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FEATURE EXTRACTION OF RETINAL IMAGE FOR DIAGNOSIS OF ABNORMAL EYES

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Abstract

Currently, medical image processing draws intense interests of scientists and physicians to aid in clinical diagnosis. The retinal Fundus image is widely used in the diagnosis and treatment of various eye diseases such as Diabetic Retinopathy, glaucoma etc. If these diseases are detected and treated early, many of the visual losses can be prevented. This paper presents the methods to detect main features of Fundus images such as optic disk, fovea, exudates and blood vessels. To determine the optic Disk and its centre we find the brightest part of the Fundus. The candidate region of fovea is defined an area circle. The detection of fovea is done by using its spatial relationship with optic disk. Exudates are found using their high grey level variation and their contours are determined by means of morphological reconstruction techniques. The blood vessels are highlighted using bottom hat transform and morphological dilation after edge detection. All the enhanced features are then combined in the Fundus image for the detection of abnormalities in eye.

Keywords:

Diabetic Retinopathy, Exudates, Image Processing, Optic Disk, Fovea, Exudates, Blood Vessels.

1. INTRODUCTION

Diabetic retinopathy, glaucoma, etc has been recognized as a leading cause of blindness among adults. Early detection and treatment of the eye diseases is the key to preventing vision loss in diabetes. The retinal Fundus image which is shown in Fig.1 can help in detecting some of the features of the retina such as Optic Disk (OD), Fovea, exudates and blood vessels. After we detect these features, we can classify the Fundus as normal and abnormal. The optic disk is the entrance of the blood vessels and the optic nerve into the retina. It appears in color Fundus images as a bright yellowish or white region. We first find the candidate region by finding the brightest part of the Fundus and we can locate the OD and mark its center. The fovea is a small depression on the Fundus, which is indicated by a deep-red or red-brown in color retinal images. It is located approximately two disk diameter away from the centre of the OD and its area is about half of that of OD. The detection and quantification of exudates will contribute to the mass screening and assessing of the diabetic retinopathy. Hence detection and quantification of the exudates automatically is one of the main objectives of our paper.

Approach based on Morphological Techniques: It is the green channel, in which the exudates appear most contrasted. Our algorithm can be divided into two parts. First, we find candidate regions; these are regions that possibly contain exudates. Then, we apply morphological techniques in order to find the exact contours. The blood vessel which also indicates the abnormalities is also enhanced using the techniques in detection of blood vessels.

Contribution of Image Analysis to the Diagnosis of Diabetic Retinopathy: The contribution of image processing to the diagnosis of diabetic retinopathy may be divided into the following three groups:

1. Image enhancement
2. Mass screening
3. Monitoring of the disease

Image Enhancement: Images taken at standard examinations are often noisy and poorly contrasted. Over and above that, illumination is not uniform. Techniques improving contrast and sharpness and reducing noise are therefore required

- As an aid for human interpretation of the Fundus images
- As a first step toward automatic analysis of the Fundus images

Mass Screening: Computer-assisted mass screening for diagnosis of Diabetic-Retinopathy is certainly the most important task to which image processing can contribute. Although the mechanisms for diabetic retinopathy are not fully understood, its progress can be inhibited by early diagnosis and treatment. However, as vision normally alters only in the later stages of the disease, many patients remain undiagnosed in the earlier stages of the disease, when treatment would be the most efficient. Hence, mass screening of all diabetic patients (Even without vision impairment) would help to diagnose this disease early enough for an optimal treatment. An automated or semiautomatic computer-assisted diagnosis could bring the following advantages:

- Diminution of the necessary resources in terms of specialists
- Diminution of the examination time

The tasks for image processing may be divided into the following.

- Automatic detection of pathologies
- Automatic detection of features of the retina
- Measurements on the detected pathologies that is difficult or too time consuming to be done manually

Monitoring: In order to assess the evolution of the disease, physicians have to compare images taken at different medical Examinations. This allows one to

- Evaluate for each patient the efficiency of the ophthalmologic and diabetic treatments
- Evaluate the efficiency of new therapeutics in a population of patients
- Observe the development of single lesions (for example in order to study the turn-over effect of micro aneurysms. However, the comparison of images taken at different mo-

ments is a very time-consuming task and open to human error due to the distortions between images that make superposition very difficult, and due to the large number of lesions that have to be compared. A computer assisted approach is needed. In addition to automatic detection of pathologies, such a tool needs a robust feature-based registration algorithm. Registration algorithms for retinal images have been proposed and morphological process is carried out to find the grey levels of the Fundus image to find the eye abnormalities

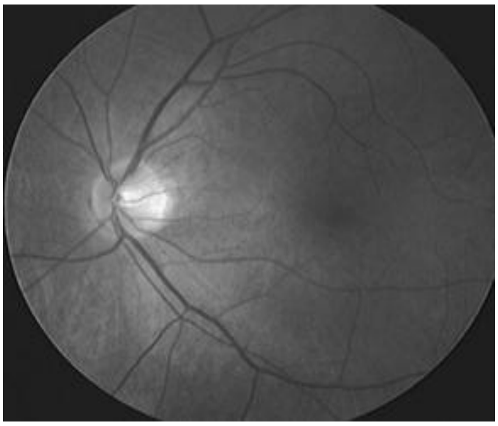


Fig.1. Retinal Fundus Image

2. DETECTION OF THE OPTIC DISK

The detection of the optic Disk in the human Retina is the most important factor. The optic disk is the entrance of the blood vessels and the optic nerve into the retina. It appears in color Fundus images as a bright yellowish or white region. Its shape is more or less circular, interrupted by outgoing vessels. Sometimes the optic disk has the form of an ellipse because of negligible angle between image plane and object plane. Its size varies between different patients and is approximately 50 pixels in 576 x 768 color photographs. The detection of the Optic disk is performed in red component because blood vessels do not appear in the red component, but they may interfere in the green component. Its Histogram is taken and the candidate area with highest 4% gray level is selected. Only these pixels are highlighted, because the exudates are also having the same intensity as that of optic disk, some of the exudates may also get highlighted.

2.1 OUTLINES

The detection of the optic disc in the human retina is a very important task. It is indispensable for our approach to detection of exudates, because the optic disc has similar attributes in terms of brightness, color and contrast, and we shall make use of these characteristics for the detection of exudates. Over and above that, the optic disc can be seen as a landmark and it can be used for a coarse registration of retinal images in order to reduce the search space for a finer one. Furthermore, its detection is a first step in understanding Fundus images. The diameter Delivers a calibration of the measurements determines approximately the localization of the center of vision, which is of great importance in the macular region affect vision immediately.

2.2 PROPERTIES OF THE OPTIC DISC

The optic disc is the entrance of the vessels and the optic nerve into the retina. It appears in color Fundus images as a bright yellowish or white region. Its shape is more or less circular, interrupted by the outgoing vessels. Sometimes the optic disc has the form of an ellipse because of a no negligible angle between image plane and object plane. The size varies from patient to patient its diameter lies between 40 and 60 pixels in 640 480 color photographs.

2.3 STATE OF THE ART

The optic disc is localized exploiting its high grey level variation. This approach has been shown to work well, if there are no or only few pathologies like exudates that also appear Very bright and are also well contrasted. No method is proposed for the detection of the contours. An area threshold is used to localize the optic disc. The optic disc is localized by back tracking the vessels to their origin. This is certainly one of the safest ways to localize the optic disc, but it has to rely on vessel detection. It is desirable to separate segmentation tasks in order to avoid an accumulation of segmentation errors and to save computational time (the detection of the vascular tree is particularly time consuming).morphological filtering techniques and active contours are used to find the boundary of the optic disc area threshold is used to localize the optic disc and the watershed Transformation.

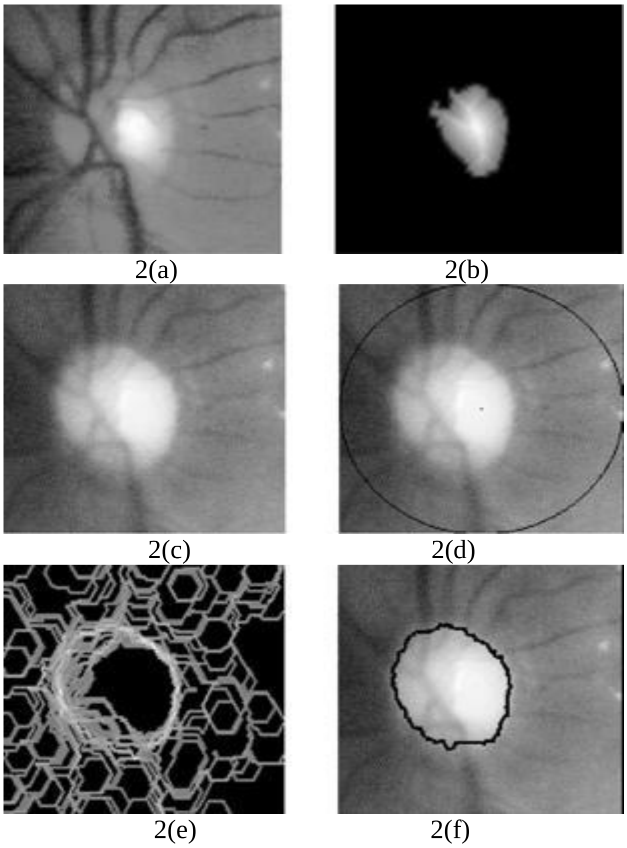


Fig.2. (a) Luminance channel; (b) distance image of the biggest particle; (c) red channel; (d) red channel with imposed marker; (e) morphological gradient and (f) result of segmentation

The detection of the optic disc:

a) Luminance channel
b) distance image of the biggest particle
c) red channel
d) red channel with imposed marker
e) morphological gradient
f) result of segmentation

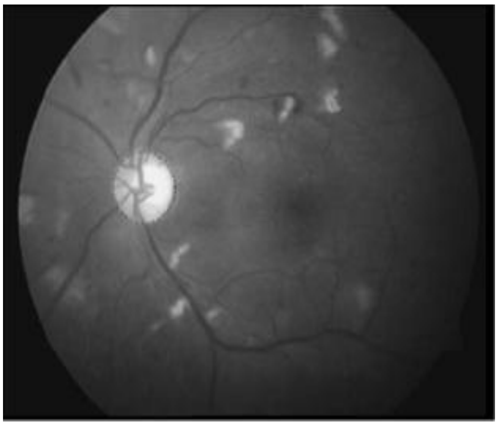


Fig.3. Detected Optic disk and its center

3. DETECTION OF THE FOVEA

The fovea is a small depression on the Fundus, which is indicated by a deep-red or red-brown color in color retinal images. It is temporal to and slightly below the optic disk. The fovea is the darkest part in most of the retinal images, while it is not obvious in some images due to high illumination or being covered by the lesions. Its geometrical relation to other structures is employed to locate the fovea robustly. The candidate region of fovea is defined as an area of circle. Its center is located at 2DD (Disk Diameter) away from the disk center along the main axis of the fitted parabola and the radius is selected as 1DD. Because the fovea is situated about 2DD temporal to the optic disk in the retinal images, the candidate region is such defined in order to ensure that the fovea is within the region.

The detection of the fovea is done by using its spatial relationship with the optic disk. A search for the darkest area about half the size of the disk and approximately two diameters away from the centre of the optic disk is carried out. After detecting the fovea it is highlighted in the main Fundus image. Hard exudates are yellowish intraregional deposits, which are usually located in the posterior pole of the Fundus.

The exudates is made up of serum lipoproteins, thought to leak from the abnormally Permeable blood vessels, especially across the walls of leaking micro aneurysms. Hard exudates are often seen in either individual streaks or clusters or in large circinate rings surrounding Clusters of microaneurysms. They have an affinity for the macula, where they are usually intimately associated with retinal thickening. Hard exudates may be observed in several retinal vascular pathologies, but are a main hallmark of diabetic macular edema. Indeed, diabetic macular edema is the main cause of visual impairment in diabetic patients. It needs to be diagnosed at an early and still asymptomatic stage; at that stage, laser treatment may prevent visual loss from macular edema. Diabetic macular edema is defined by retinal thickening involving or threatening the center of the macula. it is usually diagnosed on slit-lamp Biomicroscopy or stereo macular photographs. However, when screening for diabetic retinopathy using a nonmydriatic camera, good macular stereoscopic photographs May Be Difficult to obtain. in this case, the easiest and most effective way to diagnose macular edema is to detect hard exudates, which are usually associated with macular edema.

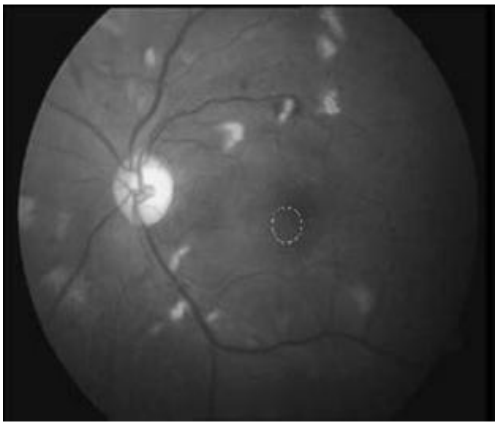


Fig.4. Retinal Fundus image with detected Fovea

4. DETECTION OF BLOOD VESSELS

The retinal vessels are usually termed arteries and veins. The central retinal artery and vein normally appear close to each other at the nasal side of the center of optic disk. The blood vessels are clearest in the green component. Information about the structure of blood vessels can help grading the severity of diseases and can also serve as landmark during operation. It also helps in image registration task where in the bifurcation point of blood vessels serves as control points in turn helping the images to be fused from the different modalities. This helps the ophthalmologists to analyze the case of diabetic Retinopathy with progression of time. The blood vessels are best detected in green component because they have low reflectance. We passed the image through smoothing filter before processing it further. Then the filtered retinal Fundus image was input for the edge detection technique. The results of edge detection was compared with the image passing before and after the smoothing filter and results were found better for the edge detection technique applied on filtered images. Similarly, we tested the image on different edge detection technique like Gaussian Laplacian, Prewit edge operator, Sobel's Operator. To our surprise, it was found that Canny's edge detection technique was the best amongst the other edge detection technique. Reason, it uses two thresholds for detecting the edges and as a result both strong and weak edges are detected. The second strategy of extracting the blood vessels is computing the bottom hat transform on the filtered retinal image. This is best step by which one can extract the blood vessels completely. For this, we defined a disk shaped structuring element with 25 neighborhoods which was operated on the filtered retinal image. Later to get results, the same structuring element was used for dilate operation on canny edge detected retinal image. The results were good. Thus the two different strategies were tested on 30 odd fundus retinal images and found our novel algorithm to be working fine.

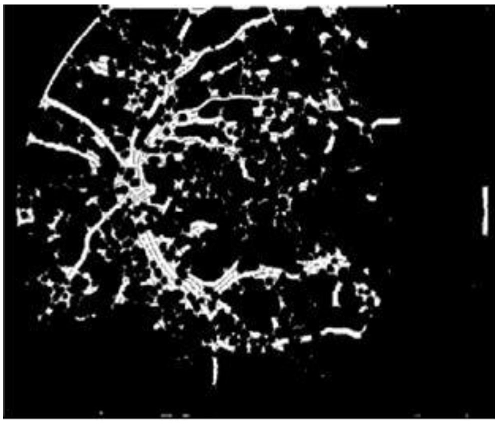


Fig.5. Fundus image with Blood vessels Detected using bottom hat transform

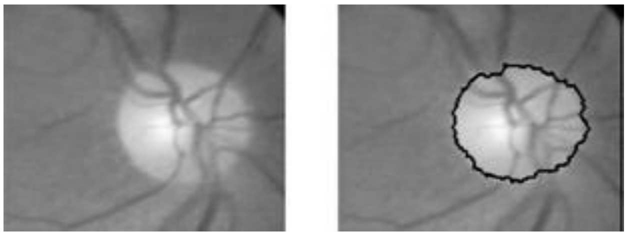
Fig.6. Fundus image with Blood vessels detected using bottom hat transform using Morphological Dilation after edge detection

5. DETECTION OF EXUDATES

It is the green channel, in which the exudates appear most contrasted. We first find the candidate regions; these are regions that possibly contain exudates. Then, we apply morphological techniques in order to find the exact contours. Regions that contain exudates are characterized by a high contrast and a high grey level. The problem that occurs if we use the local contrast to determine regions that contain exudates is that bright regions between dark vessels are also characterized by a high local contrast. So, we first eliminate the vessels by a closing. On this image, we calculate the local variation for each pixel within a window Then we threshold the image at some grey level. We obtain all regions with a standard variation larger than or equal to the grey level .i.e. small bright objects and borders of large bright objects. In order to obtain the whole candidate regions rather than their borders, we fill the holes by reconstructing the image from its borders We also dilate the candidate region in order to ensure that there are background pixels next to exudates that are included in the candidate regions, this is important for finding the contours. The suitable threshold is chosen in a very tolerant manner, i.e., we get the regions containing some exudates, but we also get some false positives. The papillary region and some other areas that are characterized by a sufficiently high grey level variation due to illumination changes in the image. Finally, we have to remove the candidate region that results from the optic disc. We remove a dilated version of the segmentation result. In that way, we obtain the candidate regions. In order to find the contours of the exudates and to distinguish them from bright well contrasted regions that are still present in the candidate region. We then set all the candidate regions to 0 in the original image and calculate the morphological reconstruction by dilation. As exudates are entirely comprised within the candidate region, they are completely removed, whereas regions that are not entirely comprised in the candidate regions are nearly entirely reconstructed. The final result is obtained by applying a simple threshold operation to the difference between the original image and the reconstructed image.

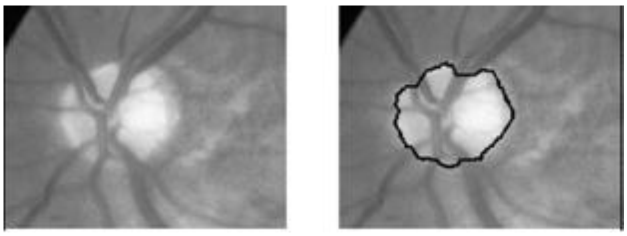
5.1 OUTLINES

Hard exudates are yellowish intra retinal deposits, which are usually located in the posterior pole of the fundus. The exudate is made up of serum lipoproteins, thought to leak from the abnormally permeable blood vessels, especially across the walls of leaking microaneurysms. Hard exudates are often seen in either individual streaks or clusters or in large circinate rings surrounding clusters of microaneurysms. They have an affinity for the macula, where they are usually intimately associated with retinal thickening. Hard exudates may be observed in several retinal vascular pathologies, but are a main hallmark of diabetic macular edema. Indeed, diabetic macular edema is the main cause of visual impairment in diabetic patients. It needs to be diagnosed at an early and still asymptomatic stage; at that stage, laser treatment may prevent visual loss from macular edema. Diabetic macular edema is defined by retinal thickening involving or threatening the center of the macula. It is usually diagnosed on slit-lamp biomicroscopy or stereo macular photographs. However, when screening for diabetic retinopathy using a nonmydriatic camera, good macular stereoscopic photographs may be difficult to obtain. In this case, the easiest and most effective way to diagnose macular edema is to detect hard exudates, which are usually associated with macular edema.



7(g) 7 (h)

Fig.7. (g) Luminance channel of the original image and (h) Segmentation result



7(i) 7(j)

Fig.7. (i) Luminance channel of the original image and (j) Segmentation result

Indeed, the presence of hard exudates within 3000m of the centre of the macula allows macular edema to be detected.

5.2 PROPERTIES

However, there are a few problems to handle. There are other features in the images that appear as bright patterns, namely the optic disc and – because of changes in illumination – ordinary background pixels. In addition, they are not the only features causing a high local contrast. The grey level variation due to vessels is often as high as the one caused by the exudates.

5.3 STATE OF THE ART

Shade correction, contrast enhancement, sharpening, and a manually chosen threshold is applied to this problem. However, we think that a full automation of exudates detection is possible. Actually, a fully automated method based on image sharpening, shade correction, and a combination of local and global thresholding has been proposed and validated Color normalization and local contrast enhancement are followed by fuzzy C-means clustering and neural networks are used for the final classification step. This has been shown to work well, but it relies on the local contrast enhancement that has been introduced and that amplifies noise particularly in areas, in which there are not many features.

5.4 APPROACH BASED ON MORPHOLOGICAL TECHNIQUES

As stated it is the green channel, in which the exudates appear most contrasted. Our algorithm can be divided into two parts. First, we find candidate regions; these are regions that possibly contain exudates. Then, we apply morphological techniques in order to find the exact contours.

5.4.1 Finding of the Candidate Regions:

Regions that contain exudates are characterized by a high contrast and a high grey level. The problem that occurs if we use the local contrast to determine regions that contain exudates is that bright regions between dark vessels are also characterized by a high local contrast. So, we first eliminate the vessels by a closing with such that is larger than the maximal width of the vessels. On this image, we calculate the local variation for each pixel, Thresholding the image at grey level, we obtain all regions with a standard variation larger than or equal to, i.e., small bright objects and borders of large bright objects. In order to obtain the whole candidate regions rather than their borders, we fill the holes by reconstructing the image from its borders. We also dilate the candidate region in order to ensure that there are background pixels next to exudates that are included in the candidate regions; this is important for finding the contours with if The threshold is chosen in a very tolerant manner, i.e., we get the regions containing some exudates, but we also get some false positives: The papillary region and some other areas that are characterized by a sufficiently high grey level variation due to illumination changes in the image. Finally, we have to remove the candidate region that results from the optic disc. We remove a dilated version of the segmentation result.

5.4.2 Finding the Contours:

In order to find the contours of the exudates and to distinguish them from bright well contrasted regions that are still present in, we set all the candidate regions to 0 in the original image and we then calculate the morphological reconstruction by dilation of the resulting image This operator propagates the values of pixels next to the candidate regions into the candidate regions by successive geodesic dilation under the mask. As exudates are entirely comprised within the candidate region, they are completely removed, whereas regions that are not entirely comprised in the Candidate regions are nearly entirely reconstructed. The final result [is obtained by applying a simple threshold operation to the difference between the original image and the reconstructed image. This algorithm has three parameters: the size of the window, and the two thresholds and the choice of the size of is not crucial, and we have found good results for a window size is chosen too large, small isolated exudates are not detected. We found that not very disturbing, because small isolated exudates do not play an important role for diagnostic purposes. The first threshold determines the minimal variation value within the window that is suspected to be a result of the presence of exudates. If is chosen too low, specificity decreases; if it is set too high, sensitivity decreases. The parameter is a contrast parameter: It determines the minimal value a candidate must differ from its surrounding background to be classified as an exudates. The influence of these two parameters is discussed in the next section.

5.5 RESULTS

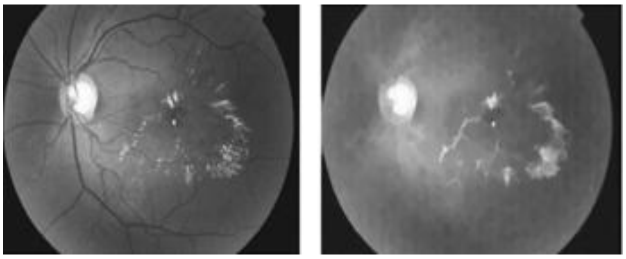
The assessment of the quality of pathology detection is not an easy task; human graders are not perfect. Hence, if a human grader does not agree with the algorithm, this can be due to an error of the human grader or due to an error of the algorithm. One more problem arises, if (as for exudates) it has to be defined, when an exudates can be considered as having been detected and when not (pixel wise against object wise comparison of segmentation results) by a human grader and by the neural network as exudates or no exudates. Comparing these two results allows one to calculate sensitivity and specificity. However, it is not the number of Exudate which is important for the diagnosis: If an algorithm can find all exudates, but not the borders in a correct manner, it will have good statistics but poor performance, a pixel wise comparison is proposed. We shall apply a variant of this method in the next section.

5.5.1 Comparison of the Proposed Method with Human Graders:

We have tested the algorithm on an image data base of 30 images 640 480 digital images these images have not been used for the development of the images did not contain exudates, and in 13 of these 15 no exudates were found by our algorithm. In two images, few false positives were found (less than 20 pixels). In order to compare the results (for the 15 images containing exudates) obtained by the algorithm with the performance of a human grader, we asked a human specialist to mark the exudates on color images. In that way, we obtained segmentation result that we considered to be correct. Then we applied the proposed algorithm and obtained a segmentation result. Let be the support of defined as the set of pixels for which, let be the number of its elements and the set difference. If a pixel has not been marked by the human grader, but it was marked by the algorithm and it is next to a pixel marked by the human grader the number of true negatives, i.e., the number of pixels that are not classified as exudates pixels, neither by the grader nor by the algorithm is very high, so the specificity is always near 100%. This is not very meaningful.

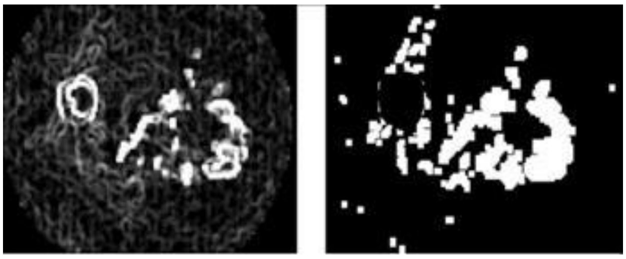
5.5.2 Influence of the Parameters:

The robustness of an algorithm can be defined in respect to changes in the parameters or to image quality (influence of noise, low contrast, resolution).We have studied the behavior of the algorithm concerning changes of parameters. Indeed, we can observe that the choice for the parameters is not independent. Sensitivity and the predictive value depending on different parameters.



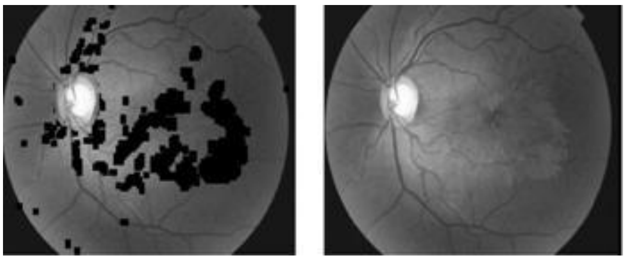
7(k) 7(l)

Fig.7. (k) Luminance channel of a color image of the human retina and (l) Closing of the luminance channel



7(m) 7 (n)

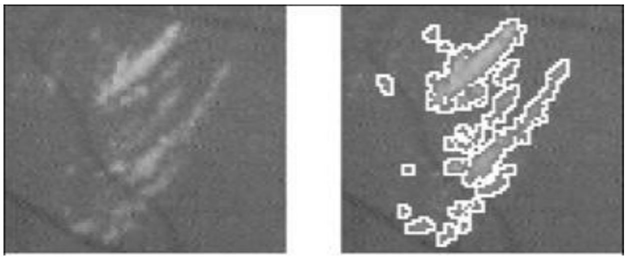
Fig.7. (m) Local standard variation in a sliding window and (n) Candidate region



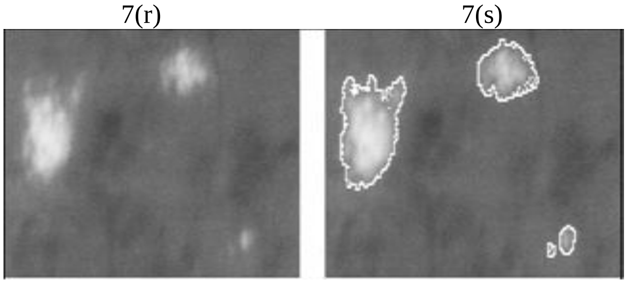
7(o) 7(p)

Fig.7. (o) Candidate regions set to 0 in the original image and (p) Morphological reconstruction

Fig.7(q). Result of the segmentation algorithm



7(r) 7(s)



7(t) 7(u)

Fig.7. (r,t) Detail of the green channel of a color image containing exudates and (s,u) Segmentation result

6. RESULTS

The Fig.3 shows the results of detection of optic disc in the fundus retinal images; subsequently Fig.4 shows the fundus image with fovea detected on the image.

Fig.7(g to u) shows the enhanced exudates and are highlighted in the fundus image affected by the diabetic retinopathy. Fig.5 and Fig.6 shows the retinal fundus image with enhanced blood vessels using bottom hat transform and morphological dilation operation after applying edge detection techniques respectively. It can be observed from the obtained results that the detected features can be used as a supporting tool for the diagnosis of diabetic retinopathy. Finally Fig.8 shows the retinal fundus image with detected exudates.

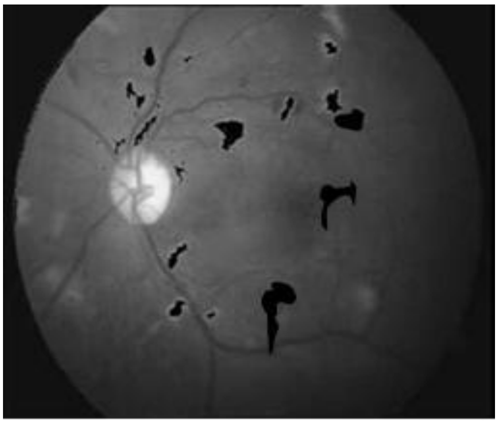


Fig.8. Retinal Fundus image with detected Exudates

Fig.9. Fundus image with all the features detected and highlighted

7. CONCLUSION

The important features in the fundus image of the retina such as optic disk, fovea, exudates and blood vessels are enhanced. This will help in detection of any kind of abnormalities in the eye, especially diabetic retinopathy. The detected exudates can be used to identify the severity of the retinal decay. Further geometrical shape and structures of this detected parameter can be utilized for automatic detection of normal and abnormal eyes. Image processing of color fundus images has the potential to play a major role in diagnosis of diabetic retinopathy. There are three different ways in which it can contribute: image enhancement, mass screening (including detection of pathologies and retinal features), and monitoring (including feature detection and registration of retinal images). Efficient algorithms for the detection of the optic disc and retinal exudates have been presented. Robustness and accuracy in comparison to human graders have been evaluated on a small image database. The results are encouraging and a clinical evaluation will be undertaken in order to be able to integrate the presented algorithm in a tool for diagnosis of diabetic retinopathy. Further steps shall be the distinction between hard exudates and soft exudates (cotton wool spots), and the evaluation of localization and distribution of the detected exudates in order to detect macular edema.

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