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Detecting Blood Vessels in Eye Image Using Fuzzy Neighbors Rules

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Abstract

In this study, fuzzy neighbors rules are exploited to detect blood vessels in eye image. For this purpose a three level algorithm is utilized which includes preprocess, fuzzy system and post-process. A preprocess is needed to be performed in order to eliminate optical disk segment and FOV before applying fuzzy algorithm. Afterwards, vessels are detected using a fuzzy algorithm and presented rules for fuzzy set. Finally, applying complementary morphology operation improves segmentation. Images used in this article are chosen from eye image bank of DRIVE database including 10 retinal images. Obtained results demonstrate that proposed algorithm has suitable performance. The average of accuracy parameter of 10 images is derived 93%.

Keywords*:* blood vessel, fuzzy logic, eye image, edge detection

1. Introduction

Retinal is a prominent component of visual system in human. Retinal image of a healthy person consists of blood vessel patterns, optical disk, background and FOV region. An example of retinal image is depicted in figure 1.

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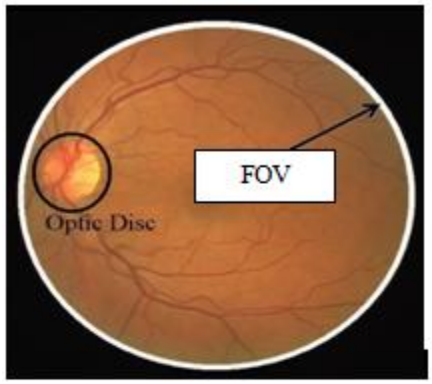

Figure1: Retinal image of an eye

Uniqueness of blood vessel patterns in retinal images were firstly introduced by two ophthalmology specialists Dr. Carleton Simon and Dr. Isodore Goldstein in an article which was published in 1935 [1]. They believed that distribution pattern of blood vessels in retinal of each human or even animal is unique. Then, in 1978 Hill introduced retinal as a biometric element and patented identification via retinal images [2].

To take retinal images, retinal scanners are utilized. Retinal scanner uses intrinsic properties of optical reflection and absorption in eye to depict pattern of retinal vessels. To do so, retinal is exposed to a light beam and its reflection to scanner is recorded. The dark points of output image are blood vessels which absorb larger portion of light. Usually retinal diameter is about 40 mm and average diameter of vessel is 250 um [3]. Vessels are darker than background in retinal image. In literature, image green channel is commonly utilized as it provides more contrast between vessels and background in comparison with other channels [4]. Images exploited in this study are taken from eye image bank of DRIVE database [5]. A significant point regarding DRIVE database images is that the vessels are specified manually. Figure 2 illustrates image number 1 of this database and the image which is segmented by an expert.

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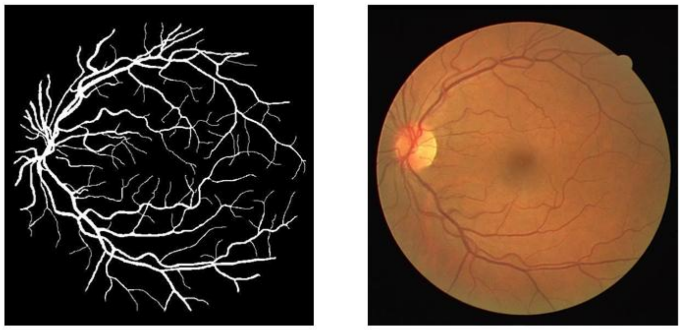

Fig.b **fig.a**

Figure2: a. Shows retinal image and b. manually derived vessel patterns

In addition to main retinal image and image of vessels extracted by two experts, this database also includes images extracted by other researchers such as Niemeijer [6], Jiang [7], Chaudhuri [8], Staal [9], Perez [10] and Zana [11]. Teng et al have exclusively studied on methods for detection of vessels in retinal images. This study was conducted in 2002. They divided detection techniques into 4 groups including local operators, matched filters, vessel tracking and artificial neural network [12]. Dua et al proposed a technique based on edge detection for vessel detection [13]. Estabridis et al utilized local Radon transform for detection [14].

2. Fuzzy inference system

A fuzzy system consists of four segments: Fuzzy rule base, fuzzy inference engine, fuzzifier and defuzzifier. In fact, to interpret fuzzy rules set inputs need to be fuzzified which means that input variables should take a value between 0 and 1. In the next step, if-thhen fuzzy rules should be combined using fuzzy inference engine and outputs must be calculated. Then, outputs are aggregated using logical operators and finally outputs are defuzzified.

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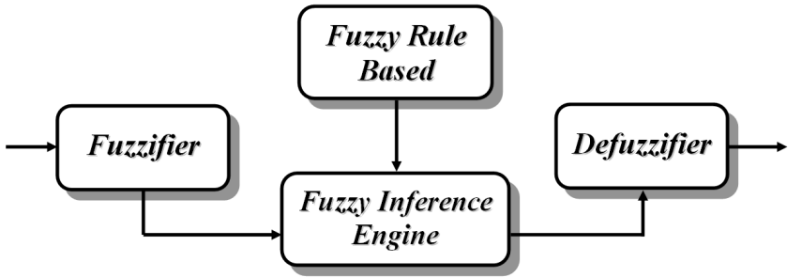

Figure 3: Main structure of a fuzzy system

Principal steps for employing fuzzy logic are as follows:

1) If-then fuzzy rules: stating the problem based on inputs, assumptions and outputs in the form of if-then fuzzy rules is the first step. The more precisely defined rules, the better system performance.
2) Inputs fuzzification: The corresponding fuzzy value for each input is calculated. This will be performed through mapping input to [0,1] interval. This mapping is done using fuzzy membership function (fuzzy set) of each rule.
3) Applying necessary fuzzy operators: the output of conditional parts of fuzzy rules should be combined using AND and OR operators to achieve one value. The number of conditional segments of logical operator which are utilized for connecting segments might be different in each rule.
4) Applying a fuzzy inference method: in this step antecedent output (if) of each rule is utilized to generate the corresponding output of that rule by fuzzy inference engine. The output of each rule is a fuzzy set. These outputs should be aggregated to provide one output fuzzy set.
5) Defuzzification of final output set: there are several methods for defuzzification and obtaining the output. One of the most popular one is calculating center of gravity of fuzzy set.

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3. Problem solving algorithm

The algorithm includes three parts; pre-process, FIS and morphology. Algorithm block diagram is demonstrated in figure 4.

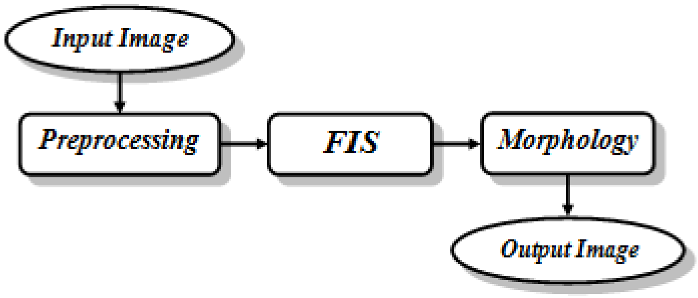

Figure 4: Algorithm block diagram

Each of three stages is investigated separately in the following. To exemplify resulted image of each stage for a few images of DRIVE database are shown as well.

First stage: Preprocess

Due to several issues retinal images force us to perform a multi-level preprocess. These issues are as follows:

- Low contrast between vessel and background
- Optical disk
- Noise
- FOV segment

By preprocessing we aim to eliminate or damp the effect of above mentioned issues before we attempt to apply algorithm to images. Retinal images format is RGB and G channel has the highest contrast. This fact is mentioned in some publications such as [12] and [13]. Therefore, G channel is needed to be detached from image and processed separately.

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Second stage: FIS system

Subsequent to preprocessing of image, the result is exposed to a fuzzy algorithm to segment the vessels. For this purpose the algorithm discussed below is employed. This algorithm is based on determining fuzzy neighbor features. These features specify what the rules are going to detect. Here, boundary detection fuzzy algorithm is supposed to be generated. A general fuzzy rule states that if a pixel belongs to a uniform segment, make it white; otherwise, change it to black. Here black and white are fuzzy variables. To demonstrate fuzzy concept of uniform segment, difference of brightness between central pixel in a neighborhood and the neighboring pixels might be considered. In 3x3 neighborhood of figure 5.a difference of central pixel, z_5, and each neighboring pixel create a sub-image in figure 5.b where d_i is difference between i[th] neighbor and central pixel i.e. $d_i = z_i - z_5$ where z_i are intensity values.

d_1	d_2	d_3
d_4	0	d_6
d_7	d_8	d_9

b

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

a

Figure 5: a. 3x3 neighborhoods and b. intensity difference between central pixel and pixels in neighborhood

Four if-then rules and one else rule implement mentioned fuzzy expression:

$IF\ d_2\ is\ zero\ AND\ d_6\ is\ zero\ THEN\ z_5\ is\ white$

$IF\ d_6\ is\ zero\ AND\ d_8\ is\ zero\ THEN\ z_5\ is\ white$

$IF\ d_8\ is\ zero\ AND\ d_4\ is\ zero\ THEN\ z_5\ is\ white$

$IF\ d_4\ is\ zero\ AND\ d_2\ is\ zero\ THEN\ z_5\ is\ white$

$ELSE\ z_5\ is\ black$

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Where “zero” is also a fuzzy set. The result of each rule defines a value to which the central pixel (z_5) is mapped. Thus, $"THEN\ z_5\ is\ white"$ means that intensity of pixel which is located in the center of neighborhood is mapped to white. These rules point out that if the intensity difference is “zero”, central pixel is in the uniform segment and otherwise it is a black (boundary) pixel.

Third stage: morphology

After implementation of FIS on image, it is promoted using a series of morphological operations in order to optimize segmentation.

4. Simulations

The designed algorithm is applied to 10 images of DRIVE database. Figure 6 shows fuzzy rules of above algorithm.

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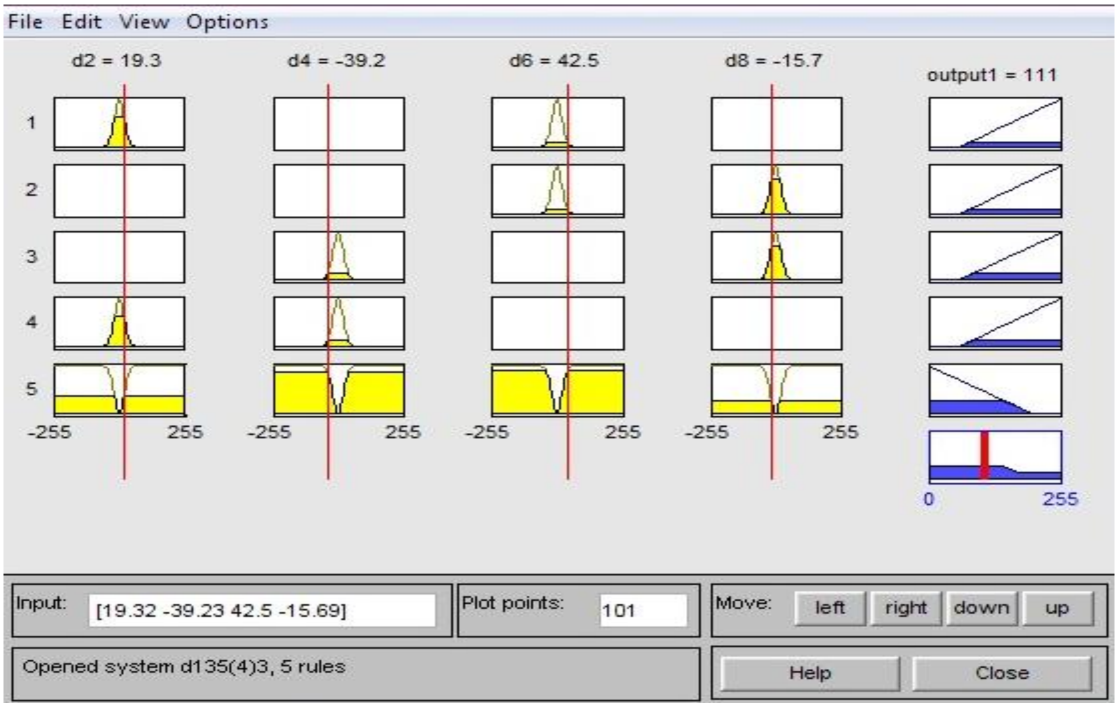
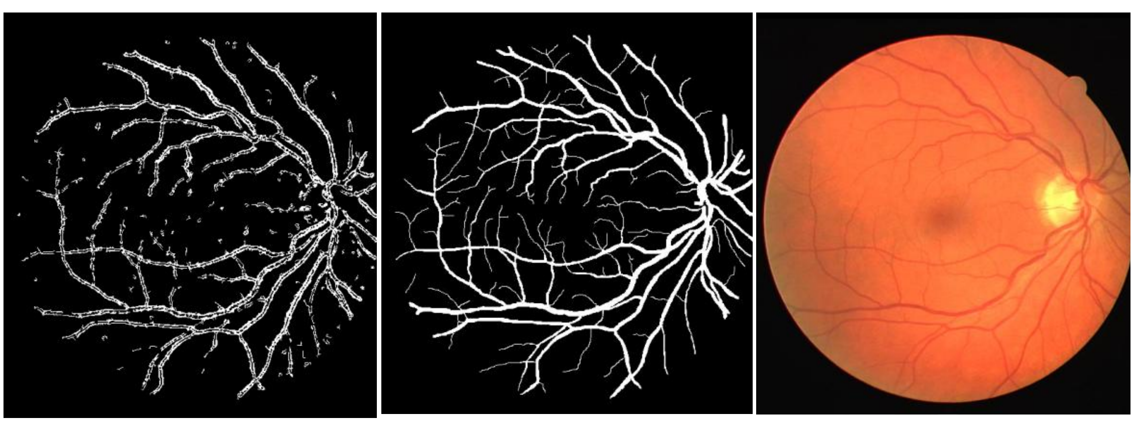


Figure 6: Fuzzy rules display

Figure 7 depicts image number 2 from database together with manual image and fuzzy output image.



c b a

Figure 7: a. Image number 2 of DRIVE database, b. its manual image and c. fuzzy image

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Researchers usually use accuracy parameter for evaluation. This parameter illustrates how much the researcher was successful in vessel detection. To define this parameter four quantities must be introduced including True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN). Since pixels of segmented image (result) are divided to two classes, vessel (1) and non-vessel (0). Above mentioned parameters are described in the following. Moreover, the approach to achieving each of them is explained.

TP parameter:

Definition: number of pixels in result image which are correctly detected as vessels.

To obtain this parameter for each image, reference segmented image must be utilized. Assume that reference and result images are denoted by A and B, respectively. The method is as follows; corresponding pixels in A and B are compared in whole image and the number of states where A=1 and B=1 are counted. The derived number is TP.

FP parameter:

Definition: number of pixels in result image which are incorrectly detected as vessels.

To derive this parameters states where A=1 and B=0 are counted.

TN parameter:

Definition: number of pixels in result image which are correctly detected as non-vessels.

To derive this parameters states where A=0 and B=0 are counted.

FN parameter:

Definition: number of pixels in result image which are incorrectly detected as non-vessels.

To derive this parameters states where A=0 and B=1 are counted.

Obviously, the lower FP and FN values, the better segmentation is performed.

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Accuracy parameter

According to mentioned facts, accuracy parameter denoted by ACC is defined as follows

$$Acc = \frac{TP + TN}{TP + FP + TN + FN}$$

In the ideal conditions, when segmentation exactly matches reference segmentation, this parameter will equal to 1 (ACC=1). The proposed algorithm is applied to 10 images from DRIVE database and the segmentation of vessels is performed in these images. Accuracy parameters derived for each image are presented in table 1. In the last row of this table average value of these parameters is calculated so that it could be considered to compare our proposed method to other methods.

Table1: Accuracy parameter for 10 images from DRIVE database

Number of figure	Acc parameter
1	0.922
2	0.924
3	0.921
4	0.931
5	0.929
6	0.923
7	0.927
8	0.930
9	0.933
10	0.932
Average	0.930

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Conclusion

In this article a method based on fuzzy neighbors is proposed to extract blood vessels in eye image. The algorithm is implemented using MATLAB7.8 software (lap top whit RAM:4G, CPU:2.3G) and it takes 6 seconds for each image which is considered a proper process speed. The precision of this method is averagely 93% which is acceptable. Considering precision the proposed algorithm is categorized as high speed algorithms. Conventional algorithms face challenges regarding elimination of optical disk boundary effect and FOV segment. These parameters are considerably eliminated in our method. The simulation results confirm accuracy of our proposed method so it might be exploited for process of other medical images.

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