal diabetic retinal images. The results have shown with an average accuracy of 97.2% and 96.5%. For detecting bright and dark lesions. STARE and DRIVE dataset is used for develop and evaluation of the system [26]. Ramasubramanian et al. [27] presented an automatic method of detecting DR and localizes the presence of exudates from color fundus images with non-dilated pupils. The set of features extracted from selected cluster using GLCM for further classification. The features extracted from the selected clusters are contrast, correlation, cluster prominence, cluster shade, dissimilarity, entropy, energy, homogeneity, and sum of the squares. Feature selection is done using particle swarm optimization [PSO]. The feature vector determined is given as input for KNN classifier. It is classified into normal or abnormal using KNN. The success rate of detection of exudates is 97%. The dataset used is DRIVE, MESSIDOR database. Different color spaces such as RGB, YIQ HSI, HSL, Luv are selected for classification approach [28], among these Luv color space is used for segmentation. Six features were selected as input, four features from the preprocessing step and two features from the number of edge pixels and standard deviation of preprocessed intensity value around a pixel. Classification is pixel-based. The SVM classifier showed a sensitivity of 94.46%, specificity of 89.92% and overall accuracy of 92.14%.Data set used is local database.

Wei Bu et al. [29] proposed a method of hierarchical detection of hard exudates in color retinal images. This method consists of two stages coarse level and fine level segmentation. The objective of the work is to coarsely segment all bright candidates, such as OD, cotton wool spots, HE regions which directly use the intensity feature of retinal image. Integrate histogram segmentation and morphological reconstruction to coarsely segment the candidate regions. To remove the OD region vessels direction matched filter is used. A multi-directional Gaussian matched filter is designed to detect the vessel network. For classifying the HEs or non-HEs, a set of 44 features are defined as the input for classification. Feature extraction consists of

Area, Circularity, Compactness, Edge strength, The Grey-level value of the centroid of the region [Il, Iu, Iv, Ih], Mean grey-level value of the region [Il, Iu, Iv, Ih], Standard deviation values of the region [Il, Iu, Iv, Ih] Mean Grey-level values of the surrounding region in [Il, Iu, Iv, Ih], Standard deviation values of the surrounding region in [Il, Iu, Iv, Ih], Difference of the mean value between the original and its surrounding region in [Il, Iu, Iv, Ih], Homogeneity of the candidate region in [Il, Iu, Iv, Ih], Mean response values of the candidate region obtained by applying 2-D LoG (Laplacian of Gaussian) filter. PCA is used to reduce the dimension of these features. Statistical learning method a two-class SVM model with a RBF kernel is used in the classification process to separate HEs or non-HEs. DIARETDB1 is the database used. The results showed a sensitivity of 94.7% and Positive Predictive value of 90%.

A novel method presented by Nan yang et al. [30] for automatic segmentation of hard exudates in fundus images. Soft segmentation is used to segment pixels in the region into foreground and background. Ada boost is used in classification. In coarse segmentation stage the background subtraction method, multi-scale median filter bank is used to filter out HEs and the OD. In the fine segmentation stage OD and cotton wool spots are detected by vessels direction matched filter, where the vessels are segmented by using Gabor Wavelet filters. Features extracted are mean [Ig, Il, Iy] background subtraction values inside the region, standard deviation of [Ig, Il, Iy] background subtraction values inside the region, mean [Ig, Il, Iy] background subtraction values outside the region, standard deviation of [Ig, Il, Iy] background subtraction values outside the region, [Ig, Il, Iy] background subtraction values of the region centroid, region edge strength on [Ig, Il, Iy] and the result of boosted soft segmentation [BSS]. The edge value are computed by using prewitt operator. SVM classifier is used to classify candidate regions as HEs and non-HEs with a set of input features. The performance of lesion based, showed a sensitivity of 91.36% and PPV of 86.43% and the image-based, results in a sensitivity of 99.64%, specificity of 87.86% and accuracy of 93.78%. Publicly available dataset DIARETDB1 database is used for experiments.

Anam Tariq et al. [31] have developed a computer aided diagnostic system for grading diabetic retinopathy. Microaneurysm and hemorrhages are detected using morphological operator. The features extracted for this purpose are area, eccentricity, perimeter, compactness, aspect ratio, mean and standard deviation of pixels in candidate region for a green channel image, mean and standard deviation value of enhanced intensity values, mean gradient value for boundary pixel, mean gradient value of neighboring pixels outside lesion, mean, hue, saturation and intensity values inside lesion, standard deviation hue, saturation and intensity values inside lesion. These feature extracted for candidate region are given as input to the SVM. SVM is used along with RBF Least squares kernel function for classification. The performance is achieved with a sensitivity of 95.15%, specificity with 98.42% and accuracy of 97.69%. The publicly available dataset DIARETDB0, DIARETDB1 are the database used. A novel method is proposed by Flavio et al. [32] for DR detection in color retinal images. The algorithm combines two image classification methodologies using ensemble learning. The first methodology extracts the image attributes using speeded up robustness features (SURF) algorithm and determines the presence of DR using a SVM. The second methodology consists in the classification of an image based on the segmentation of exudates regions. In the first methodology, SURF algorithm is used for image attributes extraction which will generate an attribute vector having different number of points per image. Visual dictionary constitute an approach in which each image is treated as a collection of regions, in order to generate a single feature vector to be passed to the classifier. The performance measure achieved by first methodology is a sensitivity of 80%, specificity of 83.33% and accuracy of 81.25%. In the second methodology, feature vector f1=(H,S,V,I) and f2=(R,G,L,u,v) are used as input to fuzzy k-means algorithm. The output of this algorithm consists of two images (I1 and I2) resulting in feature vector (f1 and f2). In order to classify the exudates region, the features extracted are divided into two groups non-color group consisting of 6 features such as area, perimeter, circularity, homogeneity, (x,y) coordinates of the region center and color group consisting of 18 features such as average and standard deviation of all the component of color model RGB, Luv and, HSI. Finally 12 features were selected that performed best such as area, perimeter, circularity, average of components (L,u,v,H,I,G), standard deviation of the component (G) and (x,y) coordinates of the region center. OD is detected using the region of the focal point of the blood vessels. Blood vessels are segmented and are converted into straight lines using Hough

Transform. The elimination of OD was performed by removal of the region connected to the center. To eliminate false candidate regions classification techniques such as K-Nearest Neighbor (KNN), Multilayer Perceptron (MLP), Radial Basis Function (RBF) and Support Vector Machine (SVM). After the exudates candidate segmentation, MLP was used for classifying the images in pathological and non-pathological. The resultant is the combination of two methodologies is performed using ensemble learning. Using these techniques MLP presented the best performance with 97.29% of exudates and 81.57% non-exudates. The performance measure achieved by second methodology is a sensitivity of 88%, specificity of 78.95% and accuracy of 84.09%. The Dataset used is DIARETDB1 database.

Balazs Harangi et al. [33] propose a method for the automatic segmentation of exudates consisting of a candidate extraction step followed by exact contour detection and region wise classification. This method starts with candidate extraction using grayscale morphology operators. Based on the candidates, Markovian segmentation model has been applied to detect the precise boundaries of the candidates. Finally, as a post-processing step, false candidates have been excluded with a supervised SVM classifier. In an experimental study on a publicly available database, They have found that this approach achieved higher F-Score figure in comparison with several state-of-the-art approaches at both pixel and image levels. The proposed method showed an F-Score value 0.71, Sensitivity 0.73 and PPV 0.69 at pixel level classification. But at image level F-Score value is 0.81 sensitivity is 0.90 and PPV 0.73. So Image level classification is the best classification according to the results.

An automated model to identify retinopathy has been developed [34] for patients having diabetic using fundus color images from MESSIDOR database. After pre-processing they were extracted texture features and they used KNN classifier to classify normal and abnormal fundus images. Then from the abnormal images they extracted standard deviation of the texture features and apply classifier to classify and detect diabetic retinopathy diseases such as hemorrhages or exudates which falls between back ground diabetic retinopathy (BDR) and proliferative diabetic retinopathy (PDR) stages of the disease. During performance comparison, specificity of 90%, sensitivity as 100% and CCR as 96% has been achieved. A flow of general procedure adopted by research is shown in Fig. 1.

The summary of the research is presented in Table 2.

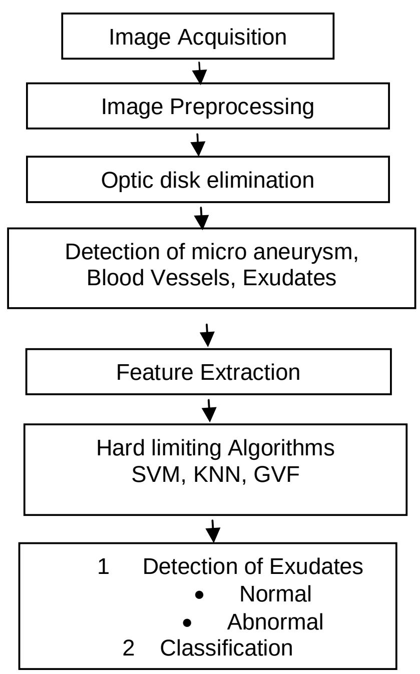

Fig. 1. Sequence of steps in hard limiting algorithms aided exudates detection

Table 2. Summary of research pertaining to application of hard limiting techniques

Sl no	Year	Author / Researcher	Features extracted
1	2014	L R Sudha et al.	Entropy, Entropy filter, Range filter, Standard deviation filter
2	2014	Balazs Harangi et al.	Mean, SD, compactness, area, number of holes, elongatedness, eccentricity, perimeter
3	2013	Flavio Araujo et al.	Area, perimeter, circularity, homogeneity, x, y coordinates of region center, 18 color features- average and standard deviation - RGB, Luv and HSI.
4	2013	Anam Tariq et al.	Area, eccentricity, perimeter, compactness, spect ratio, mean and standard deviation -green channel, Intensity value, mean gradient value -boundary pixel, neighboring pixels outside lesion, mean, hue, saturation and intensity values inside lesion, standard deviation
5	2013	Nan Yang et al.	Mean and SD [Ig, Il, Iy]-background subtraction values inside and outside the region, Ig, Il, Iy]-Region Centroid iii) [Ig, Il, Iy]-Region Edge Strength
6	2013	Wei Bu et al.	Area, Circularity ,Compactness, Edge strength, region centroid [Il, Iu, Iv, Ih], Mean grey-level value of the region and surrounding region [Il, Iu,Iv, Ih], Standard deviation values of the region and the surrounding region [Il, Iu,Iv, Ih], Difference of the mean value between the original and its surrounding region in [Il, Iu,Iv, Ih] ix)
7	2013	Kittipol Wisaeng et al.	RGB,YIQ,HIS,HSL,Lab,Luv are selected, Luv is selected color space for segmentation iii)Number of Edge Pixels, SD of preprocessed intensity value around a pixel
8	2013	B. Ramasubramanian et al.	Contrast, correlation, cluster prominence, cluster shade,dissimilarity, entropy, energy, homogeneity, sum of the squares
9	2012	M. Madheswaran et al.	Block Processing Method, Thresholding is performed, Pixel Flushing
10	2012	Selvathi D et al.	Contrast, Homogeneity, Correlation, Energy
11	2012	G.S.Annie Grace et al.	Contrast, Homogeneity, Entropy, variance, Shade, PROM
12	2011	Asha G.K et al.	Hue, Intensity, Mean Intensity, SD of Intensity, Distance between OD and Intensity
13	2010	Sopharak, A et al.	15 features extracted
14	2009	Berrichi Fatima Zohra et al.	Energy, Entropy, Correlation, Inertia, Local Homogeneity
15	2009	Giri Babu Kande et al.	Region Edge Strength, Gray Level difference between inside region area and surrounding area.
16	2008	Wei Lin et al.	Edge Sharpness by Kirschs mask Segmentation by Fast agglomerative Clustering method. Mean Intensity.
17	2007	M. Niemeijer et al.	Lesion Probability Map, Pixel Color, Pixel Cluster, Gaussian Derivative Filter.

4. SOFTCOMPUTING TECHNIQUES

Though hard computing techniques are proven to be efficient in solving real life problems, they suffer from a major limitation of being computationally expensive in terms of time and are being unable to handle imprecise and uncertain information. Many contemporary problems do not accommodate hard computing techniques for precise solutions. Predominant among them are reorganization problems (hand writing, speech, objects and images), mobile robot coordinate and forecasting and finally the combinatorial problems. Therefore exudates detection being object recognition task is surely a candidate problem amenable to be analyzed using soft computing techniques. Copious literature is available on application of soft computing techniques in automated detection of exudates.

Akara et al. [35] proposed an automatic method to detect exudates from low-contrast digital images of retinopathy patients with non-dilated pupils using a fuzzy C-Means (FCM) Clustering technique. The features extraction in this work are intensity value after preprocessing, standard deviation of intensity, Hue and number of edge pixels from an edge image were selected for fuzzy clustering Forty test images were used and 8 clusters were evolved. The work has shown high accuracy of 92.18% and 91.52% for sensitivity and specificity respectively. Contextual Clustering and Fuzzy Art Neural Network were conjointly used for the detection of hard exudates. Contextual clustering algorithm is used to segment the image to identify diverse classes based on intensity distribution. In order to classify exudates and non-exudates the features such as convex area, solidity, and orientation were used as input to fuzzy art neural network. This work has shown a sensitivity of 93.4% and 80% specificity [36].

Saheb Basha et al. [37] presented a novel approach to automatically detect the presence of DR in color digital retinal images. This approach utilizes the morphological operations for the segmentation and fuzzy logic for the identification of features. Features like hard exudates, soft exudates and red lesions such as microaneurysm, hemorrhages are detected. The digital retinal images are segmented using the morphological operations. Fuzzy sets are formed from the feature values. Then fuzzy rules are derived from the fuzzy sets based on fuzzy logic. These fuzzy rules are used to detect DR. The dataset used is DIARETDB0 database. Detection of hard exudates in retinal images by using Neural network method has been attempted [38]. This method can be divided into four steps, luminosity and color normalization, segmentation, feature extraction and classification using Multi-layer perceptron, Radial Basis Function or Support Vector Machine is used. In the preprocessing step, green channel is selected and normalization is done to increase the contrast. The similarity measure used is Mahalanobis distance which is used to find the intensity of pixel and the mean intensity value. Local properties of exudates and combined global and adaptive histogram thresholding methods are applied. The locally and globally segmented images are combined using AND operator. OD centers are selected using a combination of mathematical morphology and regional maxima detection. Blood vessels are detected using a two-dimensional matched filter with Gaussian cross-profile in vertical direction. Hough transform is used to detect vertical lines in the neighborhood of each candidate point. Features were extracted which include color and shape features. The features extracted are Mean RGB values inside the region, Standard deviation of RGB values inside the region, mean RGB values outside the region, Standard deviation of RGB values outside the region, RGB values of the region centroid, region size, region compactness and region edge strength. These features are taken as input values, where the three classifiers contained an input layer with 18 nodes and a single neuron output layer. If the output is greater than a given threshold, the region is considered as exudates otherwise labeled as non-exudates. The performance achieved by the MLP with a sensitivity of 91.34%, specificity of 92.06% and accuracy of 91.70%. The performance achieved by the RBF with a sensitivity of 90.31%, specificity of 91.44% and accuracy of 90.88%. The performance achieved by the SVM with a sensitivity of 90.21%, specificity of 91.96% and accuracy of 91.08%.Dataset used is a local database.

A computational-intelligence based approach has been proposed for detection of exudates in diabetic retinopathy images [39]. The segmentation approach is based on coarse and fine stage segmentation. The coarse segmentation is responsible for evaluating Gaussian smoothed histograms of each color band of the image. In the fine stage, FCM clustering assigns any remaining unclassified pixels to the closest class based on the minimization of an objective function. The segmented regions are differentiated using features such as color, size, edge strength and texture. Image segmentation feature is based on color. The number of color spaces includes RGB, YIQ, HSI, HSL, Lab and found Luv color space the most appropriate space for segmentation. Feature selection is based on Genetic Algorithms where three main points are taken into account i) representation of the candidate solutions, ii) objective function to be maximized, and iii) genetic operators that are used and their probability of occurrence. A set of 124 initial features are considered to discriminate exudates regions from other segmented regions .The features extracted are compactness of the region, region size, length of the perimeter of the region, region edge strength, mean Luv values inside the region, mean luv values outside the region, standard deviation of luv values inside the region, standard deviation of luv values outside the region and region mean Gabor filter responses. For classification of segmented region, multilayer NN discriminative classifier is used. Having selected the optimum feature set based on GA, corresponding 65-D feature vector is computed for each segmented region. In terms of pixel resolution 93.5% sensitivity and 92.1% predictivity was achieved. In terms of image-based criterion a specificity of 94.6% and sensitivity of 96.0% was achieved. Dataset used is local dataset. Akara et al. [40] proposed an automatic method to detect exudates from low-contrast digital images of retinopathy patients with non-dilated pupils using a FCM clustering technique. Optic disc is detected and eliminated using an entropy feature. Four features extracted are the intensity value after preprocessing, Standard deviation of intensity, Hue and the number of edge pixels from an edge image. Features extracted were used in the segmentation process using FCM clustering. This method detected exudates with 92.18% sensitivity and 91.52% specificity. Contrast exaggeration is used to expand the range of intensities of highly correlated images and the resulting image is thresholded for detecting blood vessels. Four features are extracted namely the intensity value after pre processing, the standard deviation of intensity, Hue and number of edge pixels from an edge image [41]. These extracted features are supplied as input parameters to coarse segmentation using FCM clustering method. The result from this is a rough estimation of exudates. In order to get a better result, a fine segmentation using morphological reconstruction is applied based on dilation on two images, a marker and a mask. It is found that the proposed method detects exudates with sensitivity 87.28%, specificity 99.24%, PPV 42.77% and accuracy 99.11%. Maria Garcia et al. [42] have reported a method for detecting hard exudates using radial basis function classifier. Features extracted in this work are region size, mean RGB values inside the region, standard deviation of RGB values inside the region, mean RGB values around the region, standard deviation of the RGB values around the region, RGB values of the region center, region compactness, region edge strength, homogeneity of the region and the ratio of the mean RGB values. Statistical model-building strategy and logistic regression is used for feature selection and 12 features are identified for classification. The optimal subsets of features identified are taken as inputs to RBF classifier. CWs are removed by Kirsch edge operator which is used to assign each edge a value, which is higher for the sharper edges. The multilayer perceptron neural network achieves a sensitivity of 85.4%, PPV of 85.4% for lesion-based and sensitivity of 100%, specificity of 63.0% and accuracy of 85.1% for image-based results. The RBF achieves a sensitivity of 92.1%, PPV of 86.4% for lesion-based and sensitivity of 100%, specificity of 70.4% and accuracy of 88.1% for image-based results.

Gerald Schaefer et al. [43] presented an approach of automatically detecting exudates in retinal images using neural networks. Sliding window approach is used to extract sub regions of an image. Modification of the color histograms of the images is used to match a common reference image. Dimensionality reduction is employed by PCA which reduces the complexity of neural network and improves training and classification. A back propagation neural network is trained to distinguish from exudates and non-exudates. Early detection of DR using image analysis techniques has been presented by Neera et al. [44]. Detection of hard and soft exudates is done through optic disc localization through three methods namely Hausdorff's distances, Genetic algorithm based location of the optic disc and optic disc detection and boundary estimation using geometric active contours. Image segmentation is done on the image feature color which is separated into different regions. Fuzzy C-Means clustering allow pixels to belong to multiple classes with varying degree of membership. In order to classify the segmented regions into exudates and non-exudates, the segmented regions are differentiated using features such as color, size, edge and texture. Classification is done through NN using two different learning methods namely standard back propagation and scaled conjugate gradient descent. Detection of microaneurysms and hemorrhages is done through fuzzy clustering method. Application of Genetic Algorithm has been reported [45] for retinal image analysis. In total 14 Features are extracted in which 11 are based on statistical feature i.e. texture and three are disease based features. Statistical features extracted are Mean, Standard de deviation, Variance, Entropy, Contrast correlation, homogeneity, angular second moment, Inverse differential moment and skewness. Disease based feature extracted are Area, Minimum Intensity and mean intensity. All the 14 features are represented by 15 bit strings where in 1means selected feature and '0' means unselected feature. Optimization of features extracted is done using Genetic Algorithm. Radial basis function (RBF) together with contextual clustering (CC) [46] are used for feature extraction. The extracted features are input to the RBF network. A contextual clustering algorithm segments a data into two categories. The data of the background are assumed to be drawn from standard normal distribution. The statistical features extracted are convex area, solidity, orientation and filled area. OD is detected using threshold and eliminated using bounding box concept, where it is filled with black. Segmentation is done using Contextual clustering and classification of exudates is done using RBF. The network has an input layer, hidden layer (RBF Layer) and output layer. The statistical features are input to RBF and labeling is given in the output layer of RBF. The labeling indicates the exudates. The final weights obtained after training the RBF is used to identify the exudates. The performance of RBF is 96%. Feroui et al. [47] used a method of computer-aided diagnosis of diabetic retinopathy. Combined method of k-means clustering algorithm and mathematical morphology is used to detect hard exudates. K-means algorithm is applied to the vector it is converted into a matrix of each cluster value for each pixel of the image. Regions that do not correspond to exudates are mainly on the edge of the image. These regions have to be removed to keep only the hard exudates. Optic Disc is eliminated by thresholding operation, morphological reconstruction by dilation and the final result of the optic disc segmentation. To the elimination of Lesions with blurred edge, the Kirsch operator is applied which detects edges using eight compass filters on green channel of the original image with the maximum being retained for the original image. The choice of threshold values, structural elements, and the cluster k are considered as main parameters to get correct detection of small exudates in the retinal image. The algorithm obtained a sensitivity of 95.92%, predictive value of 92.28% and accuracy of 99.70% using lesion-based criteria. Various methodologies are used by Kathikeyan et al. [48] to detect and quantify lesions associated with diabetic retinopathy as well as classification schemes for classifying the severity of DR. After pre processing, R, G, B planes of the image are clustered individually using fuzzy C-means clustering. The fuzzy approach is preferred over hard segmentation method. In total 24 features extracted were mean RGB values inside the region, standard deviation of the RGB values inside the region, mean RGB value around the region, standard deviation of the RGB value around the region, RGB values of the region centroid, region size, region compactness, region edge strength, homogeneity of the region and the color difference of the RGB values. Logistic Regression is a classifier independent method commonly used for feature selection to avoid misclassification. Abnormality in retinal images can be detected by Support Vector Machine, Back Propagation neural network classification, Kohenon SOM classification and minimum distance classifier. The classification accuracy of 64%. 88% and 92% has been achieved by minimum distance classifier, Kohenon network classifier and Back Propagation neural network classifier respectively. A system is developed to automated identification of exudates for detection of macular edema [49]. The proposed system consists of three stages i.e. candidate exudates detection, feature extraction and classification. For candidate exudates detection, morphological closing operator is used to smooth dark regions such as hemorrhages and blood vessels. The features extracted used for classification of exudates and non-exudates regions are, area, compactness, mean intensity of green channel, mean hue, saturation, mean value for each candidate region are calculated and mean gradient magnitude. Bayesian classifier using Gaussian function known as Gaussian mixture model is used for final classification by dividing dataset into training and testing subsets based on Bayes decision rule to obtain estimates from the training set. The present method achieves a sensitivity of 96.36% and specificity of 98.25%. The dataset used is STARE, DIARETDB0, and DIARETDB1.

Kitiipol Wisaeng et al. [50] presented an automatic method of exudates detection in diabetic retinopathy. In the Coarse segmentation stage FCM clustering is used in which each data point belongs to a cluster, to a degree specified by a membership grade. The result from FCM clustering is a rough estimation of exudates. Fine Segmentation using morphological reconstruction is applied based on two images, a marker and a mask. The FCM clustering followed by morphological reconstruction technique yielded a sensitivity of 92.06%, specificity of 92.92% and accuracy of 92.49% respectively. A novel method is introduced for segmentation of hard exudates in retinal images using Fuzzy C-Means clustering with spatial correlation [51]. This method has several steps such as generation of a neighborhood matrix, determination of local image feature, weighting step, initialization of centroid cluster and assignment of membership pixel using FCM with spatial correlation. The proposed method detects hard exudates with the average accuracy of 79%. Statistical feature based on Fuzzy C-mean clustering method was presented by Sidra et al. [52]. To detect exudates from low-contrast digital images with non-dilated pupils using feature based Fuzzy C-Means clustering technique with a combination of morphology techniques and preprocessing to improve the robustness of blood vessel and optic disc detection. FCM assigns unclassified pixels to the closest cluster based on a weighted similarity measure between the pixels in the image and each of cluster centers. Possible candidate features extracted are entropy of the image, Hue, Edge strength, enhanced intensity image, standard deviation, perimeter of region, color, image size, compactness of region and mean are used in the segmentation process as an input to FCM clustering. Data set used is DIARETDB0 database.

In another work involving ANN two feature vectors were built viz. f1= (H,S,V,I) and f2=(R,G,L,U,V) which are taken as input for fuzzy k-means algorithm [53]. Blood vessels are segmented by zana and klein [2001] algorithm and converted into straight line using Hough transform and optic disc center is chosen which converge to the center with higher quantity of white pixels. Feature extraction is done using [oserah-2002] and [sopharak-2010] which were divided into two groups 6 non color features consisting of Area, perimeter, circularity, homogeneity, (x,y) coordinates of the region center and 18 color features namely average and standard deviation of all components of the color models RGB, Luv and HSI. Classification techniques such as Multilayer Perceptron [MLP], Radial Basis Function [RBF] and Support Vector Machine [SVM] were used to eliminate false candidate region. Results show MLP presented the best performance with 97.29% of accuracy in exudates detection and 81.57% of non-exudates detection. Dataset used is DIARETDB1. Shantala Giraddi et al. [54] proposes a novel hybrid mechanism for the detection of exudates based DBSCAN clustering. Unlike other algorithms, DBSCAN clustering algorithm does not require the number of clusters to be specified. Classification of regions is being done using a system based on Back propagation Neural Network. The authors have assessed the performance of algorithm using DIARETDB1 database. Sensitivity of 90% and a specificity of 85% are achieved using a lesion based performance evaluation criterion and an accuracy of 100% is obtained on image based performance evaluation criterion. K.Udaya Bhaskar et al. [55] have used Functional Link Artificial Neural Network (FLANN) classifier to extract exudates in a retinal fundus image. Classification performances were compared between Multi-Layered Perceptron (MLP), Radial Basis Function (RBF) and FLANN classifiers. Better classification performance was observed for FLANN classifier. This method uses publicly available DIARET DB1 & DB0 database. For training the classifiers 1290 exudates regions and 900 non exudates regions were used. For training the classifiers the minimum size of an exudates region is assumed to be 10. The performance of FLANN is achieved by sensitivity of 99%, specificity of 89% and accuracy of 94.7%. A schematic view of general procedures adopted by cross section of researchers is shown in the Fig. 2.

The summary the research is presented in Table 3.

Table 3. Summary of research pertaining to application of soft computing techniques

Sl	Year	Author / Researcher	Features extracted
1	2015	K. Udaya Bhaskar et al.	Mean of blue channel intensity inside-the-region, mean of green channel intensity inside-the-region, Standard deviation of red channel inside-the-region, Standard deviation of blue channel inside-the-region, Mean of green channel intensity around-the-region, Mean of blue channel intensity around-the-region, Region centroid in blue channel, Region centroid in

Sl	Year	Author / Researcher	Features extracted
			blue channel, Color difference of the Red channel, Color difference of the green channel, Color difference of the blue channel, Region compactness, Homogeneity
2	2014	Shantala Giraddi et al.	Area, orientation, Eccentricity, Solidity, Extent, Mean(green), Variance(green) Max(green), Mean(Intensity),Variance(Intensity),Energy(Intensity)
3	2013	Flavio et al.	Area, perimeter, circularity, homogeneity, (x, y) coordinates of the region center and 18 color features namely average and standard deviation of all components of the color models RGB, Luv and HIS
4.	2013	Sidra Rashid et al.	Entropy, Hue, Edge strength, enhanced intensity image, standard deviation, perimeter of region, color, image size, compactness of region
5	2013	Handayani Tjandrasa et al.	Generation of Neighborhood matrix, Local Image Feature, Weighting step, Centroid Cluster, Assignment of Membership pixel
6	2012	Kittipol Wisaeng et al.	Color normalization, local contrast enhancement, median filtering, RGB to Luv space
7	2012	Umer Aftab et al.	Area, Compactness, Mean Intensity of Green Channel, Mean Hue, Saturation, Mean value for candidate region, mean gradient magnitude
8	2012	Karthikeyan et al.	Mean and SD of RGB values inside and around the region, Region centroid, Region size, Region compactness, Region edge strength, Homogeneity of the region, Difference of the RGB values
9	2012	Feroui Amel et al.	Kirsch operator for sharp edges
10	2011	R.Vijayamadheswaran et al.	Convex Area, Solidity, Orientation, Filled Area
11	2011	Jestin.V et al.	Mean, Standard deviation, Variance, Entropy, Contrast, Correlation, Energy, Homogeneity, Angular second moment, Inverse differential moment, Skewness, Area, Minimum Intensity, mean intensity.
12	2010	Neera Singh et al.	Segmented regions are differentiated using features such as color,size,edge and texture.
13	2009	Gerald Schaefer et al.	Sliding window approach is used to extract sub regions of image.
14	2009	Maria Garcia et al.	Region size, mean RGB values and SD values inside and around the region, RGB values of the region center, region compactness, region edge strength homogeneity of the region, ratio of the mean RGB values
15	2009	Akara Sopharak et al.	Intensity value after preprocessing, SD of Intensity, Hue, The number of Edge pixels – sobel edge detector
16	2009	Akara Sopharak et al.	Intensity value after preprocessing, SD of Intensity, Hue, The number of Edge pixels.
17	2009	Alireza Osareh et al.	Image Segmentation feature is color, RGB, YIQ, HSI, HSL, Lab and Luv, Luv is selected, 124 features are considered. 65 features computed for each segmented region.
18	2009	M. Garcia et al.	Mean RGB values inside and outside the region, Standard deviation of RGB values inside and outside the region, RGB values of the region centroid, region

Sl	Year	Author / Researcher	Features extracted
			size, region compactness, region edge strength.
19	2007	C.Jayakumari et al.	Convex Area, Solidity, Orientation
20	2007	Akara et al.	Intensity, Standard deviation, Hue, Number of edge pixels.

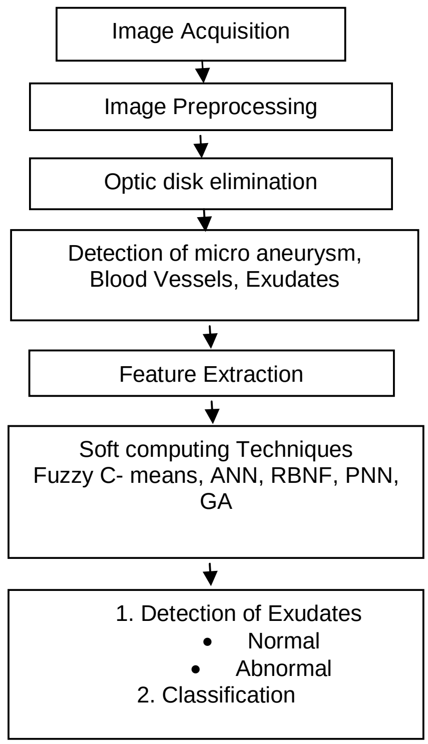

Fig. 2. Sequence of steps in soft computing assisted exudates detection

5. THE FUTURISTIC REVIEW

From the foregone discussion it is evident that retinal digital image analysis assisted by any of the techniques discussed has the sole aim of exploiting the ease with which the retinal damages can be visualized, quantize and analyze and non invasively *in vivo*. The literature survey revealed that the multivariate techniques involving image processing, image processing assisted by hard computing techniques, processing assisted by soft computing techniques and hybrid systems have been applied since two decades.

Though hard limiting computational techniques used by researchers provided accurate detection and classification of retinal damages, the common observation is that they need more time and they are computationally complex. Therefore in future it is anticipated that soft computational algorithms will slowly replace hard limiting algorithms. Further as the research related to application of soft computing techniques in exudates detection is scanty when compared to application of hard limiting techniques. The reported application of soft computing techniques mostly concentrated to classification. However, in future the prospective research community in this domain may consider the following possible applications of soft computing techniques. Fuzzy c-means algorithm in morphological processing in fundus images.

- Fuzzy grading of damages found in retinal images.
- Extensive use of PCA to eliminate features that are less influential and to use the PCA driven attributes/features for further detection and associated tasks.
- Use of boosted soft segmentation algorithm to delineate hemorrhages from

fundus images to identify stages of retinopathy.

- Application of hybrid approaches like fuzzy-neuro, fuzzy-evolutionary computing techniques could be tried to optimize the number of features and also to make detection process more focused.
- Development of robust clinical applications that are enabled to recognize minute areas corresponding to either micro aneurisms or hemorrhages by appropriate segmentation techniques.
- Simulation of blood vessel trees and its damage patterns using fractals.

6. CONCLUSION

This paper presented a detailed study on exudates detection techniques for early identification of Diabetic Retinopathy (DR). An automated DR detection system is a very important need due to the growing number of diabetic patients around the world so that preventive measures can be augmented .In this direction a number of algorithms are surveyed and the work done by various researchers is presented. Supervised and Unsupervised learning techniques are the major methods used in exudates detection. Several preprocessing steps, followed by techniques of feature extraction for clustering and classification is identified and their performance have been presented. This survey gives a theoretical background and do not exactly cover all the work in their entirety. It assists reader to understand the methods and techniques employed for detection of exudates.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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