THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION

INSTITUE OF SCIENCE AND TECHNOLOGY

DEVELOPING AN EFFICIENT METHOD IN HUMAN RETINA OPTIC DISC LOCALIZATION AND SEGMENTATION

MASTER THESIS

Jahana Attwan Mohsin Alsubaihawi

THE DEPARTMENT OF INFORMATION TECHNOLOGY

THE PROGRAM OF INFORMATION TECHNOLOGY

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Supervisor: Assist. Prof. Dr. Meltem YILDIRIM İMAMOĞLU

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I hereby declare that all the information in this study I presented as my Master's Thesis, called: DEVELOPING AN EFFICIENT METHOD IN HUMAN RETINA OPTIC DISC LOCALIZATION AND SEGMENTATION, has been presented in accordance with the academic rules and ethical conduct. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

September 2017

Jahana Attwan Mohsin Alsubaihawi

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Jahana Attwan Mohsin Alsubaihawi

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LIST OF ABBRIVIATION

OD	Optic Disk
FCM	Fuzzy Clustering Mean
ACO	Ant Colony Optimization
HIS	Hue Saturation Intensity
DRIVE	Digital Retina Image Vessel Extraction
MRF	Markov Random Field
PCA	Principal Component Analysis
FOV	Field Of View
MESSIDOR	Methods to Evaluate Segmentation and Indexing techniques in the field of retinal ophthalmology

ABSTRACT

DEVELOPING AN EFFICIENT METHOD IN HUMAN RETINA OPTIC DISC LOCALIZATION AND SEGMENTATION

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In diabetic retinopathy optic disc is a major segment in human eyes. The finding of optic disc in retinal images is one of the critical steps in ophthalmology operations. In this thesis a new method is implemented for the optic disc segmentation and localization in human retina images. As it is estimated this method will be very fast and simple iterative with convergent. Also, this new method can find the boundary of optic disc by an initial fuzzy clustering means algorithm. For database, MESSIDOR database is used, and it is available in the world open source database. In proposed method the H-minima transformation is adapted to find the location of the optic disc in retinal images. The result is compared to various methods which available in the literature, and it is concluded that the new method is more accurate and time efficient than the existing methods. The approach in this thesis, the fuzzy and morphological operation is combined for getting the high accuracy and get the fast processing time, as a new approach.

Keywords: Retina Image, FCM, Optic disk Segmentation, Image processing.

ÖZET

İNSAN RETİNA OPTİK DİSK LOKALİZASYON VE BÖLÜMLEME ETKİLİ YÖNTEMİN GELİŞİMİ

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Tez Danışmanı: Doç. Dr. Meltem Imamoglu

Eylül -2017, 63 sayfa

Diyabetik retinopatide optik disk insan gözlerinde çok önemli bir bölümdür. Retina görüntülerinde optik disk bulgusu oftalmoloji operasyonlarında önemli adımlardır. Bu tezde optik disk bölümlemesi ve lokalizasyonu yapılacaktır. Bu tezde, insan retina görüntülerinde optik diskin lokalizasyonu ve segmentasyonu için yeni bir yöntem uygulanacaktır. Tahmin ettiğimiz gibi, bu yöntem çok yakın hızlı ve basit iteratif olacaktır. Ayrıca, bu yeni yöntem, ilk bulanık kümeleme aracı algoritması ile optik disk sınırını bulabilir. Veri tabanı için dünyadaki açık kaynak veritabanında bulunan MESSIDOR veritabanı kullanılmıştır. Önerilen yöntemde retina görüntülerinde optik diskin konumunu bulmak için H minima dönüşümünü kullanılmıştır. Elde edilen sounçlar, literatürde mevcut olan çeşitli yöntemlerle karşılaştırılmış ve yeni yöntemin mevcut yöntemlerden daha doğru ve zaman açısından verimli olduğu sonucuna varılmıştır. Bu tezde, yüksek doğruluğu elde etmek ve hızlı işlem süresini elde etmek için bulanık ve morfolojik işlem, birlikte kullanilarak yeni bir yaklasım denenmiştir.

Anahtar Kelimeler: Retina Görüntüsü, FCM, Optik disk Segmentasyonu, Görüntü işleme.

Birleştirilmiştir.

CHAPTER 1

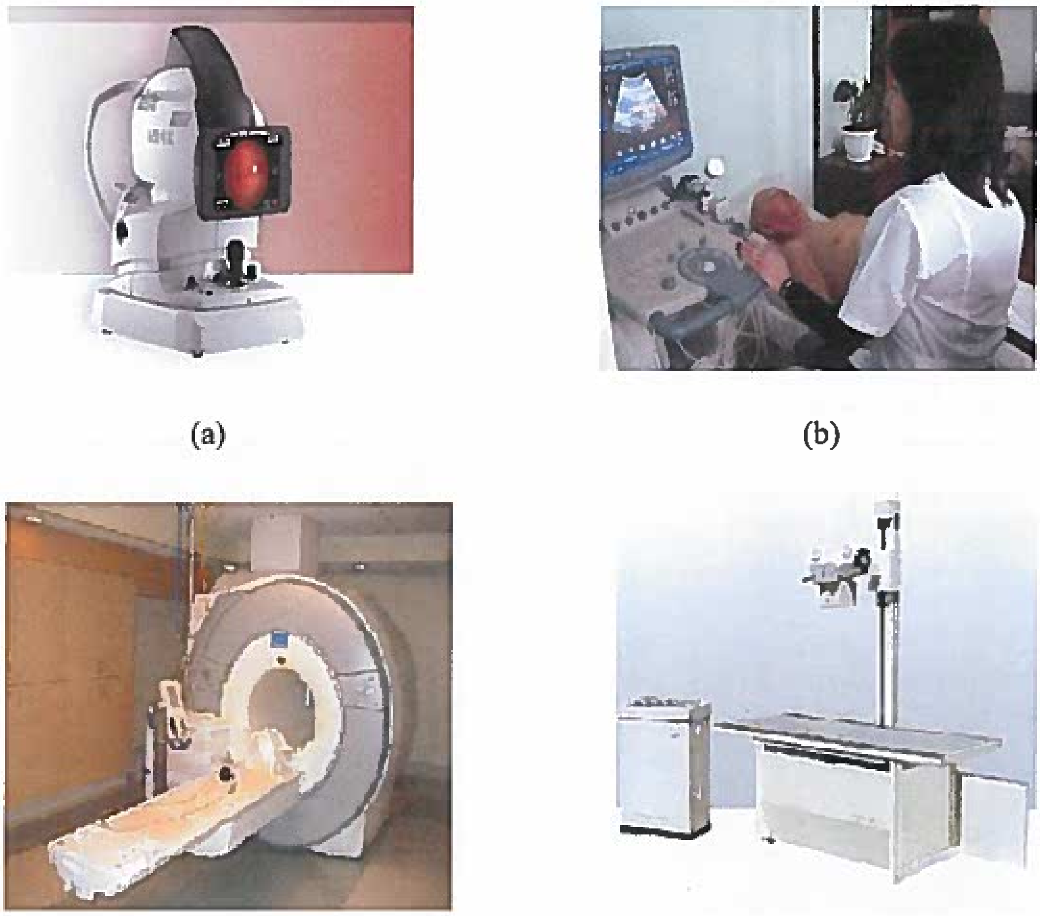
INTRODUCTION

1.1 Background

Recently and after all the developed devices(Fundus camera, Ultrasound machine, Magnetic resonance camera (see figure 1.1), many researchers deal with the image processing as an efficient mechanism to automation the medical works and use this benefit to get the right diagnosis of diseases.

Nowadays, the diabetic causes a lot of problems for many people all over the world, (especially in Iraq after all these wars and battles there are a huge number of diabetics, adults and infants). It affects on the human's body and damages some parts of the body especially the retina and the optical disc which will cause the blindness, and as a result they need to treatment. The treatment cost is very expensive, so most of them go to the governmental hospitals. Each patient must wait for a long time to get the image of his retina and optical disc (actually my sister suffered too much from this problem). Most of the diabetics suffer from dizzy or weakness. Indeed this problem is happened because the operation is performed manually by the doctor that takes long time. Thus, the situation needs a mechanism that solves this problem and helps the patients. The shape of the retina and optic disc gives the doctor much information to get the right diagnoses. Indeed the diagnoses is done after detecting and segmenting the retina and the optic disc which is performed manually by the doctors. Many studies and approaches have been adopted to automation this operation to solve this problem [1-4].

This study propose a new technique that will be briefly mentioned which combining the work of the morphology, fuzzy clustering and level set algorithms to get the more efficient and accuracy segmentation.



(a) (b)

(c) (d)

Figure 1.1 (a) Fundus camera, (b) Ultrasound machine, (c) Magnetic resonance camera, (d) Medical X-ray camera [5]

1.2 Retina and Optic Disc

The retina likes a fluffy layer of tissue that locates to the back of the eyeball on the inside. It is near to the optic nerve. The major purpose of the retina is receiving the light which the lens has focused, changes the light into neural signals, and transfer these signals on to the brain for visual recognition. The major operation of retina is processing the light inside to eye through a tissue of photoreceptor cells. These cells are essentially sensitive to the light and in charge of detecting the qualities such as the intensity and colors. After that, it sends the collected information to the brain via the optical nerve. Since the retina plays a vital role in vision, any damage or problem in it can make total blindness. Conditions such as retinal detachment, where the shape of retina is unusual or its location is abnormal, these reasons can make it unable to receive the light signal that make the brain incapable to collect and recognize the signals [6, 7].

1.3 The Optic Disc

The optical disc is a circular area in the center of the retina, where they exit the eye axons of retinal ganglion cell forming the optic nerve. This area measures 1.5 x 2.5 mm in the human eye and lacks sensitivity to light stimuli because it has neither cones nor sticks, this causes a blind area within the visual field known as blind spot. Inside the papilla there is a physiological excavation called the dome. The ratio of the diameter of the dome to the diameter of the optical disc (normal index is less than 0. 3) is an indicator of the damage that causes glaucoma. The optic nerve of a normal human eye is made up of axons between 1 and 1.2 million neurons that carry visual information from the retina to the brain. Modern developments, particularly in the area of medical image processing, enable the automatic perception of different features, changes, diseases and degenerations in retinal images. Retinal image analysis with image processing techniques and studies on detection and follow-up of diseases that can be perceived by changes in retinal structure based on these analyzes are made [6, 8, 9].

1.4 The Goal of The Study

This study aims to use the great benefits of computer science and image processing to arrange and enhance the work of the government hospitals and medical centers by supporting them with smart automatically mechanism to reduce the efforts and time that are spend by using the traditional ways and in other hand the horrible spread of the diabetes.

This study develops an efficient method by combining the work of three functions, morphology, fuzzy clustering and level set to get more accuracy detection for the optical disc to get the right diagnoses. We aim to develop this study to deal with the cancer of some parts of human body in the future.

1.5 Organization of Thesis

In chapter 2 we discuss about image processing techniques. The literature review is presented in chapter 3. The methodology is discussed in chapter 4. The simulation result is shown in chapter 5. Finally the thesis finishes in chapter 6 with conclusion and future works.

CHAPTER 2

IMAGE PROCESSING TECHNIQUES IN OPTIC DISC SEGMENTATION

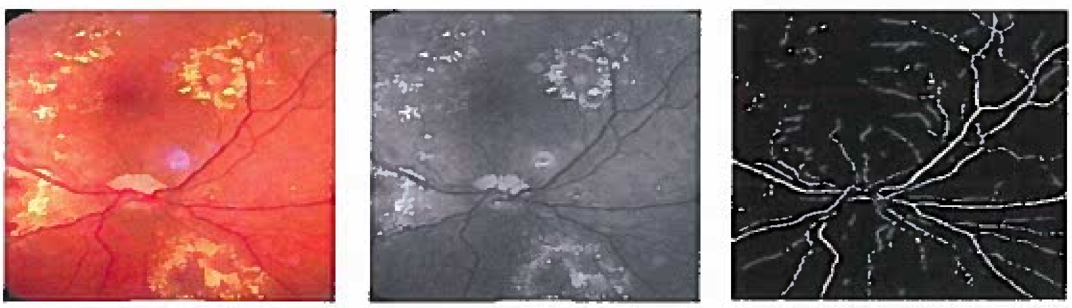
2.1 Background

Image processing is understood in the field of computer science and electrical engineering to process signals which represent images, for example photographs or individual images from videos. The result of image processing can again be an image or a set of characteristics of the input image. In most cases, images are viewed as a two-dimensional signal, so that conventional methods can be applied from signal processing. Image processing is to be distinguished from the image processing, which deals with the manipulation of images for the subsequent representation. Image processing is now used in almost all scientific and engineering disciplines, such as in modern microscopy, medical diagnostics, astronomy, mechanical engineering and remote sensing (environmental observation, espionage). Using image processing methods, machine objects are counted, measured, objects inspected or coded information is read. X-ray and ultrasound systems provide images that the physician can interpret more easily. X-ray machines in safety zones automatically check luggage and clothing for dangerous objects (weapons etc.). Another field is quality assurance in production and production processes. The so-called handle in the robotics is also supported by image processing [10].

2.2 Image Processing

The formation and structure of digital images allows these images to be mathematically compatible with operations and to perform various operations on them. If an image is desired to be expressed as an equation or function, the image at any point or coordinate (x, y) is set to a brightness value. If (x, y) and the corresponding brightness value in this coordinate are specified with values that are defined finitely and explicitly, then the image is regarded as digital image [10].

The brightness value of each pixel for a monochromatic image is called the gray level value of this point. Thus, a gray-level image can be defined as a two-dimensional function f (x, y). Where x and y are the local coordinates and f (x, y) is the brightness value of (x, y). The other pixels surrounding one pixel are called neighboring pixels of this pixel [10]. These explanations form the basis of image processing and analysis.



(a) (b) (c)

Figure 2.1 (a) A retinal image with a normal color, (b) A retinal image with a gray level, (c) A binary retinal image in which the vein structure is segmented [10]

In color images, there are three channels (Red, Green, and Blue-RGB) different from gray level images. Therefore, it is necessary to define a three-dimensional array as opposed to a two-dimensional array in gray level images to represent these images. This line represents the first component red (R), the second component green (G) and the third component blue (B). The indexed images use a color map containing the combination of the matrix or a predefined limited number of RGB values. However, the binary image (Figure 2.1 (c)) consists only of black and white pixels. These images are represented by binary arrays of zero and one value. Any image in any format can be converted to binary image format for analysis or processing. In image creation and analysis, the following steps can be followed in sequence (Figure 2.2) [11].

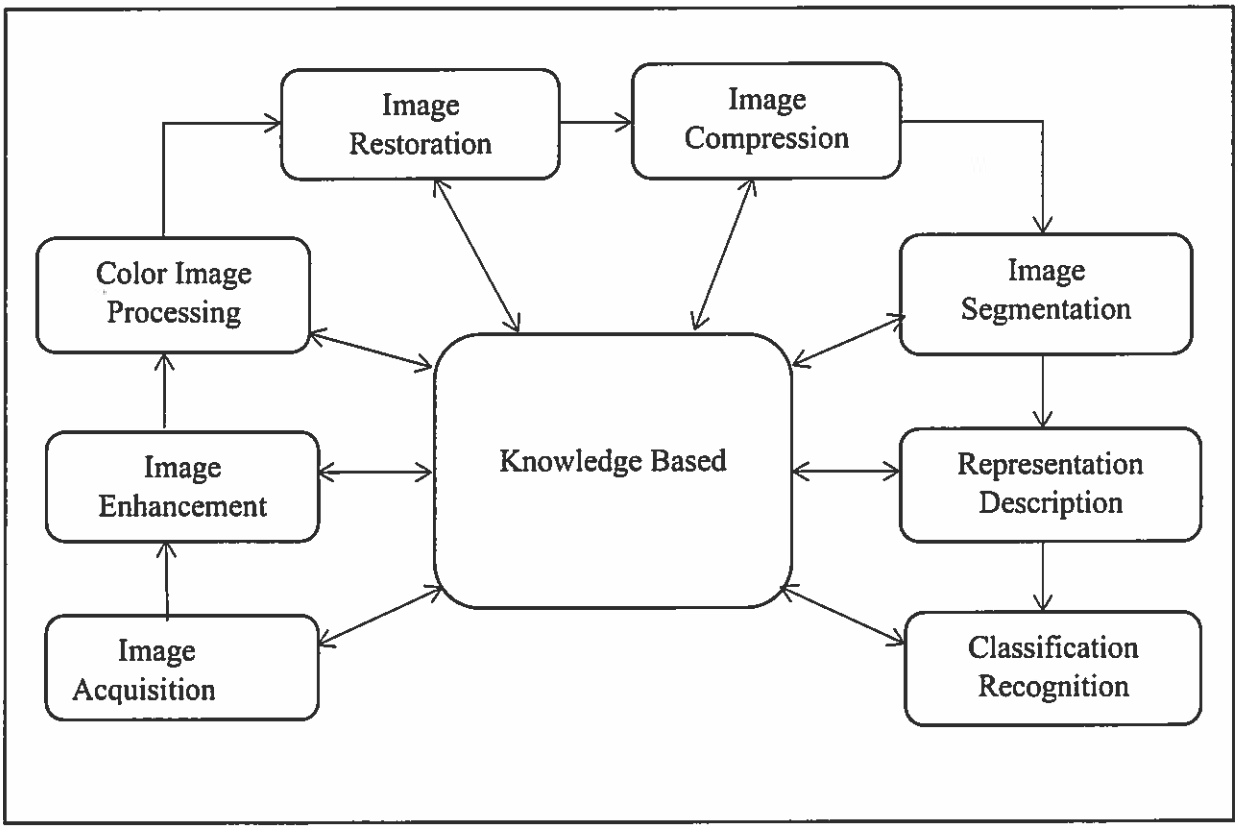


Figure 2.2 Steps of image processing [11].

The first step in the processing and analysis of retinal fundus images is the stage of production or acquisition of the image with different tools (fundus camera, etc.). For fundus images, this step is performed with the fundus camera. The device used to view retinal images is the Digital Fundus Angiography Device. Veins and vascular functions in this region are important in diseases of retina and macula. With angiography devices, the images of the patient's eye as they pass through the veins are recorded with a digital imaging device after the patient's pupil has been enlarged. In this setup, the digital camera operates like normal traditional cameras, but instead of film, the image sensor is used [12].

After the digital images are obtained, the next step is the preprocessing step. At this stage, the image is clearer and clearer so that it can be processed easily and accurately in the next step.

Some of these operations in digital image processing are:

- Visualize.
- Filter the impurities present in the image
- Destroying or minimizing structural defects on the image.

The next step is the image splitting process that splits itself into sub-images. This is called image separation or segmentation. Detailed image splitting operations are counted as the most difficult operations in image processing. The segmentation is the object in the image and the regions with different characteristics of interest in the image or in the human retinal images [13]. Segmentation can be considered as the most difficult application of image processing, and there is a certain error rate in the results of segmentation techniques.

The segmentation produces raw information for instance the boundaries of an object in an image, the area of a sequence or object. If we are dealing with the shapes of the objects, we are waiting for the segmentation to equip us information about the edges, corners and boundaries of that object. However, if the object in the picture is concerned with its internal lineaments such as surface coverage, area, colors, skeleton, the regional segmentation should be used.

The next step in the division is the definition of the image and the definition of the structure of the optic disc. The raw information is carried out in this stage in the foreground of the details and information of interest in the picture. The last part is recognition and interpretation. In this phase, objects or regions within the image are labeled according to predefined definitions [13].

2.3 Image Processing Techniques

Image processing algorithms can be basically divided into three main groups. These groups are:

2.3.1 Point Processing

That allows the point or value of any point in the image to be changed by considering of its features.

2.3.2 Field Processing

That allows the points to be changed in relation to neighboring points around themselves.

2.3.3 Geometric Operations

That provided by changing a specific field in common. Another common name for dot or other images is pixel processing, which is the simplest processing technique because it only concerns the pixel location or color value of the pixel in question. Field processing is an approach that reconstructs the pixels in the image by associating the density value with the pixel values of neighboring pixels or the entire image. Geometric processing is the process of recalculating the position of pixels with some geometric transformations. The main idea is to shift the pixels for the image. The algorithms which are used in our work will be explained in detail in this section.

2.3.4 Convolutions (masking)

Convolutions are a commonly used method for image-wise sharpening, blur reduction, edge removal, and other image effects. The structural element used to implement the process is called the mask in brief. Convolutions, also called masking, are the recalculation of all pixels in an image with the help of other pixels [14]. This recalculation is performed with the help of predetermined structural elements. The structural element is a matrix whose dimensions are odd numbers and contains numerical values. In figure 2.3 a structural element and the general form of the image part to be applied are given.

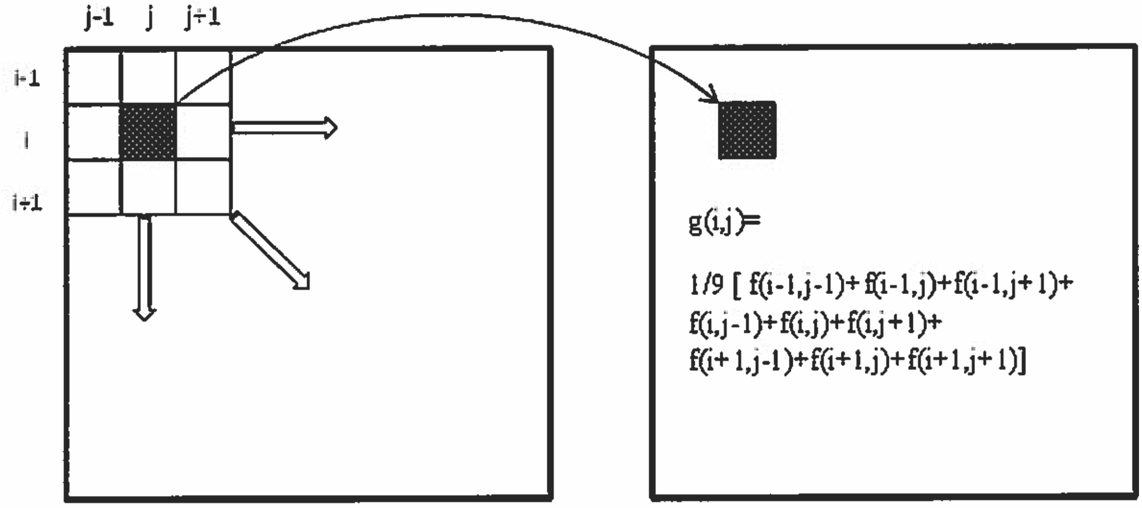


Figure 2.3 Apply masking [15]

The convolution operation is performed by multiplying each value in the structural element matrix by a pixel in the image, multiplying each value by the color code of the pixel to which each value is connected, and assigning the multiplied values to the corresponding pixels in the middle of the matrix. Assuming that z values in figure 2.4 are the numerical product values in the structural element and p values are the color values of the pixels in the image part after be applied to the structural element, the mathematical representation of this calculation is as in equation 2.1.

$$P'[\frac{n}{2}] = \sum_{i=1}^{n} z_i p_i \qquad (2.1)$$

Z1	Z2	Z3	…	…
…	…	…	…	…
…	…	…	…	…
…	…	…	Z_{n-1}	Z_n

(a)

P_1	P_2	P_3	…	…
…	…	…	…	…
…	…	…	…	…
…	…	…	P_{n-1}	P_n

(b)

Figure 2.4 (a) The original image, (b) The image after applied [15]

2.3.5 Edge Removal

The edges in an image contain vital information about the image, because the edges in an image give information about where the objects are, their shapes and their dimensions. The edge is where the intensity value in the image makes a sudden transition from low values to high values or from low values to high values.

The edge-based methods try to find where one color differs from another color, or where fast transitions from one contrast value to the other. The main principle is to calculate gradient transitions on the whole image with gradient operators. The value of the gradient will be large, because the regions grow with fast transitions. After the boundaries are merged in this way, it is assumed that these boundaries are enclosed in a closed space to contain objects. Operators such as Laplacian of Gaussian, Canny and Sobel are used in defining the border [16].

2.3.6 Morphological Operations

In image processing, mathematical morphology provides suitable methods for analyzing and analyzing the shapes present in the image. Here are two important processes that come to our attention: dilation and erosion. The operations are performed by a special mechanism in which two pixel sets are combined. Usually the first pixel in the processing of the image, sets the other smaller cluster that is called the kernel. Expanding from this process, each pixel and surrounding pixels on the image are overlapped with the core pixel. At the end of this process a certain expansion occurs in the object in the image. In other words, expanding a numerical image means enlarging the parts that intersect with the formal structural element. To do this, the structural element is pixel-pixel-wise on the picture. If the origin of the structural element corresponds to a pixel with a value of "0" on the picture, no change will occur. If a pixel with a value of "1" is encountered, the pixels under the structural element are subjected to a logical "or" operation. That is, any "1" value is converted to "1". With dilation, the objects on the picture swell. If there are holes in the object, they tend to close. Discrete objects close together or connect.

It is also overlapped with the core main image, but the end result here is that the center pixel is assumed to be in the case of matching only with all neighboring pixels. This causes a contraction. In other words, wear can be seen as the opposite of expansion. Here again, the structural element is circulated on the picture pixel-by-pixel, but this time the position of the pixels in the structural element is checked if the central pixel of the structural element is encountered with the value "1". If there is a value of "0" in the picture under any of the pixels in the structural element "1", this pixel is converted to "0" along with the other under the other "1" of the structural element. That is, the objects in the picture shrink, and if there are holes, the expansions and bound objects tend to separate [10].

The opening and closing algorithms are based on these operations. It is aimed at smoothing the view by applying the erosion and then the expansion process by the opening process, destroying the narrow junction points and the floods in the objects. With the closing process, erosion is first applied after expansion and it is aimed at smoothing the view again. This time, however, there are a number of narrow fractures and fused voids and the elimination of small holes [10].

Along with the algorithms mentioned above; Edge detection, noise elimination, background elimination, and some specific patterns.

2.4 Image Segmentation

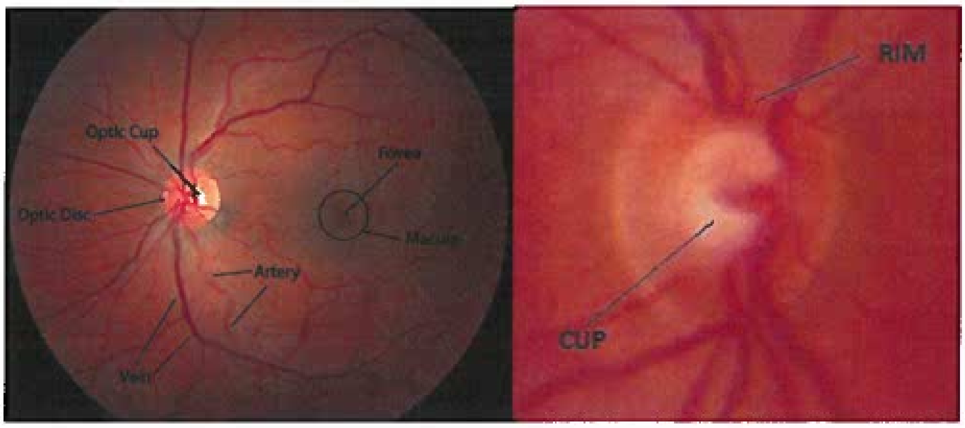
Image segmentation is an intermediate step in analyzing or distinguishing the object of interest from the background image. Segmentation aims to identify and define a part of the image, such as the identification of parts with specific features of the image to be analyzed, circular structures, lines in the form of lines and some other shapes, in terms of a specific purpose and interest. Segmentation can also be defined in terms of visual characteristics and can be perceived as the separation of the interested object from the background, thus focusing on one feature and other parts of the picture [17].

CHAPTER 3

LITERATURE REVIEW AND THE OPTIC DISK CONCEPTS

3.1 Background

The optic disc is the emergence of the optic nerve within the eyeball and collects all the axons which originate from the photoreceptors of the retina. It is defined as the blind spot of the retina. The shape of the optical disc is oval with greater vertical diameter, with a large physiological central depression about one quarter of the entire papillary area, which never reaches its edges. The developments of digital image processing support the field of ophthalmology with more sophisticated benefits like: Automatic determination of diabetic retinopathy (DR) conditions, glaucoma, age-related macular degeneration, etc. It is difficult to detect and diagnose discomforts such as DR (diabetic retinopathy) because it does not cause visual impairment in the first stages of illness. For this reason, the detection of such diseases needs regular eye inspections. Due to resource anxieties, it may not be possible to regularly examine a large number of people with conventional methods. This inspection can be carried out with automatic systems. However, in such a case, the diagnosis of the condition and the guidance to the treatment will not be very fast because doctors cannot quickly control the human or retinal images in a lot of patients. For these reasons, the development of such automated systems is very important [9, 18-21]. When the retina images are checked automatically by the system, if the discomfort is obviously encountered in the automatic control, it can be checked and diagnosed by the professional doctors. In order to effectively and successfully examine the optical disc, it must first be carefully studied and carefully analyzed on the physical properties such as retina image and brightness, width etc. that form the basis of the program. At this point, optic disc brightness and combination with blood vessels are the most important features [2]. The optic disk is ellipse and its dimensions are 1.8 with tolerances 0.2 mm as width, 1.9 with tolerance 0.2 mm as the length [22]. Also this size was described to be 1.5 mm on average [23]. It can find clearly in the middle of the optic disc a brighter region in the same location of nerve fibers, this region is called the CUP (see Figure 3.1). The optic disc edge (RIM) is structured as a narrow band surrounding the optical disc (see Figure 3.1).



(a) (b)

Figure 3.1 (a) The position of original retinal image (b) Location of CUP and RIM [23]

The optic papilla is closely related to the central artery of the retina and the homonym vein , which emerge in the ocular bulb at the level of the optic nerve emergency, then divide into four branches directed to the four retinal quadrants (upper and lower temporal, Upper and lower nasal). The arched branches are not anatomized and vascularization is therefore of terminal type. At the eyepiece examination the arteries are red colored and less than the diameter of the veins.

3.2 Literature Review

However, there can be big differences between these internal displays. Sometimes the optical disc looks brighter than its surroundings, and sometimes it looks like an empty ring. Illness sometimes causes bright spots outside the rim area. Veins can also partially alter the optic disc image [24].

3.2.1 Graph Cut Technique

Depending on the graph cut technique, Salazar-Gonzalez et al [25] constructed the graph using the prior knowledge of the foreground and background, taking into account the relationship between neighboring pixels and their probabilities. This method was tested on two data sets, DiaRetDB1 and DRIVE. The calculation of the overlapping performance of this method measures the average absolute distance with respect to sensitivity and hand-tagged images.

In the [26] they implemented with a new graph-based optimum segmentation method. This method is applied to optic disc and cup segmentation in 70 recorded fundus and SD-OCT images of glaucoma patients. A fixed digital beam system is used to make the correct segmentation of the star shape and constant, without the interpolation image required by other methods. The problem is formulated as a Markov Random Field (MRF) optimization problem.

In the [27] as the first step, retinal vessel excision is performed using the graph cut technique, and then blood vessel information is used to predict the location of the optic disc. Within the graph cut method, MRF offered a new approach to segmenting blood vessels and optic discs in retinal images by integrating image reconstruction, compensation factor and flux mechanism.

3.2.2 Ant Colony Based

The algorithm which is discussed in [28] is established on ACO (ANT COLONY OPTIMIZATION ALGORITHM), aiming to soften the vessels in the retina, using anisotropic diffusion process, the ACO algorithm could examine the optic disc boundaries. In fact, the ACO algorithm can be used effectively in removing other clear features for instance the macula (yellow dot) and major blood vessels in the image.

3.2.3 Hue Saturation Method

Elbalaoui et al. [29] presented an automated method for detection of retinal colored fundus images with high accuracy. First, the image is transformed into the Hue Saturation Intensity (HIS) model, then it is done in possible regions that contain the exudates (Exudates). They then use the graph cut algorithm for segmented images without using an Optical Disc (OD).

The methods that used to distinguish optical disc in the formal methods have brightness and geometric properties which are used in Bayesian based statistical methods and, on the other hand, standard methods are such as the Hough transformation and template mapping method. With this approach, studies on optical dystrophy stability can be grouped in different ways. While some of the studies carried out in this regard paid attention to the number of optic discs [2], some methods followed the edge of the disc area [6, 30]. While some studies use the template mapping method [23], some methods apply the active edge or snakes method [31]. There are many approaches which use machine learning [20] and also threshold of the multilevel and the shape determination methods which available in [32, 33]. The approach of these classifications methods bases on the overview and many studies have applied different ways in a mixed way [34, 35].

3.2.4 Filtering Based

Below, some examples of work that finds and separates optical dichroic compartments are mentioned. I a study which conducted by Fleming et al. [36], the center of the optical disc was detected by utilizing a half-ellipse. In the study, the optical disc inspection failure was given as 98.4%, but no success rate was given for the optical disc edge lines. On the other hand, Carmona and colleagues did not see optic disc and resorted to a genetic algorithm for the identification of their edges. Furthermore, as a result of the tests on 110 images, a 96% success rate was reported in defining optical dissecting edges for images with less than 5 pixel ambiguity. Lupascu et al. [8] conducted studies on the geometric position and edge lines of the optical disk. In the study, where success rates of 95% optical disc vision and 70% optical disc edge line were reported, the most suitable circle limiting the optical disc was tried to be defined by tissue definition and regression based methods. The result of locating is that the position of the center of the optical disc is determined in the most accurate way, or the minimum point of error or the area of the optical disc is limited by a circle or a circle. In [3] they applied the Sobel filter for the most circular structure between the specified edges, using CHT to reveal the edges in the image. This study was successful in detecting optical disk in 39 out of 40 pictures from the DRIVE retina database (97.5%).

In the retinal fundus images, the part which is generally round and looks brighter than its surroundings is known as an optical disc. For the automatic detection of many retinal diseases, it is crucial to detect and interpret retinal optic discs to facilitate the detection and activation of ocular degenerations for the detection of macular degeneration due to the constant distance with the macula, in order to remove the vein web when it forms a starting point in the vein network [37].

In [38], optical disk sites were identified by extracting the brightest spots within the circular images and retina images, then comparing them with CHT considering them as different candidates . When they applied this method they used, 85% success rate was obtained in retinal images taken from Karadeniz Technical University, Faculty of Medicine, and Ophthalmology Department.

3.2.5 Optic Disc Segmentation Based on Wavelet Transformation

Lalonde et al. [23] conducted a pyramidal analysis of the green color channels of retinal images by Haar Wavelet Transformation method to determine the location of the optical disk, and then performed edge segmentation using the Hausdorf based template matching method. In this study, 93% success rate was obtained from 40 retinal images.

Morales and colleagues [39], first, exchanged the image into gray scale using Principal Component Analysis (PCA), after that they used the stochastic basin algorithm (segmentation) to determine optical disk location and segment the edges. Using the DRINOS retina database, they achieved 86.89% segmentation success rate in optical disc location from 110 retinal images.

In order to be able to effectively and successfully examine the optical disc, it must first be carefully studied and carefully studied on physical properties such as retinal image and brightness, width, which form the basis of the program. At this point, optical dazzle brightness and combination with blood vessels are the most important features.

Many methods have been used for optical disk detection and segmentation like the approach that adopted the Brightness and other one take the geometric properties in account, from statistical ways for example Bayesian to standard methods for instance Hough transformation and template matching. With this approach, studies on optical dystocia detection can be grouped in different ways. While some of the studies carried out in this regard paid attention to the number of optic discs [2], some methods followed the edge of the disc area [6, 30].

CHAPTER 4

METHODOLOGY

4.1 Cluster Analysis

The clustering is denoted as one of the highly effective and variable data analysis techniques that recently have been used frequently in business and science. The major purpose of this technique is to separate the data elements in the given data set into subgroups (clusters) according to similarities (similar characteristics) (Figure 4.1).

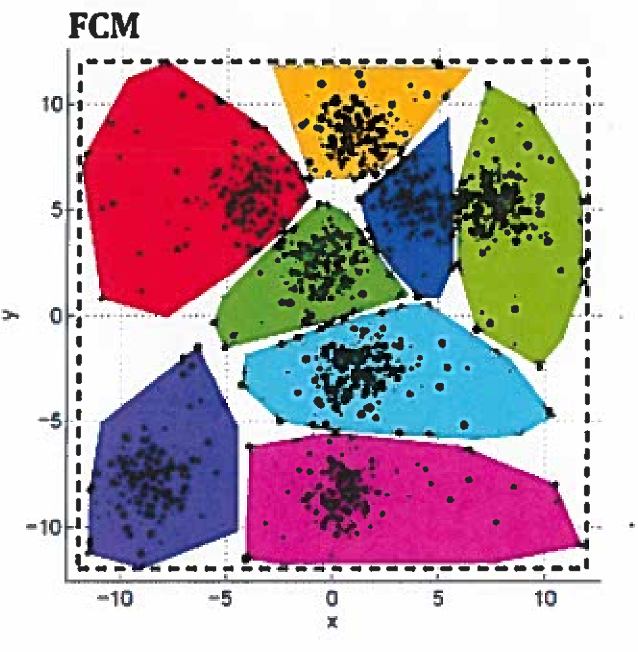


Figure 4.2 An image obtained as a result of clustering [40]

The clustering analysis is to ensure that similar data points are clustered in the same group or cluster, taking into account the similarities (characteristics) between the data points (Figure 4.1). While the elements in the same cluster are similar to one another, they are different from the elements of other clusters [41].

Clustering is a method of learning without instruction. It is a widely used method for statistical analysis of multidimensional data [42]. It is also widely used in topics such as optimization, machine learning, image analysis, bioinformatics and information access.

In the clustering model, there are no data classes that are in the clustering model. In the classification model, the classes of data are known, and when a new data arrives it is predicted which class this data will be. In the clustering model, however, clusters are divided into groups of data that do not have classes. In some applications, the clustering model can act as a preliminary to the clustering model [43].

The advantages of clustering analysis are listed;

1. Relationship display: One of the most important features of clustering is the ability to display graphics with graphics. Visual results enable easy identification of similarities.

2. Detection of anomalies: Graphics allow easy detection of outliers so that extraordinary data is determined.

The disadvantages of clustering methods are listed;

1. Most of these methods do not determine the optimum number of clusters; usually the cluster numbers are chosen by the user.

2. Algorithm performance may vary depending on the size of the data set.

3. Algorithms depend on initial selections.

Clustering analysis methods are basically divided into hierarchical and non-hierarchical approaches. In a hierarchical clustering approach, data points are aggregated or decomposed at specific levels until the optimal clustering structure is achieved. The number of clusters for these algorithms need not be known in advance. Non-hierarchical clustering approaches are preferred in that the theoretical basis is stronger, if it is a priori knowledge about the number of the clusters, or if the researcher can decide the number of clusters that are meaningful. In this study, Fuzzy C-Average algorithms are used from fuzzy clustering algorithms based on non-hierarchical clustering approaches.

4.2 Fuzzy C-Mean Algorithm (Fuzzy C-Means)

The fuzzy c-mean (FCM) algorithm is one of the best known and frequently used methods of fuzzy split clustering techniques. The least square error method used in the K-Means algorithm is obtained by fuzzy logic expansion [44].

The greatest vantage of the K-means algorithm is that each object has a level of belongingness to the clusters. The fuzzy c-means method allows objects to belong to two or more clusters. Each data according to the principle of fuzzy logic belongs to a membership value which varies between [0, 1] of each of the clusters. The summation of the membership values of a class to entire classes must be "1". If the object is closer to the cluster center, then the belonging member of that cluster will be larger than the belonging membership of the other cluster. Clustering is completed by approximating the objective function to the specified minimum advance value [45].

This algorithm with fuzzy logic is especially suitable for data blocks with intersecting clusters. Therefore, when color image segmentation or image reduction is performed, it is captured in transitions in the images.The algorithm works to minimize the following objective function, which is the generalization of the least squares method [46].

$$j_m = \sum_{i=1}^{N} \sum_{j=1}^{c} u_{ij}^{m} \|x_i - c_j\|^2 \tag{3.1}$$

U membership matrix is randomly assigned to start the algorithm. In the second step, the center vectors are calculated. Centers (5.2) are calculated by equation [46].

$$C_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} x_i}{\sum_{i=1}^{N} u_{ij}^{m}} \tag{3.2}$$

According to the calculated cluster centers, U membership matrix (3.3) is recalculated using the equation. The old matrix is compared with the new matrix and the operations continue until the difference is smaller than ε [46].

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\|x_i - c_i\|}{\|x_i - c_k\|} \right)} \tag{3.3}$$

The membership matrix U, which contains fuzzy values as a result of the clustering operation, reflects the result of the clustering. If desired, the results obtained in the membership matrix can be converted to values between 0 and 1 by blurring. In the Fuzzy C-Means algorithm

In the first iterations, the averages are located near the entire data set, because each point has a significant membership in each cluster.

- In the following iterations, averages are separated and each unit takes a rating between 0.0 and 1.0.
- The graded neighborhood system has disadvantages compared to the normal average when it increases consistency.
- The probability that a point is a member of cluster I depends on the number of clusters.
- If the number of clusters is incorrectly determined, serious clustering problems may occur.

Problems in Fuzzy C Means algorithm;

- The formation of similar clusters.
- Depends on the initial condition.

Problems such as the detection of the number of clusters in advance are listed by the user.

The Fuzzy C Means algorithm is summarized as follows.

- Random creation of cluster centers.

The creation of the neighborhood matrix, the random assignment of neighborhoods.

- Until the termination condition is reached.
    - Calculation of the objective function (3.1).
    - Recalculation of cluster centers (3.2).
    - Creation of membership matrix (3.3).

The matrix of the old one is compared with the matrix of the new one, and the process is terminated when the difference is less than ε.

There are many studies in the literature where the fuzzy c means algorithm is used. There are also studies in which the algorithm has been modified to increase the segmentation success or to shorten the processing time by modifying various parameters or objective functions. Some of these studies; A method has been proposed by Wang et al. [44] aimed at solving the problem of dependence on the initial values of the classical fuzzy c-means algorithms, called global fuzzy c-means. According to the proposed method, the cluster center values to be selected at the beginning are selected from the data set instead of randomly assigned as in the conventional BCO algorithm. Judging from the results, it is seen that the method has its dependence on the initial value and gives the same result every time it is run [44]. In a study using the classical fuzzy C Means algorithm by Kalaiselvi et al. [46], initial values of cluster centers were assigned based on histogram rather than random selection. In the proposed method, the initial values of cluster centers are assigned by equally dividing the largest and smallest cluster center values by 255 and 0, respectively, with respect to the number of picks between 0 and 255 in the intermediate region histogram. The method was applied to magnetic resonance imaging of the brain and consequently a shortening was observed in the procedure. In another study [47] by Shasidhar and colleagues aiming to shorten the processing time, the number of data is reduced by the data compression technique (quantization / aggregation) and the processing time is shortened accordingly. Hwang and Rhee [48] have adapted the interval type-2 approach to the classical FCM (fuzzy C Means) algorithm in another work they do. The uncertainty of the blurriness constant (m) is emphasized in the study and the membership function is represented by an interval for two different m values. Accordingly, the cluster center updates are also made using Karnik-Mendel algorithm for a range. Thus, it is aimed to obtain more efficient results in clustering clusters with different volumes and densities. This proposed algorithm is used for two different image segmentations with four widely used data sets and efficient results are obtained.

CHAPTER 5

EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Proposed Method

In this study, the application of the Level Set Function, which has many different usage areas, on image processing will be examined. In addition, the cluster image segmentation was performed with the Modified Fuzzy C-Mean Algorithm. In application, segmentation was performed by applying median filter for removing the vessel algorithm on images for detection of optical disc in retinal images. In this part of the work, Level Set algorithms explained.

5.1.1 Level Set Algorithm

The idea of the Level Set function, known as the level set, was first shown by Osher and Sethian for the numerical solution of functions for time-dependent moving objects by the Hamilton-Jacobi approach [49]. The level set function (LSF) has been developed to solve high-dimensional functions. The level set algorithm [49] has been used in many areas such as fluid dynamics, computational geometry, computer vision and image processing, after Osher et al. Another vantage of the Level Set function is that it can represent and manipulate the complex topology environment. In this way it is possible to handle division, merging, and naturally topological changes at the same time. Another feature is that the level set function can be computed numerically. It is also a preferred method because it can adjust the level set without having to constantly parameterization on a Cartesian grid. Because of these superior features, level set methods have improved their application to a large extent. There are also many studies in the field of image segmentation that have achieved successful results using the level set algorithm [4, 50-52].

Level set function can segment for a long time due to reaching high number of iterations despite these common usage areas. Due to this disadvantage of level set algorithm in our study, clusters have been formed by applying Fuzzy C-Mean algorithm in our study. Thus, the number of iterations in the operation of the level set function is reduced by selecting the best fit from the set of images instead of scanning the whole image.

5.1.2 Level Set Function

The spatial parameter s in the level set function indicates the time zone between [0, 1] and t in the range [1, ∞). Curve development due to these parameters,

$$FN = \frac{\partial C(s,t)}{\partial t} \quad (5.1)$$

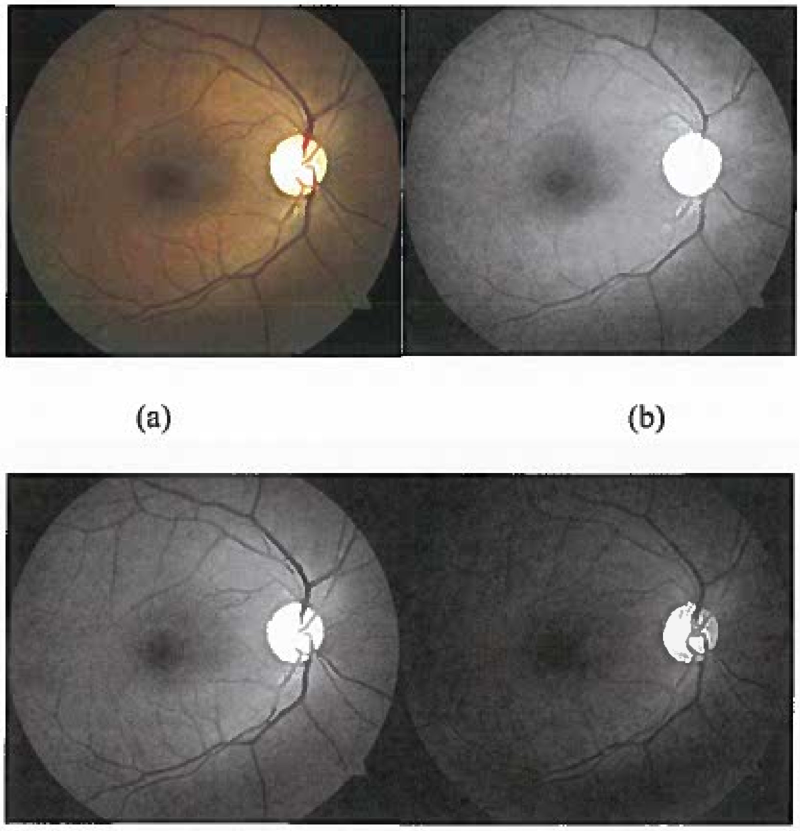
where F denotes to the speed function that provides motion control for the F-space and N is the inner normal vector of the surrounding vector.

Here, if the curve development is transformed into the level set function in the formula (4.1), the dynamic environment C (s, t) turns into a time-dependent zero-level Set function, ie, Φ (x, y, t). It is supposed that the level set function receives negative values in the environment and positive values in the environment.

In this study, it was aimed to denote the site of the optical disc which constitutes the basic and first step of many studies aiming at diagnosis and recognition of many common retinal diseases. Optical disk identification, detection and measurement of retinal parameters are also very important for the automatic diagnosis of retinal diseases and detection of optical disk;

- Remove the vein web as it creates a starting point in the vein web
- In determining the reason for the fixed distance with the Macula.

- Optic disk has importance in facilitating the detection of degenerations by elimination.
- To provide doctors with a helpful tool to ease their workload in their daily lives.
- Prevention of losing of work power.
- Get detailed statistical information on the obtained images.
- Locating, segmentation on retinal images taken at different times and making early diagnosis and diagnosis by using this information.
- The optical disc localization and segmentation method presented in our study consists of three basic operations:
- According to the different image resolution, the optical disk location is estimated,
- Fuzzy clustering algorithm is applied to pixel clustering in optic disk.
- The optical disk boundaries are determined by the level set algorithm.
- These steps will be elaborated later in the work. Generally, retina images have a green channel to detect veins (Fig. 5.1).



(a) (b)

(c) (d)

Figure 5.1 (a) Original retinal image, (b) Red channel, (c) Green channel, (d) Blue channel (MESSIDOR database)

In the optical disc positioning and segmentation stages, the red channel is generally preferred. Figure (5.1-b) shows the red channel, where the optical disc is shown more clearly and clearly. For this reason, a red channel is usually selected for optic disk. However, in some retinal images this channel preference may vary according to the image properties in the database we use for optical dystrophy detection. The red channel was selected because the optical disc showed clearer and clearer image in the work we did. Optical disinfection is the step number one that must be applied for partition. Most techniques to analyze the retinal image are in the literature. These can be arranged as those who perform only optical disc localizations and those that perform with segmentation. Hoover and colleagues have developed a method for optical disc localization based on the finding of fusion of blood vessels. As a result of the absence of a reliable convergence, the algorithm will identify the brightest region in the image as the location of the optical disk [21]. In our study, both localization and segmentation were applied on retinal images in MESSIDOR and DRIVE databases for optical disc detection. MESSIDOR database images are obtained with a 45 FOV (field of view) resulting in a retina area of 124.8 mm2 [53].

5.2 Optical Disc Location Estimation

The algorithm flow diagram for estimating optical disk location is as in figure 5.2.

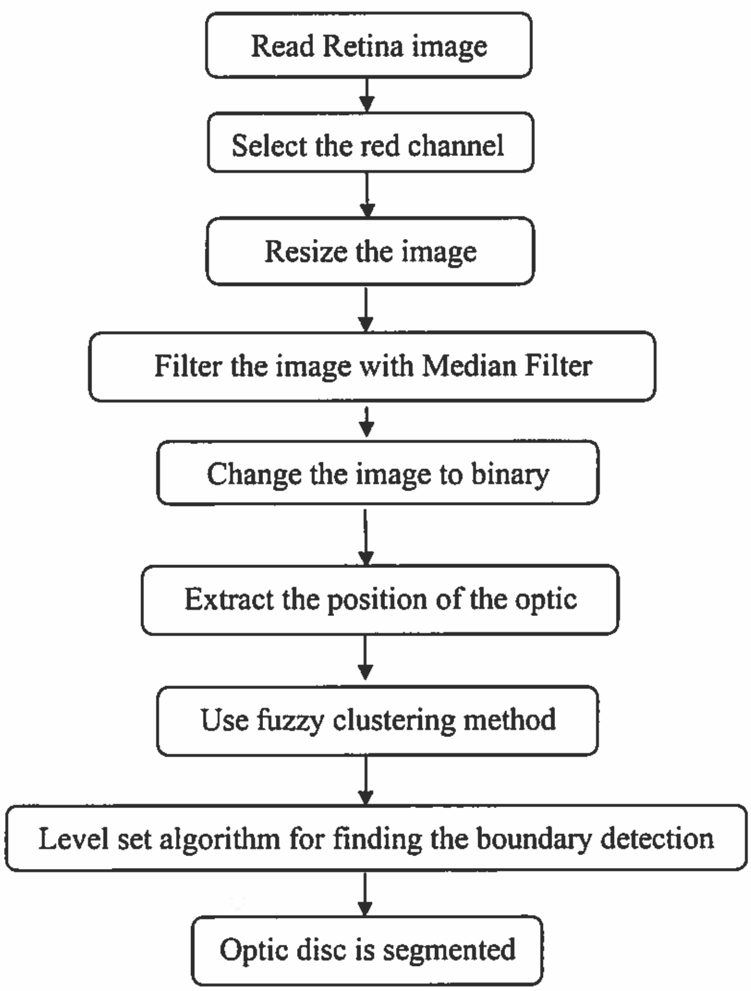


Figure 5.2 The flow diagram for optic disc localization

As seen in the flow chart, first the retinal image is read from the database and then the veins are removed from the image. Dimensions are reduced to 256 * 256 because images are larger in size. Morphological operations have been implemented to remove the veins. This process is to improve the view, to remove the roughness, to remove the noise from the center. The most commonly used filter to eliminate noise on the image is the median filter. The basis of this filter is to place nearby pixels at the desired pixel average. Since linear smoothing filters of the same size have more complexity, this leads to blurring on the image, so the median filter is used in this study. In addition, the median filter can filter out the sharp edges of the retina without blurring it. Essentially, the median (mask) filter modifies the average amount the pixel of the image f(x,y) by the averaging of wholly nearby pixels (equation 4.1).

$$f_{med}(x,y) = median\{f(s,t)\}, \quad (s,t) \in W_{xy} \tag{5.1}$$

Where W denotes to the neighboring center locations (x, y) in the image. Figure (5.3) displays the effects of performing the median filter on the light intensity of the retina image.

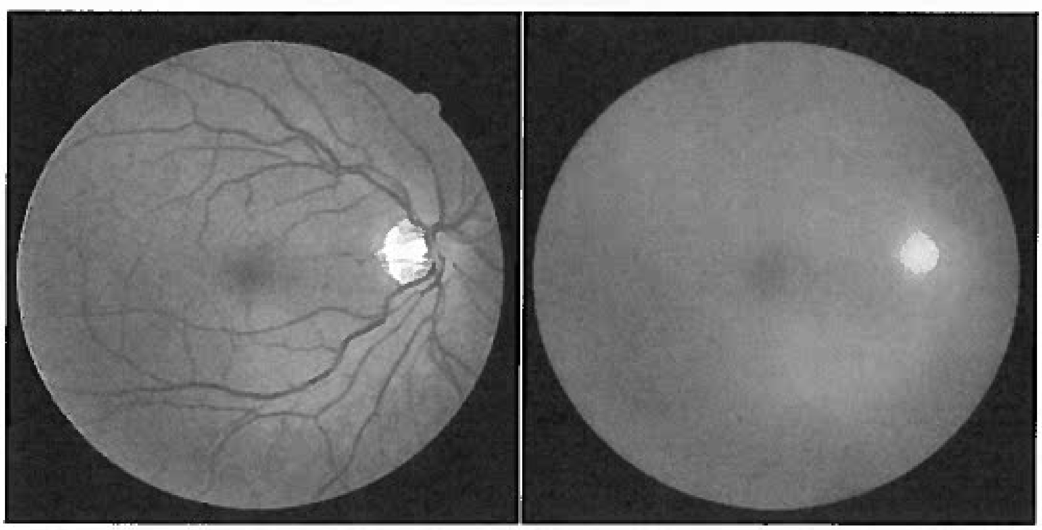


Figure 5.3 (a) Basic retinal image (gray level image), (b) Result image after filtration (MESSIDOR database)

After applying this filter, we convert the image to binary image using the result obtained with Otsu method. Then the estimate of the location of the optical disc is found.

5.3 Fuzzy Clustering Algorithm

The Fuzzy C Means algorithm is summarized as follows.

- Randomly generated cluster centers.
- Generate the neighborhood matrix, assign neighborhood ratios randomly.
- Until the termination condition is reached, the objective function is calculated recalculated cluster centers.

Create membership matrix

The matrix of the old one is compared with the matrix of the new one, and the process is terminated when the difference is less than ε.

The median filter is performed on the image of the optical disc location, and then the image must be exchanged into one-dimensional array. The fuzzy clustering algorithm is applied on this array so that the member function is obtained. The number of clusters in this study is denoted by the user and the number of clusters is specified as 3 in this study.

The standard deviation is calculated after the member function is obtained. The standard deviation is specified as the largest set of optical discs with the greatest clearness. The image obtained in this stage is given as input to the level set algorithm. Then, the gradient method is used to obtain the edges of the original image. Gradient edge-based algorithm is used for this step. Gradient edge-based algorithm is preferred because it has less complexity than other algorithms.

The Level Set contour model is applied to the image obtained after this step. The level set algorithm used in this phase is the edge-based Level Set algorithm. After these operations are applied, optical disc boundaries are found.

Table 5.1 Experimental results

Image	True Positive	True Negative	False Positive	False Negative	Accuracy
1	0.431099	1	0	0.568901	0.835797
2	0.872028	0.994326	0.005674	0.127972	0.947326
3	0.381833	1	0	0.618167	0.793335
4	0.623963	1	0	0.376037	0.890352
5	0.87963	0.984742	0.015258	0.12037	0.948132
6	0.936803	0.971267	0.028733	0.063197	0.961301
7	0.384959	1	0	0.615041	0.778017
8	0.954512	0.986566	0.013434	0.045488	0.979257
9	0.474635	0.963643	0.036357	0.525365	0.810804
10	0.871442	0.946809	0.053191	0.128558	0.924751
11	0.510975	0.959334	0.040666	0.489025	0.822091
12	0.52751	0.818857	0.181143	0.47249	0.716731
13	0.337349	1	0	0.662651	0.778285
14	0.60356	0.993561	0.006439	0.39644	0.864015
15	0.953829	0.984803	0.015197	0.046171	0.977267
16	0.666986	0.972347	0.027653	0.333014	0.88659
17	0.922401	0.965693	0.034307	0.077599	0.952592
18	0.610487	0.998743	0.001257	0.389513	0.859446
19	0.411052	0.993333	0.006667	0.588948	0.786617
20	0.596786	0.999575	0.000425	0.403214	0.851384
Average	**0.6476**	**0.9767**	**0.0233**	**0.3524**	**0.8682**

As seen in the figure (5.4) the dark blue color shows the True Positive percentage result. The maximum value for this database is got for image 8 and this value is 0.954512, the lowest result is got for image 13 and this value is 0.337349. The Celestial color shows the True Negative percentage result. The maximum value for these database is got for image 1, 3, 4, 7 and 13 which the this value is 1, the lowest result is got for image 12 and this value is 0.818857. The green color shows the False Positive percentage result. The maximum value for these database is got for image 12 which this value is 0.181143, the lowest result is got for image 1, 3, 4, 7 and 13 which the this value is 0. The orange color shows the False Negative percentage result. The maximum value for this database is got for image 13 which this value is 0.662651. The lowest result is got for image 8 which this value is 0.045488. Dark red color shows the accuracy.

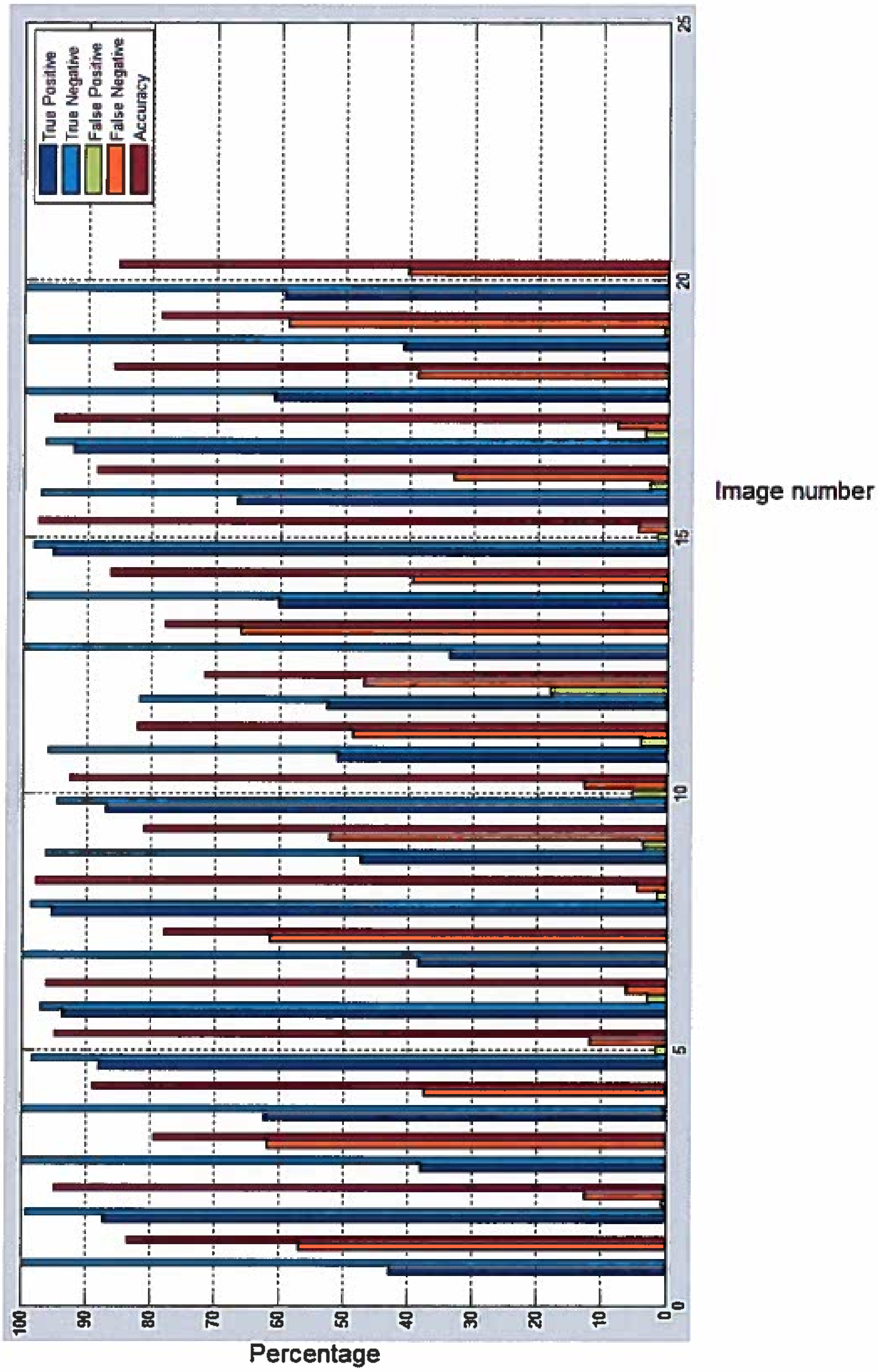
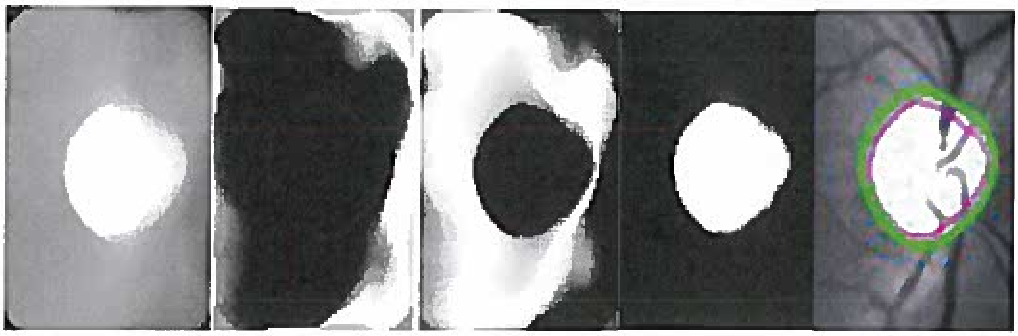


Figure 5.4 Experimental results

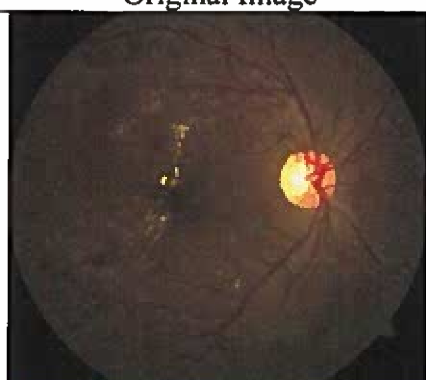
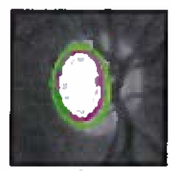
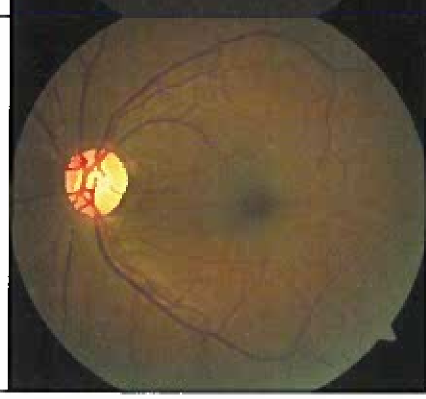
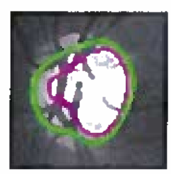


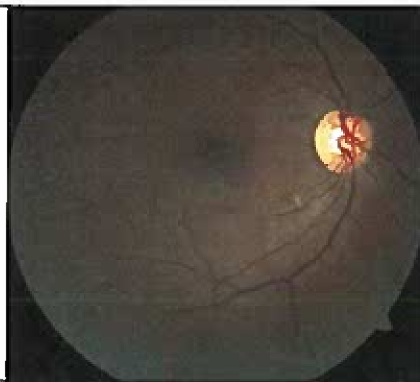
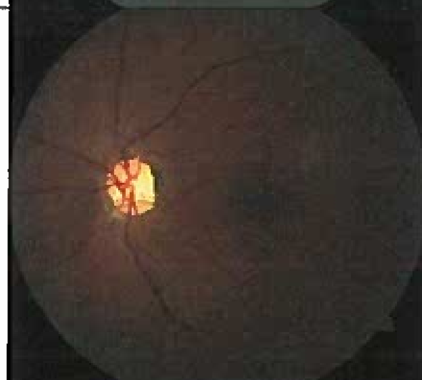
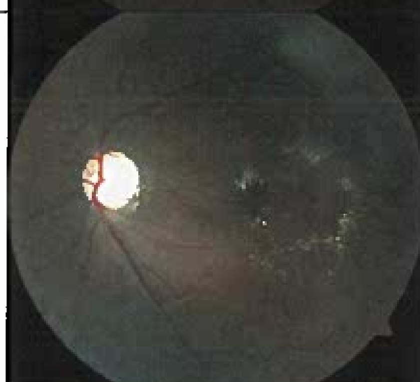
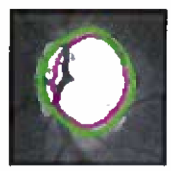
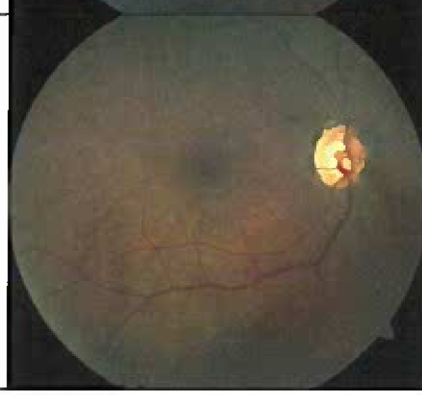
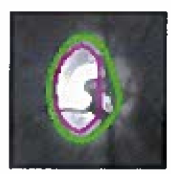
(a) (b) (c) (d) (e)

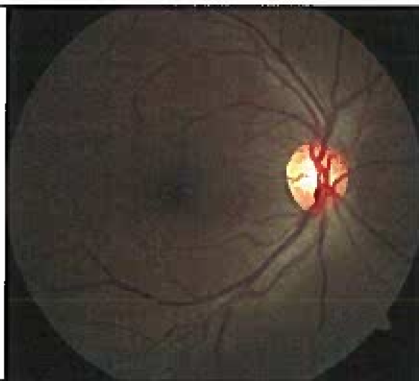
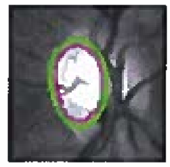
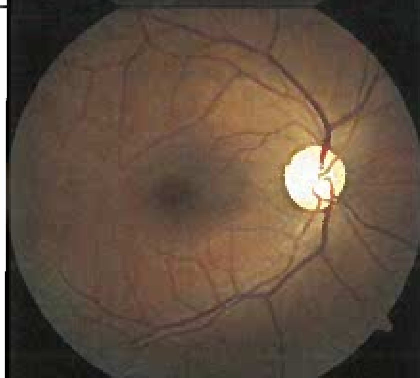
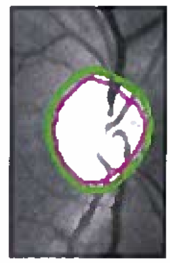
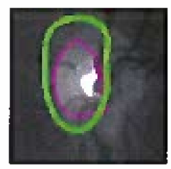
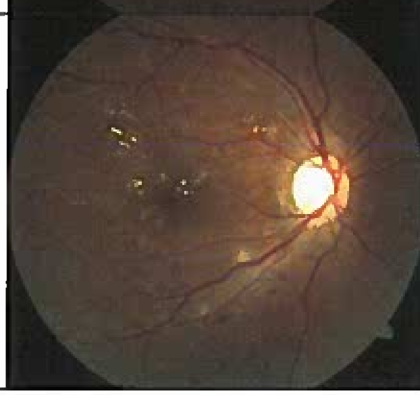
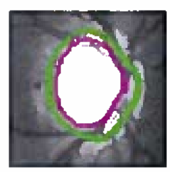
Figure 5.5 Result for image 8 in database, (a) Gray level image, (b) First cluster, (c) Second cluster, (d) Forth cluster, (e) Final result

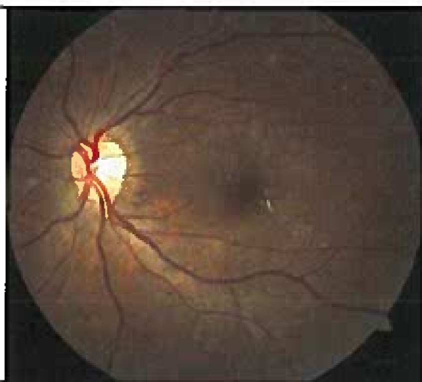
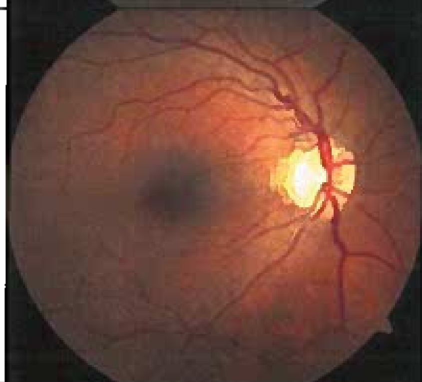
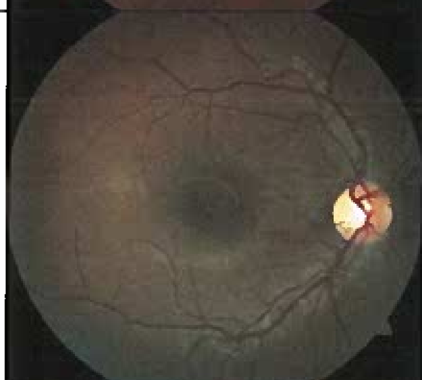
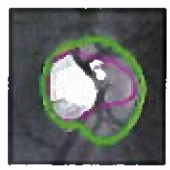
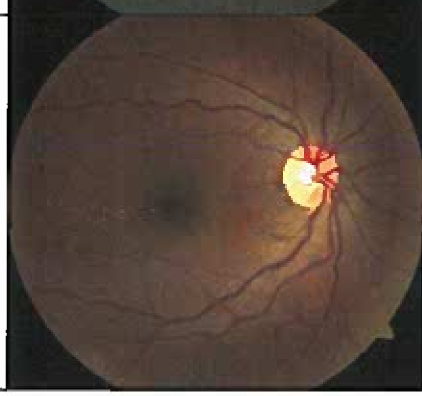
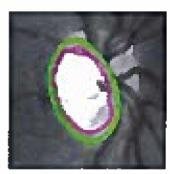
The results for 20 images of database are illustrated in table 5.2.

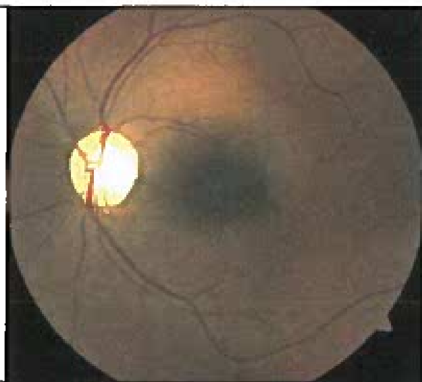
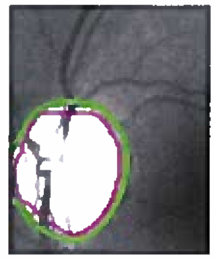
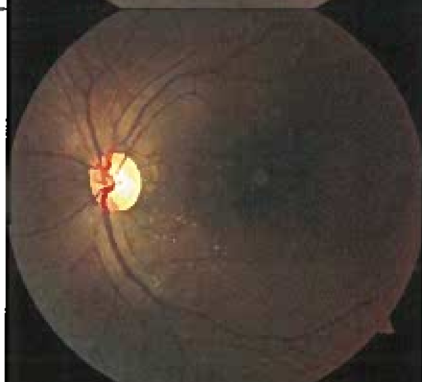
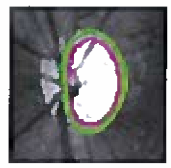
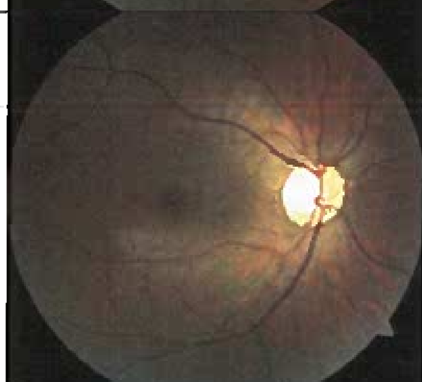
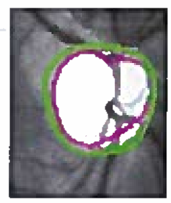
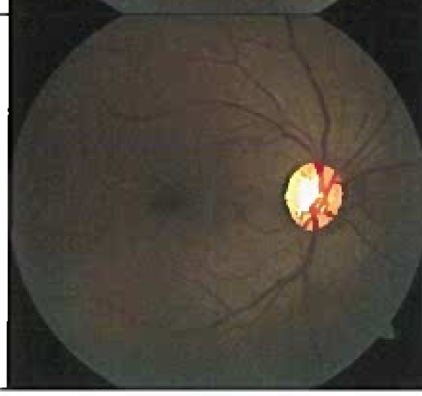
Table 5.2 Results for 20 images of database

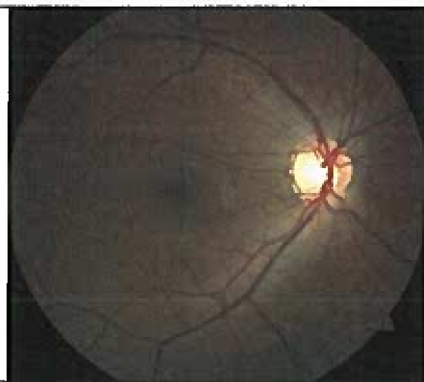
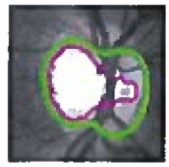
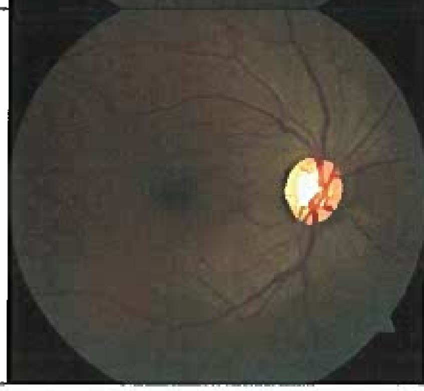
Image number	Original Image	Segmentation result
1		
2		

3		
4		
5		
6		

7		
8		
9		
10		

11		
12		
13		
14		

15		
16		
17		
18		

19		
20		

As shown in this table the images have two results, the magenta color shows the beginning of the contour and the green one shows the final result of the evolution.

The comparison of our result and other papers are shown in table 5.3.

Table 5.3 Localization results in literatures.

Localization methods	Accuracy
Aquino et al. (2010) [1]	0.86
Yu et al. (2012) [54]	0.83
Morales et al. (2013) [55]	0.823
S. Roychowdhury (2016) [7]	0.84
LSFCM Method (Our method)	**0.8682**

As shown in this table the method which is proposed has high accuracy than the other methods and we got 0.8682. Aquino et al. (2010) [51] presents a template-based methodology for optic disc segmenting. Their methodology uses morphological and edge detection techniques which based on the Circular Hough Transform for getting the circular OD boundary. In their method they got the true OD regions of 86%. Morales et al. (2013) [54] proposed a mathematical morphology with principal component analysis (PCA) for the extraction of the optic disc contour. In their method they got the true OD regions of 82%. S. Roychowdhury (2016) [53] used a classification method for OD segmentation. In first step they used the circular structuring element for green channel and they resized the image. Then the bright regions are removed from the morphologically reconstructed image. After that, they used the six region features and a Gaussian mixture model classifier. In their experimental they got 84% accuracy percentage. Yu et al. (2012) [52] used matched filter based on the level set method and they got 0.84 percentage for optic disc segmentation. In the first step they identified the location of the optic disc by template matching. After that the vessel characteristics on the optic disc are used to decide the optic disc location.

CHAPTER 6

CONCLUSION

The field of biomedical image processing has evolved into an area that has been working on it in recent years with the development of technology and is expected to be observed much more clearly all over the world in the near future. One of the areas that the biomedical image processor has recently been interested in is retinal images. High resolution retinal images at most clinical sites provide features that can be used in the diagnosis and treatment of many diseases.

In diabetic retinopathy optic disc is very important part in human eyes. The finding of optic disc in retinal images is the important steps in ophthalmology operations. In this thesis we did the optic disc segmentation and localization. In this thesis a new method implemented to localization and segmentation of optic disc in human retina images. As we estimated this method was very fast and simple iterative with convergent. Also, this new method can find the boundary of optic disc by an initial fuzzy clustering means algorithm. For database we used MESSIDOR database which available in the world open source database. In proposed method we used the H-minima transformation to find the location of the optic disc in retinal images. The result will compare to various methods which available in the literature, and it is concluded that the new method is more accurate and time efficient than the existing methods. In this thesis we will combine the fuzzy and morphological operation for getting the high accuracy and get the fast processing time.

The aim of this study was to determine and segment the position of the optical disc, which constitutes the basic and first step of many studies aimed at diagnosing many common retinal diseases. Optic Disc is not only diagnostic of disease, but also Optical Disc relates to retinal vascular distribution and orientation, such as micro-aneurysm, intraregional micro vascular abnormalities and neovascularization. In addition, since the veins in the optical disc differ from person to person, it can be done by working on identification. Application of optical disk macular distance, area estimation of cup area, and diagnosis of disease can also be improved.

The purpose of this study is to automatically detect and segment the optical disk location in retinal images that have been extensively investigated. In this study, algorithms such as level set algorithm was applied to retinal images to detect optical disc which has a very complex structure and which has a very important place in diagnosis such as diagnosis and diagnosis, vascular diseases detection, vein removal. Successful results have been achieved. In addition, the clustered optical disk partition created by the modified Fuzzy C-Mean Algorithm will be done. This optical disc segmentation application will be performed with the fundus retina images and the iteration counts, study time and segmentation quality are investigated according to the Fuzzy C-Mean Algorithm, the Modified C-Mean Algorithm and the method recommended in the study. The Level Set algorithms proposed for this are applied to the images in the MESSIDOR database.

In the literature studies done, optical disc detection and segmentation are very important for disease detection based on these analyzes. Therefore, methods developed for detecting optical disc should always be improved, more effective and more successful methods should be developed in undesirable situations such as degeneration in retinal images, decrease in image quality.

The retinal fundus images used in the study were obtained from the MESIDOR databases, which are publicly available on the internet. Since this database is open to the public, there will be no problems in using these data sets.

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APPENDIX

Matlab code

Matlab code for Evolution function

```
function phi = Evolution(phi_0, g, lambda,mu, alfa, epsilon, timestep, iter)
phi = phi_0;
[vx, vy] = gradient(g);
for k = 1:iter
   phi = NeumannBoundCond(phi);
   [phi_x,phi_y] = gradient(phi);
   s = sqrt(phi_x.^2 + phi_y.^2);
   smallNumber = 1e-10;
   Nx = phi_x./(s+smallNumber);
   Ny = phi_y./(s+smallNumber);
   curvature = div(Nx,Ny);
   distRegTerm = Regular(phi);  % (3)
   diracPhi = Dirac(phi,epsilon);
   areaTerm = diracPhi.*g; % balloon/pressure force
   edgeTerm = diracPhi.*(vx.*Nx+vy.*Ny) + diracPhi.*g.*curvature;
   phi = phi + timestep*(mu*distRegTerm + lambda*edgeTerm + alfa*areaTerm);
% (6) ve (8)
end
```

Matlab code for Regular function

```
function f = Regular(phi)
[phi_x,phi_y] = gradient(phi);
s = sqrt(phi_x.^2 + phi_y.^2);
a = (s>=0) & (s<=1);
b = (s>1);
ps = a.*sin(2*pi*s)/(2*pi)+b.*(s-1);  %(4)
dps = ((ps~=0).*ps+(ps==0))./((s~=0).*s+(s==0));  %  (2) ve (5)
f = div(dps.*phi_x - phi_x, dps.*phi_y - phi_y) + 4*del2(phi);  % (1)
```

Matlab code for Neuman Boundary function

```
function g = NeumannBoundCond(f)
```

```
% Make a function satisfy Neumann boundary condition
[nrow,ncol] = size(f);
g = f;
g([1 nrow],[1 ncol]) = g([3 nrow-2],[3 ncol-2]);
g([1 nrow],2:end-1) = g([3 nrow-2],2:end-1);
g(2:end-1,[1 ncol]) = g(2:end-1,[3 ncol-2]);
```

Matlab code for Dirac function

```
function f = Dirac(x, Epsilon) % (7)
f = (1/(2*Epsilon))*(1+cos(pi*x/Epsilon));
b = (x<=Epsilon) & (x>=-Epsilon);
f = f.*b;
```

Matlab code for Div function

```
function f = div(nx,ny)
[nxx,junk] = gradient(nx);
[junk,nyy] = gradient(ny);
f = nxx+nyy;
```

CURRICULUM VITAE

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