# AUTOMATIC DETECTION AND CLASSIFICATION OF DIABETIC MACULAR EDEMA BY USING NEURAL NETWORK CLASSIFIER

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*Abstract*— **Diabetic Macular Edema (DME) is a common vision threatening complication of Diabetic Retinopathy. In a large scale screening environment DME can be assessed by detecting exudates (a type of bright lesions) in fundus images. Two new methods for the detection of exudates are presented. The significant contributions of this work can be classified as two levels as a first level, to classify an image as normal/abnormal (containing HE), and a second level, to assess the severity of risk of DME as moderate or severe. A two-stage methodology for the detection and classification of DME severity from color fundus images is proposed. DME detection is carried out via a supervised learning approach using the normal fundus images. A feature extraction technique is introduced to capture the global characteristics of the fundus images and discriminate the normal from DME images.**

*Keywords*—**Abnormality detection, diabetic macular edema, hard exudates, learning normal.**

## I. INTRODUCTION

Diabetic Macular Edema (DME) is caused by leaking macular capillaries. There are many causes of macular edema. It is often associated with diabetes, where broken blood vessels in the retina begin to leak fluids, containing small amount of blood, into the retina. At times, deposits of fats may leak in to the retina. This leakage causes swelling in the macula region. Eye surgery, comprising cataract surgery, can increase the risk of developing macular edema due to blood vessels becoming irritated and leaking fluids. Macular edema that matures after cataract surgery is called Cystoid Macular Edema (CME). Macular edema is often painless and may display few symptoms when it advances. When symptoms do follow, they are a sign that the blood vessels in the eye may be leaking. Symptoms of macular edema may include blurred or wavy central vision and/or colors appear washed out or changed. If left untreated, macular edema can cause severe vision loss and even blindness. Macular edema occurs when fluid and protein deposits collect on or under the macula of the eye (a yellow central area of the retina) causing it to thicken and swell. DME is the major cause of vision loss in people with diabetic retin retinopathy. People with diabetes have a 10 percent risk of developing the condition during their lifetime. Alimera estimates that close to one million people in the United States alone currently have DME and approximately 300,000 new cases develop annually.The swelling may damage one's central vision, as the macula is present near the center of the retina at the back of the eyeball. Diabetic macular edema is mainly classified into focal and diffuse types.

## II. LITERATURE REVIEW

Keerthi Ram*et al.*,(2009) developed that the exudates are a class of lipid retinal lesions visible through optical fundus imaging, and indicative of diabetic retinopathy. A clustering-based method to segment exudates, using multi-space clustering, and color space features. Gopal Datt Joshi *et al.*,(2008) developed the extraction of anatomical structures (landmarks), such as optic disk (OD), fovea and blood vessels, from fundus images was useful in automatic diagnosis. An appearance-based method for detecting fovea and OD from color images. The performance of the proposed method can be significantly improved by incorporating domain knowledge about the structure of interest in the selection criteria.

 

## III. PAST WORK

Among recent approaches to direct detection of edema from color fundus images, multiple uncalibrated fundus images have been used to estimate a height map of macula in. The estimated height map is generally noisy. A difference in the mean height is demonstrated between the height maps of normal and edema cases on synthetic images and only four sets of color fundus images. This difference is used to determine normal and abnormal cases. While the proposed method is encouraging, it requires more rigorous validation.

Using monocular color fundus image for detecting DME indirectly is still considered a reliable method in DR screening. Detecting DME is also done indirectly by detecting the presence of HE in images. Automated solutions following this approach can be categorized as: 1) local schemes that perform localization of HE or HE clusters and 2) global schemes for detecting the presence/absence of HE in images.

### *A. Local Schemes*

Given the relatively high contrast between the HE and retinal structures (except optic disc), the most common approach has been to process the green channel of the color fundus image and thresholding (fixed or adaptive/dynamic) the intensity histogram .Background suppression is another approach that has been used for finding HE candidates. Techniques explored for background estimation include median filtering ,morphological operations, and clustering. These approaches are sensitive to illumination changes that arise due to imaging conditions as well as changes in tissue pigmentation. This is addressed via an intensity normalization as a preprocessing step and/or removal of false positives with post-processing in the above methods. The well-defined edges of HE has also been used as a cue to identify candidate pixels. However, small or faint HE detection is difficult and hence additional rules are used to handle them. In general, edge detection yields noisy results and hence pre processing and post processing steps are required to reduce the large number of false candidates. The distinct bright yellow color of HE has been the motivation for using color features. Even though the use of color seems to be sufficient in principle, high variation in color witnessed in images across and within different ethnicities require a color and luminosity normalization step before detection.

The purpose of all the local schemes described here is to successfully segment or localize the exudate clusters with high accuracy so as to enable further assessment. As a result, several normal pixels are also detected as candidates in normal images. This affects the overall specificity of the system at image level HE detection.

### *B. Global Schemes*

While the goal of local schemes in applying these approaches is to detect maximum number of HE, the global schemes relax this and try to ensure that *at least* the brightest pixels corresponding to HE in the image are detected. On these lines, perform an initial candidate detection using a fixed threshold after a background subtraction step on the green channel image. This is followed by assignment of confidence values to every candidate based on the edge strength at that location. The confidence map is thresholded to obtain the final HE.A given image is considered to exhibit DME if at least one candidate is detected in the image. As observed with edge based methods earlier, a preprocessing step is required to avoid detection of a large number of non-HE edges. Thus for DME detection, the strength of local schemes is the ability to detect small HE while the global schemes remove the burden of having to detect/segment every HE. We aim to explore using the global characteristics of an image while retaining the sensitivity to small HE. Towards this, we propose to transform the given image to an intermediate representation called motion pattern that spatially enhances the HE presence regardless of their size. This is followed by derivation of global features on the motion pattern for detection of HE.

## III. PROPOSED METHOD

The macula is a dark structure roughly at the center of the retina. Hard Exudates which appear as clusters of bright lesions are usually well localized. In the absence of any HE (i.e., a normal retina), there is a rough rotational symmetry about the macula in the circular region of roughly twice the diameter of the optic disc. We use this observation to derive relevant features to describe the normal and abnormal cases. Given a color fundus image, a circular region of interest (ROI) is first extracted and an intermediate representation also known as the motion pattern of the ROI is created. Relevant features are then derived for to classify the given image as normal or abnormal.

The detection process of DME can be done as follows. The image taken for evaluation is first assumed to be normal. Any deviation from normal characteristics is taken to be indicative of abnormality. For every abnormal image the severity of DME is assessed by determining the location of HE relative to the macula with fovea detection.

## IV. ALGORITHM FOR DETECTING MACULAR EDEMA

The image under evaluation is first ascertained to be normal (abnormality detection) by learning the characteristics of normal retinal images. Any deviation from normal characteristics is taken to be indicative of abnormality as in Fig.1.

For every abnormal image the severity of DME is assessed by determining the location of HE relative to the macula. In the next section, details of the proposed method is presented. This observation can be used to derive relevant features to describe the normal and abnormal cases. Given a color fundus image, a circular region of interest (ROI) is first extracted and an inter-mediate representation $I_{MP}$ also known as the motion pattern of the ROI is created. This novel representation captures the global image characteristics. Such global features have not been used successfully earlier for HE detection.

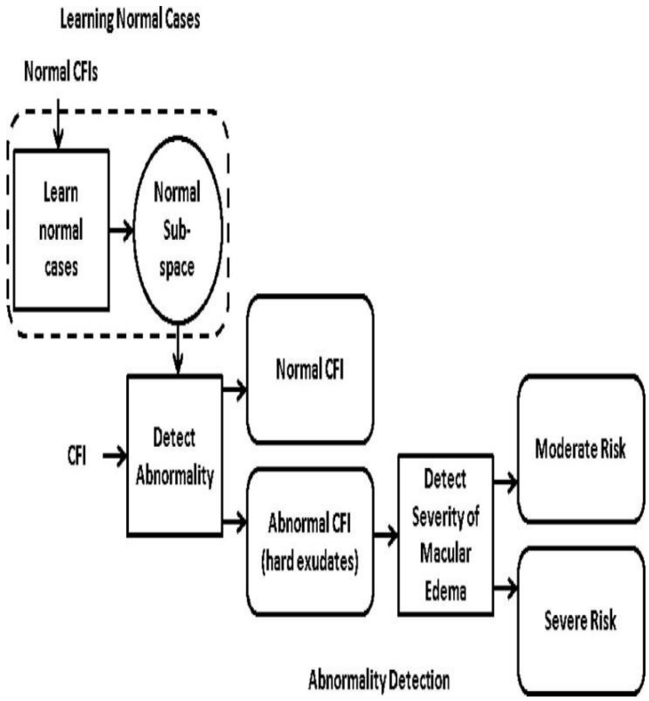


Fig 1 Processing Pipeline for Detection and Assessment of DME

In the first level, a supervised technique based on learning the image characteristics of only normal patients is used for detecting the abnormal cases pertaining to HE. Relevant features are then derived for $I_{MP}$ to classify the given image as normal or abnormal (containing HE) as in Fig.2.The well-defined edges of HE has also been used as a cue to identify candidate pixels. However, small or faint HE detection is difficult and hence additional rules are used to handle them. It uses edge properties in conjunction with other features to classify the detected candidates. Edge detection yields noisy results and hence preprocessing and post processing steps are required to reduce the large number of false candidates.

Our strategy for detecting macular edema and evaluating its severity is as follows: the image under evaluation is first ascertained to be normal (abnormality detection) by learning the characteristics of normal retinal images. Any deviation from normal characteristics is taken to be indicative of abnormality. For every abnormal image the severity of DME is assessed by determining the location of HE relative to the macula. Macular Edema severity is classified to be Moderate risk and Severe risk based on the given color fundus images.

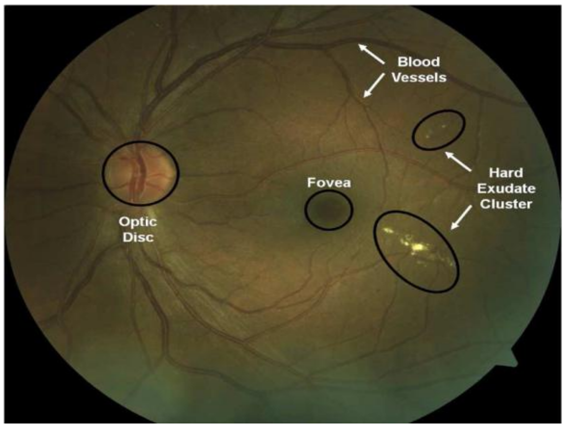


Fig. 2 Color fundus image with anatomical structures and lesions annotated

## V. MACULA LOCALIZATION (ROI EXTRACTION)

The severity of DME is determined based on the location of HE clusters relative to the macula, the images acquired for DME detection usually focus around the macular region. We find the best fit circle within the fundus mask with macula at the center for a given image. The region within this circle is the desired ROI denoted as in Fig 3.

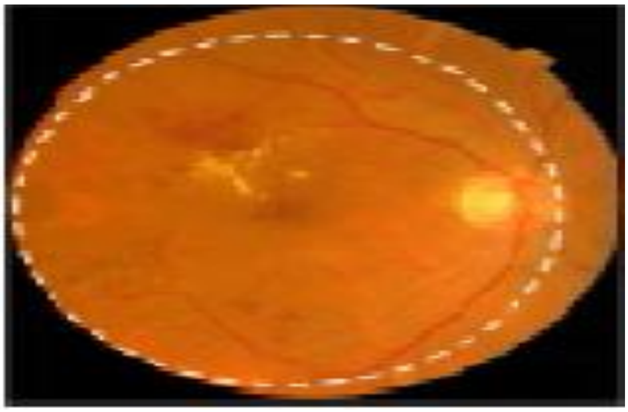

Fig. 3 The Region of Interest centered on macula in a fundus image

## VI. DETECTION OF OPTIC DISC

An efficient detection of optic disc in color retinal images is a significant task in an automated retinal image analysis system. Its detection is prerequisite for the segmentation of other normal and pathological features. The position of optic disc can be used as a reference length for measuring distances in retinal images, especially for the location of macula. In case of blood vessel tracking algorithms the location of optic disc becomes the starting point for vessel tracking.

The attributes of optic disc is similar to attributes of hard exudates in terms of color and brightness. Therefore it is located and removed during the hard exudates detection process, thereby avoiding false positives. In color fundus photograph, optic disc appears as a bright spot of circular or elliptical shape, interrupted by the outgoing vessels. It can be seen that optic nerves and vessels emerge into the retina through optic disc. It is situated on the nasal side of the macula and it does not contain any photoreceptor. Therefore it is also called the blind spot.

## VII. LOCALIZATION OF OPTIC DISC

The localization of optic disc is important for two purposes. First, it serves as the baseline for finding the exact boundary of the disc. Secondly, optic disc center and diameter are used to locate the macula in the image .In a color retinal image the optic disc belongs to the brighter parts along with some lesions. The central portion of disc is the brightest region called optic cup, where the blood vessels and nerve fibers are not present. A threshold is to be applied, that will separate part of the optic disc and some other unconnected bright regions from the background.

## VIII. ELIMINATION OF VESSELS

The optic disc region is usually fragmented into multiple sub-regions by blood vessels that have comparable gradient values. A homogeneous optic disc region is needed for segmentation using geometric active contour algorithm. Median filter with appropriate size is used to remove interfering blood vessels from the optic disc region resulted in heavy blurring of disc boundaries. Instead a better result is achieved with gray level mathematical morphology to remove irrelevant vessels from the optic disc region. Gray scale mathematical morphology provides a tool for extracting geometric information from gray scale images.

A structuring element is used to build an image operator whose output depends on whether or not this element fits inside a given image. Shape and size of the structuring element is chosen in accordance with the segmentation task. The two fundamental morphological operations are dilation and erosion. Due to dilation operation the small interfering blood vessels are detached. Next, erosion is done to restore the boundaries to their former position. The macula is a depression in the center of macular region and appears as a darker area in a color retinal image. It is located temporal to the optic disc and has no blood vessels present in its center. Thus macula can be detected.

The location of macula varies from individual to individual, a rectangular search area has to be defined. In a standard retinal image the macula is situated about 2 disc diameter temporal to the optic disc.The width of the search area is taken equal to two disc diameter as the mean angle between the macula and the center of the optic disc to the horizontal. A small pixel window of particular size is formed to scan the entire area and the average intensity at each pixel location is calculated. The center of the window having the lowest average intensity is taken as the center of the macula shows the result of automatic macula detection method. As the macula is localized, the whole macular region can be determined for detecting the presence or absence of hard exudates.The macula is a depression in the center of macular region and appears as a darker area in a color retinal image.

## IX. REGION OF INTEREST EXTRACTION

The severity of DME is determined based on the location of HE clusters relative to the macula, the images acquired for DME detection usually focus around the macular region. We find the best fit circle within the fundus mask with macula at the center, for a given image. The region within this circle is the desired ROI as shown in Fig 3.The green channel of forms the input for all subsequent processing. The center of macula is automatically detected using and restricting the search to a central region of the given image since the acquired images for DME detection are macula centric. Since the OD shares a brightness characteristic similar to HE, it is also automatically detected and masked. The result of macula and optic disc detection can be seen in where the macula is shown as a circular patch and the OD is shown as a rectangular patch. The images acquired for DME detection usually focus around the macular region. The best fit circle within the image mask with macula at the center, for a given image is found. The green channel which has been extracted forms the input for all subsequent processing. The center of macula is automatically detected using and avoiding the search to a central region of the image since the acquired images for DME detection are macula-centric. Since the OD shares a brightness characteristic similar to HE, it is also automatically detected and masked.Given a color fundus image, a circular region of interest (ROI) I is first extracted and an inter-mediate representation also known as the motion pattern of the ROI is created. Relevant features are then derived , to classify the given image as normal or abnormal**.**

## X. DETERMINING THE SEVERITY OF MACULAR EDEMA

Assessment of the severity of macular edema is the next task. Here, the macular region which is the circular ROI within 1 optic disc diameter from the center, is of key interest as any HE within this region indicates high risk for DME, requiring immediate attention. The macula in a normal imageis relatively darker than other regions in the fundus image and is characterized by (rough) rotational symmetry. We use this symmetry information to establish the risk of exhibiting edema: good degree of symmetry is taken to indicate the abnormality is not inside macula and hence it is declared as a moderate case. Asymmetry of the macula on the other hand implies abnormality is within the macula and hence the case is deemed severe. HE appear as clusters of bright, high contrast lesions and are usually well localized. The macula is a dark structure roughly at the center of the retina and causes the vision loss. The well-defined edges of HE has also been used as a cue to identify candidate pixels. However, small or faint HE detection is difficult and hence additional rules are used to handle them. The distinct bright yellow color of HE has been the motivation for using color features. The use of color seems to be sufficient in principle, high variation in color witnessed in images across and within different ethnicities require a color and luminosity normalization step before detection. The performance of the proposed methodology and features are evaluated against several publicly available datasets.The proposed method follows mainly six steps for the detection of diabetic retinopathy. Preprocessing, region of interest extraction, generation of motion patterns, feature selection, abnormality detection and classification based on severity. In preprocessing step the green channel extraction is done on the image.

## XI. SIMULATION AND OUTPUT

The simulation tool used for processing input color fundus images is MATLAB. The version of MATLAB is R2013a. Image processing toolbox is used for simulation. The input contains both normal and abnormal images. The input eye images are in digital format. It is in .jpg format.

### *A. Conversion to Gray Scale Image*

RGB image is converted into gray-scale as input image as shown in Fig 4. It is to reduce the correlated color information in color fundus image. The Fig 4 shows the image under evaluation is first ascertained to be normal (abnormality detection) by learning the characteristics of normal retinal images and adjust the intensities**.**

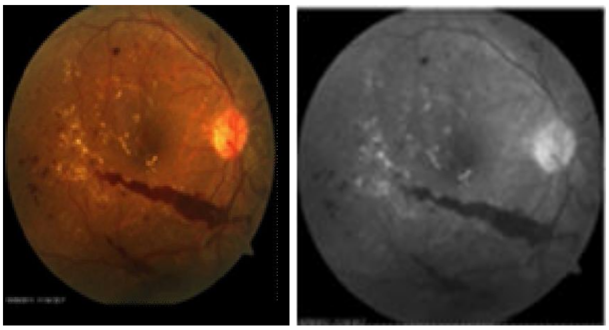

Fig .4 Color Fundus Image and Gray Scale Image

### *B. Morphological Operations on Gray Scale Image*

Morphological opening operation and Morphological closing operation are applied to a disk shaped structuring element on gray-scale image to reduce the small noise and to remove the vessels structure. Due to dilation operation, the small interfering blood vessels are detached. This will make the input image slightly blurred. Next, erosion is done to restore the boundaries to their former position. Determining the severity of macular edema is an another task.

### *C. Blood Vessel Extraction and Optic Disc Detection*

The blood vessels of the disk are found using MATLAB morphological filters. Based on the adaptive mathematical morphology, the origin of the optic disc is identified. The macula, which is a depression in the center of macular region, appears as a darker area in a color retinal image as shown in Fig 5. It is located temporal to the optic disc and has no blood vessels present in it.

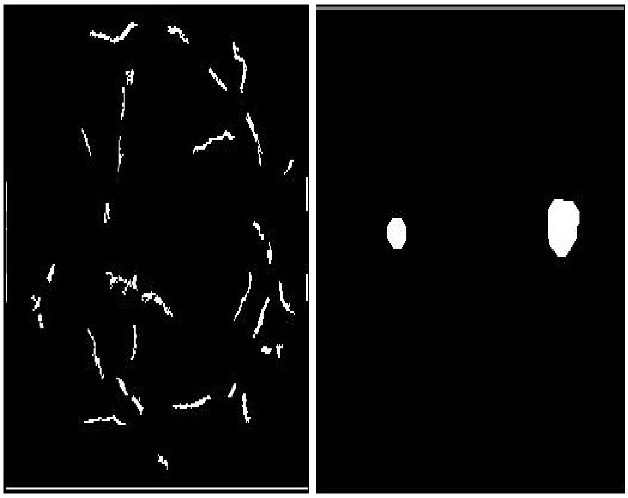

Fig. 5 Blood Vessel Extraction and OD Detection

### *D. Generation of Motion Patterns*

When rotation is applied to the disk pattern in steps, a set of patterns is generated. When two patterns will be generated and their union is the second pattern. The remaining patterns are the result of the union of patterns generated with decreasing step size. The motion pattern is obtained by using the union operation as the coalescing function. As shown in Fig 6 similar eight motion patterns can be generated in the decreasing rotation steps. The transformation function is applied to the image (I) to generate a sequence of N images, which are rotated versions of I. Here induce motion in a given image to generate a sequence of images. First consider a disk with a lesion at any point. Then apply rotation motion to this pattern.

 

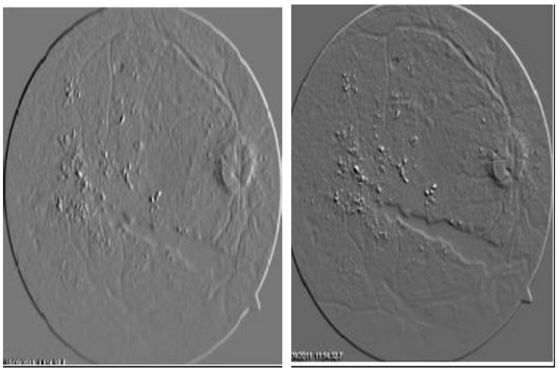

Fig. 6 Motion patterns of decreasing rotation steps E

*E. Combined Motion Patterns and Segmented Image*

Combining the eight motion by applying the rotation steps in decreasing order from (0 to 2 π) is obtained and its segmented image with affected areas are obtained as shown in the Fig 7.

Determining the severity of macular edema is an another task. The macula in a normal image is relatively darker than other regions in the fundus image and is characterized by rotational symmetry. Good degree of symmetry is taken to indicate the abnormality is not present inside macula and hence it is declared as a moderate case. Asymmetry of the macula on the other hand implies abnormality is within the macula and hence the case is severe.

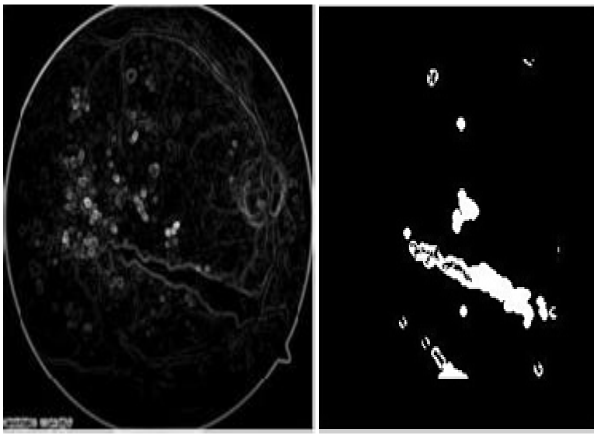

Fig. 7 Combined Motion Pattern and Segmented Image

*F. Fovea Extraction and the Image with Affected Areas*

A point is located horizontally at a distance 2.5×d from optic disk center towards the centroid. A k×k sliding window is applied along the strip and forms chain of numbers denoting the black pixels in the window. Maximum run length of zeros is found in the number chain. That is known as a fovea region. It is marked by a red colored circle as shown in Fig 8 and checking of that image to spot the disease is done by visualizing the change in the shape of fovea. The affected areas of the retinal image are shown in Fig 8.

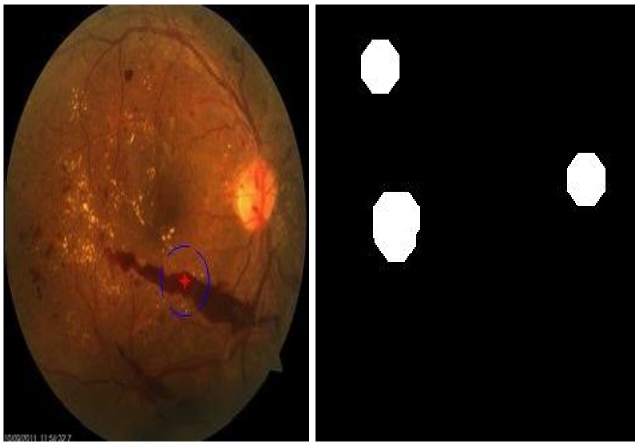

Fig. 8 Fovea localization and affected areas

Presence of lesion in the abnormal image results in smearing of lesion intensities over the motion path in the motion pattern. The severity of DME is assessed by determining the location of HE relative to the macula.

Table I
CLASSIFICATION OF DME BASED ON ACCURACY

| DME | Moderate Accuracy (%) | Severe Accuracy(%) |
|---|---|---|
| Accuracy | 80 | 90 |

## XII. CONCLUSIONS

DME detection and assessment provides significant contributions which include a hierarchical approach to the problem, a novel representation for the first level, to classify an image as normal or abnormal (containing HE) and a second level, to assess the severity of DME. This novel representation captures the global image characteristics. Such global features have not been used successfully earlier for HE detection. In the first level, a supervised technique based on learning the image characteristics of only normal patients is used for detecting the abnormal cases pertaining to HE. In the second level, the severity of the abnormality is assessed by analyzing the macular region in retina. Proposed scheme is simple but efficient in extracting the fovea region. The extracted macula and fovea region may help in further diagnosis of eye related diseases. The severity of the risk of edema is evaluated based on the proximity of HE (Hard Exudate) to the macula. Thus DME (Diabetic Macular Edema) detection and assessment done from a set of color fundus image and assess the severity of risk.With the generation of patterns the abnormality detection and severity classification will be more accurate. Proposed system will overcome the problems listed in the above methods by using an automatic DME detection and DR screening infrastructure by helping automate the detection and assessment of DME.

The future enhancement is done by identifying the gabbor features using neural network classifier by selecting an input and a target ie, database images, which is already trained. If the features of the selected input match with the target, then the severity stage can be detected.

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