ARUNAI PUBLICATIONS

Asian Journal of Applied Research

DOI: http://dx.doi.org/10.20468/ajar.2018.10.15

Research Article

Real-Time Detection of Retinal Detachment and Exudates Using Digital Fundus Image with Superpixel Multi-Feature Classification

R. Priyanka[1], J. Kanimozhi[1], Vengat Narayanan[2], P. Vasuki[1]

[1]Department of ECE, K.L.N. College of Information Technology, Sivagangai, Tamil Nadu, India,
[2]Department of EEE, K.L.N. College of Engineering, Sivagangai, Tamil Nadu, India

ABSTRACT

Exudates are primary indication of diabetic retinopathy. The automatic detection of exudates is developed with the help of superpixel multi-feature classification. The images were segmented with the help of simple linear iterative clustering algorithm as considered as candidates. Then, a total of 20 features, including 19 multi-channel intensity features and a novel contextual feature, are proposed for characterizing each candidate. A supervised multivariable classification algorithm (Fisher discriminant analysis classifier) is also introduced to distinguish the true exudates from the other candidates. The retinal images are collected in two publicly available DiaretDB1 and e-ophtha EX databases along with real-time database. We collecting the images from Aravind Eye Hospital.

Address for correspondence:
R. Priyanka, Department of ECE, K.L.N. College of Information Technology, Sivagangai, Tamil Nadu, India. E-mail: priyankar2495@gmail.com

Keywords:
Computer-aided diagnosis, Exudates, Multi-feature Classification, Retinal, Simple linear iterative clustering, Superpixel

Received: 05th February 2018
Accepted: 20th September 2018
Published: 13th October 2018

INTRODUCTION

Diabetic retinopathy (DR) is a one of the severe eye diseases which can lead to vision defects and even blindness. It is most common cause of blindness in diabetic patients. After 10–15 years of diabetes, 10% of diabetic patients are become blind and approximately 2% develop severe visual impairment. DR is associated with an appearance of yellowish spots in the retina called as hard exudates. It is possible to have DR and not know it. In fact, it is uncommon to have symptoms in the early stages of DR. As the condition progresses, DR symptoms may include as follows: (1) Spots or dark strings floating in your vision (floaters), (2) blurred vision, (3) fluctuating vision, (4) dark or empty areas in your vision, (5) poor night vision, (6) impaired color vision, and (7) vision loss. Exudates are yellow lipid sediments of serious leakage from the damaged minute blood vessels. A reliable detection and accurate identification of these abnormalities may be helpful in computer-aided diagnosis screening of DR at early stages to prevent loss of vision. Exudates form by the blood leakage from blood vessels which is the major cause of blindness in diabetic patients and old age people. Most techniques are used to the exudates detection in fundus retinal image. In retinal image, exudates are appeared in various size and locations. Exudates are representing in yellowish part seen in retina, usually near the macula [Figure 1].

Automatic detection of exudates is a complex issue since the retinal fundus images often have some uneven illumination and poor clarity images. Under these difficult conditions, similar related exudates detection methods have been proposed, which can be divided into four categories: (1) Thresholding-based, (2) region growing-based, (3) morphological-based, and (4) pixel-based classification.

Thresholding-based detection is the simplest manner to segment the white lesion from other lesions. Applied global and adaptive thresholding techniques are used to create lesion candidates. Then, true exudates are extracted from the series of features and basis function classifiers. Further, exudate candidates were extracted by thresholding a distance map. However, the automatic detection is difficult in uneven illumination of exudates in fundus image; it weakens the final classification performance.

In region, growing segmentation-based algorithms are time consuming. Along with gray level contiguity, edge detection is used to extract the exudate candidates. Several approaches like morphological operators with different structuring elements are used to extract

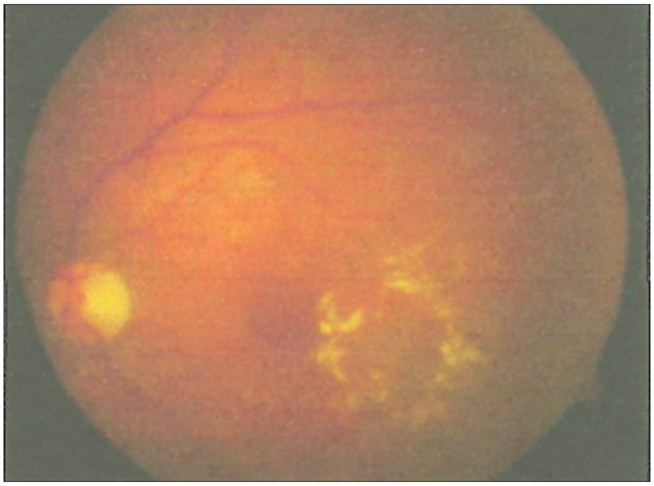

Figure 1: Fundus retinal images

the exudate candidates. Morphological operators include morphological reconstruction, regional minima detection, and H-maxima transformation to segment exudates. Combined process of mathematical morphology with active contours used for the detection of exudates adopted mathematical morphology to select the candidates from retinal images. Then, multi-feature classification was used for removing non-exudate regions from the fundus image.

Good performance can be yield using mathematical morphological-based approaches. Other approaches like pixel level classification are also incorporated into exudate detection; a fuzzy C-means clustering algorithm is to classify segmented regions from the retinal images. In this method, pixel-based features such as color, size, edge strength, and texture features were extracted for each segmented region, and then a multilayer neural network classifier was used to classify the retinal images. Bayesian classifier is used to distinguish exudate regions from non-exudate regions.

A naive Bayes classifier was utilized only for feature selection and pixel classification. A three-stage detection approach for exudate. First, they used image equalization and histogram analysis for extracting bright lesion candidates. Then, a classifier was trained based on the multi-scale local binary pattern.

Exudates have sharp edges and varying shape, so it is important to identify the exudate boundaries for detection. Compared to the pixel-based image representation, grouping individual pixels into superpixels is an effective processing step among any other steps because superpixel-based image representations reduce the complexity of image processing tasks and improve its stability and robustness.

Simple linear iterative clustering (SLIC). This approach controls the size and regularity of superpixels, and it produces good accuracy and boundary recall properties to improve the performance of segmentation process. An automatic exudate detection approach based on SLIC superpixel segmentation and multi-feature classification is introduced, which consists of four main steps. First, retinal images are segmented into SLIC superpixels to obtain a series of candidates in the retinal images. Then, these candidates are characterized by extracting into different channels (gray, RGB three color, and saturation channels), and the contextual feature is based on enhanced green channel. Next, Fisher discriminant analysis (FDA) is used to distinguish the exudate candidates from the non-exudate candidates.

The main contributions of this work are as follows:

1. Superpixels are good for the detection of the exudates, which reduces the complexity of image processing tasks and improves its stability and robustness.
2. A novel contextual feature is able to consider the global image information
3. A set of intensity features and a novel contextual feature are proposed to characterize these candidates from the non-exudate candidates.
4. A novel superpixel multi-feature classification (SMFC) method is proposed.
5. The proposed approach has been evaluated on two publicly available DiaretDB1 and e-ophtha EX databases along with real-time database. We collected the images from Aravind Eye Hospital.

METHODOLOGY

In this section, the proposed SMFC method for exudate detection is introduced, which consists of the following four stages: (1) Image preprocessing, (2) candidate extraction, (3) feature extraction, (4) classification, and (5) post-processing. In the first stage, the retinal images are adjusted to the normalization illumination. In the second stage, SLIC is adopted to obtain candidates. Next, multi-features characterize the candidates. Then, FDA is used as a linear classier to classify exudate candidates. Along with the public database, real-time database also used to evaluate the detection of exudates. Finally, post-processing is applied to differentiate the true exudates candidates from the non-exudates candidates. Each stage is discussed in detail [Figure 2].

Input image acquisition from database

The input is a retinal fundus image. The inputs are obtained from retinal image databases. The following are the publicly available databases. A sample retinal fundus image is shown in Figure 3.

From the above-mentioned databases, Image-Ret (DIARETB0 and DIARETB1) is used to evaluate the performance of the proposed method. These databases are low-resolution image databases, and the proposed method shows high accuracy for the detection of lesions by the proposed method. It achieves an accuracy of 99% when compared with the ground truth images.

Preprocessing

The image is usually represented in RGB color space and separated into its constituent channels. Only the green channel is retained. Green channels offer balance in terms of the intensity of the pixels required. The blood vessels in the retina would give a red hue to the red channel, and therefore, the separation of optic disc and exudates becomes challenging in red channel. In the blue channel, the image appears dark, and therefore, the separation of features becomes a daunting

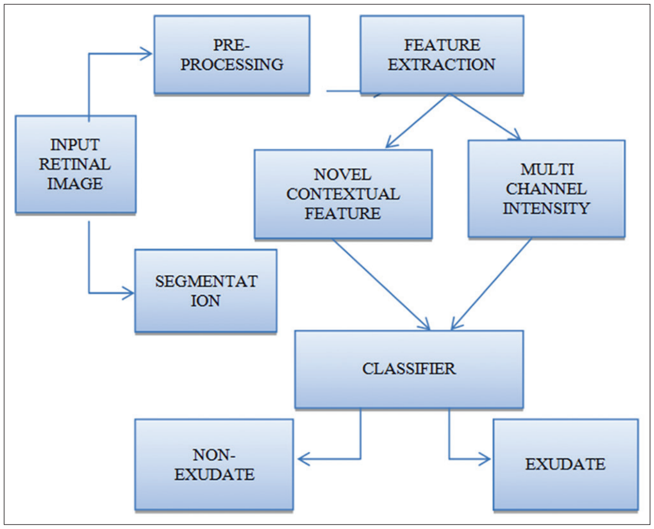

Figure 2: Block diagram

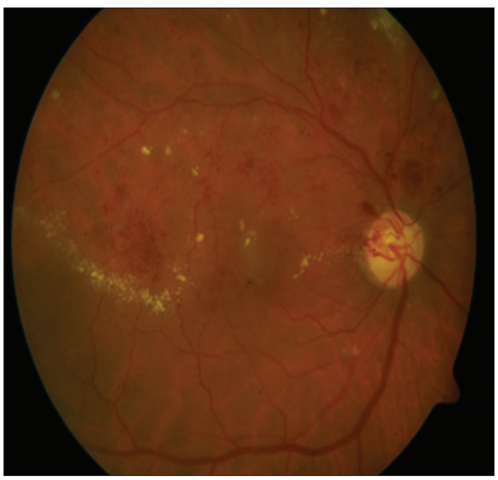

Figure 3: Original retinal image

task. Green channel offers balance in terms of the intensity of the pixels. Therefore, the green channel is chosen for further steps of image processing. Then, the input retinal image is converted into gray channel. The enhanced images are developed by applying adaptive histogram equalization to the gray channel image. Contrast Limited AHE (CLAHE) differs from ordinary adaptive histogram equalization in its contrast limiting.

This feature can also be applied to global histogram equalization, giving rise to contrast limited histogram equalization, which is rarely used in practice.

In the case of CLAHE, the contrast limiting procedure has to be applied for each neighborhood from which a transformation function is derived. CLAHE was developed to prevent the overamplification of noise that adaptive histogram equalization can give rise to.[1]

Saturation channel image is derived by the conversion of RGB to HSV of original retinal input image. Saturation channel gives global information about the image compared with red, green, blue, enhanced, and gray channel image [Figures 4-9].

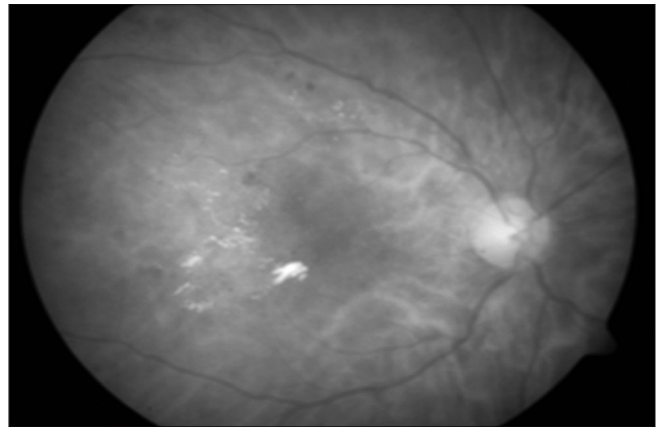

Figure 4: Red channel image

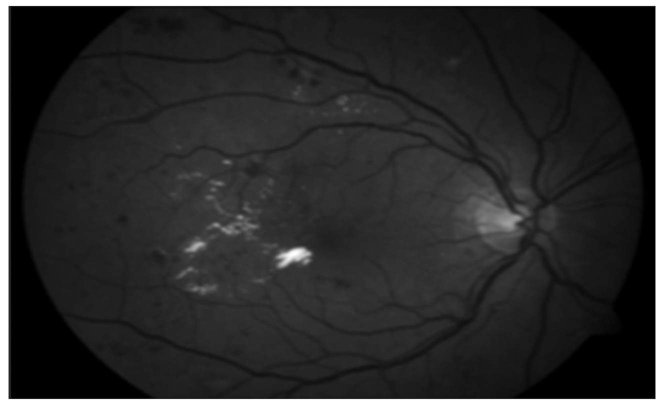

Figure 5: Green channel image

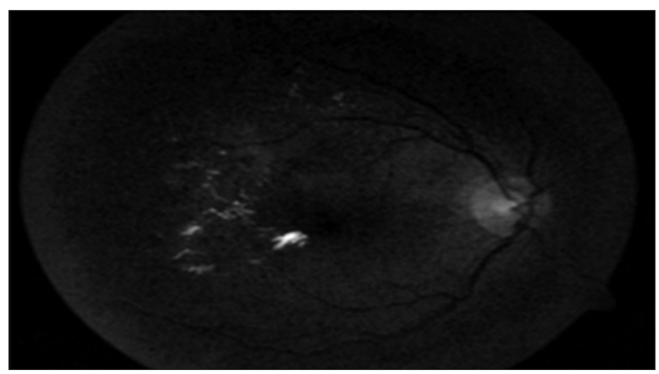

Figure 6: Blue channel image

Candidate extraction

The images were segmented with the help of SLIC algorithm. The SLIC algorithm segments the images according to the block size using DCT transformation. SLIC produces smooth regular-sized superpixels in the smooth regions and highly irregular superpixels in the textured regions. In SLIC, the following two parameters need to be set: The region size is fixed corresponding to the size of superpixel segmentation and the regularizer, which is the spatial proximity. A larger regularizer can make the result to be more compact. On the contrary, a small regularizer means that the resulting superpixels are more tightly

Table 1

Name	Image acquisition	Number of images	Resolution	Uses
Drive	3-CCD camera with 45-fold view	20 color fundus testing images. 20 color fundus training images	768×584	Exudates, hemorrhages, microaneurysms, and abnormal blood vessels detection
Image-Ret (DIARETB0, DIARETB1)	50-fold view	DIARETB0: Total 130 images in which 20 images are normal and 110 with DR DIARETB1: Total 89 images: Five images are normal and 84 images with DR	1500×1152	Exudates, hemorrhages, microaneurysms, and abnormal blood vessels detection
Messidor	3CCD camera at 45-fold view	200 images	1440×960, 2240×1488, and 2304×1536	Exudates, hemorrhages, microaneurysms, and abnormal blood vessels detection
E-ophtha_EX	OPHDIAT© Tele-medical network	It contains 47 images with exudates and 35 images with no lesion	2048×1360	Exudates detection
Real-time images	Aravind Eye Hospital	It contains 15 images with exudates and 3 no lesion	768×584	Exudate detection

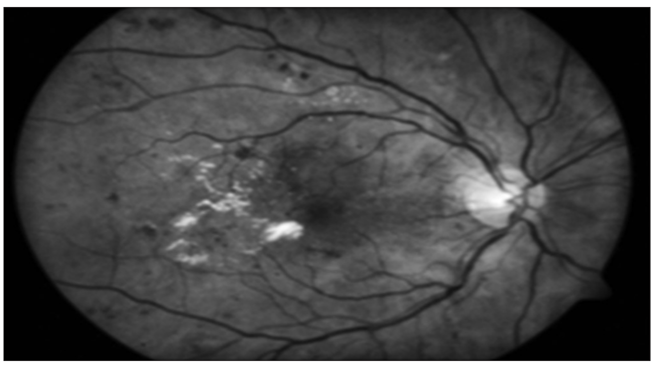

Figure 7: Enhanced image

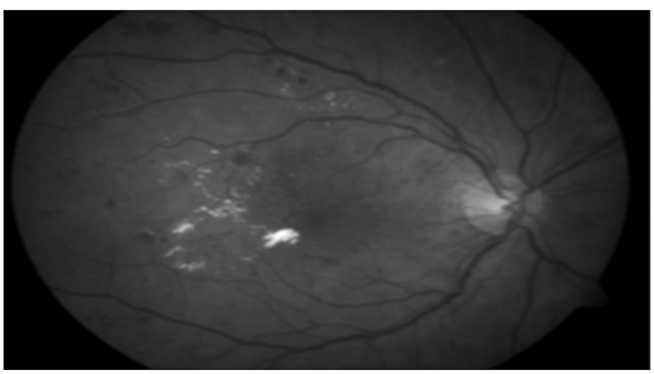

Figure 8: Gray image

to image boundaries with less regular size and shape. These parameters cannot only impact the classification performance and reduce the computation complexity [Figure 10].

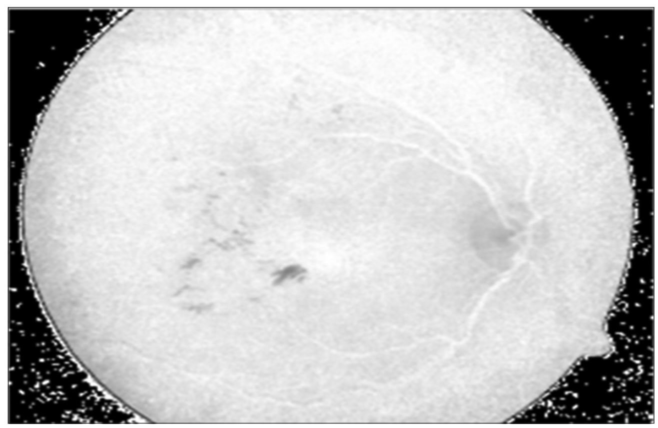

Figure 9: Saturation image

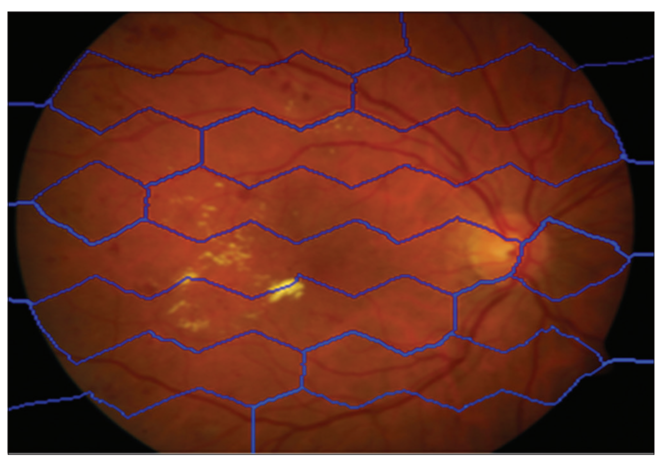

Figure 10: Superpixel segmentation

Feature extraction

To differentiate exudate candidates from non-exudate candidates, a set of features are proposed including 19 multichannel features and a contextual feature.

Multichannel intensity features

An enhanced retinal image is shown in Figure 6. Several varying images in gray, red, green, blue, and saturation channels are illustrated.

Several varying images in gray, red, green, blue and saturation channels. It is difficult to distinguish the artifacts from the exudates in any of the RGB channels. Fortunately, they can be detected well in the saturation channel. However, for the same type of image, the reflections are darker than other bright structures in the saturation channel. Mean, variance, and standard deviation count are measured from the saturation channel. Features are collected from the retinal image and fed into the input of FDA classifier. Apart from the above extracted 19 features, a novel and effective feature is developed with the aim of identifying the exudate candidates better and differentiating the exudate candidates from non-exudate candidates.

Contextual feature

Image preprocessing and superpixel segmentation are processed, then contextual feature in enhanced green channel image I is calculated. Suppose that there are P spatial compact candidate regions Ri (i D 1; 2; 3;:::; P) with relative consistent size.

$$Si = \frac{1}{Ni} \times \frac{mean\_Ri}{2!} \times \sum_{j\int N(i)} \left(\frac{dj}{Dj} \right)$$

$$dj = Mean\_Ri - Mean\text{–}Rj$$

The contextual feature is an enhancement of the mean gray value of each candidate. Candidate superpixels characterize sharp edges and gray scale difference compared to its neighbors. Hence, to differentiate exudates with other bright structures, the gray distance d between neighboring superpixels is taken into consideration, the spatial distance constraint D is also combined for weighting the neighbors. The global mean gives more information of the image and eliminating the influence caused by the varying retinal pigmentations and different image acquisition processes.

Classifier

We utilize it to classify the exudate candidates and the non-exudate candidates. FDA is a transformation matrix that maximizes the between-class scatter and minimizes the within-class scatter simultaneously [Figures 11 and 12].

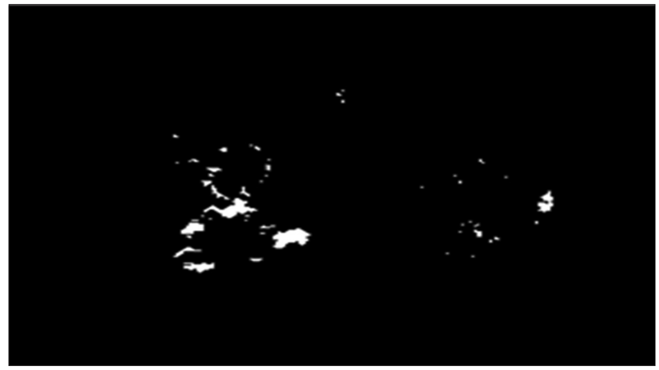

Figure 11: Exudate detection

Figure 12: Detected exudate after thickening

PERFORMANCE METRICS

Here, two publicly available databases including DiaretDB1 and e-ophtha EX along with real-time database are used to evaluate the performance of this approach.

Table 2

Image from database DIARETB1 and real-time images	Accuracy	Specificity
Image 01	99.68	98.80
Image 02	98.40	91.04
Image 03	98.87	97.18
Image 04	99.08	98.39
Image 05	98.96	98.10
Image 06	98.23	92.48
Image 07	99.10	91.23
Image 08	97.54	91.67
Image 09	98.66	91.71
Image 10	98.27	92.15

Software requirements

- OS: Windows
- Software: Matlab.

Hardware requirements

- Processor: Intel Pentium.
- RAM: 2GB.

CONCLUSION

In this study, a novel SMFC method is implemented. First, the whole image is segmented into superpixels considered as candidates. Then, a set of multichannel intensity features and a novel contextual feature are introduced to characterize these candidates. A supervised multivariable classification algorithm is introduced to distinguish the exudate candidates from the non-exudate candidates. The proposed approach has been evaluated on two publicly available DiaretDB1 and e-ophtha EX databases using two different criteria including image based and pixel based. Accordingly, the accuracy of 0.9840 and 0.9655 is achieved. Along with real-time database, the accuracy of 0.9710 is achieved.

REFERENCES

1. Sidibé D, Sadek I, Mériaudeau F. Discrimination of retinal images containing bright lesions using sparse coded features and SVM. Comput Biol Med 2015;62:175-84.
2. Figueiredo IN, Kumar S, Oliveira CM, Ramos JD, Engquist B. Automated lesion detectors in retinal fundus images. Comput Biol Med 2015;66:47-65.
3. Abràmoff MD, Niemeijer M, Suttorp-Schulten MS, Viergever MA, Russell SR, van Ginneken B, *et al.* Evaluation of a system for automatic detection of diabetic retinopathy from color fundus photographs in a large population of patients with diabetes. Diabetes Care 2008;31:193-8.
4. Naqvi SA, Zafar MF, Haq Iu. Referral system for hard exudates in eye fundus. Comput Biol Med 2015;64:217-35.
5. García M, Sánchez CI, Poza J, López MI, Hornero R. Detection of hard exudates in retinal images using a radial basis function classifier. Ann Biomed Eng 2009;37:1448-63.
6. Ali S, Sidibéa D, Adala KM, Giancardob L, Chaumc E, Karnowskid TP, *et al.* Statistical atlas based exudate segmentation. Compute Med Imag Graph 2013;37:358-68.
7. Pereira C, Gonçalves L, Ferreira M. Exudate segmentation in fundus images using an ant colony optimization approach. Inf Sci 2015;296:14-24.
8. Sinthanayothin C, Boyce JF, Williamson TH, Cook HL, Mensah E, Lal S, *et al.* Automated detection of diabetic retinopathy on digital fundus images. Diabet Med 2002;19:105-12.
9. Li H, Chutatape O. Automated feature extraction in color retinal images by a model based approach. IEEE Trans Biomed Eng 2004;51:246-54.
10. Welfer D, Scharcanski J, Marinho DR. A coarse-to-fine strategy for automatically detecting exudates in color eye fundus images. Comput Med Imaging Graph 2010;34:228-35.
11. Harangi B, Hajdu A. Automatic exudate detection by fusing multiple active contours and region wise classification. Comput Biol Med 2014;54:156-71.
12. Zhang X, Thibault G, Decencière E, Erginay A. Exudate detection in color retinal images for mass screening of diabetic retinopathy. Med Image Anal 2014;18:1026-43.
13. Sidibé D, Sadek I, Mériaudeau F. Discrimination of retinal images containing bright lesions using sparse coded features and SVM. Comput Biol Med 2015;62:175-84.
14. Figueiredo IN, Kumar S, Oliveira CM, Ramos JD, Engquist B. Automated lesion detectors in retinal fundus images. Comput Biol Med 2015;66:47-65.
15. Abràmoff MD, Niemeijer M, Suttorp-Schulten MS, Viergever MA, Russell SR, van Ginneken B, *et al.* Evaluation of a system for automatic detection of diabetic retinopathy from color fundus photographs in a large population of patients with diabetes. Diabetes Care 2008;31:193-8.
16. Naqvi SA, Zafar MF, Haq Iu. Referral system for hard exudates in eye fundus. Comput Biol Med 2015;64:217-35.
17. García M, Sánchez CI, Poza J, López MI, Hornero R. Detection of hard exudates in retinal images using a radial basis function classifier. Ann Biomed Eng 2009;37:1448-63.
18. Ali S, Sidibéa D, Adala KM, Giancardob L, Chaumc E, Karnowskid TP, *et al.* Statistical atlas based exudate segmentation. Compute Med Imag Graph 2013;37:358-68.
19. Pereira C, Gonçalves L, Ferreira M. Exudate segmentation in fundus images using an ant colony optimization approach. Inf Sci 2015;296:14-24.
20. Sinthanayothin C, Boyce JF, Williamson TH, Cook HL, Mensah E, Lal S, *et al.* Automated detection of diabetic retinopathy on digital fundus images. Diabet Med 2002;19:105-12.
21. Li H, Chutatape O. Automated feature extraction in color retinal images by a model based approach. IEEE Trans Biomed Eng 2004;51:246-54.
22. Welfer D, Scharcanski J, Marinho DR. A coarse-to-fine strategy for automatically detecting exudates in color eye fundus images. Comput Med Imaging Graph 2010;34:228-35.
23. Harangi B, Hajdu A. Automatic exudate detection by fusing multiple active contours and region wise classification. Comput Biol Med 2014;54:156-71.
24. Zhang X, Thibault G, Decencière E, Erginay A. Exudate detection in color retinal images for mass screening of diabetic retinopathy. Med Image Anal 2014;18:1026-43.

Cite this article: Priyanka R, Kanimozhi J, Narayanan V, Vasuki P. Real-Time Detection of Retinal Detachment and Exudates Using Digital Fundus Image with Superpixel Multi-Feature Classification. Asian J Appl Res 2018;4(2):76-81.

Source of Support: Nil, **Conflict of Interest:** None declared.