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A Comparative Study on Medical Image Segmentation Models

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***Abstract* — Prediction of diseases with the help of computer technology enhances vast applications in bioinformatics .In this survey paper, we find out efficient segmentation based on the studies of various methods. Semi supervised learning focus to high performance in multiple image segmentation and highly controllable by user. We have presented detailed and comparative study to analyze both computational and biological validation. Elaborative experiments on multiple collection of medical image dataset show the efficiency of variation with different methods.**

Keywords-component; bioinformatics, semi supervised learning, segmentation, multi images.

I. INTRODUCTION

The use of computer technology has greatly enhanced in medical field. This is mostly in hospital environments where reliability and quality are critical factors. Many computer applications such as patient information system, monitoring and control system can be efficiently done by computer technology. The impact of science and technology has facilitated the advancement of medical technology constantly .So the research interests are in the area of bioinformatics. Wide applications of computer technology to the management of biological information are referred to bioinformatics. It is an ambidextrous field that develops and improves [16] upon methods for collecting, organizing, retrieving biological data. Bioinformatics has become vital part of many areas of biology. These can consist of information stored in the genetic code, patient statistics, and scientific literature .Bioinformatics has various applications in medicine, biotechnology, agriculture etc .Many technologies are using in bioinformatics such as catalog and information system, artificial intelligence, data mining, image processing, neural network etc. bioinformatics play an contribution to identify genomes and their mutation in genetics. Bioinformatics have application in the textual mining of biological literature and the progress of biological and gene ontologisms to categorize and query biological data. [16] In molecular biology, bioinformatics techniques such as image and signal processing allow mining of useful results from large amounts of unprocessed data. Many troubles are facing in area of bioinformatics such as protein structure prediction, model support for restoration of hearing, vision and locomotion, problem of segmentation of large collection of images. This paper focus to overcome the problem of segmentation of large collection of images. Single image segmenting is very successful. Multiple image segmentation is not stronger and segmentation is not regular. Automatic image segmentation has much natural difficulty and is still a very hard problem and segmentation time is high. To overcome the problem a semi supervised optimization model is an efficient segmentation of many input images.[7] The model has dual achievements 1. The segmentation is highly convenient by the user. User to provide, either offline or interactively labeled pixels in images as strong priors for the model. 2. The model requires only least modification of model parameters during the initial stage. If previously starting tuning is completed, then segmentation of large collection of images can be done using [7] unlabeled data.

II. COMPARATIVE STUDY

The author[1] Yuri Boykov and Vladimir Kolmogorov focus on energy minimization in low level vision .In this paper main goal is comparison of min cut/max flow algorithms for applications in vision.. . [1] To complete this work successfully provide the algorithms such as Goldberg-Tarjan style ”push relabel” methods and algorithms based on[1] Ford-Fulkerson style ”augmenting paths”. A directed weighted [1]graph g=(V,E) consist of set of nodes V and edges E that connect them.The graph terminals such that source s and terminal t.[1] In optimization theory, states that in a flow network,the maximum amount of flow from the Source to the Sink is equal to the minimum capacity that when removed in a specific way from the network causes the situation that no flow pass from the source to the sink. In push relabel algorithm using three steps.First step is that starting with a preflow,push excess flow closer to the sink.Second step is that if excess flow can’t reach at the sink,it backwards to source.Third step is that Eventually preflow becomes flow and infact the maximum flow.

Augmenting Path is the path through the graph using only edges with positive capacity from the source S and sink T.If we can’t find a path from the source to the sink only we use positive capacity edges then the flow can’t be increased.Flow through the network is perfect if and only if contains no augmenting path.

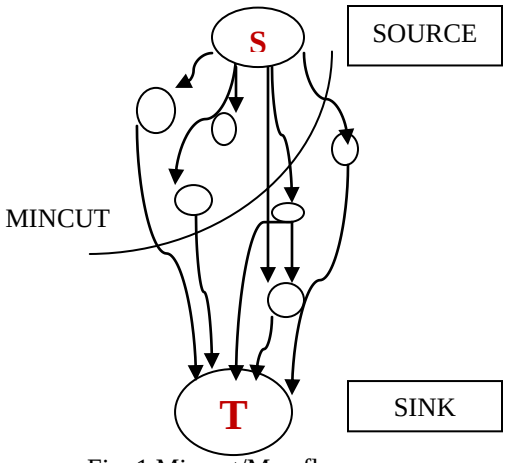

Fig .1 Min cut/Max flow

Nowadays ,rapid increasing of the volume of image collections, Content Based Image Retrieval(CBIR)[2] has attracted a lot of research in recent years.[2]The authors Zhi-Hua Zhou, Ke-Jia Chen, and Yuan Jiang are focused to Exploiting Unlabeled Data in Content- Based Image Retrieval. The user [2] could pose an example of relevant images from the database. One of the difficulties is the gap between high level semantics and low level features due to the rich content. Relevance feedback has been shown that a powerful tool for bridging this gap. [2] Here user has the option of labeling a few of images according to whether they are relevant or not. Labeled images are then given to CBIR system as complementary queries so that more images relevant to the user query could be retrieved from the database. [2]The SSAIR (Semi-Supervised Active Image Retrieval) approach, which attempts to utilize unlabeled data to improve the performance of content-based image retrieval (CBIR), is proposed. This approach [2] combines the qualities of semi-supervised learning and active learning. [2] In detail, in each round of relevance feedback, two simple learners are trained from the labeled data, i.e. [2] images from user query and user response. Each learner then classifies the unlabeled images [2] in the database and passes the most relevant/irrelevant images to the other learner. [2]After re-training with the extra labeled records, [2] the learners ordered the images in the catalog again and then their classifications are fused. Active learning is close to SL, except that training data are not independent and identically distributed variables. Some of them are added to the training set thanks to dedicated process.

The authors Alexander Vezhnevets and Vittorio Ferrari focus their research work in [3] softly supervised semantic segmentation with a multi image model. [3]Introduce "objectness" that help separating objects (eg.car, dog, human) from background classes (e.g. grass, sky, road) .Achieve accuracy compared to fully supervised methods.

Diabetic due to high blood sugar and pancreas does not produce enough blood sugar. Diabetes reasons serious long term obstacles such as heart disease, renal failure, Diabetics retinopathy.[4]Diabetic retinopathy is retinopathy(damage to retina) caused by complication of Diabetes which can eventually lead to lost vision. Other diseases caused by diabetic such as hypertension, glaucoma ,obesity etc. Vessel extraction is a kind of line detection problem. [4]Here using supervised method and unsupervised method are using. Supervised Methods exploit some prior labeling information to decide whether a pixel belongs to a vessel or not, while unsupervised method do the vessel segmentation without any prior labeling knowledge [4]**.** The Matched Filter (MF) [4] is a simple yet effective method for vessel extraction. However, a MF [4] will react not only to vessels but also to non-vessel boundaries. This leads to false vessel detection. The proposed MF-FDOG [4] is self-possessed of the original MF, which is a [4] zero-mean Gaussian function, and the first-order derivative of Gaussian (FDOG). The vessels are identified by thresholding the retinal image's response to the MF [4], while the threshold is adjusted by the image's response to the FDOG. [4]The proposed MF-FDOG method is very simple; however, it reduces significantly the false detections [21] produced by the original MF and detects many fine vessels that are missed by the MF. It [4] achieves competitive vessel detection [21] results as compared with those modern schemes but with much lower complexity. In addition, it performs well at extracting vessels from diseased retinal images [4].

Method used is True positive rate, false positive rate, and Accuracy. Compare to other research work paper have advantages simplicity, effectiveness, lower complexity and easy to implement.

To study about the blood vessel segmentation authors Diego Marín, Arturo Aquino, Manuel Emilio Gegúndez-Arias, and José Manuel Bravo proposed a new supervised method [5].In this method [5] they focuses on gray level and moment invariant features.With the help of two retinal image datase (DRIVE and STARE)[5] enable to do the comparative study of diseased images or patient's images.

Diabetic retinopathy is a major eye disease which is due to the complication of diabetic.Diabetic retinopathy is a condition occurring in persons with diabetes, which causes progressive damage to the retina. These patients[5] shows no symptoms until visual loss develops, and also in late disease stages treatment is less effective.So to overcome this drastic situation providing a method to easily identify the patients to diagonose the diabetic retinopathy,glucoma or obesity. [5]segmentation is an important process in an automated retinal image analysis system. Here, authors depicts image segmentation with supervised learning.Supervised learning is machine learning task of inferring a function from labeled training data.

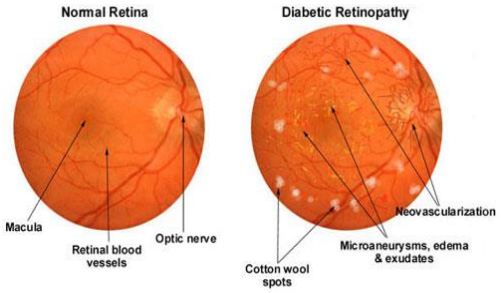

Fig. 2 Image of normal and abnormal images of retina

The authors obtain excellent results when the results on both databases (DRIVE and STARE) are jointly analyzed. In previous research papers accuracy significantly worsens when the method is trained and tested on different databases. Neural network method is provided to enhance the segmentation result [11]. Neural network [10] is a system of programs and data structures that approximates the operation of the human brain[11].

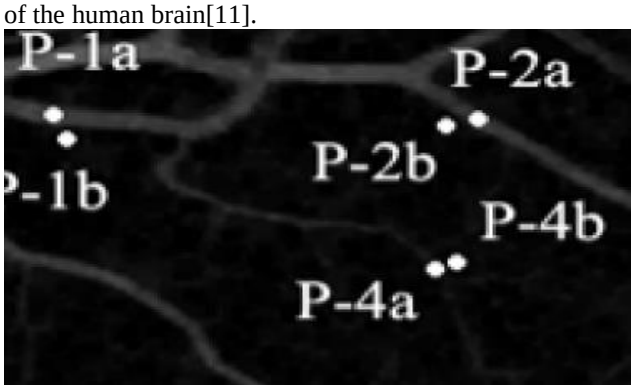

Fig.3. supervised segmentation of retina image [5]

A neural network usually involves a large number of processors operating in parallel[10] . In this method Simplicity and high accuracy is achieved.

Cancer is easier to delicacy and relieve if it is diagnosed early. So an enormous amount of effort has gone into developing ways to *detect* early signs of the disease .From this idea, authors[6] Chun-Hou Zheng and De-Shuang Huang proposed a method nonnegative matrix factorization with gene selection for tumor clustering process .For the effective treatment of cancer reliable and precise identification of the type of tumors is essential. [6]In this paper they highlighted unsupervised clustering. For that using nonnegative matrix factorization [6](NMF), and its extensions have been used successfully for cancer clustering .Unsupervised clustering is the clustering mechanism where no class value denoting an a priori grouping of the data instances are given ,which is the case in the supervised learning done .ICA(Independent Component Analysis) is using for selecting malignant cells from large amount of data by using the gene selection method [6].They enhances the experiments of three publicly available datasets, i.e., leukemia dataset[6], central nervous system embryonal tumors dataset [6], and medulloblastoma dataset [6] to identify diseases and comparing NMF method with other unsupervised clustering such as hierarchical clustering and self organizing maps .From the studies NMF gives improved result and better performance.

III. SEMISUPERVISED SEGMENTATION MODEL FOR MULTIPLE IMAGE SEGMENTATION

In computer vision ,image segmentation is the procedure of dividing a digital image into multiple segments .In image processing segmentation is used to simplify and/or change the depiction of an image into something that is more meaningful and easier to analyze .Image segmentation typically used to locate objects and boundaries in medical images .Image segmentation is the procedure of assigning label to every pixel in an image such that pixels with same label share certain visual characteristics .Segmentation can be done by supervised, unsupervised and semi supervised methods. Semi supervised learning consists of both supervised learning and unsupervised learning .Supervised learning is the mechanism of machine learning task which is inferring a function from labeled training data. Unsupervised learning trying to find concealed structure in unlabeled data. Semi supervised segmentation is act as the core ground between supervised and unsupervised methods. A semi supervised optimization model that determines an efficient segmentation of many input images. The user [7] can specify some sample pixels or objects in one or more images once and for all so that the segmentation of all other images is fully practice.

The author concerned about the problem of segmentation of large collections of images [7]. Other research work leads to single image segmentation is very successful but multiple image segmentation is not efficient .In semi supervised image segmentation the user marks some sample pixels from each class of objects. The computational algorithm then computes a classification of other pixels. This way, the resulting segmentation is highly controllable by the user and thereby eliminates much haziness in defining a partition [7]. An optimization- based two-class segmentation model, in which an optimal set membership function is computed through the minimization of a quadratic cost function [20] with user-supplied samples as linear constraints. The basic plan is that two pixels should have similar membership if they have either similar location or similar color or both [7]. The results are quite impressive. Single-image optimization models were extended to the multiple- image case in the context of image retrieval. However, the method assumes the availability of a suitable dictionary that typically contains thousands of texture patches (prototypes) to serve as a common ground for comparison between images.

Finally, [7] this model find out that successful in segmenting multiple images and the user can specify some sample pixels or objects in one or more images once and for all so that the segmentation of all other images is fully regular.

Comparing this model with above explained six other methods which lead to analyses the performance of multiple image segmentation with semi supervised learning.

A. *Min- cut/max-flow algorithm*

Establishing minimum cut and maximum flow [1] with the help of augmenting path and push relabel algorithm.Main drawback is that time complexity and establishment of augmenting path is not necessarily shortest.

B. *Exploiting unlabeled data in content based image retrieval*

SSAIR [2] (Semisupervised Active Image Retrieval) approach, which attempts to exploit unlabeled data to improve the performance of Content Based Image Retrieval. This approach combines the merits of semi-supervised learning and active learning. By comparing to semisupervised modeling with multiple images this method creates noise problem and can't implement in multiple images.

C. *Weakly supervised semantic segmentation*

From the above two methods, here using [3] multi image mode .Achieve accuracy compared to fully supervised method such that concept of "objectness" [3] is using. The drawback of the paper is that it does not focus on large training set of data

D. *Retinal vessel extraction by MF with FODG*

In this method using [4] matched filter and first order derivative of Gaussian and separately using supervised method and unsupervised method. For some input images supervised learning is using and others using unsupervised learning. Providing lower complexity compared to above other methods. To distinguish blobs and lesions in input images shows less sensitivity and accuracy.

E. *A new supervised method for blood vessel segmentation*

Supervised [5] method using training data set for image segmentation. But the process leads to much human laborious. Because each time we will aware about training data set. During the image segmentation particularly in medical input images background lightening variation is causing that leads to degrade the performance of image segmentation.

F. *Tumor cluster using nonnegative matrix factorization*

This method providing higher accuracy than previously reported cancer clustering method .But efficiency is not much acquired to compare with semi supervised multi image segmentation .Systematic studies on larger datasets can't be achieved.

Semi supervised image segmentation for multi image model encompassing semi supervised image segmentation[7] of collection of images .To show the validity of the method apply three input medical image data set.[7]They are retinal images ,retinal layer images and segmentation of malignant images.

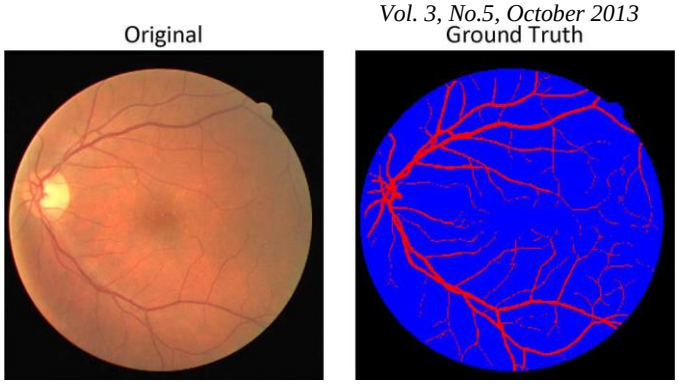

Fig. 4 Original image and its ground truth segmentation[7].

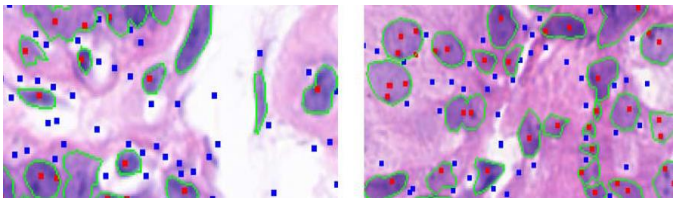

Fig. 5 (a) Benign cells (b)Malignant cells[7]

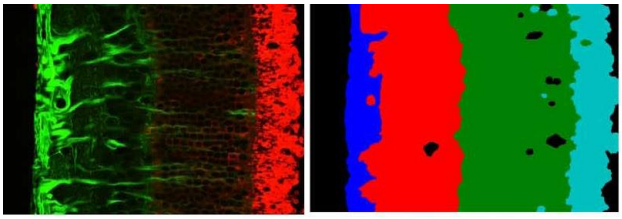

Fig. 6 Retinal layer images [7]

IV PERFORMANCE ANALYSIS

From the experiments with medical image [7] data set(such as retina image ,retinal layer images, and malignant images) analyzing the performance compared with previous methods.

By providing optimization model, similarity measures, optimality conditions, applications to collection of images and computational complexity are tested with unsupervised method(such as K-means),supervised method(SVM and K-nearest neighbor) and semi-supervised learning[7].

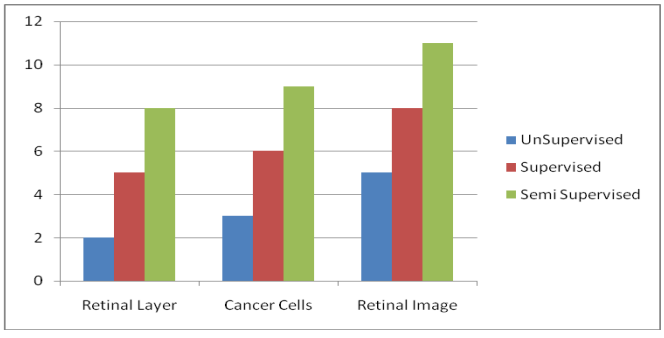

Fig. 7 Performance of supervised, unsupervised and semi supervised learning (SSL) based on three categories of images.

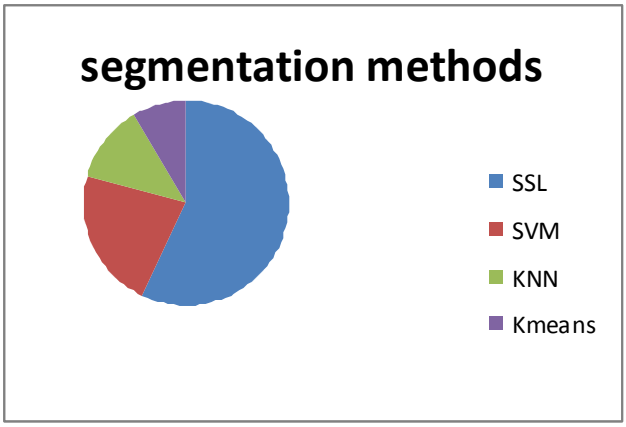

Fig. 8 Efficiency analysis study of the Segmentation of testing image with four methods.

Semi-supervised learning improved ability to study the diseased images and non diseased images. Compared to other methods Semi supervised multiple image model shows high sensitivity, specificity, precision, and accuracy. So SSL of collection of images shows high efficiency than other methods.

A. Sensitivity

SSL model is sensitive to various settings of image segmentation. Computed solution of SSL gets less and less sensitive to noise.

B. Specificity

SSL can efficiently specify relevant and irrelevant data. With the specification doctors can easily predict the diseases that leading one of the contribution of SSL.

C. Precision

Minimum of test errors are facing in SSL model. So SSL free from noise and outliers.

D. Accuracy

SSL have high accuracy because of self training method is invoked. Initially using labeled data and then segmentation continue with unlabeled data.

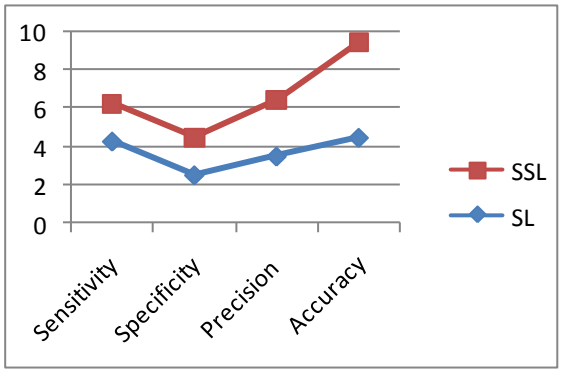

Fig .9 Performance analyses of SSL and SL

TABLE I. IMPLEMENTATION IN SSL

Semi-Supervised Learning		
Classes of algorithms	***Validation***	***SSL in practice***
Generative models & diagnostic techniques	*Computational validation*	*Speech recognition*
Low density separation	Biological validation	Protein sequences
Graph based method	User validation	Identify relevant data from medical images

v conclusion

In this survey paper, first evaluating the importance of bioinformatics and its applications in medical field. We analyzed different segmentation methods such as supervised, unsupervised and semi-supervised method with the help of previous research papers. From these studies, realized that semi-supervised multi image model[7] is highly efficient than other methods.SSL[7] method using both labeled data and unlabeled data, so that one initial tuning is done the segment can be easily applied to entire image .Here, multiple image segmentation is stronger and resulting high performance. This method reduces the overhead due to initial manual intervention. Further implementation work based on the constraints in SSL such as brightness and contrast of outcome of resulting images.

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References

[1] Yuri Boykov and Vladimir Kolmogorov " An Experimental Comparison of Min-Cut/Max-Flow Algorithms for Energy Minimization in Vision" SEPT 2004

[2] Zhi-Hua Zhou, Ke-Jia Chen, and Yuan Jiang "Exploiting Unlabeled Data in Content- Based Image Retrieval".

[3] Alexander Vezhnevets and Vittorio Ferrari "Weakly Supervised Semantic Segmentation with a Multi-Image Model".

[4] Bob Zhang, Lin Zhang, Lei Zhang and Fakhri Karray1 ," Retinal Vessel Extraction by Matched Filter with First-Order Derivative of Gaussian" ,July 2008

[5] Diego Marín, Arturo Aquino*, Manuel Emilio Gegúndez-Arias, and José Manuel Bravo "A New Supervised Method for Blood Vessel Segmentation in Retinal Images by Using Gray-Level and Moment Invariants-Based Features" Jan 2011

[6] Chun-Hou Zheng, De-Shuang Huang," Tumor Clustering Using Nonnegative Matrix Factorization With Gene Selection "*July 2009*

[7] Yan Nei Law, Hwee Kuan Lee, Michael K. Ng, and Andy M. Yip **"** A Semi supervised Segmentation Model for Collections of Images**"** JUNE 2012

[8] C. Heneghan, J. Flynn, M. O'Keefe, and M. Cahill, "Characterization of changes in blood vessel width and tortuosity in retinopathy of prematurity using image analysis," *Med. Image Anal.*, vol. 6, pp. 407–429,2002

[9] Grisan and A. Ruggeri, "A divide and impera strategy for the automatic classification of retinal vessels into arteries and veins," in *Proc. 25th Int. Conf. IEEE Eng. Med. Biol. Soc.*, 2003, pp. 890–893.

[10] Daneshwari I. Hatti, Siddalingesh S.Navalgund, Vijaya.C " Neural Network based DCT Computation"

[11] Weibin Hong, Wei Chen, and Rui Zhang "The Application o Neural Network in the Technology of Image Processing" *IEEE Trans. MedImag.*, vol. 23, no. 10, pp. 1189–1195, Oct. 2004.

[12] A. A. H. A. R. Youssif, A. Z. Ghalwash, and A. R. Ghoneim, "Optic disc detection from normalized digital fundus images by means of a vessels' direction matched filter," *IEEE Trans. Med. Imag.*, vol. 27, no.1, pp. 11–18, Jan. 2008.

[13] A. Can, H. Shen, J. N. Turner, H. L. Tanenbaum, and B. Roysam, "Rapid automated tracing and feature extraction from retinal fundus images using direct exploratory algorithms," *IEEE Trans. Inform. Technol. Biomed.*, vol. 3, no. 2, pp. 125–138, Jun. 1999.

[14] F. Zana and J. C. Klein, "Segmentation of vessel-like patterns using mathematical morphology and curvature evaluation," *IEEE Trans. Image Process.*, vol. 10, no. 7, pp. 1010–1019, Jul. 2001

[15] A. M. Mendonça and A. Campilho, "Segmentation of retinal blood vessels by combining the detection of centerlines and morphological reconstruction," *IEEE Trans. Med. Imag.*, vol. 25, no. 9, pp. 1200–1213 Sep. 2006.

[16] Wall M, Rechtsteiner A, Rocha L: Singular Value Decomposition and Principal Component Analysis. In *A Practical Approach to Microarray Data*

[17] *Analysis* Edited by: Berrar D, Dubitzky W. Granzow M: Kluwer; 2003:91-109.L. Gang, O. Chutatape, and S. M. Krishnan, "Detection and measurement of retinal vessels in fundus images using amplitude modified second-order Gaussian filter," *IEEE Trans. Biomed. Eng.*, vol. 49, pp. 168–172, Feb.2002.

[18] M. Al-Rawi and H. Karajeh, "Genetic algorithm matched filter optimization for automated detection of blood vessels from digital retinal images," *Comput. Methods Programs Biomed.*, vol. 87, pp. 248–253,2007.

[19] T. McInerney and D. Terzopoulos, "T-snakes: Topology adaptive snakes," *Med. Imag. Anal.*, vol. 4, pp. 73–91, 2000.

[20] G.SARANYA, L.M.VARALAKSHMI, R.DEEPA "Computationally Efficient Segmentation Model for Collection of Images"

[21] Mohammed Al-Rawi*, Munib Qutaishat, Mohammed Arrar "Animproved matched filter for blood vessel detection of digital retinal images"Aug 2005

[22] B. S. Y. Lam and H. Yan, "A novel vessel segmentation algorithm for pathological retina images based on the divergence of vector fields," *IEEE Trans. Med. Imag.*, vol. 27, no. 2, pp. 237–246, Feb. 2008.

[23] G. G. Gardner, D. Keating, T. H.Williamson, and A. T. Elliott, "Automatic detection of diabetic retinopathy using an artificial neural network: A screening tool," *Br. J. Ophthalmol.*, vol. 80, pp. 940–944, 1996.

[24] M. Niemeijer, J. Staal, B. v. Ginneken, M. Loog, and M. D. Abramoff, J. Fitzpatrick and M. Sonka, Eds., "Comparative study of retinal vessel segmentation methods on a new publicly available database," in *SPIE Med. Imag.*, 2004, vol. 5370, pp. 648–656.

[25] J. Staal, M. D. Abràmoff, M. Niemeijer, M. A. Viergever, and B. v. Ginneken, "Ridge based vessel segmentation in color images of the retina," *IEEE Trans. Med. Imag.*, vol. 23, no. 4, pp. 501–509, Apr. 2004.

[26] J. V. B. Soares, J. J. G. Leandro, R. M. Cesar, Jr., H. F. Jelinek, and M.J. Cree, "Retinal vessel segmentation using the 2D Gabor wavelet and supervised classification," *IEEE Trans. Med. Imag.*, vol. 25, no. 9, pp. 1214–1222, Sep. 2006.

[27] E. Ricci and R. Perfetti, "Retinal blood vessel segmentation using line operators and support vector classification," *IEEE Trans. Med. Imag.*, vol. 26, no. 10, pp. 1357–1365, Oct. 2007.

[28] T. Walter, P. Massin, A. Erginay, R. Ordonez, C. Jeulin, and J. C. Klein, "Automatic detection of microaneurysms in color fundus images," *Med. Image Anal.*, vol. 11, pp. 555–566, 2007.

[29] B. Zhang, X. Wu, J. You, Q. Li, and F. Karray, "Detection of microaneurysms using multi-scale correlation coefficients," *Pattern Recognit.*, vol. 43, pp. 2237–2248, 2010.

[30] L. Streeter and M. J. Cree, "Microaneurysm detection in colour fundus images," in *Image Vision Comput.*, Nov. 2003, pp. 280–284.

[31] R. Jagoe, J. Arnold, C. Blauth, P. L. C. Smith, K. M. Taylor, and R. Wootton, "Measurement of capillary dropout in retinal angiograms by computerised image analysis," *Pattern Recognit. Lett*, vol. 13, pp. 143–151, 1992.

[32] M. K. Hu, "Visual pattern recognition by moment invariants," *IRE Trans. Inform. Theory*, vol. IT-8, pp. 179–187, 1962.

[33] S. Bioux, M. Martin-Fernandez, L. Ungar, M. Nakamura, M. -. Koo,R. W. McCarley, and M. E. Shenton, "On evaluating brain tissue classifiers without a ground truth," *NeuroImage*, vol. 36, no. 4, pp. 1207–1224, 2007.

[34] D. E. Rumelhart and J. L. McClellandthe, *Parallel Distributed Processing, Explanations in the Micro Structure of Cognition, 1: Foundations.A Bradford Book*. Cambridge, MA: MIT Press, 1988.

[35] M. Martínez-Pérez, A. Hughes, A. Stanton, S. Thom, A. Bharath, and K. Parker, "Scale-space analysis for the characterisation of retinal blood vessels," *Medical Image Computing and Computer-Assisted Intervention*, pp. 90–97, 1999.

[36] A. Hoover, V. Kouznetsova, and M. Goldbaum, "Locating blood vessels in retinal images by piecewise threshold probing of a matched filter response," *IEEE Trans. Med. Imag.*, vol. 19, no. 3, pp. 203–210,

[37] X. Jiang and D. Mojon, "Adaptive local thresholding by verification based multithreshold probing with application to vessel detection in retinal images," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 25, no. 1, pp. 131–137, 2003.

[38] A.M. Mendonca and A. Campilho, "Segmentation of retinal blood vessels by combining the detection of centerlines and morphological reconstruction", *IEEE Transactions on Medical Imaging*, vol. 25, no. 9, pp.1200–1213, 2006.

[39] M.E. Martinez-Perez, A.D. Hughes, S.A. Thom, A. A. Bharath, and K.H. Parker, "Segmentation of blood vessels from red-free and fluorescein retinal images", *Medical Image Analysis*, vol. 11, no. 1, pp. 47–61, 2007.

[40] S. Chaudhuri, S. Chatterjee, N. Katz, M. Nelson, and M. Goldbaum, "Detection of blood vessels in retinal images using two-dimensional matched filters," *IEEE Trans. Med. Imaging*, pp. 263–269, 1989

[41] H. Leung, J.J. Wang, E. Rochtchina, T.Y. Wong, R. Klein, and P. Mitchell, "Impact of current and past blood pressure on retinal arteriolar diameter in older population," *J. Hypertens*., pp.1543–1549, 2003.

[42] P. Mitchell, H. Leung, J.J. Wang, E. Rochtchina, A.J. Lee, T.Y. Wong, and R. Klein, "Retinal vessel diameter and open-angle glaucoma: the Blue Mountains eye study," *Ophthalmology*,pp. 245–250, 2005.

[43] R. Perfetti, E. Ricci, D. Casali, and G. Costantini, "Cellular neural networks with virtual template expansion for retinal vessel segmentation," *IEEE Transactions on Circuits and Systems II*, vol. 54, pp. 141 – 145, 2007.

[44] T. Tuytelaars, C. H. Lampert, M. B. Blaschko, and W. Buntine. Unsupervised object discovery: A comparison. IJCV, 88(2), 2010

[45] . J. Verbeek and B. Triggs. Region classification with markov field aspect models. In CVPR, 2007.