

Study on Digitization of TCM Diagnosis Applied Extraction Method of Blood Vessel

Cong Wu, Koichi Harada

Graduate School of Engineering, Hiroshima University, Hiroshima, Japan.
Email: oidipous@gmail.com, harada@cedar.mis.hiroshima-u.ac.jp

Received June 3rd, 2011; revised September 14th, 2011; accepted September 25th, 2011.

ABSTRACT

This paper presents a study on digitization of Traditional Chinese Medicine diagnosis. The research consists of two aspects: 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 blood vessels information can be obtained fast and accurately for the further TCM diagnosis by artificial system.

Keywords: Traditional Chinese Medicine, Blood Vessel in White Eye Ball, Binary Processing, Pseudo Vessel Removal, Digitalization, Edge Analyze, Feature Parameter

1. Introduction

In China and also other countries in the world, there are still many people benefit by Traditional Chinese Medicine (TCM) for the early diagnosis. No need much diagnosis equipment, TCM diagnosis can provide cheaper and quicker diagnosis process to the patients than western ways [1].

Traditional Chinese Medicine has been the cornerstone of oriental traditional medicine, which comprise of other variants of Hindu, Arab, Korea and Japan. One of the most unique features among oriental traditional medicine is Non-intrusive Diagnosis and Treatment, and it is best exemplified by Chinese traditional medicine's famous Four Methods: Looking, Palpating, Asking and Listening/Smelling, with which a doctor diagnose the patients thoroughly, analyze, and follow up measures. This methodology has been working very well for the past 2000 years, and made a significant contribution on human health. However, it's not without drawback on the other hand. Comparing to its strong competitors—Western Orthodox Medicine, TCM has came up short of diagnosis precision and, in particular, is lack of concrete basis on which to make a sound judgment, which in turn makes it difficult for inexperienced doctor to diagnose [2].

The digitization of TCM diagnosis can develop its correctness which is usually doubted by the public. Bl-

ood 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 [3].

Therefore, for the above reasons, 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 [4]. "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 [3]. This diagnosis method collects the features of Sclera-conjunctiva (especially the vessel feature) to discriminate the diseases in the whole body. **Figure 1** shows the patient's eye diagnosed by "Differentiation of syndromes by observing eyes" Method in TCM.



Figure 1 The patient's eye diagnosed by "Differentiation of syndromes by observing eyes" Method in TCM.

The digitalization of “Differentiation of syndromes by observing eyes” can help to build an objective and quantitative diagnostic standard for TCM [4].

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 [4], 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 [5].

However, there is not so much researches focus on establishing digital vessel model applied on TCM diagnosis. Like ZHU’s research, he proposed an automatic vessel extraction, however, lack of enough support for digitization of the extracted vessel data [6].

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 of blood vessels extraction 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. Some codes will be shown in the according sections.

2. Blood Vessels Extraction in Sclera-Conjunctiva Images

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 as preprocessing are introduced (as shown in **Figure 2**): 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

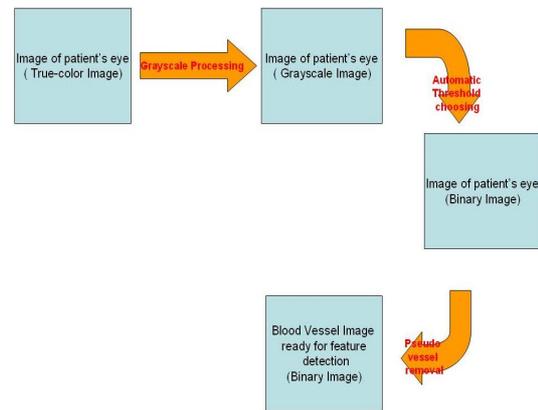


Figure 2. Framework of preprocessing.

gray-level) is a data matrix whose values represent intensities within some range. MATLAB stores a grayscale image as an individual matrix, with each element of the matrix corresponding to one image pixel [7].

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 [8,9].

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 threshold. 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 Choice

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. Threshold 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 [10].

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 [11].

From our experiment result shown in Section 4, 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 Proposed 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 an 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.

The simple example is shown in **Figure 3**. We also add key part of codes below.

3. The Digitization of Blood Vessels in Sclera-Conjunctiva Region

3.1. Original Method for Boundary Searching

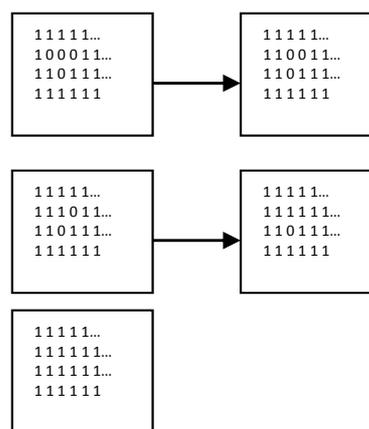
After the binary processing and the elimination of the pseudo target, the next work is the confirmation of edge of blood vessels.

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 [12].

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;



```
for i=2:row
    for j=2:col
if(I2(i,j)==0)&&(I2(i-1,j-1)==1)&&(I2(i,j-1)==1)&&(I2(i+1,j-1)==1)
%Isolated island judging
        I2(i,j)=1;
    end
end
end
```

Figure 3. Example of pseudo vessel removal.

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

Figure 4 illustrates the method how to search the boundary point.

3.2. Edge Feature Parameters 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 and b is the width feature. The creation methods of each parameter are shown as below.

3.2.1. Extending Parameter λ_1

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

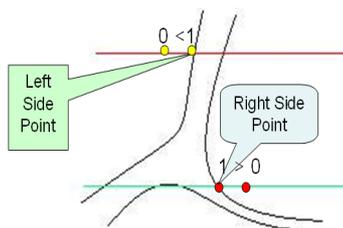
The algorithm is as follows:

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. **Figure 5** illustrates Extending Parameter λ_1 .

3.2.2. Branching Parameter λ_2

The branch is one of the most important factors 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.



```

for i=1:row % Searching the leftside of blood vessel
    for j=2:col
        if I1(i,j)>I1(i,j-1)
            x(i,j)=0;
        end
    end
    for j=1:(col-1) % Searching the rightside of blood vessel
        if I1(i,j)>I1(i,j+1)
            x(i,j)=0;
        end
    end
end
end
    
```

Figure 4. Search the boundary point.

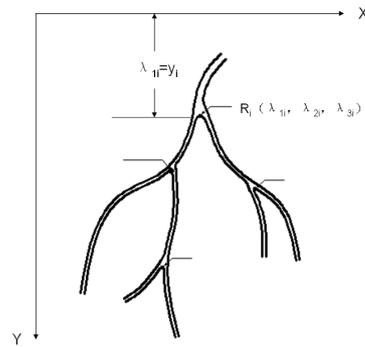


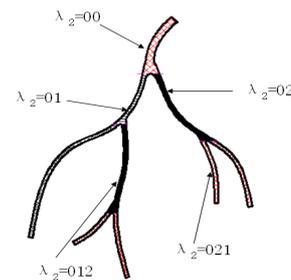
Figure 5. Extending parameter λ_1 .

We choose the vertical parameter y in the branch point to be the branching attribute, as illustrated in **Figure 6**.

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.

3.2.3. Two-Sides Parameter λ_3

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



```

%ascertain T2
if (KK(i)<2)&&(i>=KK1(1))&&(x(i,j)==0) % main vessel
    t2(i,j)=T20;
end
if
(KK(i)<2)&&(i>=KK1(2))&&(x(i,j)==0)&&(jj<3)&&(jj>0)
    t2(i,j)=T21; % 1st branch on the left
end
if (KK(i)<2)&&(i>=KK1(2))&&(x(i,j)==0)&&(jj>2)
    t2(i,j)=T22; % 1st branch on the right
end
if (KK(i)>1)&&(i>=KK2(1))&&(x(i,j)==0)
    t2(i,j)=T22;
end
if
(KK(i)<2)&&(i>=KK1(3))&&(x(i,j)==0)&&(jj<3)&&(jj>0)
    t2(i,j)=T221; % 2nd branch on the left
end
if (KK(i)<2)&&(i>=KK1(3))&&(x(i,j)==0)&&(jj>2)
    t2(i,j)=T222; % 2nd branch on the right
end
if (KK(i)>1)&&(i>=KK2(2))&&(x(i,j)==0)
    t2(i,j)=T222; %
end
end
    
```

Figure 6. Branch parameter λ_2 .

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 T_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, as shown in **Figure 7**.

3.2.4. The Width Parameter 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.

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

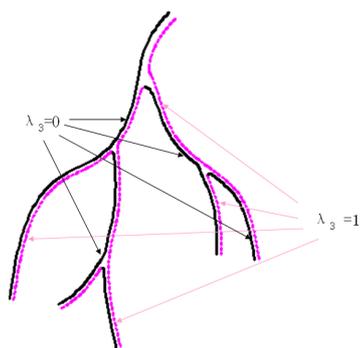
$$b(\lambda_1, \lambda_2) = R(\lambda_1, \lambda_2, \lambda_{3A}) - R(\lambda_1, \lambda_2, \lambda_{3B})$$

As shown in **Figure 8**, 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.

4. Experimental 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.



```
%ascertain T3
if (x(i,j)==0)&&(jj==1) % 1st edge point of column i
    t3(i,j)=T31;
end
if (x(i,j)==0)&&(jj==2) % 2nd edge point of column i
    t3(i,j)=T32;
end
if (x(i,j)==0)&&(jj==3) % 3rd edge point of column i
    t3(i,j)=T31;
end
if (x(i,j)==0)&&(jj==4) % 4th edge point of column i
    t3(i,j)=T32;
```

Figure 7. Two-sides parameter λ_3 .

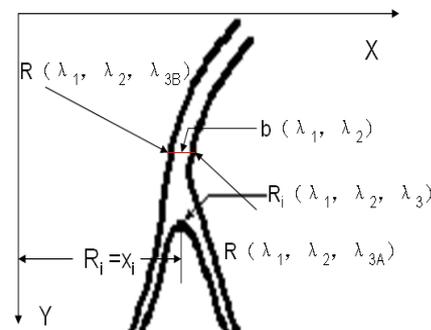


Figure 8. Width parameter b .

Figure 9 shows preprocessing of our research: From the original eye image captured from our patient, we extract the blood vessel part which we are interested in. Then, we transform the image of blood vessel in Sclera-conjunctiva into grayscale image by grayscale transformation.

Figure 10(a) shows the result of binary transformation. This result obviously contains lots of noise. **Figure 10(b)** shows the result by applying Otsu's method and "isolated island" removal. The noise has been cleared.

The method of edge detection and digitization has been given in Section 3. The results of the edge parameters of blood vessel have been shown as follows. **Figure 10(c)** shows boundary. **Figure 10(d)** shows the Branching Parameter λ_2 . The red area shows main branch, in which $\lambda_2 = 00$; The area in black represents the left branch (1st level), in which $\lambda_2 = 01$; The area in green represents the right branch (1st level), in which $\lambda_2 = 02$. **Figure 10(e)** shows Two-sides Parameter λ_3 , in which red line refers to left side and blue line refers to right side. **Figure 10(f)** shows the width parameter b . There are three curves to represent different widths: red—width of left branch, green—width of right branch and black—width of main branch. The horizontal and vertical axis in **Figures 10(c) to (e)** represent x and y coordinate respectively. In **Figure 10(f)**, the horizontal axis represents the extending attribute λ_1 , and the vertical represents the value of b .

5. Conclusions

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.

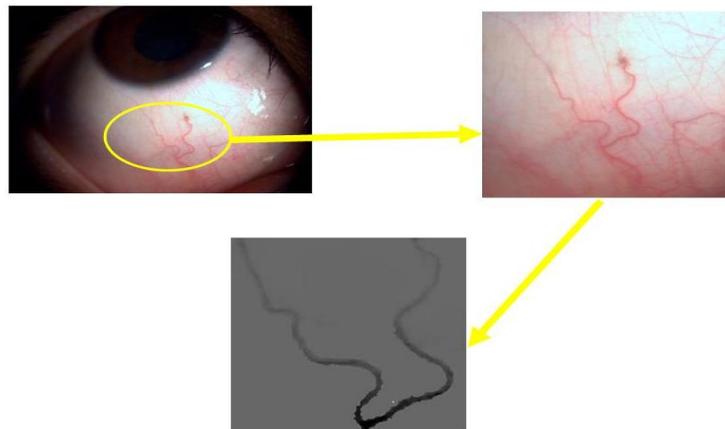


Figure 9. Preprocessing.

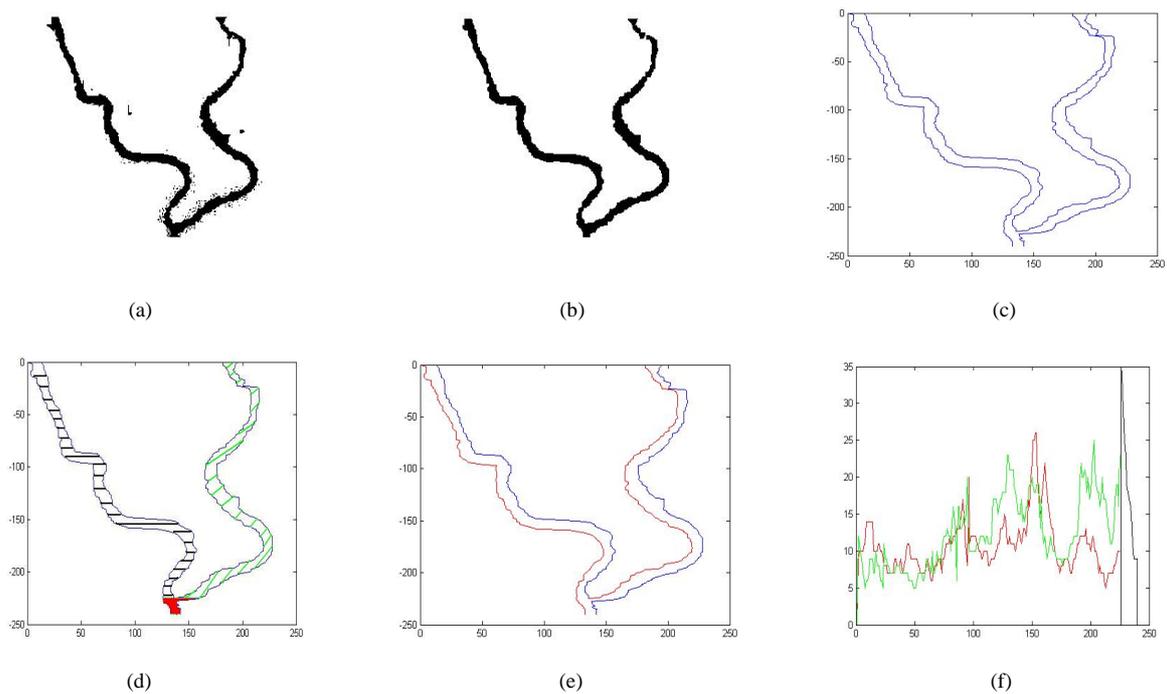


Figure 10. Experimental results in MATLAB. (a) Binary image with noise; (b) Binary image (after noise removal); (c) Boundary; (d) Branching parameter λ_2 ; (e) Two-sides parameter λ_3 ; (f) Width parameter b .

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 10(d)** to **Figure 10(e)**, 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.

With these result, we are able to not only get an unprecedented high quality image of blood vessel of patient, but also better explain to the patients of their symptoms, store and transfer all pertaining information readily.

As our future work, we will completely study on the relationship between the parameters retrieved 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.

6. Acknowledgements

The authors would like to acknowledge all the anonymous reviewers gratefully for their carefully considered feedback and valuable comments. The modification is due to their effort.

REFERENCES

- [1] J. J. Wang, "The Theory of Differentiation of Syndromes by Observing Eyes in Traditional Chinese Medicine," *Chinese Journal of Basic Medicine in Traditional Chinese Medicine*, Vol. 11, No. 5, 2005, pp. 324-325.
- [2] D. L. Zheng and Z. F. Zheng, "Ocular Diagnostic-Understand Fully at a Glance and Diagnose Patient's Disease," Liaoning Science and Technology Publishing House, Liaoning, 2003.
- [3] D. L. Zheng, "Complete Guide to Visualized Diagnostics via Eye Study," Liaoning Science and Technology Publishing House, Liaoning, 2008.
- [4] G. D. Zhu, "Research on the Digitalization Technology of 'Differentiation of Syndromes by Observing Eyes'," Doctoral Dissertation, Graduate University of Chinese Academy of Sciences, 2006.
- [5] S. Paripurana, W. Chiracharit, K. Chamnongthai and K. Higuchi, "Retinal Blood Vessel Segmentation Based on Fractal Dimension in Spatial-Frequency Domain", *10th International Symposium on Communications and Information Technologies*, Tokyo, 26-29 October 2010, pp. 1185-1190.
- [6] G. D. Zhu, L. Shen and J. J. Wang, "Automatic Vessel Extraction for Sclera-Conjunctiva Images Based on Exploratory Tracking," *Computer Engineering*, Vol. 31, No. 17, 2005, pp. 6-8.
- [7] R. C. Gonzalez, R. E. Woods and S. L. Eddins, "Digital Image Processing Using MATLAB," Prentice Hall, Upper Saddle River, 2003.
- [8] J. Canny, "A Computational Approach for Edge Detection," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 8, No. 6, 1986, pp.679-698. [doi:10.1109/TPAMI.1986.4767851](https://doi.org/10.1109/TPAMI.1986.4767851)
- [9] R. C. Gonzalez and R. E. Woods, "Digital Image Processing," 2nd Edition, Prentice Hall, Upper Saddle River, 2002.
- [10] A. D. Brinka, "Thresholding of Digital Images Using Two-Dimensional Entropies," *Pattern Recognition*, Vol. 25, No. 8, 1992, pp. 803-808. [doi:10.1016/0031-3203\(92\)90034-G](https://doi.org/10.1016/0031-3203(92)90034-G)
- [11] N. Otsu, "A Threshold Selection Method from Gray-Level Histograms," *IEEE Transactions on Systems, Man and Cybernetics*, Vol. 9, 1979, pp. 62-66.
- [12] Y. Sun, "Automatic Identification of Vessel Contours in Coronary Arteriograms by an Adaptive Tracking Algorithm," *IEEE Transactions on Medical Imaging*, Vol. 8, No. 1, 1989, pp. 78-88.