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SHIFT REDUCING OF RETINAL VESSEL IMAGE SERIES BY USING EDGE BASED TEMPLATE MATCHING ALGORITHM

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Abstract: **This paper presents a shift reducing algorithm of fundus images consisting of the following steps: edge detection by a rule based gradient algorithm, algorithm to search significant templates and a template matching algorithm based on edge lists. The result of the shift reducing algorithm depends on the capability of the edge detection algorithm and the detected templates. The shift reducing algorithm works well and effectively.**

Keywords: **fundus image, cross correlation, edge detection, radon transformation, template matching**

Introduction

A major problem during analysis of human fundus images is the compensation of eye movements in the image sequence. Shift reducing algorithms for fundus images have to work well even under difficult conditions like low contrast, variability of brightness, distortion or noise. Furthermore fast processing of these algorithms is necessary. There are a lot of shift reducing algorithms based on different methods.

This paper presents a shift reducing algorithm based on edge lists only. A rule based gradient algorithm computes the edge lists. Based on this edge lists, a template detecting algorithm searches for significant templates and an edge based template matching algorithm calculates the translation parameter for the shift compensation.

Materials and Methods

For the development of this algorithms 8 bit grayscale image series of a retinal camera[I] with the resolution of 768 x 576 pixels were used[II].

The edge detection algorithm has to fulfill several requirements for instance getting only one edge point for each edge, the differentiation between positive and negative gradient, the fast processing of the algorithm and the possibility to adapt the processing parameters. Several standard algorithms were tested.

Finally an algorithm was chosen which can be described as a rule based gradient algorithm [1]. Gradient filters of different length are combined to build a block of gradient filters. A convolution is performed on the image using this block. The results are combined by special rules and allow the detection of long edges. Besides it is possible to calculate the value of the gradient and to separate the start or endpoint of the edge.

Next an algorithm has to detect significant and unique templates of the fundus image. Based on the computed edge list two different methods were tested. Firstly an edge based template matching algorithm with a set of different edge lists of typical vessel configurations, like crossovers and bifurcation was tested. Secondly an algorithm was tested which uses an edge list based radon transformation algorithm to detect lines. These lines are used to compute useful templates. The following edge based template matching algorithm can use the computed templates to calculate the translation parameters.

The edge based template matching algorithm is based on the cross correlation algorithm.

$$\Phi_{xy}(kT_a) = \frac{1}{N}\sum_{n=1}^{N} x_n y_{n-k} \qquad (1)$$

By using the two dimensional cross correlation it is necessary to compute the correlation value for all positions of the template inside the image. The runtime of the two dimensional cross correlation is $O_{Corr}(n_I \cdot m_I \cdot n_T \cdot m_T)$.[III] When we examine equation (1) we realize:

$$x_n y_{n-k} = \begin{cases} 0 & for\ x_n = 0 \cup y_{n-k} = 0 \\ x_n y_{n-k} & else \end{cases} \qquad (2)$$

Only when x_n and y_{n-k} unequal zero, we have to compute the correlation value. Most of the values in an edge image are zeros. Furthermore the result of the edge detection of the image and the templates are edge lists. Based on equation (2) we can compute the cross correlation as follows:

$$\begin{aligned} &S_{pos_x,pos_y} = S_{pos_x,pos_y} + O_{d_i} T_{d_j} \\ &where \\ &pos_x = O_{x_i} - T \qquad i = 0,1,...,N-1 \\ &pos_y = O_{y_i} - T \qquad j = 0,1,...,M-1 \end{aligned} \qquad (3)$$

O – image edge list
T – template edge list
S – correlation image
x, y –position of the edge
d – edge difference
M – size of template edge list
N – size of image edge list

The edge difference of each edge point of the template list is multiplied with the edge difference of each

[I] type FF450 connected to a CCD-Camera
[II] provided by IMEDOS GmbH [2]

[III] n_I, m_I size of Image; n_T, m_T size of Template edge point of the image list. The result of each multiplication is added up to the correlation image, at the position calculated by using the position of the template edge point and the image edge point.

The runtime of this cross correlation algorithm depends on the size of the edge lists. In addition to the runtime of the edge detection algorithm we get the runtime $O_{Corr}(N \cdot M)+O_{EdgeDetect}(n_I \cdot m_I)$.[III] The length of the edge list depends on the image and the used edge detection algorithm.

Results

The used edge detection algorithm works effectively and robust. The result can be influenced by noise. This could be compensated using smoothing filters. Furthermore the algorithm has different parameters like threshold value and sensibility, which allows the adaptation of the algorithm.

Both algorithms to detect new templates of the fundus image try to detect typical vessel configurations, like crossovers and bifurcation. These templates are significant but sometimes not unique. In that case the following template matching algorithm can't differentiate the templates. It's necessary to verify the uniqueness of the used templates in the future work.

The results of the cross correlation algorithm based on edge lists and the cross correlation algorithm based on grayscale edge images are equal. The former is mostly faster than the latter.

The analysis of the results of the cross correlation algorithm shows, that sometimes the vessel template is incorrectly detected. The reason for this problem is demonstrated in Table 1:

Image	Template	Equation (3)	Equation (4)
0 10 0	0 1 0	0 0 10 0 0	0 0 1 0 0
0 0 0	1 1 1	0 10 10 10 0	0 1 1 1 0
0 1 0	0 1 0	0 0 11 0 0	0 0 11 0 0
1 1 1		0 2 2 2 0	0 20 20 20 0
0 1 0		1 2 5 2 1	10 20 50 20 10
		0 2 2 2 0	0 20 20 20 0
		0 0 1 0 0	0 0 10 0 0

Table 1: Result of different matching algorithms

The template in Table 1 has small edge differences, it demonstrates a small vessel. The image in Table 1 include the small vessel and also a strong edge difference. This strong difference overlaid the result.

This problem can be solved by using another matching algorithm, like using the difference instead of multiplication between template and image. But when using the difference inside the algorithm based on equation (3) the equation (2) becomes invalid and therefore the result of the algorithm is mathematically incorrect. However the algorithm unites the advantages of both algorithms.

$$S_{pos_x,pos_y} = S_{pos_x,pos_y} + a - (O_{d_i} - T_{d_j}) \quad (4)$$

a – maximum gray scale; see equation (3)

By using the difference the best match has the lowest value. It is useful that the best match has the highest value. Therefore the result is subtracted with the maximum gray scale value. In the example of Table 1 the maximum value is 10. Based on the maximum of the result, a translation matrix is created. This translation matrix is used for shift compensation of the fundus images. By analysing different image sequences the algorithm based on equation (4) adduced the best results.

Discussion

The result of the edge based template matching algorithm depends on the capability of the edge detection algorithm. The used edge detection algorithm works effectively by using empirically specified parameters.

To find new templates both presented algorithms detect typical vessel configurations. If a vessel configurations exists several times in the fundus image, the detected template is useless for the following template matching algorithm. It is necessary to check the uniqueness of the template inside one fundus image.

Depending on the length of the edge list and the used templates the edge based template matching algorithm works fast and accurately. Edge lists of fundus images are mostly short enough to be faster than cross correlation with grayscale templates. However the calculation of the gradient algorithm needs additional processing time. But the calculated edge list can be used for further analysis.

The advantage of using templates is the possibility to compensate image distortion by using several templates. This problem will be solved in the future.

Furthermore it is possible, that the image of the same vessel changed within the image sequence. An adaptation of the template could solve this problem.

Conclusions

This paper presents a shift reducing algorithm consisting of the following steps: edge detection by a rule based gradient algorithm, search for significant templates and a correlation based on edge lists. The presented template matching algorithm works accurate and robust.

Further enhancements could be achieved by estimating the quality of the templates and subsequent adaptation of the templates. Other improvements include adaptive computation of other processing parameters, parallelizing parts of the process and the compensation of distortion.

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[2] IMEDOS GmbH, Schwanseestr. 48, D-99423 Weimar; http://www.imedos.de;