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# LOCATION OF FOVEA CENTRALIS IN DIGITAL FUNDUS IMAGES USING ADAPTIVE THRESHOLDING METHOD

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## ABSTRACT

In the field of biomedical, one of the most significant research area is pathology identification in human eyes. In the fundus image analysis, fovea detection plays a vital role in screening Diabetic Retinopathy. Blood vessels that originate from the optic disc may leak fluid which leads to microaneurysms and deposit in the fovea region. Detecting the fovea center helps in identifying the presence of microaneurysms, exudates, and hemorrhages which causes diabetic retinopathy. Exhaustive survey of literature shows that Wellner's adaptive thresholding method has not been applied to retinal images to detect Diabetic Retinopathy. In this paper, Wellner's adaptive thresholding method is used to locate the center of fovea for early detection of Diabetic Retinopathy. This method uses local threshold values that separate the foreground from the background region which helps in identifying the fovea region more clearly than other method. Both the healthy and pathological images were analysed for the detection of fovea center. The experiment was carried out with 1200 fundus images from MESSIDOR database. In which 660 images were pathological and 540 images were healthy retina. It is found that the proposed method has an improvement of 3.1 percent and an accuracy of 99.25 percent in detecting the fovea center compared to the existing methods.

**KEY WORDS: Diabetic Retinopathy, Optic Disc, Exudates, Microaneurysms, Fovea, Macula.**

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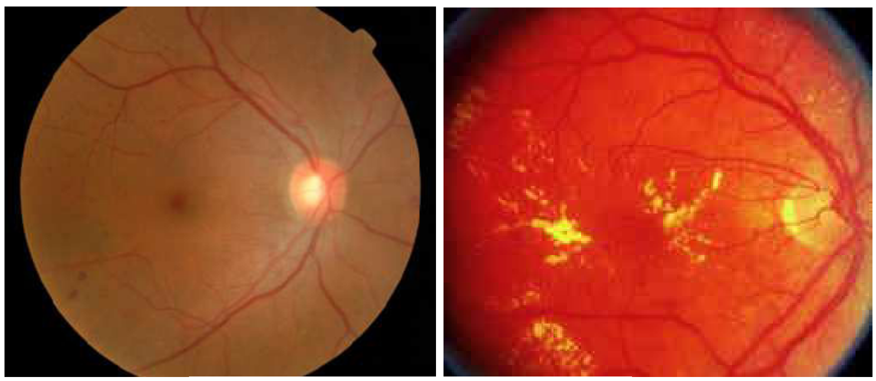
# 1. INTRODUCTION

Diabetic retinopathy (DR) is a visual complication of diabetics that is caused by chronic hyperglycemia and the leading cause of visual impairment to people all over the world. Diabetic retinopathy causes blindness among adults who are of 20-74 years of age. Around 12,000 to 24,000 people per year lose their eye sight due to diabetes. The number of people who are affected by diabetes is suspected to rise from 285 million in 2010 to 439 million in 2030. DR may cause various forms of retinal lesion. The initial stage of retinopathy is the microaneurysm. These can emerge in the screening photography as small red dots. Microaneurysms, exudates, and hemorrhages are some of the retinal changes that occur due to diabetic mellitus, sometimes by neovascularization are referred to as Diabetic Retinopathy.



(a) (b)

**Figure 1**
***(a) Healthy Fundus Image (b) Fundus image with Diabetic Retinopathy***

Figure 1a, b shows the healthy fundus image and the diabetic affected images respectively. A healthy fundus image is necessary for good vision. The fundus that are affected by diabetic retinopathy may lead to vision blur. The optic nerve formation occurs in the optic disc region where ganglion cell axons leave from the eye. The major blood vessels that originate from the optic disc supply blood to the retina. It is known that about 50% of information are carried out by the optic nerve from the fovea, while the other 50% of the rest of the retina. The capillary vessels in the retina will leak fluid, lipid deposits when the disease increases due to chronic hyperglycemia, which forms exudates and they are materialized as yellow or white lesions in the fovea region. The fovea is about 1 mm in diameter and as a round dark area present in the center of the macula region of the retina. The small avascular region represents the fovea that obtains oxygen from the vessels in the choroid. Blood vessels that originate from the optic disc may leak fluid which leads to microaneurysms exudates, hemorrhages and macular edema. These are defined below

***Microaneurysms:*** Small bulges in blood vessels of the retina that often leak fluid.

***Retinal hemorrhages:*** Tiny spots of blood that leak into the retina.

***Hard exudates:*** Deposits of cholesterol or other fats from the blood that have leaked into the retina.

From the above definitions, it can be understood that fovea is the region were these deposits occur. Therefore fovea helps in the diagnosis of diabetic retinopathy. The paper is organised such that section 2 describes on the related work that has been done to detect the optic disc, blood vessels and fovea. Section 3 describes the proposed method and section 4, 5 describes the experimental results and conclusion respectively.

# 2. RELATED WORK

S. Sekhar et al[4] presented a method to detect optic disk with morphological operations using

Hough transform. The spatial relationship of the optic disk and the macula lutea helps in detecting the fovea region. The Hough transform is applied to the gradient image to localize the boundary of the optic disk. The shapes of an image are found using Hough transform technique which result in circular contour. After locating optic disk, the macula region is identified by the anatomical distance from the OD radius and which is the center portion of the fundus image. The centroid of the macula area is marked as the fovea region. The intensity variation shows the major difference between the fovea and the macular region. The macula has less variation in intensity range when compared to fovea. This separates the fovea from the macular area in the fundus images. Jaspreet Kaur et al[5] proposed a method to detect the optic disc and the macula in the fundus image using connected components and iterative thresholding methods. The optic disc is the brightest region in the retinal images. The authors have used an optimal thresholding based on Otsu method which separates brighter regions from dark background. When an image is thresholded, a number of connected components like optic disc and other bright features in an image are obtained with some noise. This process is iteratively used until the disc of an optimal size is obtained. The macula is detected based on the distance and position corresponding to the optic disc. After the detection of optic disc, the macula region can be identified by detecting the darkest region within a particular area in the image. Once the macula is detected, total macular region can be localised for detecting the presence or absence of maculopathy. H YU et al[6] identified the optic disc region using template matching with directional matched filter. In the retinal image, white pixel represents the value 1 and black pixel as 0 to create a binary template. The radius of an optic disc is measured by the average area of the optic nerve. The OD radius determines the template parameters. The length of the template is trice the radius of an optic disc. The main objective of template matching is to locate the exact candidate region of the optic disc. The exact candidate region is differentiated from the real location using the directional matched filtering method. The candidate region is the brightest region where the vessel passes through the retina such as myelinated nerve fibers etc. Within the OD candidates, only the vertical vessels are improved by directional matched filtering. The OD location is determined by the candidate region with the maximum standard deviation after applying a matched filter. In the optic disc region, the point with the lowest matched filter within a search area locates the fovea region. Meindert Niemeijer et al[7] proposed a fast method to detect the optic disc and the fovea in digital fundus image. This work uses a kNN regressor with a template to find the distance of an optic disc location in an image. The kNN regressor is used to find the distance in pixel to the object of interest in the image. The image is preprocessed before the localization of fovea and the optic disc. After preprocessing, the binary vessel map is obtained by thresholding the image. The binary map is thinned until the central line vessel is detected. A template based feature extraction method is used to segment the region of interest in the fundus images. A set of features are considered for the comparison of two circular templates. The main difference between the two templates is that inner section is present in one template and outer section is in another template. The intensity difference between the inner and outer parts of the template is measured using the features of the previous template. These features in the template detect the optic disc and fovea region. Soumitra Samanta et al[8] proposed a fast algorithm for detection of fovea. Mathematical morphology method is used to detect the blood vessels. The blood vessels that originate from the optic disc are segmented by morphological opening and morphological closing operation. The morphological opening operation with structuring element is used to reduce the noise in the blood vessels and the morphological closing operation is used to reduce the vessel structure. Then the vessels like structure and the inner information of an image are extracted using Top-Hat transformation. The connected component analysis reduces the noise of arbitrary shapes. A point from the optic disc center towards centroid is located. The sliding-window technique is used, which form a chain of number denoting black pixel in the window. Maximum number of zeros in the chain represents the fovea region. After the detection of fovea region, the region of interest is extracted in retinal image using feature extraction method to detect the diabetic retinopathy.

## 3. SYSTEM DESIGN

The main objective of the proposed work is to locate the center of fovea in retinal image for detection of diabetic retinopathy. The proposed approach mainly focuses on application of Wellner's adaptive thresholding method, which uses local threshold values that separate the foreground from the background region and helps in identifying the fovea region more clearly comparatively than the other methods. For this the retinal images are pre-processed and segmented to obtain avascular region. The avascular region helps in detection of center of fovea in retinal images. The architecture diagram of the proposed system is shown in Figure 2.

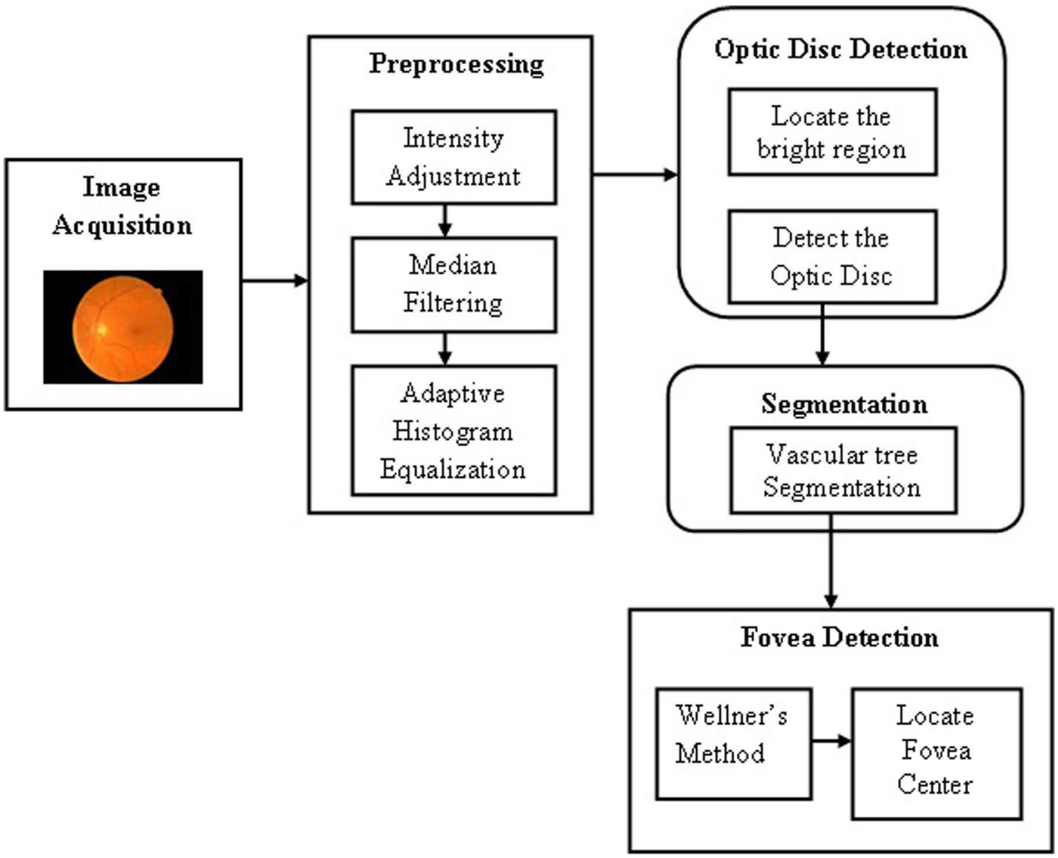



**Figure 2**
***Architecture of Proposed System***

In this section, the proposed method is explained as follows

### *A. IMAGE ACQUISITION*

The retinal images of 1200 images are collected from the MESSIDOR database. The fundus image is captured using a fundus camera with specialized low power microscope with an attached camera. The database consists of both the healthy and pathological images.

### *B. PRE-PROCESSING*

Pre-Processing is done in order to detect the abnormalities, to correct the problems of uneven illumination and to remove the unwanted pixels present in the input fundus image. The given retinal image intensity value is mapped into a new range using an enhancement technique called intensity adjustment. The contrast of the image is adjusted with an intensity range of [0,255] to fill the entire range by remapping the data values.

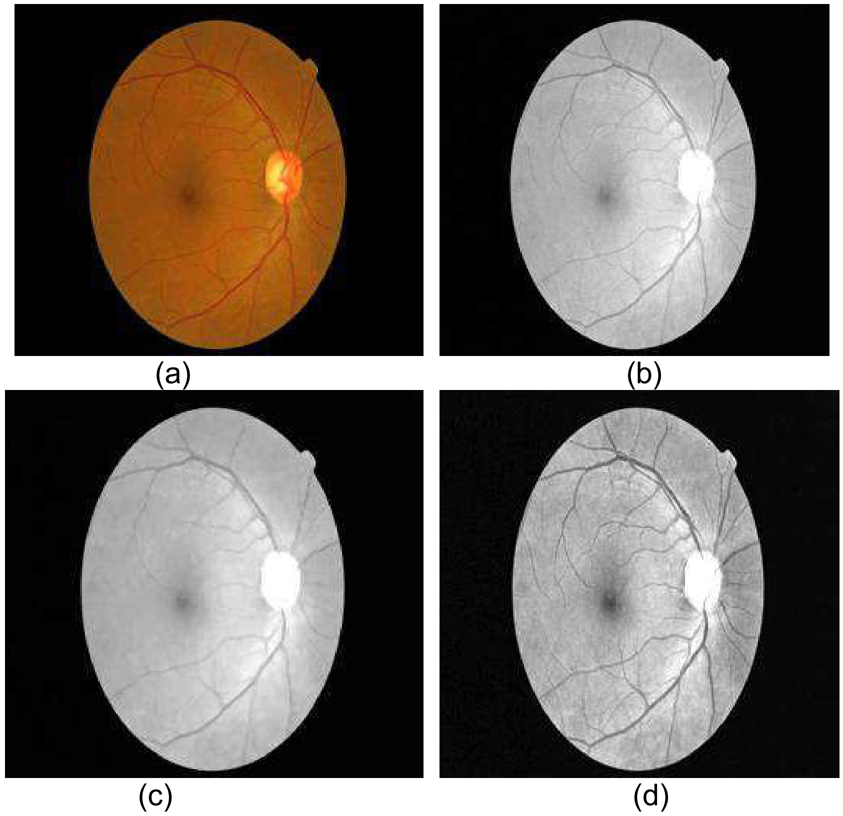
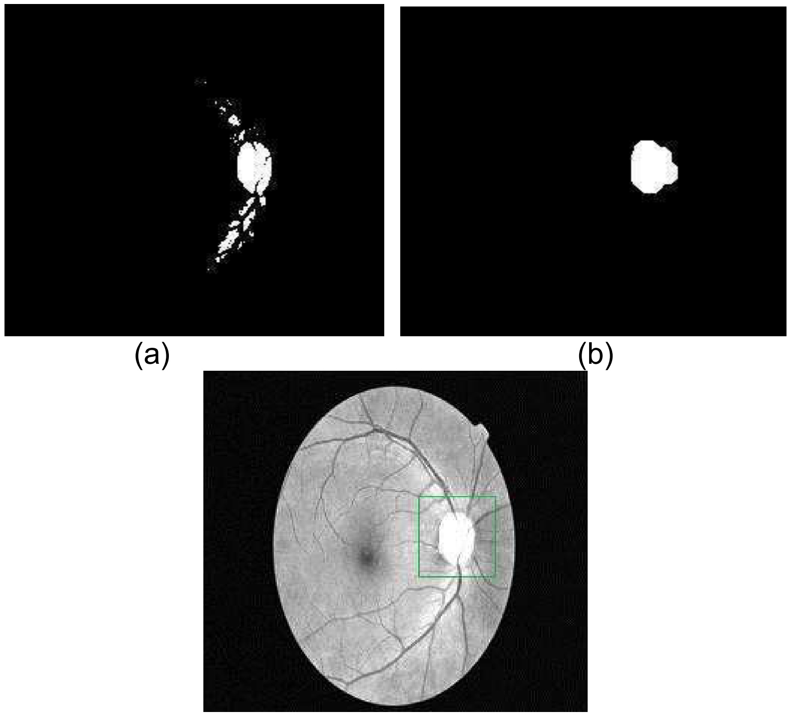



**Figure 3**
***(a) Original Image (b) Intensity Adjusted Image (c) Image after Median filtering (d) Adaptive Histogram Equalized Image***

The noise present in the intensity adjusted image is removed using median filter. The median filter gives better performance over other filters in digital images[1]. The median filter is an effective filter for retinal images, since it reduces the pixel distortions in an image without blurring the edges. The pixel values are sorted in numerical order and the middle pixel value is considered to replace all other pixel in the image. In the denoised image, the adaptive histogram equalization is applied to obtain the background information in the retinal image such as blood vessels, optic nerve head etc. The adaptive histogram equalization transforms a point in a local window to whole image with the intensity value by local distribution. The centres and edges of the retinal images are not affected with gradual variation in the intensity range within the local window. The point transformation distribution is localised and the intensity range of the entire image is covered. Figure 3 (a) shows an original retinal image to which the pre-processing techniques like intensity adjustment, median filtering and adaptive histogram equalisation are applied and shown in Figure 3(b), 3(c), 3(d) respectively.

### *C. OPTIC DISC DETECTION*

In order to extract the features of the optic disc, Morphological operation is applied to the gray scale retinal image and binary retinal image is obtained. Morphological operation uses dilation and erosion method in processing the image based on shapes. To obtain a binary image, the intensity values are added to the boundaries of an object using dilation. The maximum value of neighbourhood pixel in the binary form of retinal image represents the value of the output pixel. In a binary image, if any of the pixels value one, then the dilation process output for the corresponding pixel is also one.



(a) (b) (c)

**Figure 4**
***(a) Binary form of Preprocessed image (b) Optic disc Region detected using morphological operation (c) Optic disc located using bounding box***

The optic disc region is obtained by removing the intensity value on the boundaries of an image using erosion. The minimum value of the neighbourhood pixel in the region represents the output pixel value. If any of the pixel vlaue is zero then the erosion process output for the corresponding pixel is set to zero. The output of an input image is obtained with the same size by applying structuring element. The values 0 and 1 forms a matrix which represents the structuring element may have any shape and size. The disc shaped structuring element of size 5 is applied to eliminate the region that are wrongly located as an optic disc region. The lowest mean intensity value in the image represents the region of interest (i.e) Optic Disc (OD). The region of interest is mapped in the original retinal image and bounding box is drawn to locate the OD region. Fig 4(a)-4(c) shows the various stages of optic disc detection process.

### *D. BLOOD VESSEL SEGMENTATION*

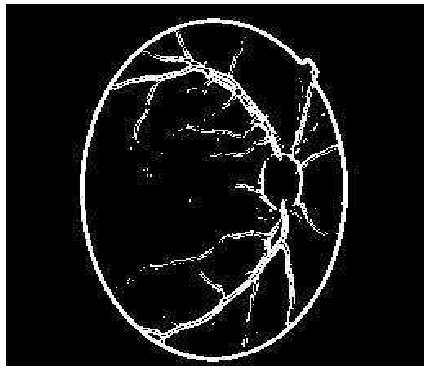


**Figure 5**
***Blood Vessel extraction***

The blood vessels in the retina may leak fluid in the avascular region. The leakage occurs due to damage in the blood vessels caused by high glucose level in blood. The fluid that leaks in avascular region are seems to be yellow or white lesions. Various techniques are used to obtain the vascular tree to find the abnormal vessels in the retina. One of the methods, Kirsch’s template is generated to extract the main blood vessels from the retina to identify the avascular region. This template uses size of 3x3 matrixes to extract the blood vessel and the operator is used to calculate the maximum magnitude of the edge in all directions. The vascular tree in the retina is considered as the foreground image which is separated by resetting the threshold value. Figure 5 shows the extracted blood vessels in the retinal image.

### *E. DETECTION OF FOVEA*

The fovea center are located using the Wellner’s adaptive thresholding method. The extracted vascular tree image shows the avascular region in the fundus image. This helps to locate the fovea region from the optic disc. The fovea is located 2.5 times the diameter of the optic disc. Exhaustive experimental study shows that Wellner’s method helps in detecting fovea region accurately than other methods. Wellner’s method is a local thresholding method which separates the foreground from the background region in an image. Different threshold values are set by varying the window size. The adaptive thresholding method uses local threshold value within a window, and substitute’s pixel under consideration with mean or median value to segment the region of interest. Figure 6 shows the fovea center region and the procedure for adaptive thresholding is given below

```
Procedure
im=adaptivethreshold(img,ws,c,t)
img=mat2gray(img);
if t==0
img1=imfilter(img, fspecial('average', ws), 'replicate');
else
img1=medfilt2(img, [ws ws]);
img2=img1-img-c;
im=im2bw(img2, 0);
im=imcomplement(im);
```

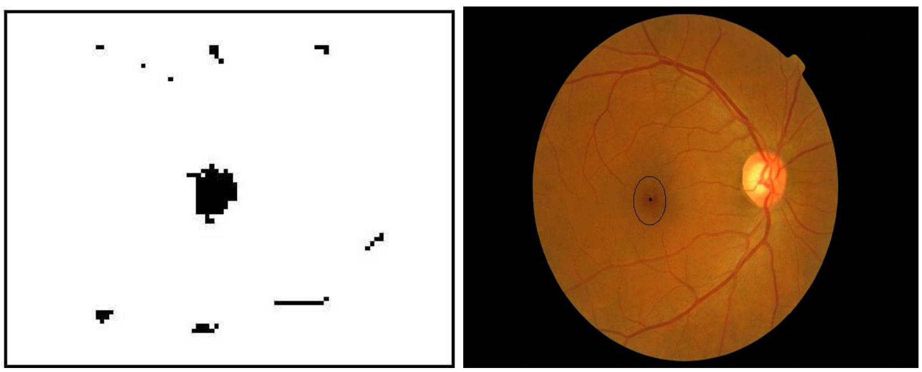


**Figure 6**
*Stages of location of Fovea center*

## 4. EXPERIMENTAL RESULTS

The experiment was carried out with 1200 fundus images from MESSIDOR database. Both the healthy and pathological images were analysed for the detection of optic disc and fovea center. In which, 660 images were pathological and 540 images were healthy retina. Figure 7 shows the optic disc detection on various images. Table 1 gives the results on detection of the optic disc by morphological operation using the bounding box method. The result is based on the DR Grade. For a healthy image the risk level of Macular Edema (ME) is zero and the risk level for pathological image is not equal to zero.

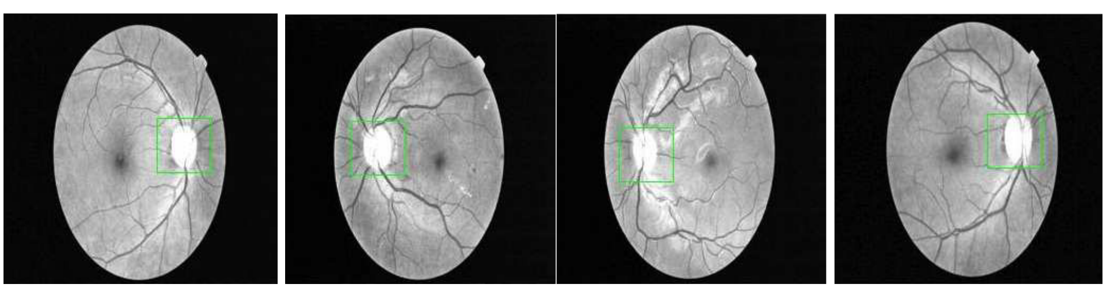


**Figure 7**
*Optic disc detection on various images*

**Table 1**
***Performance of Morphological method on detection of optic disc***

| DR Grade | Number of Images | Detection of Optic Disc |
|---|---|---|
| ME Risk=0 | 540 | 99.44% |
| ME Risk≠0 | 660 | 99.24% |

**Figure 8**
***Fovea center location on various images***

**Table 2**
***Performance of Wellner's method on detection of Fovea***

| DR Grade | Number of Images | Detection of Fovea center |
|---|---|---|
| Healthy Image | 540 | 99.62% |
| Pathological Image | 660 | 98.93% |

Figure 8 shows the fovea and its center position on various images after applying Wellner's method. Table 2 gives the results on detection of fovea center using Wellner's adaptive thresholding method. The result of this method shows better accuracy of finding fovea than other methods.

**Table 3**
***Performance Analysis with other methodologies in the literature.***

| Method | Number of Images | Accuracy in percent |
|---|---|---|
| Fleming et al.[14] | 1056 | 96.50 |
| Niemeijer et al.[7] | 500 | 96.80 |
| Yu et al.[13] | 1200 | 95.00 |
| Manuel et al.[15] | 1200 | 96.92 |
| Proposed Work | 1200 | 99.25 |

Table 3 shows the comparison of the existing methods in the literature with the proposed method. The improvement percent of the proposed work is calculated by

$$improvement\ percent(ip) = \left(\frac{current\ value}{starting\ value} - 1\right) \times 100$$

$$improvement\ percent(ip) = \left(\frac{99.25}{96.31} - 1\right) \times 100$$

= 3.1 percent

Compared to the methods discussed in the literature so far, which has an average accuracy of 96.31 percent, the proposed method has an improvement of 3.1 percent with an accuracy of 99.25 percent in detecting the fovea center.

## 5. CONCLUSION

Various methods are used for detection of fovea in fundus images. In this paper, Wellner's method which uses a local threshold value is used to obtain the fovea region to find the center of fovea. This helps in diagnosis of diabetic retinopathy in early stages. The method used in this work sets different threshold values within a window. Before locating the region of interest, the optic disc and vascular tree in the fundus are extracted by their anatomical position using morphological and kirsch method. The known optic disc region helps in the identification of macular region. Exhaustive experimental study shows that Wellner's method helps in detecting fovea region with an accuracy of 99.25 percent and an improvement of 3.1 percent compared to other methods. As a future work, this can be extended to find the cell density of the fovea to identify the type of diabetic retinopathy.

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