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Futuristic Approach With Lesion Detection And Grading In Diabetic Retinopathy Based On Hybrid Classifier

[1]Ujwala W. Wasekar , [2]R. K. Bathla

[1,2]Department of Computer Science, Desh Bhagat University, Mandi Gobindgarh, Punjab, India

Abstract

Diabetic retinopathy has become one of the major reasons for vision loss in the world. Proper care and timely treatment may save one's eyesight. Early detection of diabetic retinopathy is a challenging task. But, with the help of automated systems, detection can be made easy. The process of recognition of diabetic retinopathy goes through several stages such as image acquisition, image pre-processing, segmentation, feature extraction and classification. This paper is an extension of our previous work. It emphasizes on various aspects of implementation of the method on different platform that can enhance the performance in future.

Keywords Diabetic Retinopathy, Image Processing, Lesion, Detection, Classification

1. Introduction

In the era of developing technology, people are witnessing the change in lifestyle, in turn, inviting many diseases. Diabetes is one such disease that is creeping over the health of a person and making them victim of various diabetes complications. Diabetes complications may include diabetic neuropathy, diabetic nephropathy, diabetic retinopathy (DR), heart problems, diabetic foot and other related conditions. According to the report of South-East Asia regional office of World Health Organization, prevalence of DR in South East Asia countries may increase from 11.3% in 2019, to 12.2% in 2030. Globally, the increment of DR patients may be witnessed from 126.6 million in 2010 to 191.0 million by 2030 [1].

Diabetic retinopathy is a chronic disease that may take 15-20 years after the beginning of the disease, to develop. It does not show any symptoms at the early stage. But, as DR progresses, symptoms such as blurred vision, floating vision and double vision start appearing [2]. Ophthalmologists recommend regular eye check-up and healthy diet for the diabetics to keep retinopathy at bay. DR affects the retinal part of an eye. A normal retinal fundus image contains macula, optic disc and blood vessels. If a person is DR affected, the image may show some abnormalities. Blood vessels in retina carry nourishment to the organ. Due to DR, the vessels get weakened and may rupture leaking blood and fluid on retinal surface. This leakage forms lesions on retina termed as red and bright lesions [3]. Red lesions are categorized into microaneurysms (MA) and haemorrhages (HM). Bright lesions or exudates (EX) can be divided into hard exudates (HE) and soft exudates (SE) or cotton wool spots (CWS). Figure 1 depicts the normal and abnormal fundus image showing various features [4]. Presence of MAs on image indicates the onset of the DR disease. When oxygen carrying capacity of vessels decreases due to damage, eye attempts to create new blood vessels to compensate the requirement. This is called neovascularization. These vessels are generally not normal and are more prone to leakage.

Rest of the paper is divided as follows: section 2 exhibits the diabetic retinopathy detection process. The methodology used in our previous work [5][6] has been discussed along with the scope and limitations. In section 3, whole discussion is carried out. It highlights every aspect of workflow. Section 4 concludes the discussion with crisp inference.

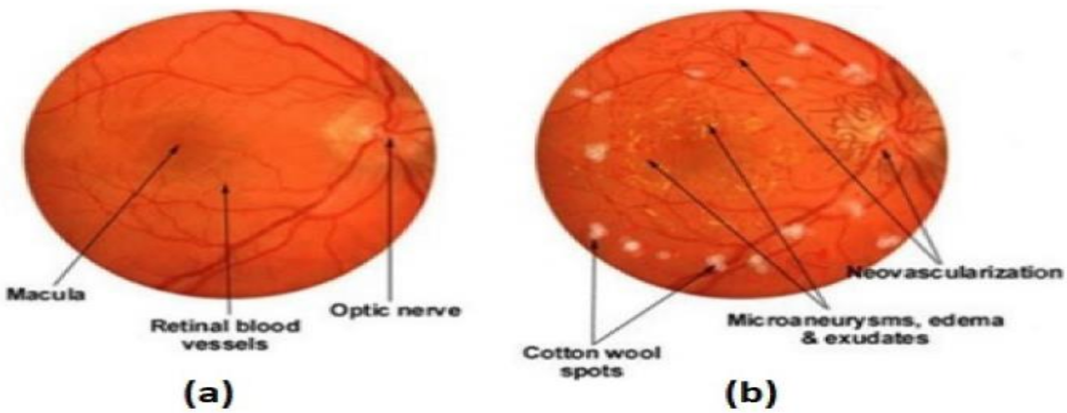
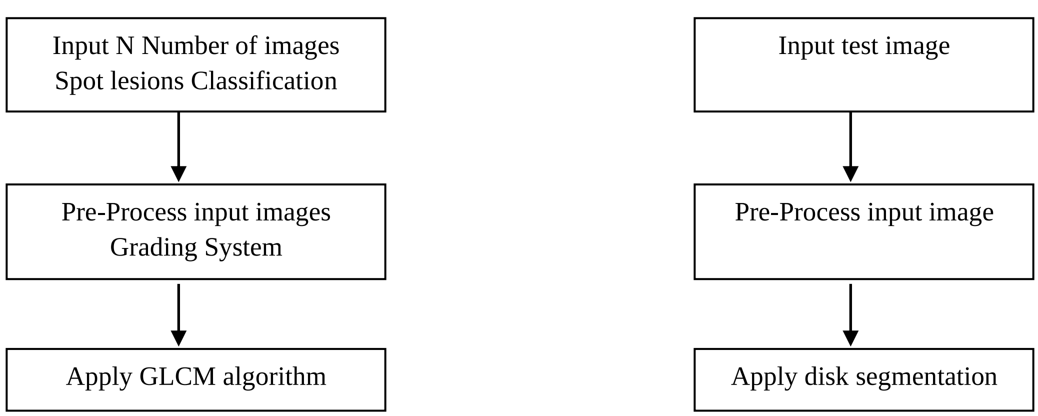


Fig 1 Retinal image (a) Normal retina (b) Abnormal retina

2. Diabetic Retinopathy detection

The process of DR detection can be divided into two stages viz. image processing and object recognition. In medical domain, image processing plays a significant role as the image has to be analyzed very carefully for accurate diagnosis. In our previous work, [6] was an improvement over [5]. In [5], the kNN classifier was used to classify the images as normal and abnormal. The method achieved the sensitivity of 92.6%, specificity of 87.56% and accuracy of 95%. Performance was found out to be better when compared with existing method [7]. Results were enhanced in [6] by using the hybrid classifier. The following sections describe the methodology used in [6] and the scope that can widen its horizon. Figure 2 represents the methodology used in [6].



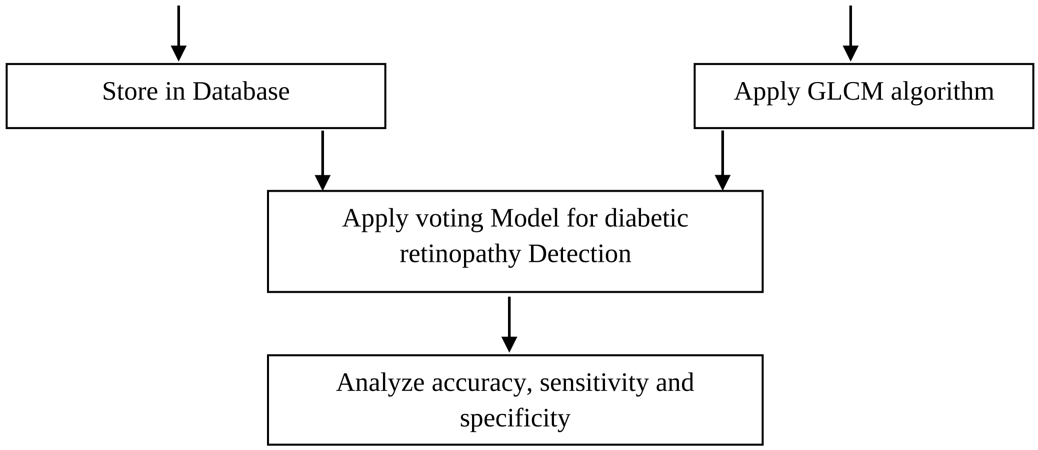


Fig 2 Proposed Methodologies

2.1 Image Processing

Image processing generally go through several stages before making the image ready to extract useful and relevant information.

2.1.1 Image acquisition

First step in image processing is the acquisition of image. There are two ways to acquire the images. Retinal fundus images can be collected from any eye care institution or publically available dataset can be used. In [6], publically available Diaretdb1 database [8] was utilized to evaluate the performance. Images are divided into training and test sets. Benefit of using public datasets is that the ground truths for the images are available which help in true evaluation and grading of image. While, in real data, images have to be resized according to the system and there is no readily marked ground truth on the image. Evaluation is based on the approval of the ophthalmologist. There are many public databases available such as Messidor, Drive and Stare, evaluation on which may give different results as images differ in each dataset.

2.1.2 Image pre-processing

At the time of clicking, some noise gets introduced in the image in the form of unwanted pixels, uneven illumination, etc. The image needs to be refined for better visual perception. Due to uneven illumination, the contrast in the image is not clearly visible, thereby leading to poor perception of the image. Adaptive histogram equalization (AHE) is an image processing technique [9] used to improve the contrast in the image which was used in our work. Problem with AHE is that it over emphasize the noise at the edges. To combat the issue, contrast limited AHE (CLAHE) [10] can be utilized as it limits the contrast while preserving edges. Once the image is contrast adjusted, noise has to be got ridden of.

Filters are used to reduce noise. Median filter was used in the previous work. Median filter gives better performance in terms of time [11]. While removing noise, it preserves the edges in an image [12]. In some cases, Gaussian filter or Denoise Autoencoder can also be utilized.

2.1.3 Segmentation

Segmentation is a technique in image processing which is used to divide the image into homogeneous parts. A DR affected retinal image consists of optic disc, blood vessels and other abnormal elements. Optic disc resembles exudates and MAs look much similar to vessels. Therefore, removal of optic disc and vessels from the image, before detecting lesions is essential. An image can be converted into different channels according to the requirement. For vessels detection, green channel of the image was extracted and structuring element of shape 'line' was used. For optic disc segmentation, image was converted into gray scale and structuring element of shape 'disk' was used.

Lesion segmentation is a very crucial task. Many segmentation algorithms have been proposed in literature in order to accurately detect the abnormalities [13]. Some of the image segmentation approaches include thresholding, edge based method, region growing approach and clustering [14]. Exudates are small bright and generally round in shape. Red channel of the image was extracted for exudate detection. Image was filtered using imtophat morphological filter. The filter works with the structuring element. However, different segmentation techniques can be used to detect lesions.

2.2 Object Recognition

The efforts to process an image are for the identification of objects and classify them accordingly [15].

2.2.1 Feature Extraction

An object can be identified by using its features such as height, color, weight, size. etc. In medical image analysis, the features of the region of interest are identified, extracted and fed to classification module. Thirteen features used in [6] are as follows:

- Contrast:- Contrast gives the difference between the intensities of pixels. It can be calculated by subtracting minimum value from maximum value.
- Correlation:- Correlation can be computed by moving a filter mask over the image and taking sum of the products at each location.
- Energy:- It is the rate of change in color or brightness.
- Homogeneity:- Homogeneity shows the similarity between the pixels of an image.
- Mean:- Mean is the sum of all values divided by the number of values.
- Standard deviation:- Standard deviation indicates the variation from the mean. Low value indicates closer pixel intensities. High value indicates far pixel intensities.
- Entropy:- Entropy is a measure of randomness that is used to get the texture of an image.
- RMS:- It is the root mean square value of the input image.
- Variance:- Variance indicates how far the values in the dataset are laid out.
- Smoothness:- Smoothness refers to how smooth or noise free the image is.
- Kurtosis:- Kurtosis is the measure of the intensity of the curve as compared to normal distribution.
- Skewness:- Skewness refers to the symmetry of the image.
- IDM:- IDM stands for inverse difference moment. It measures local homogeneity of an image.

These features were the relevant ones used in [6]. However, there are numerous features that can be added along with them so as to have a more reliable training set. Attributes such as area, perimeter may give deep detailing about the image.

2.2.2 Classification

Features drawn out of image are fed to classification module. The classes are determined according to the type and number of features. Machine learning classification can be supervised or unsupervised methodology driven. There are several classifiers available in literature. An individual classifier may not be as competent as the hybrid one. A combination of multiple classifiers overcomes the shortcomings of one another thereby giving better results. A Voting classifier which is an amalgamation of Support Vector Machine (SVM) [16], K Nearest Neighbor (KNN) [17] and Random Forest (RF) [18], was proposed.

Support Vector Machine (SVM)

SVM is based on statistical learning with binary classification. Hyperplane is the backbone of SVM which divides the dataset into classes. Distance between data points is called as margin. With the emergence of complex data, SVM has been designed as a multiclass classifier. Mapping of data can be one-to-one or one-to-all.

K Nearest Neighbor (KNN)

KNN is simple and easy to implement. It can be used for classification as well as regression. Value of k is calculated using the Euclidian distance. Data points similar to sample lie in a Voronoi cell. Euclidian distance between the two training and test samples xi and xj can be calculated using the following formula.

d(xi,xj) = $\sqrt{(xi1 - xj1)^2 + \ (xi2 - xj2)^2 + \cdots (xin - xjn)^2}$

where, i,j=1,2,3,….n

Random Forest (RF)

Random forest is a combination of multiple trees. Each tree cast a vote depending on which classes are determined. Generally, it takes only two parameters to build i.e. number of features at each node and number of trees to be grown. RF can handle categorical as well as unbalanced data.

Voting classifier

Voting classifier is an ensemble of multiple classifiers. It is based on the voting approach. Voting can be two types, hard voting and soft voting. Hard voting does not take into consideration the predicted class of each individual classifier. Instead a voting is conducted for every class. A class getting highest number of votes is considered as the output class. In soft voting, an average of the probability voting by individual classifier decides the final class for that data set [19].

3. Discussion

Diabetic retinopathy is a serious eye condition which may lead to vision loss if not treated at an early stage. The increasing statistics of DR affected people may touch a whopping number of 191.0 million by 2030 [20][21]. In the medical field, computer vision automated systems are proving themselves to be boon. Many researchers have worked in this area to detect various abnormalities in the retinal image so as to treat the patient at the earliest.

The methodology proposed in [6] is one such attempt to recognize lesions, detect and classify them according to the features. Generally, images contain some impurities which hinder the lesion detection process. Therefore, images were first refined using some pre-processing techniques. Various channels such as grayscale, red or green, of the image were extracted for different purposes. Median filter was the better option for noise removal. Poor contrast of the image was enhanced using adaptive histogram equalization method. To identify the region of interest, segmentation was applied. Segmentation divides the image into multiple segments of homogeneous nature. Thereafter, thirteen features were extracted to train the classification module. Finally, the Voting classifier was used to grade the image as healthy or DR affected.

The method was evaluated on the publically available Diaretdb1 database. The performance was assessed in terms of accuracy, sensitivity and specificity. Proposed method performed better compared to other existing approaches. Proposed method could apply other techniques, also, to enhance the performance or to give different perspective to the approach. A hybrid Voting classifier was applied which was the combination of SVM, KNN and RF. Another set with different supervised learning classifiers can also give the promising results. Evaluation on the database other than Diaretdb1 and with different performing measures could be the area to think upon.

4. Conclusion

Diabetic Retinopathy may create a severe vision threatening condition. Its detection and due care is of utmost importance for any chronic diabetic. Manual detection may be long and inaccurate chore. Automated detection helps in quick diagnosis. The approach proposed by authors gave encouraging results. Different image processing techniques were applied. The method was evaluated on Diaretdb1 database using hybrid Voting classifier. However, use of other classifiers, in future, may explore more potential in the existing methods. Also, the performance of the system can be evaluated on other publically available or real datasets.

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ABOUT AUTHORS

Ujwala W. Wasekar received M.Sc. degree in Computer Science from Nagpur University, Nagpur, Maharashtra in 2003, MCA degree from Maharshi Dayanand University, Rohtak, Haryana in 2009. She has cleared UGC National Eligibility Test (NET) in 2018. Currently, she is working as assistant professor at Sri Guru Gobind Singh college, Chandigarh, India. Her area of interest is Machine learning and image-processing . She has published papers in national and international journals.

Dr. R. K. Bathla is working as a Professor in Computer Science Department at Desh Bhagat University, Mandi Gobindgarh, Punjab, India. He has published over 100 research papers in SCI, Scopus, Springer and IEEE. He has 30 patents in his name at national and international level. He has guided 8 Ph.D. scholars, 4 have been awarded degree. In over 50 international journals, he is in editorial board or working as reviewer