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Review of Retinal Blood Vessel Segmentation

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ABSTRACT: *The human eye is that the best organ that enables to see all around the environment. This eye may be compared to a camera in a sense that the image is created on the retinal of the eye; whereas in a traditional camera the image is formed on the film. As we know, the retinal is that the solely location where blood vessel can be directly captured. Over the past decade, the research showed the retinal Image has been wide used in the medical community for diagnosing and observes the progression of the diseases. Thus retinal blood vessel is very important structures in retinal images. Automatic segmentation of the retinal blood vessel from retinal images would be a powerful and helpful tool for the medical diagnostics. So, the main purpose of the segmentation is to differentiate an object of the interest and the background from an image. This paper is presenting a review of some classifier methods for segmentation of retinal blood vessel.*

KEY WORDS: *retinal image, blood vessel, segmentation, supervised method*

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I. INTRODUCTION

Retinal images are impacted by all the factors that an effect on the body vasculature in general. The human eye is a unique organ of the human body where the vascular condition can be directly observed. Additionally to the fovea and the optic disc, the blood vessels contributes one among the most features of a retinal fundus image and several of its properties are noticeably affected by worldwide major diseases like diabetes, and hypertension. Further, some eye diseases like choroidal neovascularization [1] and retinal artery occlusion [2] also make changes within the retinal vasculature.

As we know, the segmentation of blood vessels in retinal images can be a valuable help for the detection of diabetic retinopathy. In general, vessels segmentation occupy an important place in medical image segmentation field [3–6]; therefore , the retinal vessels segmentation is suited to this category where a broad variety of algorithms and methodologies are developed and implemented for the reason of automatic identification, localization and extraction of retinal vasculature structures [7–8]. Hence, retinal vessel segmentation can simplify screening for retinopathy by reducing the number of false-positive results in microaneurysm detection and may serve as a means of image registration from the same patient taken at different times by delineating the location of the optic disc and fovea. However, the manual detection of blood vessels is not simple because the vessels in a retinal image are complex and have low contrast. So as to use these useful characteristics of retinal blood vessels, it is vital to get their locations and shapes accurately. Blood vessels appeared as networks of either deep red or orange-red filaments that originated within the optic disc and were of progressively diminishing width. The most essential step in the diagnosis of the retinal blood vessel is to identify the vessels from retinal images. Compared to manual diagnosis, automatic machine diagnosis in retinal images can reduce the probability of medical misdiagnosis.

Machine retinal vessels diagnosis, known as the segmentation of retinal blood vessels, is typically under the semantic segmentation task and has been studied with both unsupervised and supervised machine learning models. In conventional unsupervised approaches, features are manually extracted from images and are fed into a statistical model to detect blood vessels with on a threshold. Ricci et al. proposed a line detector to detect blood vessels at each pixel [9]. Unsupervised approaches doesn’t require labelled data, which can be considered as an advantage. However, the performance of such approaches is far below the satisfaction in real application scenarios and most of them are time consuming. Supervised segmentation approaches then have been proposed to overcome these limitations. The main idea of these supervised models is to discriminate vessel pixels against non-vessel ones with a binary classifier which is trained with features extracted from annotated images. Recent studies of deep neural networks which could extract features automatically leads to the boom of supervised deep learning approaches in the segmentation of retinal blood vessels. Ronneberger et al. proposed U-net, which first uses Convolutional Neural Network (CNN) to extract the features from the original medical image and then up samples these features to a segmentation image [47].

II. DIGITAL IMAGE PROCESSING

Digital image processing plays an important role in remote sensing, medical science, air traffic control system, radar system and forensic science etc. The digital image processing techniques are mainly utilised to obtain an image with clearly defined characteristics and to extract features. Today, a large number of digital image processing techniques exists e.g. image acquisition, enhancement, restoration, compression, segmentation, recognition etc. Image segmentation is a digital image processing technique which subdivides an image into different regions based on certain criterion [13].Hence, digital images are widely used nowadays and utilise of digital images made changes in everyday life and in many sciences. The main advantage of digital imaging is the possibility of relatively easy and complex image processing. Many new algorithms or improvements of existing ones were proposed for digital image processing. In addition, different applications require different adaptations of existing methods. Applicability of digital image processing to a wide range of problems makes this research field very active. Medicine is one of the sciences much improved by using digital images. Standard techniques for medical imaging include-ray radiography, magnetic resonance imaging, computed tomography, thermography, dermoscopy, etc. The first step in the processing of medical images is image enhancement which usually consists of some form of normalization and denoising. Middle level image processing usually deals with segmentation, edge detection, shape recognition, etc [14], [15]. The goal of higher-level medical image analysis is automatic disease diagnostics or to help the human diagnostics [16], [17].

2.1 Retinal Fundus Imaging

Retina photography is often conducted via an optical apparatus called a fundus camera. According to [10] fundus camera is often viewed as a low power microscope that specializes in retina fundus imaging, where the retina is illuminated and imaged via the attached camera. In particular, fundus camera is designed to capture an image for the interior surface of the human eye, which consists of major parts, including the macula, optic disk, retina and posterior pole [11].Therefore fundus photography can be viewed as a sort of documentation process for the retinal interior structure and retinal neurosensory tissues. Retinal photography can be also conducted based on the idea that the eye pupil is utilized as both an entrance and exit for the illuminating and imaging light rays that are used by the fundus camera. During the fundus photography, patients foreheads are placed against the bar and their chins placed within the chin rest, as shown in Figure 1. When the oculist aligns the fundus camera, the camera shutter is released so a flash light is discharged and a two dimensional picture for retinal fundus has been taken [12].

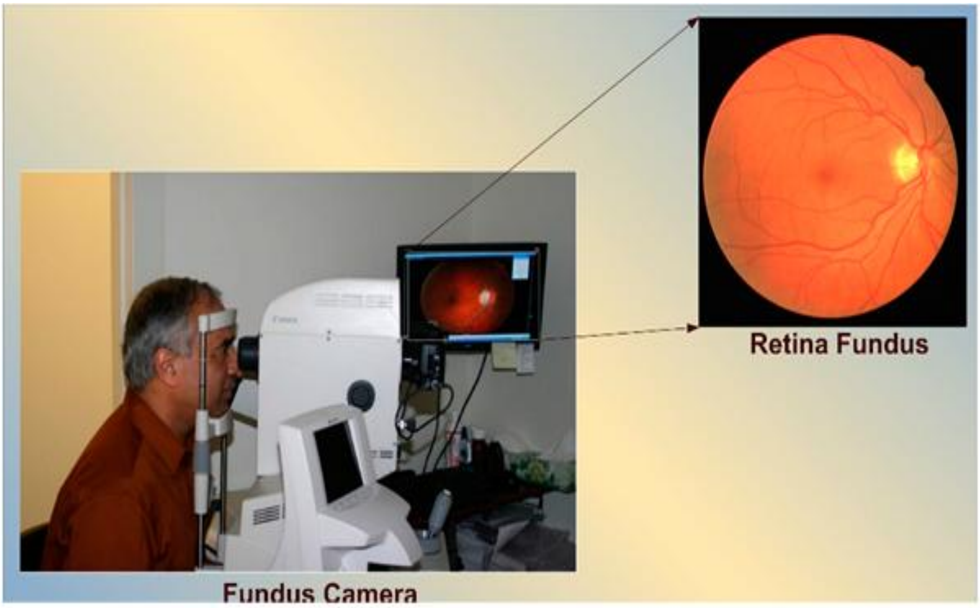


Figure1: Retinal fundus camera. Adapted with permission from [12], IEEE, 2007.

2.2 RGB Image

The colour image segmentation technique is presented based on region growing concept. The proposed colour image segmentation technique is applied to separately Red, Green and Blue channel. The resulted labelled matrixes of Red, Green and Blue channel are used to obtain the combined labelled matrix. The segmented RGB images are obtained by converting the labelled matrix to an RGB image.

The random pixel elimination methodology is applied to merge small region to large neighbour pixels. Hence, the RGB colour model is a popular model that is widely used for display images in electronic systems such as computer and television. The RGB colour images are also used in photography. The segmentation of RGB images can have an impact on human's daily life problem such as examination of images generated within the medical field, analysis of images in forensic science etc[14].The color components are considered separately because green channel displays the best vessel/background contrast whereas the red and blue ones tend to be very noisy in case of RGB. The proposed method work on the inverted green channel images, where vessels appear brighter than the background [32].

III. RETINAL IMAGE DATABASES

Datasets utilised are the most popular database used for development and testing the performance of image segmentation methods. Normally the study of retinal blood vessel segmentation starts from importing public retinal blood vessel database, where there provide researchers with retinal colour images and the corresponding information. A number of the databases provide vessel ground truth images that show precisely where each vessel pixel is located. With those databases, researchers are able to design their algorithms and compare their performances within the same criterion. Presently there exist 9 publicly available retinal blood vessel databases, among which CHASE DB1[18] , DRIVE[27] , HRF[25] , STARE [21] databases contain both retinal colour images and retinal blood vessel ground truth images, while DiaRetDB1 V2.1[24] , Messidor[22] , REVIEW[23] , ROC[26] , and VICAVR [20]databases just provide retinal colour images but without labelled images. Although the above databases are all suitable in quality and contain both normal and abnormal retinal images, however, as the study of vessel segmentation requires the vessel ground truth as a golden standard. Most of the retinal blood vessel segmentation methodologies are evaluated on DRIVE and STARE databases.

3.1 Drive Database

The name of the DRIVE (Digital Retinal Image for Vessel Extraction) [27] database has well expressed its purpose to enable comparative studies on segmentation of blood vessel in the retinal image. The DRIVE database consists of the 40 colour retinal image, the 40 images are randomly selected from 400 diabetic subjects between 25-90 years of age, and 33 do not show any sign of diabetic retinopathy whereas 7 show signs of mild early diabetic retinopathy. Every image is JPEG compressed. The set of 40 images has been divided into a training and a test set, both containing 20 images. For the training images, a single manual segmentation of the vasculature is available. For the test cases, two manual segmentations are available; one is used as a gold standard, the other one can be utilised to compare computer-generated segmentations with those of an independent human observer. All human observers that manually segmented the vasculature were instructed and trained by an experienced ophthalmologist, and they were asked to mark all pixels for which they were for at least 70% certain that they were the vessel. Consequently, the image quality within the DRIVE database is desirable and contains just 7 abnormal retinal images with mild disease. It can represent the retinal conditions of the majority of people.

3.2 Stare Database

The STARE database is suited to the STARE (Structured Analysis of the Retina) Project, Which has been created and initiated at the University of California, San Diego, and it has been funded by the U.S. National Institutes of Health [21]. The STARE database contains 400 retinal colour images. The images have been acquired using a Topcon TRV-50 fundus (bottom of the eyeball) camera with a 35-degree field of view. Each image has been captured using 8 bits per colour plane at 605 by 700 pixels, and the approximate diameter of the field of view is 650 by 500.The 20 of the images can be utilised for blood vessel segmentation because they are with the vessel ground truth images. The 20 images have been manually segmented by two different experts. The segmented results of the second expert have shown many more of the thinner vessels than the results of the first expert. Usually, the performance is computed with the segmentation of the first expert as the ground truth. Among those 20 images with ground truth, only 9 images are healthy retinal images, while the other 11 images show signs of 8 kinds of retinal diseases, mild or severe. 3 of the images even suffer from decreased sharpness. Therefore, the STARE database is the most complicated database among all the others, and it always tests the noise-resistance of an algorithm.

IV. IMAGE SEGMENTATION

The image is a way to remove information, and additionally the image contains lots of helpful information. Understanding the image and extracting information from the image to accomplish some works is a very important area of application in digital image technology, and also the first step in understanding the image is that the image segmentation. In practice, it is usually not interested in all parts of the image, but only for some certain areas which have the same characteristics [28]. Image segmentation is one amongst the hotspots in image processing and computer vision. It is additionally a very important basis for image recognition. It is based on certain criteria to divide an input image into a number of the same nature of the category in order to extract the area which people are interested in. And it is the basis for image analysis and understanding of image feature extraction and recognition. There are many commonly used image segmentation algorithms like threshold segmentation method, edge detection segmentation method and segmentation based on clustering [29].

At present, from the international image segmentation method, the specific operation of the process of segmentation method is very diverse and complex, and there is no recognized unified standard. Image segmentation is that the method of segmenting the image into varied segments that might be used for any applications like image understanding model, robotics, image analysis, medical diagnosis, etc. Hence, image segmentation is the process of partitioning an image into multiple segments, thus on modification the representation of an image into something that is more meaningful and easier to analyse [46].

4.1 Retinal Image Segmentation

The retina is a light-sensitive tissue lining the interior surface of the eye and is a layered structure with many layers of neurons interconnected by synapses. The vein and central retinal artery appear close by each other at the nasal side of the center of the optic disk [45]. Information about the structure of blood vessels can facilitate categorizing the severity of diseases and can also assist as a landmark throughout segmentation operation. Manual segmentation of retinal blood vessel is a difficult task. As the vascular structure is a tree like complex structure. It may take hours to segment blood vessel manually. Manual segmentation may not offer the actual sized blood vessel; there may a difference in actual blood vessels and segmented vessels. Also if there are two different observers observing the same retinal image. Then there may some bias in two different results. But as automatic segmentation took only a few minutes or seconds. However, it is difficult to get 100% accuracy with automatic segmentation, but it's better to have results close to 100% than to wait for hours [46].

4.2 Retinal Blood Vessel

The retinal blood vessel is the solely deep microvascular within the human body that maybe directly observed with none trauma, its physiological status check is extremely vital for the diagnosis and treatment of some disease, just like high blood pressure, diabetes, atherosclerosis and other cardiovascular diseases. A lot of significantly, the shape and structure of the retina cannot be obtained by the naked eye, it has very strong hiding, at the same time the possibility of forgery is very low. Compared with face, iris and fingerprint identification system, the retina identification system is harder to be cheated; it is a more secure recognition system. It will have higher application prospect in such aspects as identification and Security [30].

The retinal blood vessels are important structures in retinal images. The information obtained from the examination of retinal blood vessels offers many helpful parameters for the diagnosis or evaluation of ocular or systemic diseases. For example, the retinal blood vessel has shown some morphological changes like diameter, length, branchingangles or tortuosity for vascular or nonvascular pathology, such as hypertension, diabetes, cardiovascular diseases [45].

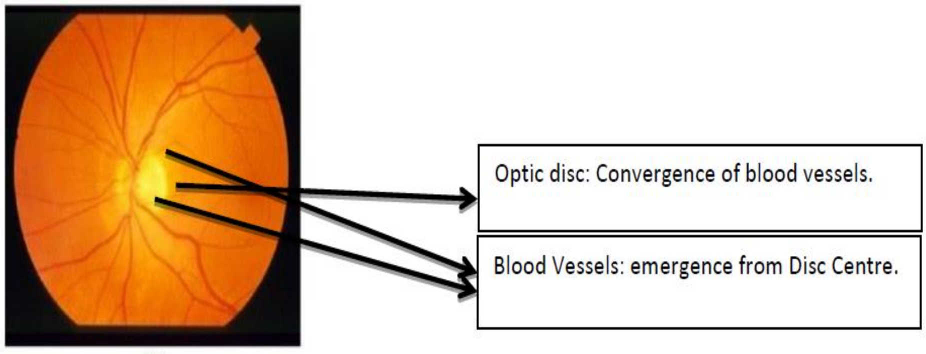
4.2.1 Blood Vessel Detection

The objective of computer-based blood vessel mapping is to extract blood vessel pixels from a digital image. The same as several alternative medical applications, blood vessel mapping is a crucial basis for various (computer-based) analyses of retinal images. Computer-aided blood vessel mapping aims at accurate extraction of the vascular structure at different generation levels [31]. Automated vessel detection has been an open problem and has been studied for many years. A blood vessel network has a self-similar geometric structure among its branches on the two dimensional image. Morphological profiling, i.e., diameters, length, tortuosity, angle of branches, of blood vessel provide basic measurements for anatomic and pathological studies. Growth, death and deformation of blood vessel segments derived from such studies can assess the general condition of the retina, and diseases like diabetic retinopathy, hypertension or other cardiovascular complications. Early detection and treatment of diabetic retinopathy (DR) increases the chance of early intervention. The blood vessels are also used as landmarks for registration of retinal images of the same patient gathered from different sources. Sometimes, retinal blood vessel should be excluded for simple detection of pathological lesions like exudates or microaneurysms. In all cases, proper segmentation of retinal blood vessel is important. Hence the blood vessel detection and segmentation is extremely crucial for diabetic retinopathy diagnosis an earlier stage.

4.2.2 Optic Disc (OD)

It is characterised by a bright patch within the back of an eye. The blood vessels emerge from its Centre. The primary step within the blood vessel segmentation process initiates from the detection of the optic disc in retinal fundus images. If there are any variations in texture or appearance then it may serve as an indication of any possible pathology. The optic disc is that the largest and brightest region of the image. The optic disc detection is helpful because it can reduce the false positive detection of the exudates. The Hough transform is used to detect the shape of the object in an image. Circular transform is implemented here which is used to find the optic disc in the fundus image the advantage is that it is tolerant of gaps in feature boundary descriptions and is relatively unaffected by image noise[33].

$(x-a)^2+(y-b)^2+r^2=0.$



V. PATTERN RECOGNITION AND MACHINE LEARNING

Pattern recognition is the process of classifying input data into objects or classes by the recognition and representation of patterns it includes and their relationships [34, 35]. It consists measurement of the object to identify attributes, extraction of features for the defining attributes, and comparison with known patterns to determine the class-memberships of objects; based totally on which classification is done. Pattern recognition is utilised in countless applications, like computer aided design (CAD), in medical science, speech recognition, optical character recognition (OCR), finger print and face detection, and retinal blood vessel segmentation [34, 36]. It is commonly categorized according to the classification procedures.

Classification is the method for arranging pixels and assigning them to particular categories. Primarily based on the classification method, pattern recognition can be either supervised or unsupervised [34]. Supervised classification is the system in which user interaction is required: user defines the decision rules for each class/pixels or provides training data for each class/pixels to guide the classification. It makes use of a supervised learning algorithm for creating a classifier, based on training data from different object classes. The input data are provided to the classifier, which assigns the appropriate label for each input. Whereas the unsupervised method tries to identify the patterns or clusters from the input dataset without predefined classification rules [37]. It learns and organizes information on its own to find the proper solution [38].

In blood vessel segmentation, the supervised method is based on pixel classification, which utilizes the a priori labelling information to determine if a pixel belongs to a vessel or non-vessel. All pixels within the image are classified into the vessel or non-vessel class by the classifier. In image classification, the training data is considered to represent the classes of interest. The quality of training data can significantly influence the performance of an algorithm and therefore, the classification accuracy [39], which shows to select proper training data. The feature extraction and the selection of parameters for the classier are also essential due to the fact they assist in determining the accuracy and overall result of the classification algorithm. The classifiers are trained by supervised learning with manually processed and segmented ground truth image. The ground truth image is precise and usually marked by an expert or ophthalmologist. Different kinds of classifiers, such as neural networks, Bayesian classifier, and support vector machine etc., have been used for improving classification [40, 41].

5.1 Support Vector Machine

Support Vector Machine (SVM) was first heard in 1992, introduced by Boser, Guyon, andVapnik in COLT-92. Support vector machines (SVMs) are a set of related supervised learning methods used for classification and regression [42]. They belong to a family of generalized linear classifiers. In another terms, Support Vector Machine (SVM) is a classification and regression prediction device that utilises machine learning theory to maximize predictive accuracy while automatically avoiding over-fit to the data.

Support Vector machines may be defined as systems which use hypothesis space of a linear functions in a high dimensional feature space, trained with a learning algorithm from optimization theory that implements a learning bias derived from statistical learning theory. Support vector machine become first of all famous with the NIPS community and now is an active part of the machine learning research around the world. SVM becomes famous whilst the usage pixel maps as input; it offers accuracy comparable to sophisticated neural networks with elaborated features in a handwriting recognition task [44].

It is also getting used for lots of applications, which include handwriting analysis, face analysis and so forth, especially for pattern classification and regression based applications. The foundations of Support Vector Machines (SVM) have been developed by way of Vapnik [48] and received popularity because of many promising features such as higher empirical performance. It is far this difference which equips SVM with a greater capability to generalize that is the purpose instatistical learning. SVMs were developed to solve the classification issue, but recently they have been extended to solve regression problems [49].Therefore, the purpose of SVM is used to improve the performance evaluation for the segmentation of blood vessels in retinal images and the detection of glaucoma.

5.2 Artificial Neural Network

Artificial neural networks are non-parametric classifiers. The structure of the neural networks is inspired by the human nervous system. The basic unit of this network is the unified process rudiment called neuron. Each neuron cell has two stages- training and exploitation part [43]. In the training part, the neuron learns to perform Associate in operation whereas within the testing part, they use the training information to predict the output. Generally, those neural networks square measure utilized in order to sight specific trends or patterns within the given data.

Neural networks have emerged as a vital tool for classification. The recent vast research activities in neural classification have established that neural networks are a promising alternative to various conventional classification methods. The benefit of neural networks lies in the following theoretical aspects. First, neural networks are data driven self-adaptive methods in that they can adjust themselves to the data without any explicit specification of functional or distributional form for the model.

Second, they are universal functional approximators in that neural networks can approximate any function with arbitrary accuracy [50]. The neural network considered as an effective classifier uses labeled training segments for classification [51]. Current classification methods rely on parametric or non-parametric multivariate analyses: discriminant analysis, cluster analyses, etc. These methods are often rather inefficient when the data are nonlinearly distributed, even after variable transformation [52].

5.3 Bayesian Classifier

Bayesian classification addresses the classification problem by learning the distribution of instances given different class values. Bayesian theory gives a mathematical calculus of degrees of belief, describing what it manner for ideals to be regular and the way they should change with evidence. In general, a Bayesian agent makes use a single real number to explain its degree of belief in each proposition of interest. This assumption, together with some other assumptions approximately how evidence should affect ideals, leads to the standard probability axioms[53].

To do a Bayesian analysis, we need to make this vague notion more precise, choosing specific mathematical formulas which say how possibly any particular mixture of evidence would be. A natural way to do this is to say that there are a sure number of classes, that a random patient has a certain probability to come from each of them, and that the patients are distributed independently – as soon as we recognize all about the underlying classes then learning about one patient doesn't help us learn what any other patient will be like.

In addition, we need to describe how each class is distributed. We need a "single class" model saying how likely any given evidence is, given that we know what class the patient comes from. For this reason, we build the multiclass model space from some other pre-existing model space, which can be arbitrarily complicated. In general, the more complex each class can be, the less of a need there is to invoke multiple classes to explain the variation in the data.

The best way to build a single-class model is to predict every attribute independently, i.e., build it from attribute-specific models. A class has a distribution for each attribute and, if you recognise the class of a case, learning the values of one attribute doesn't help you predict the value of any other attributes. For real attributes you can actually use a standard normal distribution, characterized by way of a few particular suggest and a variance around that mean. For discrete attributes one can use the standard multinomial distribution, characterized by a specific probability for each possible discrete value [53].Bayesian classification does not try to learn an explicit decision rule. Instead, learning reduces to estimating probabilities. Consequences there are some differences with other approaches to classification [54].

VI. CONCLUSION

The retinal image is reviewed with several methodologies and processing steps. It is important to segment the blood vessels in the form of the image that can be used to identify the correct disease. Although a lot of research was made in the segmentation field, however still it has some limitations and there is a need to enhance the techniques effectively. There is no further analysis to conclude the best method in general. Each method has advantages and disadvantages, which depends on the condition and needs of researchers. However, there are many ways in which these techniques are classified and categorizing these techniques into the supervised method is the most common way. The comparison of these techniques on the basis of efficiency largely depends on the type of data they are being used for.

REFERENCE

[1]. X. Xu, M. Niemeijer, Q. Song, M. Sonka, M. K. Garvin, J. M. Reinhardt, and M. D. Abràmoff,―Vessel boundary delineation on fundus images using graph-based approach, IEEE Transactions on Medical Imaging, vol. 30, no. 6, June 2011.
[2]. B. S. Y. Lam, Y, Gao, and A. W.-C. Liew, ―General retinal vessel segmentation using regularization based multiconcavity modeling, IEEE Transactions on Medical Imaging, vol. 29, no. 7, July 2010.
[3]. Lesage, D.; Angelini, E.D.; Bloch, I.; Funka-Lea, G. A review of 3D vessel lumen segmentation techniques: Models, features and extraction schemes. Med. Image Anal. **2009**, 13, 819–845.
[4]. Kirbas, C.; Quek, F. A review of vessel extraction techniques and algorithms. ACM Comput. Surv. CSUR **2004**, 36, 81–121.
[5]. Kirbas, C.; Quek, F.K. Vessel extraction techniques and algorithms: A survey. In Proceedings of the the Third IEEE symposium on Bioinformatics and Bioengineering, Bethesda, MD, USA, 12 March 2003; pp. 238–245.
[6]. Suri, J.S.; Liu, K.; Reden, L.; Laxminarayan, S. A review on MR vascular image processing: Skeleton versus nonskeleton approaches: Part II. IEEE Trans. Inf. Technol. Biomed. **2002**, 6, 338–350.
[7]. Fraz, M.M.; Remagnino, P.; Hoppe, A.; Uyyanonvara, B.; Rudnicka, A.R.; Owen, C.G.; Barman, S.A. Bloodvessel segmentation methodologies in retinal images—A survey. Comput. Methods Program Biomed. **2012**, 108,407–433.
[8]. Dash, J.; Bhoi, N. A Survey on Blood Vessel Detection Methodologies in Retinal Images. In Proceedings of the 2015 International Conference on Computational Intelligence and Networks, Bhubaneshwar, India, 12–13 January 2015; pp. 166–171.
[9]. E. Ricci and R. Perfetti, "Retinal blood vessel segmentation using line operators and support vector classification," IEEE Transactions on medical imaging, vol. 26, no. 10, pp. 1357–1365, Oct. 2007.
[10]. Kolb, H. Simple Anatomy of the Retina, 2012. Available online:http://webvision.med.utah.edu/book/parti-foundations/simple-anatomy-of-the-retina/ (accessed on 22 January 2018).
[11]. Oloumi, F.; Rangayyan, R.M.; Eshghzadeh-Zanjani, P.; Ayres, F. Detection of blood vessels in fundus Images of the retina using gabor wavelets. In Proceedings of the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Lyon, France, 22–26 August 2007; pp. 6451–6454. Available online: http://people.ucalgary.ca/~ranga/enel697/ (accessed on 12 September 2017).
[12]. Saine, P.J.; Tyler, M.E. Ophthalmic Photography: Retinal Photography, Angiography, and Electronic Imaging; Butterworth-Heinemann: Boston, MA, USA, 2002; Volume 132.
[13]. Rajesh Gothwal,''Color Image Segmentation Algorithm based on RGB channels''.
[14]. E.-S. A. El-Dahshan, H. M. Mohsen, K. Revett, and A.-B. M. Salem, "Computer-aided diagnosis of human brain tumor through mri: A surveyand a new algorithm," Expert systems with Applications, vol. 41, no. 11,pp. 5526–5545, 2014.
[15]. A. Stojak, E. Tuba, and M. Tuba, "Framework for abnormality detection in magnetic resonance brain images," in 24th Telecommunications Forum(TELFOR). IEEE, 2016, pp. 687–690.
[16]. G. Lalli, N. Manikandaprabu, D.Kalamani, and C. Marimuthu, "A development of knowledge-based inferences system for detection of breast cancer on thermogram images," in Computer Communication andInformatics (ICCCI), 2014 International Conference on. IEEE, 2014, pp. 1–6.
[17]. C. Barata, M. Ruela, M. Francisco, T. Mendonc¸a, and J. S. Marques, "Two systems for the detection of melanomas in dermoscopy images using texture and color features," IEEE Systems Journal, vol. 8, no. 3,pp. 965–979, 2014.
[18]. R. C. Gonzalez and R. E. Woods, digital image processing, Pearson education, 2002.
[19]. Retinal image analysis the chase db1 retinal image database. Available at: https://blogs.kingston.ac.uk/retinal/chasedb1/.
[20]. Vicavrdatabase varpa group. Available at: http://www.varpa.es/research/ ophtalmology.html.
[21]. The stare project structured analysis of the retina, January 2013. Available at: http://cecas.clemson.edu/~ahoover/stare/.
[22]. Bashir Al-Diri, Andrew Hunter, David Steel, Maged Habib, TaghreadHudaib, and Simon Berry. Review - a reference data set for retinal vessel pro_les. In 2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pages 2262-2265. IEEE, August 2008.
[23]. Etienne Decencire, Xiwei Zhang, Guy Cazuguel, Bruno Lay, BatriceCochener, Caroline Trone, Philippe Gain, Richard Ordonez, Pascale Massin, Ali Erginay, BatriceCharton, and Jean-Claude Klein. Feedback on a publicly distributed database: the messidor database. Image Analysis & Stereology, 33(3):231-234, August 2014.
[24]. SorriIirisRaninenAstaVoutilainenRaijaKamarainen Joni Lensu Lasse Kauppi Tomi, Kalesnykiene Valentina andUusitaloHannu. Diaretdb1 v2.1 - diabetic retinopathy database and evaluation protocol, May 2009. Available at: http://www.it.lut.fi/project/imageret/diaretdb1_v2_1/.
[25]. Thomas Kohler, Attila Budai, Martin F. Kraus, Jan Odstrcilik, Georg Michelson, and Joachim Hornegger. Automatic no-reference quality assessment for retinal fundus images using vessel segmentation. In Proceedings of the 26th IEEE International Symposium on Computer-Based Medical Systems, pages 95-100, 2013.
[26]. MeindertNiemeijer, Bram van Ginneken, Michael J Cree, Atsushi Mizutani, GwenoleQuellec, Clara I Sanchez, Bob Zhang, Roberto Hornero, Mathieu Lamard, Chisako Muramatsu, Xiangqian Wu, Guy Cazuguel, Jane You, AgustIn Mayo, Qin Li, Yuji Hatanaka, Beatrice Cochener, Christian Roux, FakhriKarray, MarIa Garcia, Hiroshi Fujita, and Michael D Abramo_. Retinopathy online challenge: Automatic detection of microaneurysms in digital color fundus photographs. IEEE Transactions on Medical Imaging, 29(1):185-195, January 2010.

[27]. Joes Staal, Michael D. Abr_amo_, MeindertNiemeijer, Max A. Viergever, and Bram van Ginneken. Ridge based vessel segmentation in color images of the retina. IEEETransactions on Medical Imaging, 23(4):501-509, 2005.
[28]. Haralick R M, Shapiro L G. Image segmentation techniques [J]. Computer vision, graphics, and image processing, 1985, 29(1): 100-132.
[29]. Marr D, HildrethE. Theory of edge detection [J]. Proceedings of the Royal Society of London B: Biological Sciences, 1980, 207(1167): 187-217.
[30]. Fraz M M, Remagnino P, Hoppe A, et al. Blood vessel segmentationmethodologiesin retinal images-a survey [J]. Computer Methods andPrograms in Biomedicine, 2012, 108(1): 407-X33.
[31]. T. L. McKay, D. J. Gedeon, M. B. Vickerman, A. G. Hylton, D. Ribita, H. H. Olar, P. K. Kaiser, and P. Parsons-Wingerter, "Selective inhibition of angiogenesis in small blood vessels and decrease in vessel diameter throughout the vascular tree by triamcinolone acetonide," Investigative Ophthalmology and Visual Science, vol. 49, pp. 1184-1190, 2008.
[32]. Detection of Blood Vessels and Measurement of Vessel Width for Diabetic Retinopathy.
[33]. Angel Suero, Diego Marin, Manuel E. Gegundez-Arias, and Jose M. Bravo**"** Locating the Optic Disc in Retinal Images Using Morphological Techniques" 18-20 March, 2013.
[34]. Pattern recognition. http://www.mathworks.com/discovery/pattern-recognition.html (07.04.2016)
[35]. Pattern recognition. http://global.britannica.com/technology/pattern-recognition-computer-science (07.04.2016)
[36]. Aksoy S. (2015): Introduction to pattern recognition http://www.cs.bilkent.edu.tr/~saksoy/courses/cs551/slides/cs551_intro.pdf (08.04.2016)
[37]. Dukart J., (2015): Basic Concepts of Image Classification Algorithms Applied to Study Neurodegenerative Diseases. Brain Mapping: An Encyclopedic Reference, vol.3, pp.641-646.
[38]. Sathya R., Abraham A., (2013): Comparison of Supervised and Unsupervised Learning Algorithms for Pattern Classification. International Journal of Advanced Research in Artificial Intelligence, vol.2(3), pp.34-38.
[39]. DongMel C. and Douglas S., (2002): The Effect of Training Strategies on Supervised Classification at Different Spatial Resolutions. Photogrammetric Engineering& Remote Sensing, vol.68(11), pp.1155-1161.
[40]. Joao V.S., Jorge J.G., Roberto M.C., Herbert F.J., Michael J.C., (2006): Retinal Vessel Segmentation Using the 2-D Gabor Wavelet and Supervised Classification. IEEE Transaction of Medical Imaging, vol.25, pp.1214-1222.
[41]. Elisa R., Renzo P., (2007): Retinal Blood Vessel Segmentation Using Line Operators and Support Vector Classification. IEEE Transaction of Medical Imaging, vol.26, pp.1357-1365.
[42]. Wikipedia Online. Http://en.wikipedia.org/wiki
[43]. Rajesh Sharma R Beaula A, Marikkannu P, AkeySungheeth, C. Sahana, "Comparative Study of Distinctive Image Classification Techniques", 10th International Conference on Intelligent Systems and Control (ISCO), 2016.
[44]. Tutorial slides by Andrew Moore. Http://www.cs.cmu.edu/~awm
[45]. George KM, Pantelis AA, Konstantinos KD, Nikolaos AM, Thierry GZ: Detection of glaucomatous change based on vessel shape analysis. Med Imaging Graphics 2006, 30:139-145.
[46]. Sujata Saini**,** A Study Analysis on the Different Image Segmentation Techniques.
[47]. Ronneberger, O., Fischer, P., &Brox, T. (2015, October). U-net: Convolutional networks for biomedical image segmentation. In International Conference on Medical Image Computing and Computer-Assisted Intervention (pp. 234-241). Springer, Cham.
[48]. V. Vapnik. The Nature of Statistical Learning Theory. Springer, N.Y., 1995. ISBN 0-387-94559-8.
[49]. V. Vapnik, S. Golowich, and A. Smola. Support vector method for function approximation, regressionestimation, and signal processing. In M. Mozer, M. Jordan, and T. Petsche, editors, Advances in Neural Information Processing Systems 9, pages 281–287, Cambridge, MA, 1997. MIT Press.
[50]. Guoqiang Peter Zhang, "Neural Networks for Classification: A Survey", IEEE Transactions On Systems, Man, And Cybernetics—Part C: Applications And Reviews, Vol. 30, No. 4, pp.451-461, 2000.
[51]. Stephen A. Zahorian, Zaki B. Nossair, "A Partitioned Neural Network Approach for Vowel Classification Using Smoothed Time/Frequency Features", IEEE Transactions On Speech And Audio Processing, Volume 7, NO. 4, pp. 414-425, 1999.
[52]. Dave, D., Lawrence, A., and Pennock, D. Mining the Peanut Gallery: Opinion Extraction and Semantic Classification of Product Reviews. Proceedings of International World Wide Web Conference (WWW'03), 2003.
[53]. Bayesian Classification Theory
[54]. Nir Friedman, Ron Kohavi " Bayesian Classification" .

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