AN APPLICATION OF IMAGE SEGMENTATION AND GRADIENT FILTER METHODS IN DETECTION OF ATHEROSCLEROSIS & EXUDATIVE MACULOPATHY IN DIABETIC PATIENTS

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Abstract

The major issue in people nowadays is the lack of awareness about eating habits. Prevalence of diabetes (mellitus) in our country has steadily increased for that reason. Today there is an increase in interest for setting up medical system that can screen a large number of people for life threatening diseases, such as Cardio Vascular Diseases (CVD),Retinal disorders in Diabetic Patients. In this paper three different methods of segmentation are discussed. K-means and Fuzzy C-means (FCM) are two methods that use distance metric for segmentation. K-means is implemented using standard Euclidean distance metric, which is usually insufficient in forming the clusters. Instead in FCM, weighted distance metric utilizing pixel co-ordinates, RGB pixel color and/or intensity and image texture is commonly used. As the datasets scale increases rapidly it is difficult to use K-means and FCM to deal with massive data. So, the focus of this work is on the Morphological Watershed segmentation algorithm which gives good results on Blood vessel images of Atherosclerosis and Gradient Filter Techniques on retinal images. The tool used in this work is MATLAB.

Keywords: Image processing, Segmentation, Watershed transformation, Fuzzy C-means clustering algorithm, K-means Clustering Algorithm.

I. INTRODUCTION

Diabetic mellitus is a metabolic disorder that characterized by inability of the pancreas to control blood glucose concentration. This problem results in blood glucose levels out of normal range [2]. Cardiovascular disease is responsible for 80%of deaths among diabetic patients much of which has been attributed to CAD (coronary artery disease). However, there is an increasing recognition that diabetic patients suffer from an additional cardiac insult termed 'diabetic Cardiomyopathy' [3]. The underlying problem in most of the diabetic patients with CVD is Atherosclerosis leading to narrowing of blood vessels supplying the heart; there by causing heart failure [7][9]. Atherosclerosis (also known as arteriosclerotic vascular disease or ASVD) is a condition in which an artery wall thickens as the result of a build-up of fatty materials such as cholesterol. Epidemiological and Clinical trial data have confirmed the greater incidence and prevalence of heart failure in diabetes [4].

Diabetic retinopathy (DR) is one of the most serious complications of diabetes and a major cause of visual morbidity. It is a progressive disease classified according to the presence of various clinical abnormalities. DR is usually asymptomatic until the disease is at a late stage, making early detection and treatment essential. Thus, there is an increasing attention for setting up medical systems that can screen a large number of people to diagnose the DR early enough for an optimal treatment [3]. DR is classified into two: (i) Background (pre or non-proliferative) Diabetic Retinopathy and (ii) Proliferative Diabetic Retinopathy. In a particular case of non-proliferative retinopathy, damaged retinal vessels leaks fatty and protein-based particles termed to as exudates. Intraretinal fatty (hard) exudates are a visible sign of DR and also a prime marker for the existence of retinal edema. If accumulate in the central part of the retina (macular area), edema and exudates are a major cause of visual loss in the non proliferative forms of DR [3][4]. When background changes occur in the central retina, the condition is termed diabetic maculopathy, and visual acuity is at risk. Much of the blindness can be prevented if the condition is detected early enough for laser treatment. Unfortunately, because visual loss is often a late symptom of advanced diabetic maculopathy, many patients remain undiagnosed even as their disease is causing severe retinal damage. Hence, there is an urgent need for mass-screening retinal examination for the early detection and treatment of such diseases [5].

Exudates are associated with patches of vascular damage with leakage and typically characterized as randomly spaced yellow-white patches of varying sizes and shapes. Here, we have concentrated on detecting exudates as the significant factor of DR disease. Because exudates are directly related to retinal edema and visual loss, and they are the single most important retinal lesion detectable in retinal images[10].

The biological vision system is one of the most important means of exploration of the world to humans, performing complex tasks with great ease such as analysis, interpretation, recognition and pattern classification[8].The ultimate aim in a large number of image processing applications is to extract important features from the image data, from which a description, interpretation, or understanding of the scene can be obtained for human viewers, or to provide 'better' input for other automated image processing techniques[1]. Segmentation of atherosclerosis images (Electron micrograph Images) and retinal images subdivides into its constituent regions or objects. The level of detail to which the sub division is carried depends on the problem being solved. Considerable care should be taken to improve the probability of accurate segmentation. Segmentation algorithms for monochrome images generally are based on one of two basic categories dealing with properties of intensity values: discontinuity and similarity. In the first category, the assumption is that boundaries of regions are sufficiently different from each other and from the background to allow boundary detection based on local discontinuities in intensity. Edge-based segmentation is the principal approach used in this category. Region-based segmentation approaches in the second category are based on partitioning an image into regions that are similar according to predefined criteria [10].

In this paper we use *k*-means and Fuzzy C-means (FCM) approach as followed in section – II for comparison with watershed algorithm presented in the section - III.

II. K-MEANS & FUZZY CLUSTERING

In non-fuzzy or hard clustering, data is divided into crisp clusters, where each data point belongs to exactly one cluster. In fuzzy clustering, the data points can belong to more than one cluster, and associated with each of the points are membership grades that indicate the degree to which the data points belong to the different clusters. Fuzzy clustering belongs to the group of soft computing techniques (which include neural nets, fuzzy systems, and genetic algorithms).

In real applications there is very often no sharp boundary between clusters so that fuzzy clustering is often better suited for the data. Membership degrees between zero and one are used in fuzzy clustering instead of crisp assignments of the data to clusters. The resulting data partition improves data understanding and reveals its internal structure. Partition clustering algorithms divide up a data set into clusters or classes, where similar data objects are assigned to the same cluster whereas dissimilar data objects should belong to different clusters. Areas of application of fuzzy cluster analysis include data analysis, pattern recognition, and image segmentation

The *k*-means clustering algorithm is commonly used in computer vision as a form of image segmentation. The results of the segmentation are used to aid border detection and object recognition. In this context, the standard Euclidean distance is usually insufficient in forming the clusters. Instead, a weighted distance measure utilizing pixel coordinates, RGB pixel color and/or intensity, and image texture is commonly used. The *k*-means algorithm assigns each point to the cluster whose center (also called centroid) is nearest. The center is the average of all the points in the cluster — that is, its coordinates are the arithmetic mean for each dimension separately over all the points in the cluster.

A. K-Means Algorithm Steps:

- Choose the number of clusters , *k*.
- Randomly generate *k* clusters and determine the cluster centers, or directly generate *k* random points as cluster centers.
- Assign each point to the nearest cluster center.
- Recomputed the new cluster centers.

- Repeat the two previous steps until some convergence criterion is met (usually that the assignment hasn't changed).

The main advantages of this algorithm are its simplicity and speed which allows it to run on large datasets.

Fuzzy c-means clustering each point has a degree of belonging to clusters, as in fuzzy logic, rather than belonging completely to just one cluster. Thus, points on the edge of a cluster, may be *in the cluster* to a lesser degree than points in the center of cluster. For each point x we have a coefficient giving the degree of being in the kth cluster $uk(x)$. Usually, the sum of those coefficients for any given x is defined to be 1.

B. The Fuzzy C-means Algorithm:

- Choose a number of clusters.
- Assign randomly to each point coefficients for being in the clusters.
- Repeat until the algorithm has converged (that is, the coefficients change between two iterations is no more than , the given sensitivity threshold) :
- Compute the centroid for each cluster.
- For each point, compute its coefficients of being in the clusters.

The algorithm minimizes intra-cluster variance as well, but has the problems of k-means is not resolved such as the minimum is a local minimum, and the results depend on the initial choice of weights.

III. WATERSHED SEGMENTATION

A well-known image segmentation technique is morphological watershed transform, which is based on mathematical morphology to divide an image due to discontinuities. The concept of watersheds is based on visualizing an image in three dimensions: two spatial co-ordinates versus intensity. In such a "topographic" interpretation, we consider three types of points: (a) points belonging to regional minimum; (b) points at which a drop of water, if placed at the location of any of those points, would fall with certainly to a single minimum; and (c) points at which water would be equally likely to fall to more than one such minimum. For a particular regional minimum, the set of points satisfying condition (b) is called *catchment basin* or *watershed* of that minimum. The points satisfying condition (c) form crest lines on the topographic surface and are termed *divide lines* or *watershed lines* [6].

The principle objective of segmentation algorithms based on these concepts is to find watershed lines. The basic idea is simple, suppose that a hole is punched in each regional minimum and that the entire topography is flooded from below by letting water rise through the holes at uniform rate[5]. When the rising water in distinct catchment basins is about to merge, a dam is built to prevent the merging. The flooding will eventually reach a stage when only the tops of the dams are visible above the waterline. These dam boundaries correspond to the divide lines of the watersheds. Therefore, they are the (connected) boundaries extracted by a watershed algorithm. In contrast to classical area based segmentation, the watershed transform is executed on the gradient image. A digital watershed is defined as a small region that cannot assigned unique to an influence zones of a local minima in the gradient image. Also these methods were successful in segmenting certain classes of images; due to the image noise and the discrete character of digital image, they require significant interactive user guidance of accurate prior knowledge on the image structure, and easy to be over segmentation and lack of smoothness.

Watershed algorithm:

- Let $M_1, M_2, M_3 \ldots M_n$ be the sets of coordinates of points in the regional minima of the image $g(x, y)$
- $C(M_i)$ be the coordinates of points of the catchment basin associated with regional minima M_i
- $T[n] = \{ (s, t) \mid g(s, t) < n \}$
- $T[n] =$ Set of points in $g(x, y)$ which are lying below the plane $g(x, y) = n$
- $n =$ Stage of flooding, varies from min $+1$ to max $+1$
- min $=$ minimum gray level value
- max $=$ maximum gray level value
- Let $C_n(M_1)$ be the set of points in the catchment basin associated with M_1 that are flooded at stage n.

- $C_n(M_i) = C(M_i) \cap T[n]$
  - ❖ $C_n(M_i) = 1$ at location (x,y) if $(x, y) \in C(M_i)$
  - ❖ AND $(x, y) \in T[n]$, otherwise it is 0.
- $C[n]$ be the union of flooded catchment basin portions at the stage n

$$C[n] = \bigcup_{i=1}^{R} C_n(M_i)$$

$$C[mx + 1] = \bigcup_{i=1}^{R} C(M_i)$$

- Algorithm keeps on increasing the level of flooding, and during the process $C_n(M_i)$ and $T[n]$ either increase or remain constant.
- Algorithm initializes $C[\min + 1] = T[romanmin + 1]$, and then proceeds recursively assuming that at step n $C[n - 1]$ has been constructed.
- Let Q be set of connected components in $T[n]$.
- For each connected component $q \in Q[n]$, there are three possibilities:

  (a) $q \cap C[n - 1]$

  (b) $q \cap C[n - 1]$

  (c) $q \cap C[n - 1]$

- Condition (a) occurs when a new minima is encountered, in this case q is added to set $C[n - 1]$ to form $C[n]$.
- Condition (b) occurs when q lies within a catchment basin of some regional minima, in that case
- Condition (c) occurs when ridge between two catchment basins is hit and further flooding will cause the waters from two basins will merge, so a dam must be built within q.

IV. GRADIENT FILTER TECHNIQUE

In this work the algorithm is constructed by making use of specific inbuilt function provided in MATLAB mathematical software package. Designing a 2-dimensional filter of specified type of edge operator (prewitt, sobel operators) is much useful in attaining X-derivative and Y-derivative of an image. This filter is treated as 'Gradient filter' as it's transfer function is designed with an edge operator. Then the input color image is subjected through this filter and resulting image seems to be quite useful than the resultant images attained by general edge detection (usually spatial domain operation on gray images). From the image gradient attained in this method we can observe the contours of each individual region are assigned a unique color.

Gradient filter algorithm:

- Prepare a 2D filter of specified type of edge operator(here 'sobel')
- Apply the input color image to this filter
- The X-derivative and Y-derivative of the image is attained
- Assign the response of the filter to an arbitrary variable
- Apply this resulting image to intensity adjustment(an image enhancement technique)
- Display the input and output images

This form of Edge detection is useful as a fundamental step in image processing, image analysis, image pattern recognition, and computer vision techniques. During recent years, however, substantial (and successful) research has also been made on computer vision methods that do not explicitly rely on edge detection as a pre-processing step.

V. INTENSITY ADJUSTMENT

Intensity adjustment is an image enhancement technique that shifts an image's intensity values to a new dynamic range. When changing the brightness of the image, a constant is added or subtracted from the luminance of all sample values. Adding a constant value to each every pixel of the image will increase the intensity of the image. Similarly the brightness can be decreased by subtracting a constant value from each and every pixel of the image. Remapping the data values to fill the entire intensity range [0, 255], will increase the image contrast value.

VI. RESULTS

(i) Detection of Atherosclerosis

To analyze the complex atherosclerosis of distal right coronary artery and luminal narrowing (Figure 1: Low Magnification Micrograph) is considered for the implementation of above discussed segmentation algorithms to extract the features needed for detection and to forecast the severity of disease.

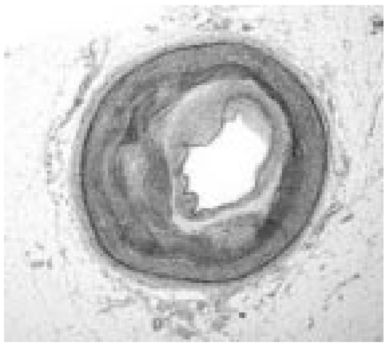

Fig. 1 Low magnification micrograph (***Courtesy***: Wikimedia Commons)

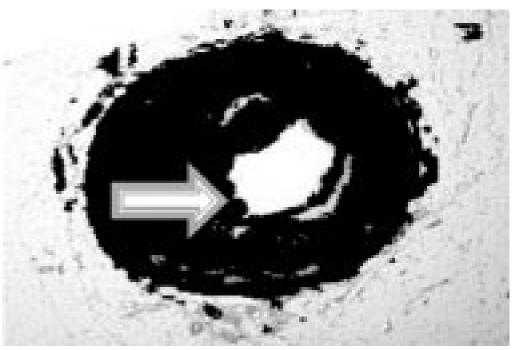

Fig. 2 K-means Segmented Image

The Fig 2 represents K-means segmented image from which the arrow indicates the amount of Lumen left for blood flow but with degraded image quality.

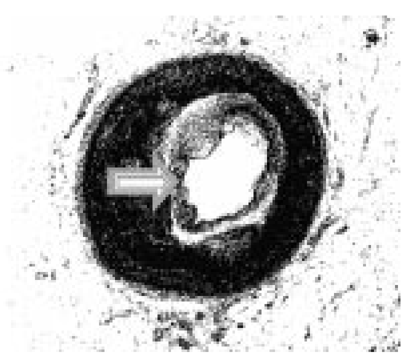

Fig. 3 FCM Segmented Image

The arrow mark in Fig 3 shows the white circular resemblance region which indicates the actual Lumen that shows the path for the flow of blood obtained using FCM segmented result.

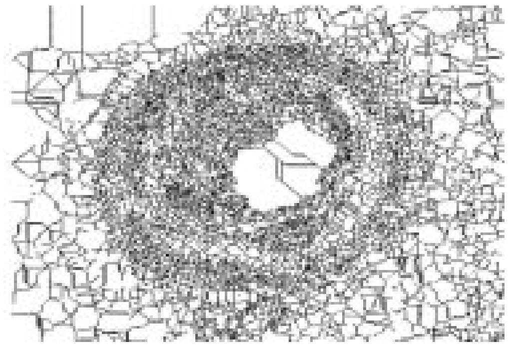

Fig. 4 Watershed- Distance transform

In this first step of Watershed method the input image is transformed to a image(Figure 4) that is appended with the calculated Euclidean distance value of each pixel from it's nearest non zero pixel. The innermost region in the original image pixels is having a little variation with the neighborhood pixels. This little variation is so important that the pixels at the contour of the innermost region are appended with one Euclidean distance value and the pixels within the innermost region are appended with other Euclidean distance value. Thus this labeled image is useful in extracting a variation in the images. As the variations generally significant at the contours the labeled image with distance transform seems to represent the region border clearly. Also note that in the original image the region far away from the center are having high intensities than the inner black regions.

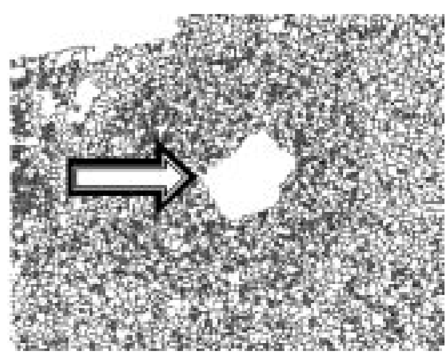

Fig. 5 Watershed –Gradient Image

Gradient of a image is useful in suppressing the noise. The regions with small variations in the intensities have small values of gradient. In the given image the inner constricted region is having greater intensity values than the next contours. Even though the 'Watershed-gradient' image is over segmented, the resulting image (Figure 5) is useful to analyze that how exact the remaining portion (Lumen) that is not constricted. This is useful in taking suitable precautions or for the cardiologist to analyze the level of complication and for necessary treatment.

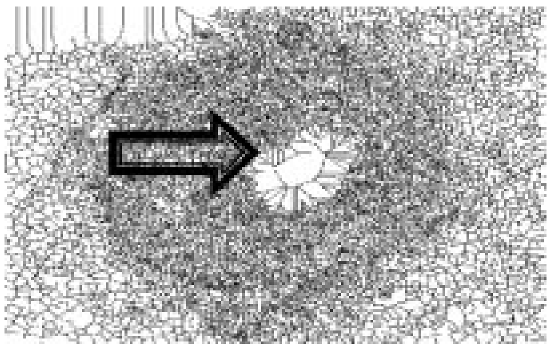

Fig. 6 Watershed – Marker Controlled Image

The Marker controlled image as shown in Figure 6 can be utilized to forecasting which clearly gives the forecast of how Lumen will be occluded if proper medication is not given. Markers are nothing but the connected regions. The image is applied to a filter so that the noise is suppressed and here the connected external markers are set to break away from each other, so the independent regions defined with its internal and external contours are segmented through the watershed algorithm.

(ii) Detection of Exudative Maculopathy

The Figure 7 represents the retinal image effected with Exudative Maculopathy.

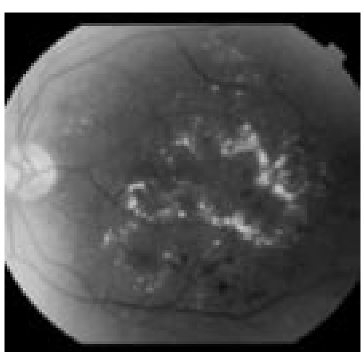

Fig. 7 Original Image (Exudative maculopathy)

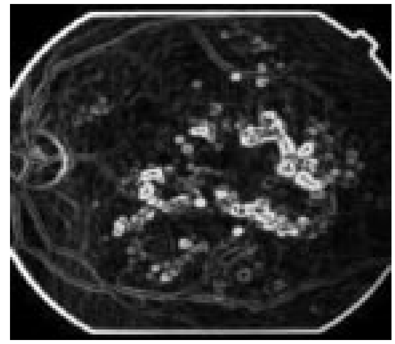

Fig. 8 Edge detection (Gradient filter technique),

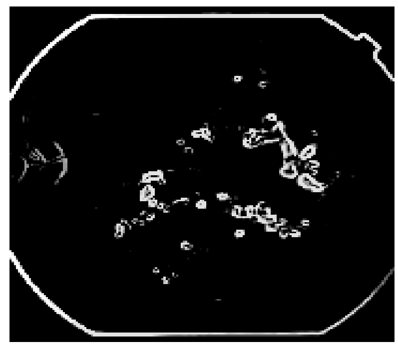

Fig. 9 Intensity adjusted image

From observing Figure 7 the Exudates are seen as yellow patches on the retina. Figure 8 is the resultant image of the proposed method. But here the Exudates are not clearly visible. Thus Intensity adjustmet is carried out to extract the features in a vsible way as shown in Figure 9.

V. CONCLUSION

The experimental results of watershed algorithm are quite suitable for forecasting of narrowing of Lumen in CVD Patients. While the other two algorithms give results lacking in prediction due to inherent drawbacks with them. In future development Watershed algorithms can give perspective results so that the Endocrinologists and Cardiologists may employ this algorithm for earlier detection of Diabetic Cardiomyopathy to avoid morbidity. It is quite evident from the end results that this proposed method quite suitabe in extracting various pathologies of Retinal disease lesions. Therefore this method of lesion segmentation is much useful for the opthomologists in diagnozing the pathologies that will cause vision morbidity throuh a simple and effective computational logic.In future much development has to be done on this algorithm such that it will much useful to the opthamalogists for easy analysis and to study the pathologies.

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