Blood Vessel Segmentation For High Resolution Retinal Images

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Abstract

Segmentation of blood vessels in retinal images used for the early diagnosis of retinal diseases such as hypertension, diabetes and glaucoma. The high resolution, variability in vessel width, brightness and low contrast make vessel segmentation as difficult task. There exist several methods for segmenting blood vessels from retinal images. However, most of these methods fail to segment high resolution (large in size) images, very few methods provide solution for such a high resolution images but it require lengthy elapsed time and the accuracy of these methods is not completely satisfactory. Parallel method have emerged to overcome these limitations by offering parallel environment and parallel algorithm to segment such an high resolution images in an acceptable time. The planned research enhances the speed and accuracy of segmentation for high resolution retinal images by involving a new data partition scheme and suitable segmentation algorithm for parallel environment.

Keywords: *High resolution, Blood vessel segmentation, Elapsed time, Parallel environment, Parallel algorithm.*

1. Introduction

Blood vessel is one of the most important features in retina for detecting retinal vein occlusion, grading the tortuosity for hypertension and early diagnosis of glaucoma [1]-[3].The segmentation of blood vessels is an important preprocessing step for the early detection of retinal diseases. Because of multifarious nature of the vascular network, the manual vessel segmentation is very difficult and time consuming, so the researchers have proposed several automated methods for retinal vessel segmentation which are grouped as supervised and unsupervised based on the vessel classification techniques. The supervised methods require a feature vector for each pixel and manually labeled images for training the algorithm. To classify the pixel as vessel or non-vessel the supervised method uses different classifiers such as neural networks[4], support vector machine[5], Bayesian classifier with class-conditioned probability density function[6], k-nearest neighbor classifier[7] and Ada boost classifier[8]. In contrast to supervised scheme, unsupervised learning methods uses other technique for pixel classification such as classification by measuring the concavity[9], template matching[11], use of adaptive thresholding techniques[13],[16] and region growing[10],[12],[14],[15].

The existing methods include background homogenization, vessel central light reflex removal and feature extraction as preprocessing step. In the follow-up phase, the extracted features are classified as vessel or non-vessel by the use of different classifier, then the post processing steps like filling pixel gaps and removing falsely detected vessel pixels are added for enhancing the segmentation performance. The high resolution, variability in vessel width, brightness and low contrast make automated vessel segmentation as difficult task. The researchers have proposed several methods, most of these methods only suitable for segmenting low resolution images.
In this paper, we review the suitable tool and method for segmenting high resolution retinal images. The proposed method involve enhancement/threshold based segmentation algorithm and new data partition scheme for enable multitasking on the parallel environment. The rest of the paper is organized as follows. In section 2, we detail and compare the tools for segmenting high resolution images. Various implementation methods are discussed and compared in section 3.In section 4, we analyze the performance of tools and methods. Section 5 discusses the framework of our planned work. We summarize our conclusions in section 6.

2. Tools for high resolution image segmentation

Matlab is the most popular and convenient tool for image segmentation, but segmenting high resolution images in large scale is not possible in Matlab, since it requires high capacity of main memory. ITK is a special tool for segmentation, written in C++, it include various high level and low level image processing algorithms, common classes, basic filters and utilities for segmentation. Because of its low level nature ITK effectively utilize the main memory and handle high resolution images.

M.E. Martinez-Perez et al., [10] compare the performance of Matlab and ITK tool by implementing a multiscale approach for vessel segmentation. This method processed in two stages; at the first stage the features such as gradient magnitude and maximum eigenvalue of the Hessian matrix are extracted using multiscale approach, then in the second stage the extracted features are segmented by region growing algorithm.
This method implemented in Pentium IV, 2.4 GHz with 1024 MB RAM under Linux environment. A local database consists of 4 different size images(imag1 – imag4) with different interval of scale used for check the capability of handling large size images and a publicly available STAR(STructural Analysis of Retina) database used for evaluating the speed and accuracy of the implementation. The STAR database consists of 20 (n) same size (605x700) images with fixed scale interval (1-12).

Table I compare Matlab and ITK implementation of the above approach.

File	Size (Pixels)	Scales	Feature Extraction(s)		Region Growing(s)	
			MATLAB	ITK	MATLAB	ITK
Imag0	605 x 700	[1-12]	219.14	19.29	37.18	2.29
Imag1	703 x 599	[2-6]	32.20	8.55	47.35	2.24
Imag2	1319 x 1518	[2-8]	320.72	55.82	328.44	23.20
Imag3	2308 x 2890	[5-25]	Out of memory	693.83	--	63.64
Imag4	3500 x 3000	[5-21]	Out of memory	900.17	--	279.69

Table I
Comparison of Matlab and ITK

Following observation made from Table I,

i) Extracting feature from high resolution image (img3, 4) in large scale [5-25] requires high capacity of main memory, so the Matlab implementation could not segment the high resolution images (Img 3, 4) and raise the out of memory exception. By the efficient utilization of main memory the ITK method successfully segment that high resolution images (Fig.1. (b)).

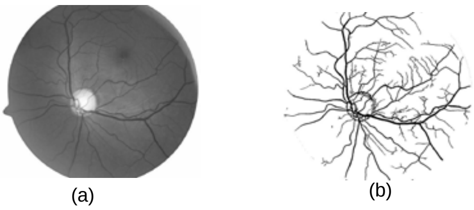

Fig. 1. (a) High resolution image Img4, size 3500x3000 pixels
(b) Img4 segmented by ITK method

ii) ITK method complete region growing more quickly than Matlab, so the overall speed of segmentation is 12 times faster than Matlab implementation.

3. Methods for high resolution image segmentation

3.1 Serial method:

In this method the segmentation algorithms are implemented in general purpose sequential processing systems. The limitation of this method is, the elapsed time is very lengthy(took about 27 minutes for segmenting 3500x3000 size image) and it could not segment large amount of high resolution images.

3.2 Parallel Method:

The purpose of parallelizing the segmentation algorithm is to process larger data sets of images in an acceptable time.
Resources for parallel computing:

- Multi threading in single computer
- Multi core processors
- FPGA (Field Programmable Gate Array) based system
- CPU with GPU(Graphics processing units)
- Network of computers with own main memory

The parallel resources provide better performance compare with sequential methods, but resources with single main memory could not provide solution for our problem; therefore a network of computers used for our proposed method. Fig.2. describes the parallel implementation with network of computers. The parallelism is applied by partitioning the image into number of sub-images (Domain Partition), and then the sub-images allotted to all participating nodes for simultaneous processing. Each participating node only processes the allotted sub-images, so this framework capable of segmenting very large size image in an acceptable time.

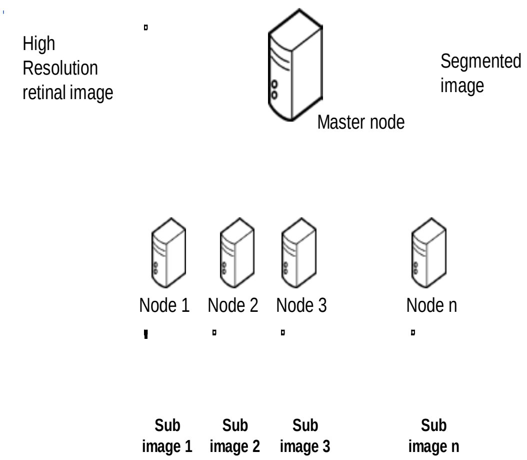

Fig.2. Frame work for parallel implementation (Domain partition)

MA Palomera-Perez et al. [15] Implement the multiscale approach described in the previous section in parallel environment.

Feature Extraction in Parallel:

Multiscale feature extraction is a local process, (i.e) it does not depend on its neighbor pixels. The input image partitioned into equal size sub images and allotted to separate processors (Fig.2), then the participating processor extract the features from allotted sub images simultaneously. After parallel feature extraction the resulting image is then compound by all resulting sub images. The boundary pixels of sub images may lead some false vessel edges; this can be avoided by the use of overlapping partition (Fig.3.). The FE phase use either horizontal or vertical partition, since it does not refer any neighbouring pixels.

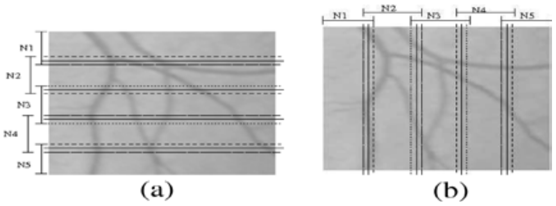

Fig. 3. (a) Horizontal overlapping partition
(b) Vertical overlapping partition

Region Growing in Parallel:

Parallelizing of RG phase requires both horizontal and vertical partition Fig.3 (a),(b)., since the RG algorithm depends on the iteration stage and on the processing of neighbour pixels. Because of this reason the parallel RG phase takes an additional time.
The parallel implementation was tested on a Beowulf cluster, composed of master node (2 Xeon, 2.6 GHz, 1.5 GM RAM, Linux kernel 2.6.8) and 13 slave nodes (13 Pentium IV, 2.6 GHz, 500 MB RAM, Linux kernel 2.6.12).
Table II compare the serial and parallel implementation of multiscale approach.

File	Size (Pixels)	Scales	Feature Extraction(s)		Region Growing(s)	
			ITK Serial	ITK Parallel	ITK Serial	ITK Parallel
Imag1	703 x 599	[2-6]	7.125	1.454	1.973	1.506
Imag2	1319 x 1518	[2-8]	49.626	6.996	20.823	10.872
Imag3	2308 x 2890	[5-25]	614.934	48.192	57.018	25.799
Imag4	3500 x 3000	[5-21]	794.217	62.897	252.304	74.593
Imag5	3500 x 3000	[5-35]	1443.860	105.761	233.864	106.794

Table II(a)
Comparison of serial and parallel methods based on Speed

True Positive Rate		False Positive Rate		Accuracy		n
ITK Serial	ITK Parallel	ITK Serial	ITK Parallel	ITK Serial	ITK Parallel	
.660	.644	.038	.033	.922	.925	20

Table II(b)
Comparison of serial and parallel methods based on Accuracy

Following observation made from Table II,
i) The speed of FE of Parallel version is linear to number of nodes used in the cluster, since the feature extraction phase not dependent to its neighbour. (The parallel version 14 times faster than serial version with 1+13 nodes (Table II (a)).
ii) The speed of RG of parallel version is not satisfactory, since this phase depends on iteration stage and on the neighbor pixels (for 1+13 nodes, parallel RG is only 2 times faster than serial version (Table II (a)).
iii) The FPR of parallel approach is less than the serial version; therefore the accuracy is slightly increased(Table II (b)).

4. Empirical comparison

In this section we measure the performance of Matlab, ITK serial and ITK parallel implementation(Table III) in terms of speed, accuracy and capability of handling high resolution images.

Measures	**Matlab[10]**	**ITK Serial[14]**	**ITK Parallel[15] (with 14 nodes)**
Rate of Speed	1	12	108
Accuracy in %	91.81	92.40	92.60
Capability to handling high resolution images	Out of memory error for high resolution (2308x2890) images	Can process high resolution images(up to 3500x3000)	Can process large amount of high resolution images

Table III
Comparison of Matlab, ITK Serial and ITK Parallel methods

4.1 Speed

Because of the low level nature and the efficient utilization of memory, the ITK tool highly reduces the elapsed time compare with Matlab implementation. The participating nodes in parallel approach process the sub images simultaneously; therefore the elapsed time highly reduced in parallel method. Fig.5. shows the rate of speed of all the three implementations.

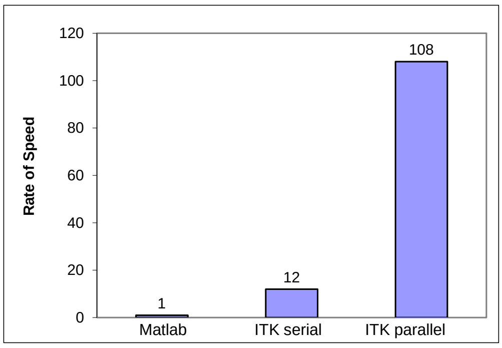

Fig.4.
Comparison of Matlab, ITK Serial and ITK Parallel methods

4.2 Accuracy

The TPR and FPR decide the accuracy of segmentation, FPR in ITK method slightly low while compared with Matlab; therefore the accuracy is slightly increased in ITK serial and parallel implementations.

4.3 Capability of handling high resolution images

Because of the low level nature and efficient utilization of main memory the ITK tool handles high resolution images when compared to Matlab. The parallel methods involve several nodes, and the participating nodes only process the allotted sub images, so it can handle large amount of high resolution images.

4.4 Limitations in current parallel method

- The algorithm used in the current parallel approach provide only 92.5% of segmentation accuracy, where as some other algorithms [5],[8],[9] and [16] provide better accuracy(about 95.5%).
- Approximately 20% of elapsed time is spent for communication and, the segmentation algorithm is not suitable for parallelization; therefore the speed of segmentation is not completely satisfactory,(it took 3.54 minutes for segmenting 3500x3000 size image).

5. Planned Research

Limitation of current parallel methods and the availability of high resolution retinal images drive the creation of new parallel technique and algorithm. Based on the review, we propose a new parallel method for segmenting high resolution retinal images.
Framework for planned research:

Environment: Segmenting very high resolution image in large scale is not possible with single computer; therefore a parallel environment (network of computer with own main memory) is used.

Tool: Because of the low level nature the ITK tool is very fast and efficiently utilize the main memory; therefore it is most suitable for segmenting high resolution images.

Data Partition: The partitioned sub image for the slave nodes is further splitted and send to the slave nodes. This new partition scheme may reduce the idle time of the nodes and enable multitasking.

Segmentation Algorithm: Enhancement / Thresholding based algorithms are fast in nature [16] and most suitable for parallelization.

6. Conclusion

Automated blood vessel segmentation is an important preprocessing step for the early diagnosis of retinal diseases. Most of the existing methods fail to segment large amount of high resolution images, since it requires high capacity of main memory. The proposed parallel method has an infrastructure (network of computer) to segment such a high resolution image. The new data partition scheme reduces the idle time of the participating nodes and enables parallel computation; therefore the speed of segmentation is increased. The use of enhancement/threshold based segmentation algorithm further enhances the speed and accuracy of segmentation.

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