Localization of Optic Disk and Exudates Detection in Retinal Fundus Images

Ahmed Hashim Al-Sharfaa¹, Ali Yakoob Yousif², Enas Hamood Al-Saadi².

¹Computer Science Dept. College of Science for Women University of Babylon, Iraq
²Mathematics Dept. College of Education for pure Sciences University of Babylon, Iraq

ahmed85hashim@gmail.com
wsci.ali.yakoob@uobabylon.edu.iq
enas_lamis@yahoo.com

Abstract. Diabetic Retinopathy (DR), is the most prevalent human retina disease. This disease occurred due to diabetes. This disease requires early treatment to avert any malfunction of organs affected by diabetes that could render them dysfunctional. Exudates are the most familiar of diabetic retinopathy earliest signs. In this context, new methods have been developed for the localization and isolation of the optical disk and the discovery of exudates in the retina image. A new algorithm was introduced to localize and segment optical disk prior to process of secretion because it appears in a similar color, density, and in contrast of other features of the retinal image. The algorithm deployed utilizes three steps to extract exudates from physiological properties. In the fundus image, first step depends on the thresholding of intensity, the second is based on Morphological processing and the third step strategically combines a joint of step1 and step 2 to disclose all exudates thereby evicting any sort of bogus positive. The proposed method was applied on several images from the database and thus far concluding accurate and promising results.

Keywords. Diabetic Retinopathy, Exudate detection, Contrast-Limited Adaptive Histogram Equalization, Fuzzy C. Mean, Intensity Thresholding.

1. Introduction
Fundus image can provide data about pathological variability owing to certain eye illnesses and early signs of certain systemic illnesses such as diabetes and hypertension. Importance of conducting ophthalmology diagnostic procedure by analyzing the fundus image is becoming increasingly an important area for researchers to conduct this procedure automatically [1]. Medical imaging currently offers an excellent assistance in various fields of medical diagnosis as it qualifies promotes possession and produces assessment means of medical images. Furthermore, it offers a wide-range of diagnostic assistance. Medical imaging is still on mounting scale of development, thus, adding novel types of imaging and chances towards unceasing refinement of the hardware trend [2][3].
Diabetes has become the most prevalent cause of blindness in the developed world, especially among working-age groups. Diabetes is known to cause cataracts, glaucoma and most importantly harm to the blood vessels inside the eye which can affect patient's sight. Sight-loss caused by diabetes is commonly known in medical-science jargon as "retinopathy with diabetes." Diabetic retinopathy is a critical eye disease triggered by diabetes manifestation on the retina. Diabetic patient screening for diabetic retinopathy growth can possibly eliminate 50% risk of blindness in these patients [4].

Accordingly, this study focuses primarily on exudates as a mechanism that produces diagnostic data-leads on early retinopathy for diabetes. The primary cause of exudates is leakage produced by damaged blood vessels of proteins and lipids from the bloodstream to the retina [5]. In retinal imaging, exudate is exhibited with distinct dimensions, shapes and positions which normally look as hard white or yellowish localized areas. It generally forms within the retina close to the leaking capillaries [6].

The ‘optic disk’ OD is one of a retinal fundus image’s primary characteristic and has a comparable appearance of exudates. OD disclosure is one of the main parts of preprocessing in algorithms intended to obtain anatomical retinal structures automatically. The OD appears as roughly circular region in the fundus image and size about one-sixth the diameter. OD image in this case, shows an area brighter than the surrounding region and converging region of the blood vessel network. By contrasting OD image with that of a healthy retina, then the features of color, shape, size, and convergence can be used to detect of the OD [7]. Computer detection of exudates can detect a faster and precise diagnosis of specific inspection as it further enables the doctor to make a timely choice on the correct therapy.

2. Related Work (Literature Review)

Studies in the field were pioneered by the 2012 Esmaeili et al. A algorithm which introduced curvelet-based system to detect (OD) and exudate using images with low contrast. This method consisted of (3) major phases without need for user configuration to identify changes in retinal appearance of image. The lesions bright candidate are initially obtained in the image using DCUT and adjusting the curvelet coefficients of the enhanced image of the retinal. After this phase, the writers presented an OD and DCUT-based boundary extraction and level adjustment technique. At last, the image of bright lesions map (BLM) was created to differentiate between exudates and OD, i.e. a spurious identification of final exudates, extracted BLM candidate pixels not in OD areas (identified in the earlier step) were regarded to be real bright lesions [8].

Abbadi and Al-Saadi in 2013 presented an automated detective method to investigate retinal image of bright lesions (exudates). This enhanced approach localizes the optic disk, separate it and detect exudates. Accordingly, a new algorithm was introduced for optical disk localization which was capable of detecting the confusion between exudates and OD. The technique utilizes certain color channels and characteristics to distinguish exudates in digital fundus image from physiological characteristics. [9].

In 2015 Zeljković et al. Cost-efficient exudate and optical disk extraction algorithms were proposed with the aim of classifying retinal images that would further assist diagnostic procedures. They represented collective effort to provide an algorithm for optic disk identification to enable easy extraction method of exudate and developing improved classification means of retinal images so as to better assist ophthalmologists during medical diagnoses. The suggested mathematical modeling algorithms allowed better focus on light intensity concentrations, an easier optical disk and exudes detection, efficient and accurate classification of retinal images [10].

In 2016 Partovi et al. A technique to automatically detection of retinal exudates in fundus images was proposed. The morphological feature was implemented in this technique to intensity parts of room for hue saturation intensity (HSI). To detect the areas of the exudates, all images were thresholded and the region of the exudates was segmented. The binary morphological features were implemented to enhance detection effectiveness. Finally, for further statistical reasons, the areas of the exudates were quantified and assessed [11].

Zhu and Rangayyan in 2017 suggested a technique for automatically locating the optical disc (OD) in the retina background images. The suggested technique, based on OD characteristics, Includes Sobel or Canny edge detection process to find the circles using the Hough transformation [7].
In 2018 Nur and Tjandrasa offered segmentation exudates using the region-based saliency technique acquired by means of severity threshold intensity. In this study, there are three primary stages, namely, optical disk removal, exudate location detection, and segmentation of exudates. Optical disks were removed using an algorithm for the midpoint circle. The image was split into smaller sub-images called patches in the detection stage of the exudate-area and then ranked into an exudate patch and an exudate-free patch based on the threshold of intensity acquired from each image. For a sub-image categorized as an exudate patch, the technique of saliency is then segmented [12].

3. Methodology
The algorithm was developed based on fundus images. Dataset used is from DRIVE database also used images that captured by a ZEISS CLARUS 500 fundus camera. That images for automatic detection of the optic disk and exudate in the retina image. The exudates were of the type DR provided in the images. The intensity of each pixel in the image ranges from 0 to 255. The areas with elevated and low image intensities may have very significant characteristics because they are labeled as image objects.

A pre-processing begins with image retention to represent an image in RGB color space which means that the image is represented in (3) channels RGB (Red, Green and Blue), each with an intensity of 0 to 255. Exudates-detection is considering a major problem which affects the performance of diagnostic method because of the high similarity ratio between optic disk and exudates.

Consequently, this work aims at finding and segmenting the optic disk in exudates detection in order to provide data about early diabetic retinopathy symptoms so that the disease can be adequately managed to reduce visual impairment opportunities.

3.1. Pre-processing
The intent of this project is to deracinate the exudates utilizing color fundus image. The optic disk is light yellow zone that have analogous semblance of exudates (See Fig.1.). The initial step of this work is to eliminate the OD prior to searching of the exudates, which is based on their yellow color criteria. The proposed method is being progressed for spontaneous disclosure of the OD to eliminate this physiologically valid, yet it has a comparable structure.

![Figure 1. Abnormal retinal image.](image)

Fundus image is an RGB color image, broadly, color retinal fundus image composed of three channels (blue, green, and red). Low disparity distinguishes the blue channel and does not contain much data. The red channel ships are noticeable but commonly have lots of noise or simply appeased because most characteristics in the red channel utter signal. In the meantime, the green element of the retina image gives the highest consequent in the comparison between blood vessels (darker blood vessels on a shiny background), on the basis of image green channel is implemented with automatic fundus image evaluation.

La*b* color space is valuable in exemplifying color merit of a image due to its robustness to all devices as it facilitates implementation. The La*b* color model is a three-axis color system with dimension L for Lightness while a* and b* refer to the chromatic information. In this suggested technique, we originally mutate RGB image to La*b*, then calculate CMY:
\[ C = 1 - R \] (1)
\[ M = 1 - G \] (2)
\[ Y = 1 - B \] (3)

Where C, M and Y from eq. (1), (2) and (3) are Cyan, Magenta and Yellow that calculate from R, G and B that extract from RGB (red, green and blue) image before.

3.2. Enhancement:
Retinal images after obsession are mostly loud and of low contrast which makes them of a non-unified lighting. Hence, we set algorithms to enhance image and noise reduction by increasing contrast and filtration. To improve contrast, a Contrast-Limited Adaptive Histogram Equalization “CLAHE” has been used. “CLAHE” run on small regions of the image and the contrast of every small region improved by the “Histogram Equalization”. The mechanism of “CLAHE” are renowned for their local contrast improvement of the images and facilitate the mission of physicians prior to image test. Enhancement shapes the first move to automatic analysis of retinal images. “CLAHE” technique used to make the image well contrasted.

An adjusted image intensity would be applied after the implementation of equalizations to increase the contrast of the output image outcome from the equalization. (i.e. adjust image in intensity value or color plan).

As a result of that, the produced image become noisy and in order to fix it we used the Morphology filtration to improve the image and noise reduction. Morphological filtration utilized by considering composite operations in which it can be opened and closed as filters. These operations can filter from an image any model with a smaller size than the structuring element. However, portions of a image can pass the filter if they fit the structuring element while the smaller structures will be blocked and eliminated from the output image. Size of the structuring element is a paramount and can be used to reduce noisy details that will not damage any objects of interest. Ultimately, more Morphological Techniques will be utilized to clean up the image that called “opening by reconstruction” or “opening closing by reconstruction”.

3.3. Optic Disk subtraction

3.3.1. ROI (Region Of Interest) Automatic detection based on maximum intensity
We want to investigate more closely a specific area within the image. To do this we need steps that modifies spatial intensity values.

First step to localize the OD to determine the optic cup that is the lightest and shiniest region (s) in the retinal image (See Fig.2).

![Retina image with labeling optic cup](image)

**Figure 2.** Retina image with labeling optic cup.

This localization achieved by splitting the retina into (3) channels (Red R, green G and blue B). The red channels are the shiniest one where the optic disk appearance is in a well-defined form. The green channel has the highest contrast, while the blue channel is normally characterized by a low contrast. In this case, we initiated another step to figure out the luminance component (\( \gamma e \)) from eq. (4) that we be
able to distinguish intensities coloration red, green and/or blue to obtain the revised channel that joint all features among the three channels. This proposed method is determined by the below formulas:

$$\text{ye}(i,j) = 0.73925 R(i,j) + 0.14675 G(i,j) + 0.114 B(i,j); \quad (4)$$

for $1 < i < 720, 1 < j < 480$

In order to remove the background lighting variations, the filtration process applied by the mean filter, which is obtained by $(fy_e)$ on $(ye)$ as in eq. (5). Thereafter, and in order to acquire the light and bright regions of an image (optic cup) (Fig 3), we have specified the maximum amount of the optic disk (Very few numbers of pixels come up with this property) by:

$$fy_e = \frac{1}{n} \sum_{i=1}^{n} x_i; \quad (5)$$

for $1 < i < n$, $n=$size of image, $x \in (x, y)$ value of ye image

$$\text{MS}(x,y) = fy_e - 0.299 M(x,y); \quad (6)$$

for $1 < x < 720, 1 < y < 480$

Figure 3. Optic cup detection

Then, we localized the optic disk by selecting the average maximum values of intensity (MS) from eq. (6) and kept their coordinates in the image followed by planting the image bound the area (OD). After that we cropped the image to the bound the area of the optic disk (see Fig 4).

Figure 4. Optic disk boundary Segmentation.

We observed that the resulting image have not only optical disk but have regions from retina image background. The Fuzzy C. Mean (FCM) is envolved to segment the cropped image into clusters to detect the bright intensity that includes the optic disk Fuzzy C-Means (FCM); which is a clustering method that grant each data point to be part of two clusters, first cluster the optic disk and the second one represent background (see Fig.5)
To reduce the white region in optic disk we implement black bottom hat which was minified from white top hat of the preceding FCM resulted a cropped image and convert the white pixels in FCM cropped image to black (see Fig 6).

3.3.2. Retrieval ROI image
To localize the OD in crop image, a black pixel covering the OD in green image with that has the same OD (see index Fig. 7).

*Note: the proposed method is successfully applied on both left and right eyes.

3.4. Exudates Detection
The fully exudates detection in the retinal image is done using three successive procedures, for correction of the exudates detection and removing *false positive*.

**P1- Exudate detection Based on Intensity Thresholding**
The initial step is focused on *Intensity Thresholding*. In this approach, the luminance constituent of the LAB color space (L) was utilized to facilitate the separation of the color apparatuses from intensity. Because of the greater intensity levels of the exudates in comparison to fundal image’s background, this allowed (L channel) to avoid undesirable noises throughout the process of exudates detection.
Subsequently, utilizing morphology-based contrast enhancement on the (L channel subtract from C channel) of input fundal image, we were able to intensify the image contrast which will eventually simplify the process of differentiating the exudates from the fundal image. This contrast enhancing technique is using white and black top hat subsequently and it transform as shown below:

- In order to increase the concentration of image exudate, intensity adjustments are applied before applying intensity thresholds for exudate identification.
- Exudates are disclosed as white pixels and other pixels as black pixels in the original output image after intensity adjustment.
- “Limited adaptive histogram equalization” (CLAHE) is used to remove reflections in certain cases on the image.
- Exudates are detected using an equalized histogram threshold.

P2: Morphological Processing

The morphological processing used to detect all the exudates in the retinal image. This will be achieved by using the green channel (G) of the retina image, and then eliminate the OD from input image as shown in fig. (4). The steps of detection of exudates based on morphological processing is explained as the following:

To extract exudates in fundal image we generated ring filter by dilation (green channel) G two times (I1 and I2) by utilizing structuring constituents with disc shape and of various sizes of 16 and 7.

\[ I_1 = G \oplus S_1 \quad (7) \]
\[ I_2 = G \oplus S_2 \quad (8) \]

Subtract eq. (7) from eq. (8) that produces the exudates’ edges.

The steps of detection of exudates based on morphological processing is explained as the following:

P3: Combination P1 and P2

As both procedures of detecting exudates show a variety sources of error, these varieties will be assumed as false positives. The combination of last output from both procedures shown above was applied in order to enable the detection of any trivial exudates originating in the image during the removal of the false positives. The presenting of false positives in the morphological output technique are because of blood vessels and reflections near to blood vessels. The steps of combination procedure are shown down:

Let me represent the production of the exudate detection technique based on morphology. Morphological S1 and S2 closure operation. S1 and S2 are disk shape structuring constituents of size 6 and 25 respectively. Closing operation with two different sizes of structuring elements is applied so each size of exudates can be detected.

\[ I_1 = I \bullet S_1 \quad (9) \]
\[ I_2 = I \bullet S_2 \quad (10) \]

Where \( \bullet \) denotes morphological closing operation, I1 and I2 are output images that involve smaller size and larger size of items respectively yet noises are due to blood vessels are also existing.

To eliminate these noises Logical “AND” operation is applied amid intensity thresholding output image I3 and output images I1 from eq. (9) and I2 from eq. (10) independently.

\[ I_3 = I_1 \cdot I_2 \quad (11) \]
\[ I_4 = I_1 \cdot I_2 \quad (12) \]

Where “,” Signifies logical “AND” operation. I3 from eq. (11) and I4 from eq. (12) are output images that comprise detected exudates through the use morphology-based technique yet some noises are existing as a result of the reflections.

Logical "AND" and "EX-OR" operations are used between output images I3 and I4 to reduce these reflections and incorporate exudates detection, and results are combined.

\[ I_5 = I_3 (+) I_4 \quad (13) \]
\[ I_6 = I_3 . I_4 \quad (14) \]
Final output $= I_5 + I_6$ \hspace{1cm} (15)
where “(+)” represents logical EX-OR operation, “.” Signifies logical “AND” operation.

Because the error of the two approaches are distinctive, taking into account only the combination of the two independent methods produces only original exudates and would overturn the false positives to promote the accuracy of detection.

The result of exudates identification is shown in Fig. (8) below:

Figure 8. (a) Input retina image (b) Detected exudates by intensity thresholding (c) Exudates detected by morphological processing (d) Outcome of combining morphological processing and intensity thresholding (e) Input retina image labeling Exudates with black pixels
Figure 9. Algorithm for exudates detection

A performance measures comparison between the proposed method with related works mentioned in [Patrovi et. al., 2016] is summarized in table (1), and the graphical representation is shown in Fig (10).

Table 1. Performance measures comparison.

| Method                        | Sensitivity | Specificity | Test set |
|-------------------------------|-------------|-------------|----------|
| Proposed Method               | 97.1%       | 99.4%       | 130      |
| Patrovi et. al., 2016         | 76%         | 98%         | 60       |
| Sopharak et al. 2008          | 80.0%       | 99.5%       | 80       |
| Fleming et al., 2007          | 95.0%       | 84.6%       | 13219    |
| Ranamuka and Meegama, 2013    | 75.4%       | 99.9%       | 40       |

Figure 10. Graphical representation of sensitivity and specificity

4. Conclusion

Thus far, the paper introduced new approach to eliminate the optic disk and automatic detection of exudates in the retina images for preemptive diagnosing of diabetic retinopathy in its early stages in order to reduce the risk of complications that can lead to total sight-loss. Several images from a standard database were applied to examine these approaches.

Automatic techniques aiming at screening the exudates were developed based on the methods of image processing that use strategic mixture of morphological based techniques and intensity thresholding that aim at the removal of false positives to obtain accurate exudates detection. False positives exist in output of intensity thresholding are largely due to the reflection near to optic disc, however, in the morphological processing false positives were present due to blood vessels and reflection near to blood vessels.
The result of this algorithm detects all the exudates in the image precisely and with a promising scale of exactness.

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