Extraction and Digitization Method of Blood Vessel in Sclera-conjunctiva Image

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Summary
This paper presents 1) algorithms for blood vessels extraction in sclera-conjunctiva images, which can be applied in syndrome differentiation by observing human eyes (named Ocular Diagnostic in Traditional Chinese Medicine); 2) digitization of extracted vessels. First, sclera-conjunctiva region is isolated by optimal threshold segmentation and mathematical operation ; Scanning and edge detection methods are used to gain the edge of the blood vessels. Moreover, the edge feature parameters are gained, which can be used to reconstruct the blood vessels. Experimental results show that the algorithms can obtain blood vessels information fast and accurately.

Key words:
blood vessel in sclera-conjunctiva region; pseudo vessel; digitalization technology; edge analyze; feature parameter in edge;

1. Introduction

Blood vessels as a promising biometric feature have drawn lots of researches in Traditional Chinese Medicine (TCM). Blood vessel owns many outstanding characteristics, such as branches detection and hard to forgery [1] [2]. These days, the digitalization of Chinese medicine diagnoses has becoming a hot topic in TCM and computer communities with recent progress of electronic and computer technology [7]. "Differentiation of syndromes by observing eyes" is one kind of diagnosis by looking into eyes, which searching the changing of the Sclera-conjunctiva region and the state of its vessel [2]. This diagnosis method collects the features of Sclera-conjunctiva (especially the vessel feature) to discriminate the diseases in the whole body. The digitalization of "Differentiation of syndromes by observing eyes" can help to build an objective and quantitative diagnostic standard for TCM [7].

In recent researches, there are a lot of methods applied in medical image processing, such as edge detection, region growing, mathematical analyze, snakes, level-sets and so on. Particularly, in blood vessel extraction, ZHU Guidong et al. proposed an automatic vessel extraction for Sclera-conjunctiva images based on exploratory tracking [3], which successfully isolate the Sclera-conjunctiva region and extract the blood vessels in it. However, it lacks supporting the reconstruction of information of blood vessels.

Vessel segmentation is very important in an automatic processing system for Sclera-conjunctiva images. Incomplete vessel removal usually causes a false positive in detection. Sukritta et al. proposed a segmentation method based on fractal dimension in spatial-frequency domain [9].

However, there is not so much researches focus on establishing digital vessel model applied on TCM diagnosis.

In this paper, we propose a scanning method for extracting the blood vessels successfully, and give an original solution for pseudo vessel removal in order to decrease the false positive in detection. We also propose a digital vessel model by using several setting feature parameters for reconstructing the blood vessel, which can be used in further medical researches.

Section 2 introduces the process from the true-color image to binary image in sclera-conjunctiva region of eye as a preprocessing for further research. An original vessel removal method is proposed. Section 3 introduces our parameters for digitization. The experiment results are shown in Section 4. Section 5 presents discussion and conclusion.

All our experiments are implemented on MATLAB environment.

2. Transformation from true-color image to binary image in Sclera-conjunctiva region

In the research of medical image processing, usually we will do some preprocessing on the target image before formal process, in order to short cut the processing time, improve the performance and so on. For these reasons, there is no exception in our case. In this section, the following processes are introduced: grayscale processing, automatic threshold choosing, binary processing, and noise removal.

2.1 The grayscale processing

A grayscale image (also called gray-scale, gray scale, or gray-level) is a data matrix whose values represent

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intensities within some range. MATLAB stores a grayscale image as an individual matrix, with each element of the matrix corresponding to one image pixel.

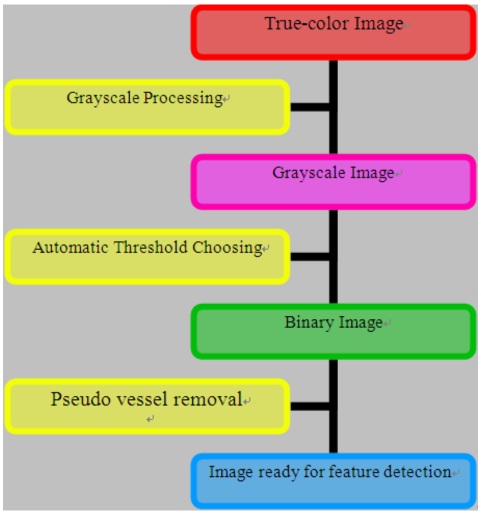

Fig. 1 Framework of Preprocessing

In order to decrease the processing time, we convert the true-color image of the blood vessel into grayscale, then binary analysis. Conversion of a color image to grayscale is not unique; different weighting of the color channels effectively represents the effect of shooting black-and-white film with different-colored photographic filters on the cameras. Our strategy is to match the luminance of the grayscale image to the luminance of the color image. To convert any color to a grayscale representation of its luminance, first one must obtain the values of its red, green, and blue (RGB) primaries in linear intensity encoding, by gamma expansion. Then, add together 30% of the red value, 59% of the green value, and 11% of the blue value (these weights depend on the exact choice of the RGB primaries, but are typical). Regardless of the scale employed (0.0 to 1.0, 0 to 255, 0% to 100%, etc.), the resultant number is the desired linear luminance value; it typically needs to be gamma compressed to get back to a conventional grayscale representation [8].

2.2 The binary processing

An image may consist of a single object or several separated objects of relatively high intensity, viewed against a background of relatively low intensity. This allows figure/ground separation by thresholding. In order to create the two-valued binary image a simple threshold may be applied so that all the pixels in the image plane are classified into object and background pixels. A binary image function can then be constructed such that pixels above the threshold are foreground ("1") and below the threshold are background ("0").

2.3 Automatic threshold choosing

From section 2.2 we know that the threshold to separate the foreground and background in grayscale image is very important for transform it into binary image. Thresholding is an important form of image segmentation and is a first step in the processing of images for many applications. Therefore, the objective and automatic threshold choosing method is introduced. The selection of suitable thresholds is ideally an automatic process, requiring the use of some criterion on which to base the selection. One such criterion is the maximization of the information theoretic entropy of the resulting background and object probability distributions. [11]

To set a global threshold or to adapt a local threshold to an area, we usually look at the histogram to see if we can find two or more distinct modes—one for the foreground and one for the background.

The introduced Otsu's algorithm assumes that the image to be threshold contains two classes of pixels (e.g. foreground and background) then calculates the optimum threshold separating those two classes so that their combined spread (intra-class variance) is minimal. Otsu's threshold method involves iterating through all the possible threshold values and calculating a measure of spread for the pixel levels each side of the threshold, i.e. the pixel that either falls in foreground or background. The aim is to find the threshold value where the sum of foreground and background spreads is at its minimum [10].

From our experiment result ---shown in Section IV, it is clear that the binary image would be much better by applying Otsu's method, however, the "isolated island" noise still remains.

Therefore, in next section, an original noise removal method is proposed.

2.4 The pseudo vessel removal

Because of the quality of the picture influenced easily by the natural texture of the eyeball surface, the changing of illumination state and any other vestiges, the pseudo targets unavoidably exist. To reduce the wrong judging in the result, it is necessary to do the pseudo vessel removal.

Usually, the vessel branches have the features as follows:

The single branch has curve feature and connectivity. It is distributed as tree or net shape. However, the pseudo blood vessel is represented as discrete block or point.

Based on these features of attribute we concluded, only the branch which have certain length and laid on certain orientation can be considered as real vessels. Otherwise, it is pseudo target and should be eliminated.

The algorithm is as follows:

1) Take the point in the binary image whose value is 0 to be the possible target;

2) For each searched point, implement the "isolated island "judging: If there is a isolated block, in which all points are value=0(or 1) and the points around it are value=1 (or 0), then it is considered as "isolated island", and should be eliminated;

3) Continue to search the next "isolated island ", if not, then remains it.

```
1 1 1 1 1...        1 1 1 1 1...
1 0 0 0 1 1...      1 1 0 0 1 1...
1 1 0 1 1 1...      1 1 0 1 1 1...
1 1 1 1 1 1         1 1 1 1 1 1

1 1 1 1 1...        1 1 1 1 1...
1 1 1 0 1 1...      1 1 1 1 1 1...
1 1 0 1 1 1...      1 1 0 1 1 1...
1 1 1 1 1 1         1 1 1 1 1 1

1 1 1 1 1...
1 1 1 1 1 1...
1 1 1 1 1 1...
1 1 1 1 1 1
```

Fig. 2 Example of pseudo vessel removal

3. The digitization of blood vessels in Sclera-conjunctiva region

3.1 Original method for boundary searching

After the binary processing and the elimination of the pseudo target, the next work is the confirmation of edge of blood vessels.

In the existing method, when the value of a point is 0 and the eight neighbor point is 1, it is considered as inner point and be eliminated. After looping this process, we can gain the boundary of the blood vessel.

However, in order to additional processing of boundary, the formal method is not applied in our proposed method algorithm, instead, a new method is proposed by searching and reserve the boundary point in the designated array:

Take the 0 value point in binary image as the possible boundary point;

(1) Make the edge judging on the searched possible point , that means when scanning, if the point value has been changed compared with its neighbors, then it is considered as boundary point, and put it into boundary point array orderly;

(2) Continue to search the boundary point, otherwise eliminate it.

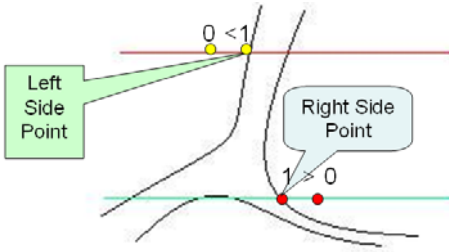

Fig. 3 Search the boundary point

3.2 Feature Parameters of edge of blood vessel

The edge of blood vessel is the main feature, which is important for medical research in TCM, and of great moment for "Differentiation of syndromes by observing eyes". Thus, the establishment of the feature parameters is necessary work in the whole research.

We propose an original digital vessel model by using feature parameters.

The feature matrix R is considered as

$R= R(\lambda_1, \lambda_2, \lambda_3, b)$

λ_1 is the extending feature, λ_2 is the branching feature, λ_3 is the two-sides feature. The creation methods of each parameter are shown as below.

3.2.1 Parameter of Extending Attribute λ_1

In order to express the extending attribute, we choose the sequence number in vertical axis to be the extending features.

The algorithm is as follows:

In the x-y plain of blood vessel picture (binary image), we set the y coordinate of the boundary point orderly as the extending feature value.

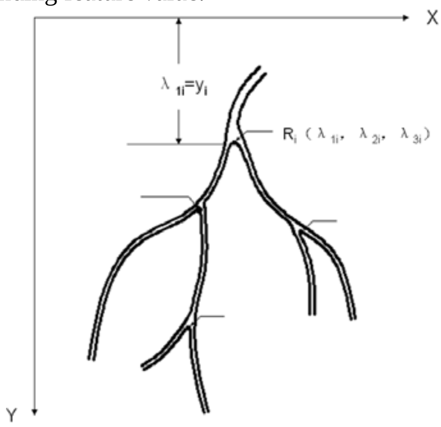

Fig. 4 Extending Attribute λ_1

3.2.2 Parameter of Branching Attribute λ_2

The branch is one of the most important factor of vessel image. In order to express the branching information accurately, we describe the vessel the as follows:

The curve of branch is separated into sub-curves, such as main branch , 1st-level branch , 2nd-level branch and so on.

We choose the vertical parameter y in the branch point to be the branching attribute

We define "00" as the main vessel without branch, and "01" as the first level branch in the left, "02" as the first level branch in the right, and also, “011”,”012”,”013”,…;”021”,”022”,”023”,…;as the second level branch and so on.

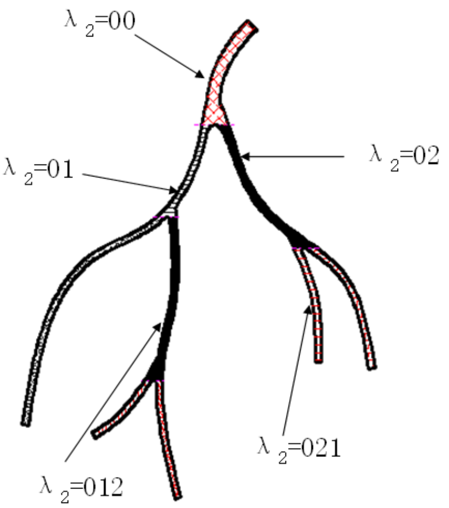

Fig. 5 Branch Attribute λ_2

3.2.3 Parameter of Two-sides Attribute λ_3

After fixing on the branching feature, the two-sides feature thus can be ensured.

The whole vessel region is separated into a certain numbers of sub-curves. Each sub-curve is enclosed by two-sides boundaries. For each one, it should be discriminate both two sides. Here, Two-sides Attribute λ_3 is used to represent the one side of the boundary (include main vessel and each sub-vessel).

The left side is defined as 0 and right side as 1.

3.2.4 The Width Attribute b

The value of R can be expressed as the value of x coordinate of boundary point along x coordinate orientation. The width of the vessel along the changing boundary, is approximately as the difference of the two sides of the boundary.

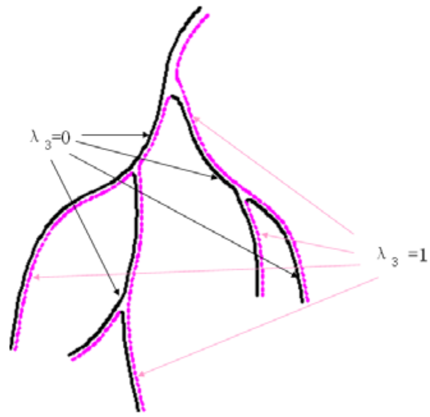

Fig. 6 Two-sides Attribute λ_3

Therefore, the width parameter can be given from this formula as follows:

$$b(\lambda_1, \lambda_2) = R(\lambda_1, \lambda_2, \lambda_{3A}) - R(\lambda_1, \lambda_2, \lambda_{3B})$$

R is the x-coordinate of boundary point value. λ_{3A} λ_{3B} represents the right and left boundary respectively. The difference of two boundary points is the width of the blood vessel.

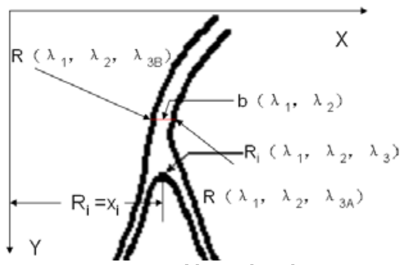

Fig. 7 Width Attribute b

4. Experiments and Results

The experiments are based on 50 eye images from different volunteers in Hiroshima University. These images are captured by CCD as 4 orientations (Up, Down, Left, Right) to gain the whole region of Sclera-conjunctiva.

The method for transformation from true-color image to binary image in Sclera-conjunctiva region has been given in Section 2, here, the results are shown as follows.

Fig ex-1 and Fig ex-2 show the original image of blood vessel in Sclera-conjunctiva. Fig ex-3 shows the result of grayscale transformation. Fig ex-4 shows the result of binary transformation, Fig ex-5 shows the result by applying Otsu's method, and Fig ex-6 shows the result after "isolated island" removal.

The method of edge detection has been given in Section 3. The results of the parameters of edge of blood vessel have been shown as follows. Fig ex-7 shows boundary, Fig ex-8 shows the Parameter of Branching Attribute λ_2 .Fig ex-9 shows Parameter of Two-sides Attribute λ_3 and Fig ex-10 shows the width attribute b. The horizontal and vertical axis in Fig ex-7 to 9 represent x and y coordinate respectively. In Fig ex-10, the horizontal axis represents the extending attribute λ_1, and the vertical represents the value of b.

5. Conclusion

In this paper, scanning and edge detection methods are used to gain the edge of the blood vessels. We apply Otsu's method to gain the thresh value automatically in the pre-processing, which is proved to improve the performance of detection. Also, we propose an original pseudo vessel removal method to remove the noise. Meanwhile, the edge feature parameters are gained, which can be used to reconstruct the blood vessels. We propose a scanning method for extracting the blood vessels and setting feature parameters for reconstructing the blood vessel, which can be used in further medical researches.

Our another contribution is we establish an original digital vessel model by using the attribute parameters we proposed, which can represent the vessel features directly.

In light of the experimental results of this work, the following conclusions can be drawn.

1.When comparing the results provided in Figure ex-4 to Figure ex-5, it can be found that the method to removal the pseudo vessel is effective.

2. Digitization method of blood vessel in sclera-conjunctiva image is presented in the paper; from sclera-conjunctiva original image to profile parameters obtained, is achieved successfully.

As our future work, we will completely study on the relationship between the parameters by our extraction and the diagnostic from human beings. The objective and quantitative result is expected to be given for the further objective --- computer-aided diagnosis in TCM.

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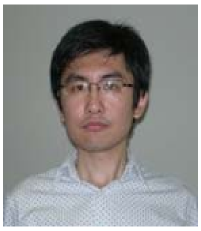

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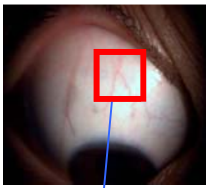

Fig ex-1 The Original Image

Fig ex-2 The Sclera-Conjunctiva Image (SCI)

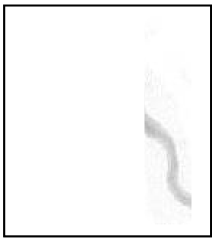

Fig ex-3 SCI in Grayscale

Fig ex-4 SCI in Binary

Fig ex-5 SCI in Binary (Otsu)

Fig ex-6 SCI in Binary (After Pseudo Vessel Removal)

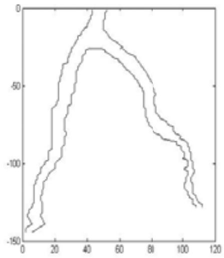

Fig ex-7 Boundary

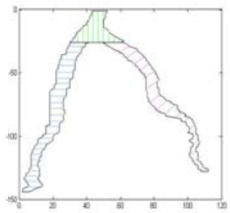

Fig ex-8 Branching Attribute λ_2

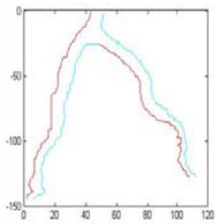

Fig ex-9 Two-sides Attribute λ_3

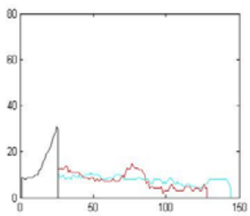

Fig ex-10 The width Attribute b