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HARD EXUDATES DETECTION IN PROLIFERATIVE DIABETIC RETINOPATHY USING GRADIENT CONTROLLED FUZZY C MEANS CLUSTERING ALGORITHM

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Abstract:
Diabetic Retinopathy, a Progressive Chronic disease that leads to vision loss. The pathology is characterized by tiny blood vessels get blocked, new blood vessels originated which are fragile, get ruptured and leaks blood and protein based particles (Exudates) in the fundus of eye. Exudates can be washed out by employing laser treatment. Upgrading the Fundoscope device with methods that extracts the exudates from background makes the physicians job simple for diagnosing and treating. Fuzzy C Means Clustering (FCM) uses a weighted distance metric that utilizes pixel co-ordinates, intensity or color, texture parameters for segmentation. FCM employs Fuzzy logic rather than Crisp logic (which is insufficient to form clusters). Image gradients help at the front end of many segmentation algorithms to improve the efficiency and accuracy.

***Keywords**: Diabetic Retinopathy, Image Segmentation, Fuzzy Clustering, Image Gradients.*

1. INTRODUCTION

Diabetes mellitus is defined as a metabolic disorder of multiple aetiologies characterised by chronic hyperglycaemia with disturbances of carbohydrate, protein and fat metabolism resulting from defects in insulin secretion, insulin action, or both[1].Diabetic retinopathy is the most well-known ocular complication of diabetes and the leading cause of blindness among people 20–64 years of age in the U.S. [2]. The pathology is characterized by: growth of new vessels leading to intraocular haemorrhage and possible retinal detachment with profound global sight loss, and localised damage to the macula / fovea of the eye with loss of central visual acuity.

At the early stages it doesn't show any warning symptoms. With time the retina macula portion will get damaged and blurs the vision. The stage 1 , non-proliferative diabetic retinopathy(NPDR) no signs of the pathology is observed. Funduscope is useful to acquire the photographs of the interior portion of eye, and is useful to detect it. In the fundus photograph, the existence of microaneurysms will be observed. Microaneurysms are the small balloons which originates due to swell in the retinal blood vessels. Further these swollen blood get ruptured and leaks blood and protein based particles into fundus of the eye. This leads to blurred and distorted vision. Fundus fluorescein angiography is implemented to visualize the narrowed, blocked and ruptured blood vessels. In the stage 2, abnormal new blood vessels are grown inside the fundus. This stage is named as Proliferative Diabetic Retinopathy (PDR). The newly born blood vessels are thin and may easily get ruptured leaking blood and protein based particles. Blood speckles, or spots, floats in the vitreous region (Vitreous hemorrhage) which leads to distorted vision for some hours. With time the fundus will be completely filled with these particles, obstructs the light to propagate towards retina and leads to complete blindness.

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2. ALGORITHMS

2.1 Fuzzy C-Means Clustering algorithm:

Image segmentation is a substantial approach which is useful in extracting the details in an image based on either intensity discontinuity or similarity. Applications like medical image pathology analysis, recognition of objects and robo vision requires high level elucidation and adaption, employs Image Segmentation. Clustering is a process of grouping pixels that carry some common characteristics eg., same or approximately equal intensities. It is classified into Hard Clustering and Fuzzy Clustering. Hard clustering is a traditional approach that limits mapping of a pixel wholly to one bunch. This is a Crisp logic and results in drastic erroneous results. As a single pixel may belongs to N number of clusters, fuzzy set theory is employed. This is a probabilistic approach that maps a pixel to a cluster based on degree of membership of the pixel to that cluster.

Fuzzy c-means (FCM) Algorithm is most popular and effective approach as it has vigorous characteristics for vagueness that preserve abundant info than hard (Crisp) segmentation procedures. Traditional FCM is sensitive to noise imaging artefacts as it do not integrate any info about spatial perspective. Images are first allowed to smoothen before segmentation.

The FCM system was first presented by Dunn and advanced by Bezdek. It is an iterative method often stated as soft clustering, which aims to build an optimal c barrier by minimizing the objective function, which is a weighted sum of squared error.

Every pel in an image is associated with different clusters makes certain amount of belongingness instead of related completely to just unique bunch. Pels at the region contours may have less membership compared to the pels at the interior of the regions. Each pixel x is governed with a quantity which gives the grade of existence in the kth group $M_k(p)$. It aims at reducing the objective function:

$$Jm = \sum_{i=1}^{N}\sum_{j=1}^{C} M_{ij} \left\| p_i - c_j \right\|^2, 1 \le n \lhd \propto \quad , \qquad [1]$$

Where n is a real integer greater than 1, M_{ij} is the degree of membership of p_i in the cluster j, p_i is the i^{th} pel in an image, c_j is the centre of the cluster, and ||*|| is any norm which expresses the likeness between the measured data and the centre. The approach tries to minimize the objective function and keep on updates membership M_{ij} and the cluster centres c_j by:

$$M_{ij} = \frac{1}{\sum_{k=1}^{C} \left[\frac{\left\| p_i - c_j \right\|}{\left\| p_i - c_k \right\|} \right]^{\frac{2}{m-1}}}, \qquad [2]$$

$$c_j = \frac{\sum_{i=1}^{N} M_{ij}{}^{m} \cdot p_j}{\sum_{i=1}^{N} M_{ij}{}^{m}} \ . \qquad [3]$$

This iteration will stop when $\max_{ij} \left\{ M_{ij}{}^{(k+1)} - M_{ij}{}^{(k)} \lhd \delta \right\}$, where δ is a termination criterion between 0 and 1, whereas k are the iteration steps.

1. Initialize M=[M_{ij}] matrix, $M^{(0)}$
2. At k-step: calculate the centers vectors $C^{(k)}$=[c_j] with $M^{(k)}$

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$$c_j = \frac{\sum_{i=1}^{N} M_{ij}^{\ m} . p_j}{\sum_{i=1}^{N} M_{ij}^{\ m}}$$

3. Update $M^{(k+1)}$

$$M_{ij} = \frac{1}{\sum_{k=1}^{C}\left[\frac{\|p_i - c_j\|}{\|p_i - c_k\|}\right]^{\frac{2}{m-1}}} \qquad [ii]$$

4. If $\| M^{(k+1)} - M^{(k)} \| < \delta$ then STOP; otherwise return to step 2.

2.2 Image gradient:

Edge detection

It is a fundamental tool in image processing, machine vision and computer vision, particularly in the areas of feature detection and feature extraction.[4].

Aims at magnifying the pixels at the fine details where sharp intensity variations are seen or enhances the blurred images. These sharp intensity variations are associated with high frequency content of the image. They can be detected either with the use of spatial kernel based filters or by the implementation of high pass filters. The sharpening or edge detection filter utilizes the differential approach to enhance edge information. 1st and 2nd order derivatives are employed to identify the intensity discontinuities.

In our work we added sobel edge detector at the pre processing stage. This method involves 3 steps. Intensity variations in X and Y direction are detected using two different kernels. 3*3 weighted kernel of sobel filter are given below.

-1	0	+1
-2	0	+2
-1	0	+1

+1	+2	+1
0	0	0
-1	-2	-1

Figure 1: X-Gradient & Y-Gradient Masks

It can be observed that the sums of all the weights are 0. This will be helpful in nullifying the regions with constant intensity and enhances the pixels at the contour of each region. Let us designate these two filters as Gx(x, y) and Gy(x, y). The Magnitude of the resultant gradient image attained gives quite optimum results [5]. Lastly the magnitude can be calculated from these gradients as

$$G(x,y) = \sqrt{G_x(x,y)^2 + G_y(x,y)^2} \qquad (3)$$

And the direction of the gradient vector is given by

$$\alpha(x,y) = \tan^{-1}(G_y(x,y)/G_x(x,y)) \quad . \qquad (4)$$

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3. RESULTS

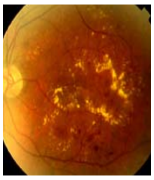

Figure 2: Exudative Maculopathy

Figure 2 shown a typical PDR suffering named Exudative Maculopathy. Hard Exudates seems to be brighter compared to the other portions of the fundus. But one can observe that the portion of the optic disc seems visibly same colors as that of the lesions. Unequal illumination is observed here, as portion near to optic disc [top and bottom left] when compared to the other portions.

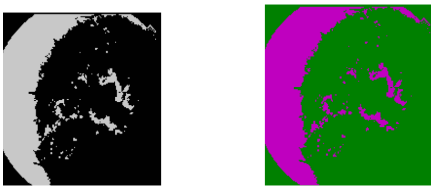

Figure 3: FCM Segmented image

Figure 3 shows the result of FCM algorithm. In this even though the exudates seems to be clustered well the same group accompanies the portion near to optic disc which is not an optimum result.

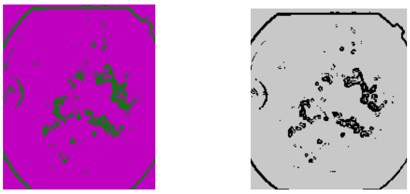

Figure 4: Gradient Controlled FCM Segmented image

To avoid such problem by direct implementation of FCM, the original image is applied to gradient filters eg., sobel filter which is useful to extract the sharp edges between regions and helps in initial grouping of different regions.From figure 4 one can observe that the exudates are nicely segmented and hence this quite useful for treating with laser operations like Photo coagulation.

4. CONCLUSION

From the above results it is quite evident that the proposed approach is better enough in extracting the lesions. Further with the addition of smoothening filters at the front end of this method can reduce the noise content in the original images as FCM is sensitive to noise. But it smoothens the edges. Edge preserving Smoothening filters can be employed in future.

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