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Localization of Macula Center Point within Human Retinal Image

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Abstract: Macula is one of the very important landmarks in the human retinal image. Detection of macula is essential in the classification of some of the ophthalmologic diseases and for the feature extraction process in the retina-based personal identification. There is a number of methods that are used to localize the center point of macula region. In this paper, some of them are being discussed: Colour K-means Segmentation method, center of mass (CoM) based method, and the proposed method; then implemented practically to determine the best one. Proposed method eliminates shortcomings of the other two methods by reducing the computational time and the noise effect. Hence, the experimental results demonstrate that this method is more efficient for localizing macula center point than the other two methods.

Keywords: macula, fovea, K-means Segmentation, center of mass.

INTRODUCTION

Human retina is a multi-layered sensory tissue that is located at the back of the eyeball. It contains millions of photoreceptors which capture light beams and transform them into electrical signals. These signals travel along the optic nerve to the human brain where they are transformed to images [1][2][3][4].

Human retina has three main components: optic disc (OD), macula and blood vessels as shown in fig. 1. OD is brighter than other portions and is mainly circular in shape with a diameter of about 3 mms. It is also the entree and the exit point where nerves enter and quit the retina to and from the brain. Macula or the "yellow spot" is the part of the retina that is most sensitive to light where it is responsible for our sharp central sight. It is located near the center of the retina about 2 OD diameter (2DD) temporal to the OD. The darkest part of the macula called fovea, which is a very small region, forms the center of it. Blood vessels are patterns that have tree shape, branch from OD and continue on the surface of the retina. [1][3][4][5][6].

Nowadays colour retinal images are widely used for the computer aided diagnosis of some ophthalmologic diseases such as Diabetic Retinopathy, Glaucoma, and Neovascularization. Diabetic Retinopathy and Glaucoma are two of the most important leading causes of blindness. Diabetic Retinopathy causes vision lost by important mechanism called macular edema. Macular edema is arised when the lesions get accumulated in the macula.

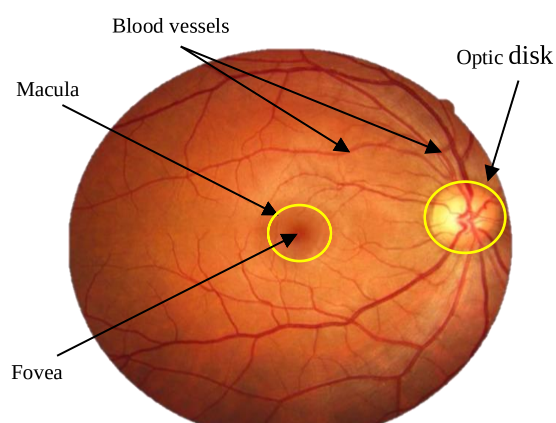

Figure 1. Retinal main components

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Thus it is very important to estimate the acuteness of Diabetic Retinopathy by examining the macula. Computer aided examining requires detection of macula region. Also, sometimes in retina-based personal identification there is a need for determining the center of macula (fovea) during the feature extraction phase [4][7][8][9].

There is a number of methods which are used to detect the center point of macula region. In this paper, three methods are being discussed: Colour K-means Segmentation method, center of mass (CoM) based method, and the proposed method. Then, the best method is determined using practical implementation. Colour K-means Segmentation method comprises many steps, and consumes a long computational time. Also, error percent from these steps, in an accumulated manner, significantly affect the accuracy of localizing the center point of macula. CoM based method localizes macula center point depending on intensities of image pixels. So, this method is very sensitive to noise and gives inaccurate result. Proposed method is a straightforward method that extremely reduces the effect of the image noise. So, it eliminates the shortcomings of the other two methods and gives a more accurate result.

The rest of this paper is organized as follows: section 2 illustrates three methods for detecting the macula center point. Section 3 shows practical implementation of these methods and discusses the results. Section 4 includes conclusion of the paper.

MACULA LOCALIZATION

In this section, three methods are being discussed: Colour K-means Segmentation method, CoM based method, and the proposed method.

A. Colour K-means Segmentation

This method is implemented by using a K-means clustering algorithm. It is an iterative process that segments the dataset or image into K pre-determined, and non-overlapping clusters. Each pixel in the image belongs to only one cluster, the intra-cluster pixels are as similar as possible and the inter-cluster pixels are as different as possible [8][10]. To implement this algorithm, four steps are needed:

1) *Pre-processing.*
2) *Segmentation.*
3) *Discrimination of macula cluster.*
4) *Locate the center of macula cluster.*

Pre-processing: Colour retinal images are usually of poor contrast and contain numerous noise. So, the pre-processing phase is needful to obtain accurate results [8]. It comprises the following steps:

- Each retinal image is resized (to reduce the computation time) and saved in JPEG format.
- Since the noise is only arised in the intensity component of the RGB colour images, this component should be separated from the image [8]. Separation is accomplished by converting the retinal image from RGB colour space to the HSV colour space. Then, the only V channel is used in the following step.
- Morphological structuring element processing is used to remove background noise from the V channel. Where, a flat structuring element is generated with disk shape and radius of 3 pixels. Open morphological operation eliminates, using this structuring element, snowflakes that have radius less than 3 pixels.
- V channel is then filtered using the adaptive median filter to remove the noise from over this entire channel.
- The contrast of the V component is enhanced using Contrast-Limited Adaptive Histogram Equalization (CLAHE) function.
- The enhanced V channel is recombined with H and S channels and turned back to the RGB colour space.

After implementing the pre-processing on the retinal image, the macula region in that image becomes more clear and distinctive from other parts in the retinal image. This result is shown in fig. 2, where (c and d) represent retinal images after implementing the pre-processing steps on images (a and b) respectively.

Segmentation: In this step K-means clustering algorithm segments the enhanced image into K clusters; one of them holds the macula region. In the segmentation process, coloured images are more usable than gray scale images. This is due to their strength in improving the image analysis process and subsequently getting better results. When coloured images are used in a certain field, it is very important to choose which colour space is the best to deal with. HSV and Lab colour spaces are frequently chosen to implement coloured image segmentation. These two colour spaces provide a more wide and convenient representation of colours compared to RGB colour space which is designed specifically for display purposes [10][11].

To select between HSV and Lab colour spaces, it is necessary to try several hypotheses and inspect their channels. After doing several experiments, Lab colour space has appeared to be the best for retinal image segmentation. It is a precise colour space and more similar to the human eye system. It uses three axes to determine colours, L represents the lightness axis, a represents (red

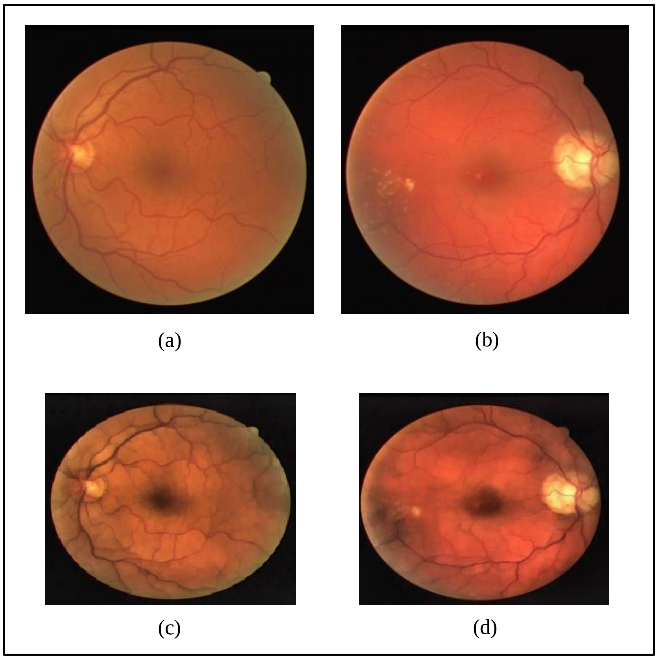

Figure 2. The effect of pre-processing on the retinal images (a, b) Original retinal images (c, d) Retinal images after pre-processing implementation.

to green) axis, and b represents (blue to yellow) axis [10][11].

From the experimental results, concatenation of (L and b) channels gave better segmentation than using (L with a) channels and even than using the entire colour space. So, the enhanced RGB retinal image is converted to Lab image and L with b channels are concatenated. Then, K-means clustering algorithm segments the result image into K clusters as illustrated in fig. 3. In this figure, the retinal image has been segmented into 4 clusters each one labeled with a different colour. Fig. 4 illustrates each cluster in a separate image; each image shows pixels of only one cluster and other parts appear in black colour. In the K-means clustering algorithm, the number of clusters is selected experimentally where it is very difficult to determine the exact number of clusters in advance [11]. A number of clusters (like: 3, 4, 5, 6, and 7) had been

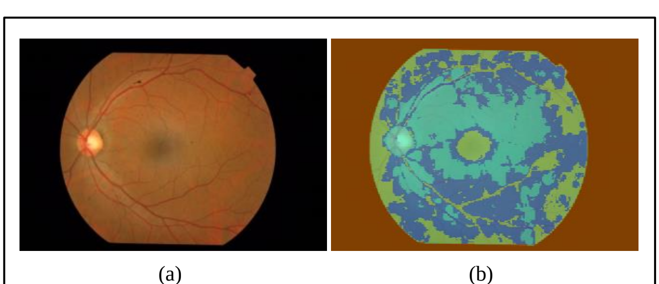

Figure 3. K-means clustering algorithm (a) Input Retinal image (b) The resulted clusters

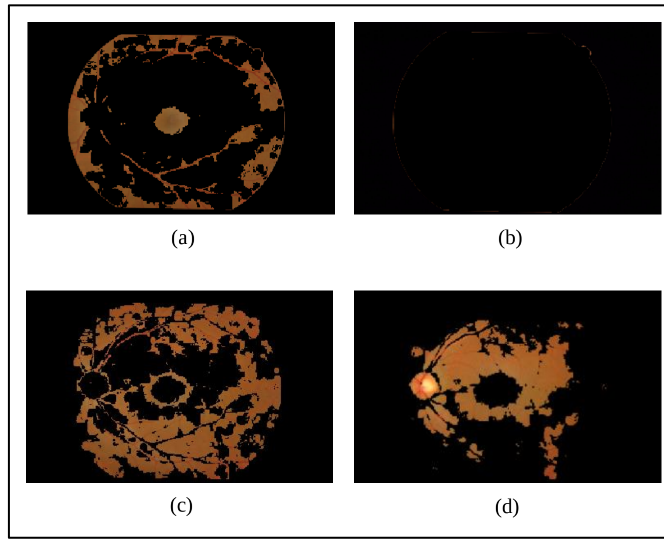

Figure 4. The region of each cluster in the retinal image (a) Cluster one (b) Cluster two (c) Cluster three (d) Cluster four

experienced on retinal image and macula cluster appeared as shown in fig. 5. It is obvious that, when the number of clusters is increased, macula cluster becomes more specific and almost contains only macula region. So, increasing the number of clusters gives better results but consumes a lot of computation time. Also, using 5, 6, and 7 clusters leads to a slight enhancement compared to the resultant increase in the time. Hence, by trade-off between accuracy and time consuming the number of clusters is selected to be 4. At this point, there is a need to separate the cluster of the macula and neglect other clusters automatically.

Discrimination of macula cluster: It is difficult to find a method to distinguish macula cluster from the other clusters in an automated manner. However, the proposed way determines the macula cluster by localizing a center point of all clusters and computing the intensity value of these points. Macula region has its distinct colour (blackish) which is different from other clusters, so it is observed that the center of macula cluster gives the minimum value among others.

Locate the center of macula cluster: The center point that has the minimum value is the center of macula. This point is determined by using CoM equations [4] since each cluster is considered as a uniform intensity region and its center is located at the CoM point [12]:

$$\bar{x} = \frac{\sum_{y=1}^{m}\sum_{x=1}^{n} x.f(x,y)}{\sum_{y=1}^{m}\sum_{x=1}^{n} f(x,y)} \quad (1)$$

$$\bar{y} = \frac{\sum_{x=1}^{n}\sum_{y=1}^{m} y.f(x,y)}{\sum_{y=1}^{m}\sum_{x=1}^{n} f(x,y)} \quad (2)$$

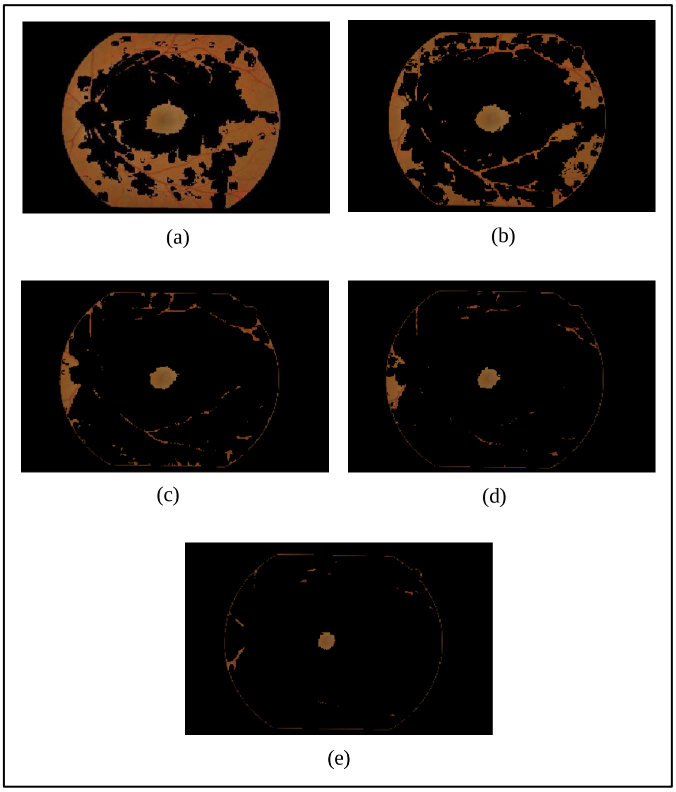

Figure 5. Macula cluster appearance using different numbers of clusters for K-means clustering algorithm (a) Three clusters (b) Four clusters (c) Five clusters (d) Six clusters (e) Seven clusters

n, m Represent the size of the retinal image (in form n × m).

B. Center of Mass Based Method

Although, a number of researchers have used K-means segmentation method to localize macula in retinal image as in references [8][13], this method did not give accurate results when it was implemented in this research work. This will be illustrated practically later in section III. So, CoM based method has also been used to get more accurate results.

In the typical retinal image, Macula is located at the CoM point of the retinal image [7]. So, the second method used to locate the Macula is implemented by locating the CoM point of the entire retinal image. Before locating CoM point, the same pre-processing steps of the previous method are used to remove the noise and enhance the retinal image. Then, equations (1 and 2) are used to get (x,y) coordinates of the macula center point.

C. Proposed Method

There are some researchers who have used CoM based method (which is mentioned in section II part B) to localize macula as in references [4][9]. This method has its advantages of simple calculation and fast speed. However when it is implemented it does not give accurate results. This is due to its sensitivity to noise and intensity inhomogeneity of the retinal image, since it depends on the intensities of image pixels.

Proposed method is used to solve this problem by reducing the effectiveness of the noise and the illumination conditions. This has been accomplished by adding spatial information of retinal image along with the intensity information of image pixels before using equations (1 and 2) to calculate the CoM point. This method is clearly illustrated in fig. 6.c.

As a result, this method is a straightforward method which means it consumes a less computational time than the Colour K-means Segmentation method. Also, it extremely reduces the effect of the image noise by considering spatial information of retinal image. So, it eliminates the shortcomings of the other two methods and gives a more accurate localization as will be illustrated practically later in section 3.

Difference between these three methods is illustrated in fig. 6.

EXPERIMENTAL RESULTS AND DISCUSSION

All experiments in this research work were conducted in the same environment which is composed of: Windows 10 Pro operating system, Intel (R) Core (TM) CPU @ 1.8 GHz, 8 GB RAM, and Matlab (R2019b).

The center point of macula was located first, using K-means segmentation method. Results of implementing this method were unsatisfactory since it did not show accurate localization of center point. Reasons of incorrect results are due to comprising many steps in this method. Each step has its own metrics and all of them need suitable values which must be selected in an experimental manner. These metrics include: selecting parameters of certain filters in the pre-processing step, selecting the number of clusters in the segmentation step, and finally selecting an appropriate manner to determine which cluster includes the macula. Hence, each of these steps has its own, albeit slightly, error percent. Errors in these steps, in an accumulated manner, become a significant error and gives inaccurate results. Moreover, implementation of these steps consumes long computational time. So, there is a need for more straightway method.

The second method used to locate the center of macula is CoM based method. This method is sensitive to noise and also gives inaccurate center point. So, the proposed method has been adopted to localize the center point of macula. This method shows significant enhancement in results as illustrated in fig. 7.

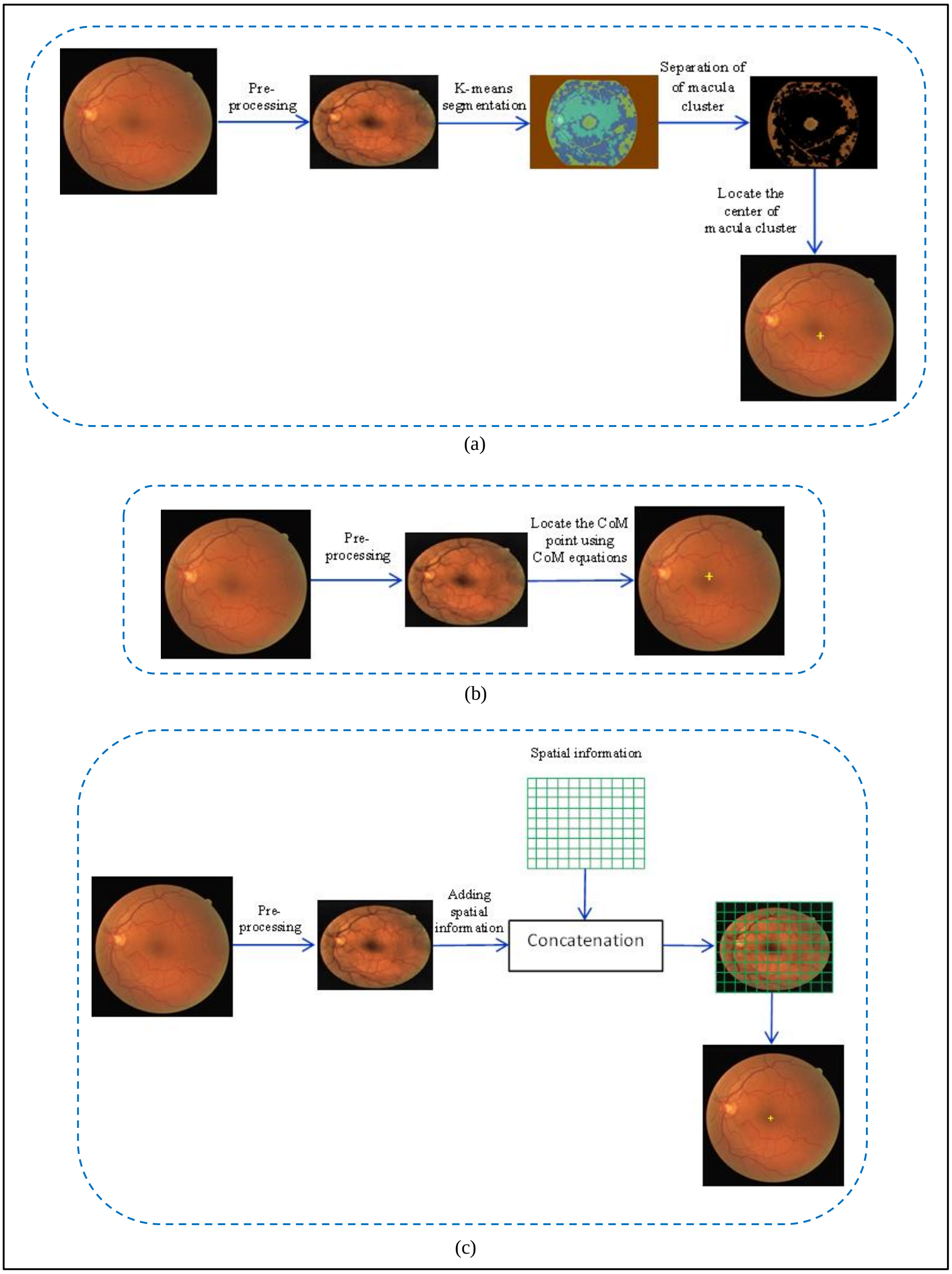

Figure 6. Localization of macula center point (a) K-means segmentation method (b) CoM based method (c) the proposed method

It is very important to develop an efficient manner to localize macula region within the retinal image. Detection of macula region is essential for both computer aided diagnosis of some ophthalmologic diseases and some of retina-based personal identification systems during feature extraction phase. In this paper, three methods has been discussed and implemented practically: Colour K-means Segmentation method, Center of Mass (CoM) based method, and the proposed method. Experimental results demonstrate that the proposed method is the best one where, it gave more accurate

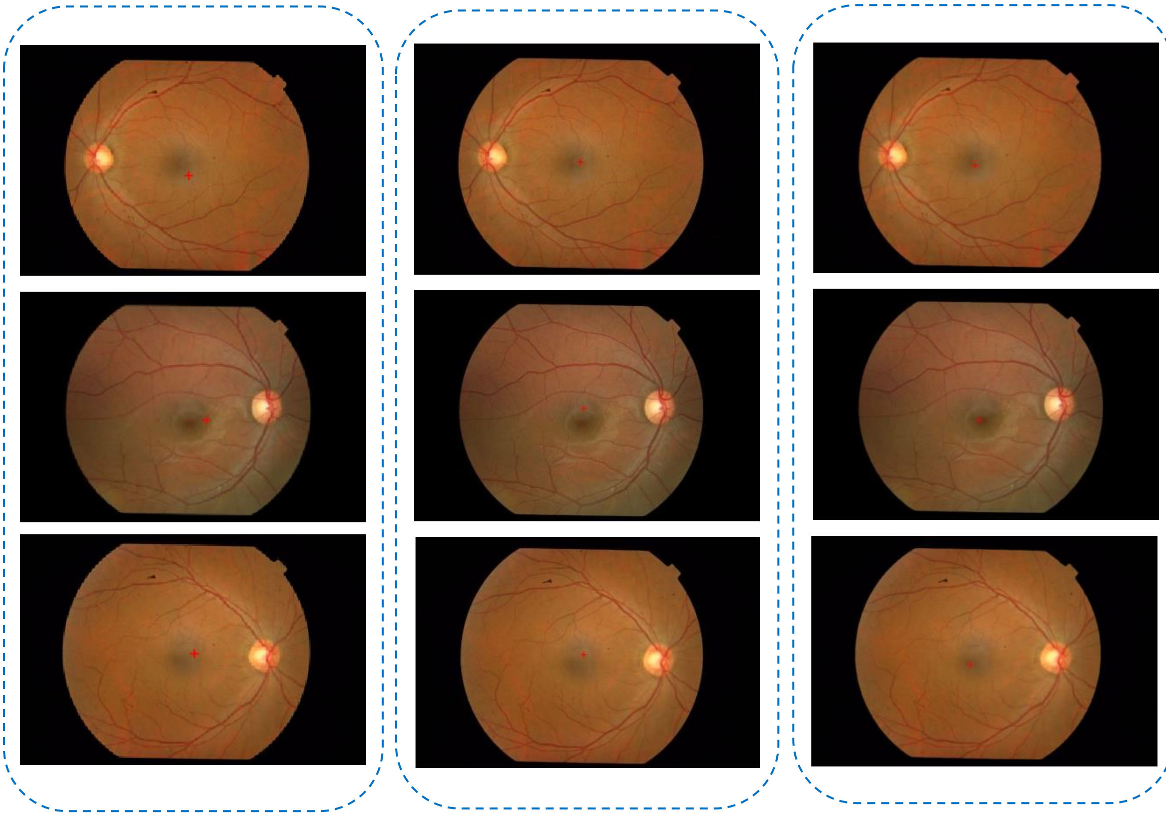

Figure 7. Localization of macula center point on some retinal images (a) Using K-means segmentation method (b) Using CoM based method (c) Using the proposed method.

results, in localizing the center point of the macula, than the other two methods.

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