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COMPUTER AIDED DIAGNOSTIC OF THE EYE BOTTOM IMAGES

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Abstract – In the paper we present results of our research concerning the fusion, digital conversion, and digital analysis of eye bottom images. We have started investigation about three years ago, and our goal is computer aided diagnosis of diabetes retinopathy. In diabetes retinopathy very important is analysis of the image of cardiovascular network of eye bottom. Many parameters of main vessels as diameters, positions, turns junctions and many others have changed in time. So in the first step of the research we decided to make a software tools for image analysis , useful for ophthalmologist for early detection of pathological changes.

Keywords: image analysis, diabetes retinopathy, eye bottom images

1. INTRODUCTION

A very fast development of computer aided diagnostic methods has been observed in last years. Especially interesting are methods and equipment using technique of digital image processing [1]

This concern for example the computer aid of the diabetes retinopathy diagnosis, which operates on the digitally transformed eye bottom images. In Poland special software for that application has not been in common use because of its high costs, so we have tried to develop it our selves.

Diabetes retinopathy affects on the cardiovascular network of eye bottom, changes main dimensions of the vessels – diameters, positions, turns, junctions and other its parameters. It is important to analyse all these changes successively, when they occurred. Mentioned above changes are not stable in time, and are dependant on the level of glycaemia, patient age and occurrence of different illnesses as for example high blood pressure, etc. From the medicine doctors point of view the analysis of the changes gives the opportunity of early diagnosis, observations of the illness development, or results of the therapy.

2. MTHERIALS AND METHODS

A material for the analysis, which we have used in our research, it has been pictures taken with so called fundus camera, the most popular tool for this application. Fundus camera has given the opportunity of taking picture from the big area of eye bottom, with a very big shooting angle – approximately 90°- 120°, or smaller for example 30°, to max. 60°. In the first case the image has no value for the medical diagnosis, because of the distortions of its geometry, especially near the borders. In the second, our case, we decided to do a fusion giving the map of the big eye bottom area.

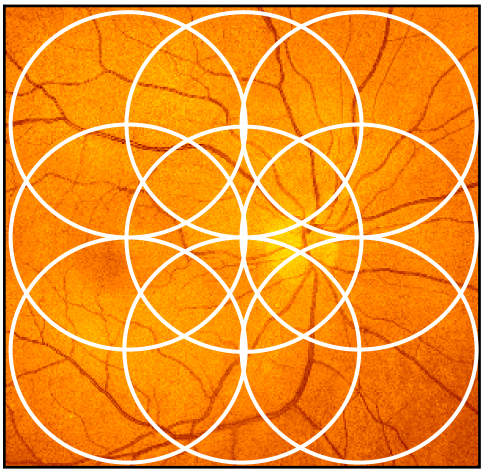

Fig. 1. Position of the picture from the fndus camera with small shooting angle.

For the diagnosis very important are: the area of visual nerve shield, the region of the blind spot and some places pointed by a doctor, and they have to be very carefully shown. So the best way for obtaining the good analytic material is taking of many pictures of small areas (Fig.1.) and making a fusion, giving a big eye bottom map. But the number of the pictures – components, and the area of picture should not be to small.

In our research we have got the materials from two sources. First it was images from fundus camera equipped in special red filter, with shooting angle, scanned on the Polaroid CCD scanner prepared for slides scanning. Second source, it was images from camera connected to the computer by the frame grabber card. Gathered materials have been written in lossless format TIFF, popular for colour images, but it still had a bad quality. There were many artefacts from some dust on the scanned film, which had to be removed. And what had also been done is decreasing of the border geometrical distortions. All these had been done with Adobe PhotoShop program.

2.1. Fusion algorithm

The pictures fusion is oriented on the obtaining of the map of big eye bottom area. The algorithm of the fusion creates the map, where unfitness on the borders of component pictures could be omitted from the medical point of view. Our algorithm firstly enabled joining of four pictures and then it has been developed to the at last nine pictures version. The preliminary analysis of the pictures transformed to the separated basic colour components R,G,B gave us some important observations – R component brings no information (because of filtration) and the best for analysis is the G component (Fig.2.). According to this our algorithm has been based only on the G component analysis. It must be stated that algorithm of fusion is full automatic.

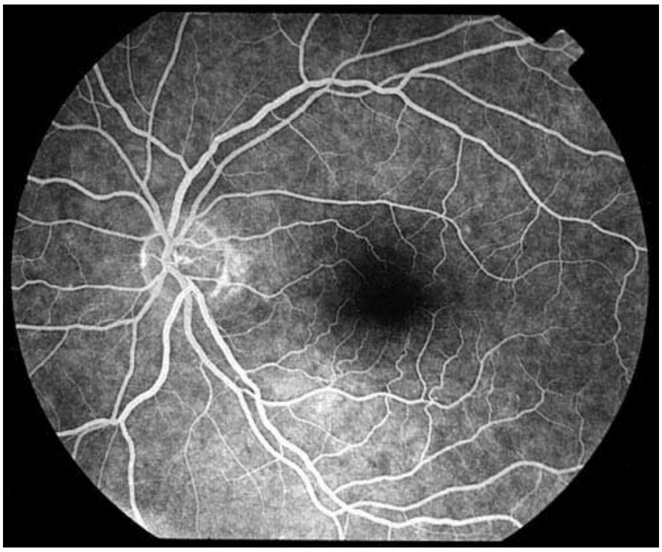

Fig. 2. Example of eye bottom image converted to grey scale form green component (G).

The maps are converted for minimizing the geometrical distortions and filtered for detection of the vessel edges[2]. After that we apply special procedure giving the skeleton (the central line equally far from two edges of the vessel) of the cardiovascular network and then we can determine some important parameters as vessel diameter, local and global bifurcation's angles, coefficient of tortuousity. This is really valid for the oculist examining the diabetes retinopathy. For obtaining the vessel, vessel skeleton we have used filters which are very often used in image processing. From the mathematical point of view filter is a function that converts one image into another. The filtration can be conducted as a tangle of the filter pulse answer with the initial image. In two dimensional discrete case (as binary image is) a tangle can be described as (1)

$$y(k,l) = \sum_{p,q} x(k-p, l-q) * h(p,q) \quad (1)$$

where: y(k,l) – the tint of point (k,l) after the filtration
x(k,l) – the tint of a point (k,l) before the filtration
h(p,q) – the answer of the filter in the point (p,q)

The pulse answer of the filter can be presented as a table, the factors of which are used as weights at calculate the average. One of the easiest ways of detecting edges is using local gradients of the image for it. We used Sobel filters which are better then Roberts. The example of Sobel filter 3X3 is presented on Fig. 3 .

A4=-1	A3=-2	A2=-1
A5=0	A0=0	A1=0
A5=1	A7=2	A8=1

Fig. 3. The matrix of the filter

The effect of tangle operation can be written as (2)

$$y = \sum_{j=0}^{8} a_i x_i \quad (2)$$

where x_i means the neighbours of the analysed point.

As it has been mentioned in introduction, software tools for picture analysis are necessary for the examination of cardiovascular network of the eye bottom. Its analysis enables calculation of the length of the vessel, the angle of vessel bifurcation, estimation of the examining the diabetes retinopathy. A very important are bifurcation angles and tourtisity of the vessel.

The idea of angle estimation relies on the simple analytical geometry (3,4). As for linear vessels analysis of angles is quite easy, so for non linear ones we proposed to use local and global angles, as on Fig. 4.

$$\alpha = atan \frac{k2 - k1}{1 + k1 * k2} \quad (3)$$

$$\text{and} \quad k1 = \frac{y1 - y}{x1 - x}, \qquad k2 = \frac{y2 - y}{x2 - x} \quad (4)$$

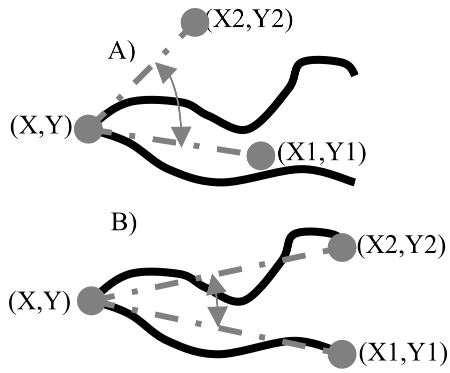

Fig. 4. A) Local angle, B) Global angle

The range of calculated angles is equal 0-180°, and for 90° the condition k1*k2=-1 is checked.

Another parameter important for the oculist is so called tortousity of the vessel. In Clinic of Ophthalmology at Medical Academy in Warsaw it has been examined by manual measuring of vessel edge L and the line segment D between chosen points. The quotient L/D gave the final information about vessel tortuousity. Normally L/D coefficient has been equal 1.2 in extreme cases over 2, but its interpretation should have been examined in groups of healthy and non-healthlt patients with different level of retinopathy. For this reason it is necessary to make the process of L/D automatic. For this skeleton of the vessel network could be applied. When we have chosen two points on the vessel skeleton special procedure calculate the coefficient. Schematic illustration (Fig. 5.) of the procedure operating and some mathematical formulas (5,6,7) are shown below.

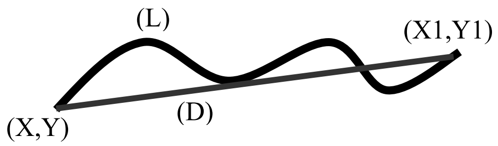

Fig. 5. Schematic of L/D estimation

$$D = \sqrt{(X - X1)^2 + (Y - Y1)^2} \qquad (5)$$

$$L = (h - \frac{s}{2}) + \frac{s}{2} * \sqrt{2} \qquad (6)$$

$$Coef = \frac{L}{D} \qquad (7)$$

where: L/D - (in pixels) is the tortuousity coefficient
s/2 - pixels with oblique neighbourhood
h - number of the skeleton pixels

2.2. ROI algorithm

Another very important problem is detection of the microarteries, which occurs with diabetes retinopathy. Now our software could half automatically detect vessel's narrowings or ruptures of the microarteries.

For this we apply 2D Fourier transform in regions of interest (ROI) and small built on neural network decision making system. This method is very often used for image recognizing and image processing[3,4]. In our research we decided that valid size of the ROI is 32x32 pixels. But before we do 2D Fourier transform we had to prepare picture for analysis.

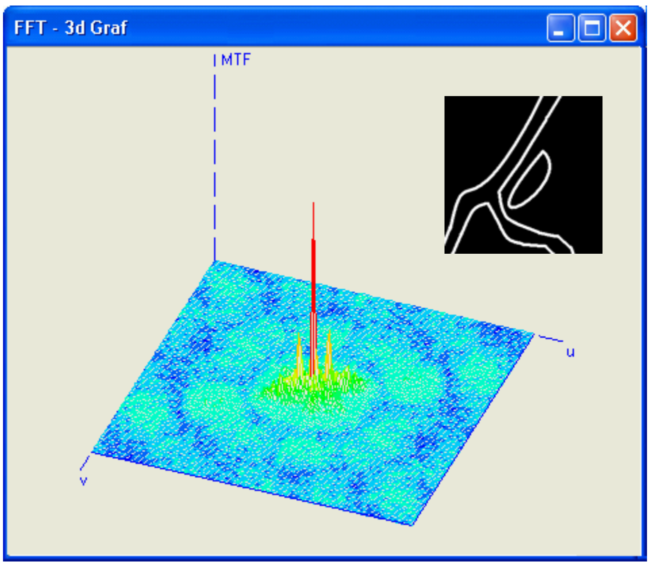

Fig. 6. Example of the ROI and its power spectrum
(with pathological change)

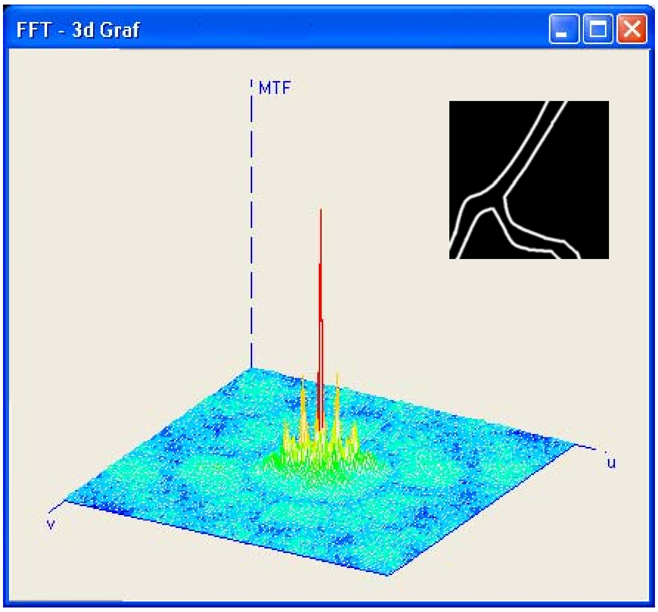

Fig. 7. Example of the ROI and its power spectrum
(without pathological change)

First like previously we had to detect edges[5] of the cardiovascular network. For this we apply filtration with 8 different angles and then from eight transformed pictures we make a final ROI picture. On this we apply 2D Fourier transform as it is shown on (Fig.6,7) – we have used MTX Vec library for Delphi. Necessary equations written by authors of this library (8,9,10) are presented below.

$$t[i, j] = \sum_{k=0}^{rows-1} \sum_{l=0}^{cols-1} r[k+1, l+1] * w_r^{-i*k} * w_c^{-j*l} \qquad (8)$$

$$\begin{aligned} & r[i+1, j+1] = t[i, j] \\ & 0 \le i \le rows - 1 \\ & 0 \le j \le cols - 1 \end{aligned} \qquad (9)$$

$$w_c = \exp\left(\frac{2\Pi * im}{cols}\right), w_r = \exp\left(\frac{2\Pi * im}{rows}\right) \qquad (10)$$

As the final result we have got the power spectrum of the ROI picture.

Firstly we tried to teach a simple Back Propagation neural network to recognize the pathological microarteries. Our previous research has shown that such system could make a correct diagnosis and could be useful in this case [6,7]. System was not very effective because the input vector was very large (1025 elements for training), so we had to make it smaller. For this we have done segmentation of the power spectrum. Our previous research also has shown that such kind of compression data could be useful[6]. The optimal size of segment was 4x4 pixels. After this operation the input vector for training has contained only 65 elements. And such prepared data, were loaded to a neural network.

TABLE 1. Cross Validation test results

Neural Network	1 CV	2 CV	3 CV	4 CV	5 CV	Average
BP	85%	70%	50%	60%	90%	71%
BP Quick	60%	70%	50%	60%	85%	70%
BP Elman	60%	55%	80%	80%	60%	67%
BP Jordan	80%	70%	50%	60%	60%	64%
Resilent BP	75%	70%	55%	65%	65%	66%
Falhman	75 %	70%	60%	80%	85%	74%

We have compared several neural networks using 5 fold cross validation test[8] to get the best results of our system. The results are presented in table 1.

As you can see the best results we obtained with Falhman neural network. That kind of neural network was the best in recognizing of pathological changes.

3. CONCLUSIONS

All presented above procedures have been tested on the picture database consisting of about 300 photos – 33 complete sets. Only for 5 cases we couldn't obtain good image of cardiovascular network of the eye bottom. The reason of this fact was that such photos have been taken incorrectly with too big dispersion. For the other correctly taken photos there were no problems. We could reconstruct the vessels, we have no problems with fusion and obtaining of the map of big area. So we can say that our software is useful for ophthalmologists, who in the past had a lot of problems in analysis of fundus camera eye bottom images. Now evaluation of the created by fusion algorithm map is much more comfortable. It is much easier to estimate of the illness level, or effectiveness of the therapy, detect early pathologies.

In future we are going to examine the sequentially taken photos, analyse its common parts and changes. We are also planning to divide the veins and arteries networks, which could be complicated because of the very small contrast difference.

In the end we have to underline that our research is still under development and we know that we are very far from the final version of the computer system for diagnosing diabetes retinopathy. As you can see the best results we obtain with Falhman neural network 74% of correct diagnosis. In future, detection of the ruptures should be full automatic, now – position of the ROI is defined by ophthalmologist.

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