The review of computer aided diagnostic hypertensive retinopathy based on the retinal image processing

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Abstract. Hypertensive retinopathy is a disease caused by acute high blood pressure. Examination of the disease can be done by analyzing the retina of the eye. Analysis can be done automatically by using the image processing of the retina from fundus cameras. The automation model is widely developed by combining a number of segmentation methods, classification algorithms and feature extraction. Unfortunately no one has reviewed a number of existing studies on the diagnosis of hypertensive retinopathy. In this study aims to conduct a review of a number of studies in the period 2010-2018 on the diagnosis of hypertensive retinopathy. The focus of the review is on the method of segmentation, feature extraction, and the classification algorithm used in the diagnostic model of hypertensive retinopathy. The review also includes comparisons of a number of diagnostic models that have been developed, and suggestions for further model development.

1. Introduction

The development of a computer-aided diagnostic model of hypertensive retinopathy (CAD- RH) using retinal image input from the acquisition of a fundus camera. In general the CAD-RH model was developed using several main stages, as shown in Figure 1. The diagnosis of hypertensive retinopathy was developed by using a number of parameters that refer to the symptoms that arise by analyzing the retinal image of the eye. Hypertensive retinopathy, when referring to grouping carried out by Keith-Wagener-Barker (1939), can be grouped into 4 stages. Stage I, one of the characteristics is tortuosity of retinal arterioles. Stage II has narrowing characteristics of blood vessel definitions. Stage III, namely with one characteristic such as spot cotton, arteriosclerosis, and hemorrhagic. Stage IV, one of the characteristics is neuroretinal edema including papilledema, siegrest line, elschig spot.

Figure 1. CAD-RH Development Model
1.1. Pre-processing
In the development of CAD-RH, the main material is the retinal image, which is the result of the acquisition of a fundus camera. Image of the acquisition results sometimes has poor image quality. A number of methods are widely used to improve the image. Image retina is an image with three channels, namely red, green and blue, so that the conversion process to grayscale is needed. This components have different qualities, where the best quality is the green channel [1]. This makes a lot of research using green channels, except for a number of studies that do diagnosis referring to the retinal texture image. Image improvement methods used include the median filter and mean filter [2], [3]. The choice of the type of filter used depends on the type of noise that is in the image.

Image acquisition sometimes lacks lighting, this also results in poor image contrast. Improved image from the side of color contrast can be done with histogram equalization (HE) [2]. The HE method better for the case in the image with the distribution of pixel values similar to the entire image, but when there is a dark area and some other areas of the image are bright, the contrast in the area is difficult to increase. These problems can be overcome by using Adaptive HE (AHE) [2]. The AHE method will increase the contrast by changing each pixel using a transformation function that originates from the region, so that the contrast changes are done dynamically. Another method is the contrast limited adaptive histogram equalization (CLAHE) [4], this method has the ability to improve image quality while reducing noise.

1.2. Segmentation Method
In the image processing system for pattern recognition, it requires a stage called image segmentation. Segmentation aims to separate the background from the object region to be analyzed. The segmentation method has a number of approaches, namely region-growing, clustering, thresholding and edge detection [5]. Each approach has a number of algorithms, such as the clustering approach has a k-means algorithm, Fuzzy C-means, Possibility Fuzzy C-Means and SOM [6]. The algorithms in each approach have a number of advantages and disadvantages, so that many studies combine a number of algorithms, to obtain better segmentation results.

1.3. Feature Extraction
Feature extraction is one dimension reduction method [7]. Another understanding is to extraction an object to obtain features that are typical of the object. Feature extraction can use a number of methods, such as fractal analysis by measuring the fractal and lacunarity dimensions [8]–[10]. Other feature extraction methods commonly used in CAD-RH research are texture, color-based, gray-level, GLCM and invariant moments. The performance of each method varies, so there are also many studies that combine a number of methods, in order to provide a better performance.

1.4. Classification Technique
The models of CAD-RH generally use classification algorithms on two things, namely when classifying blood vessels and RH positive or negative classification. The classification used is divided into two approaches, namely black-box and non-black-box [11]. Each classification approach has advantages and disadvantages. Medically, the advantage of non-black-box classification is that a clinician is able to understand the processes that occur in classification, so that if there is a rule that does not match then it can be fixed. While for the black-box, the clinician only gets the output. Classification algorithms with a black-box approach are able to provide better performance. The examples of algorithms in the black-box approach are support vector machine (SVM), artificial neural network (ANN) and naive bayesian (NB) [12]–[14].

2. Literature Survey
The development of the CAD-RH system developed in the period 2010-2018 always uses a model as shown in Figure 1. The differences of each research is the method used in each stage of the model. Literature review of a number of research CAD-RH models that have been carried out can be shown in Table 1. The review was carried out by referring to a number of methods used, especially in the stages of pre-processing, segmentation, feature extraction and classification used.
| Authors | Pre-processing | Method | Analysis | Dataset |
|---------|----------------|--------|----------|---------|
| Ortiz et al. [15], [16] | Conversion to green channel | Providing a relatively low performance when detecting veins, which only reaches 50% | Ophthalmology Department Universitario San Ignacio |
| | Morphological Operations | | |
| | Segmentation | | |
| | Gabor wavelet | | |
| | Matrix Hessian | | |
| | Thresholding | | |
| | Feature Extraction | Optical Disc Location | | |
| | Using Red Channel: Arteries have a higher intensity level than veins. The average intensity is calculated for each component after segmentation. Components that have an average intensity above the average of all components are classified as arteries and vice versa artery-vein ratio (AVR) | | |
| Irshad et al. [17] and Akram et al. [18] | Conversion to green channel | Developing the CAD-RH at level 3, with performance still below 90% | Ophthalmology Department of AFIO, Pakistan |
| | Median filtering | | |
| | Morphological closing | | |
| | Segmentation | Gabor wavelet Filter for enhancement CWS | | |
| | Otsu Thresholding | | |
| | Hough Transform | | |
| | Canny Edge detection | | |
| | Feature Extraction | Optic disc detection and subtracting optic disc region, so the CWS area is obtained. | | |
| Agurto et al. [19] | Histogram Streching | The CAD-RH system VisionQuest’s eye produced has a maximum disease screening accuracy performance of database around 80%, and by using two features. | |
| | Multi-scale linear structure enhancement Thresholding | | |
| | Segmentation | | |
| | Top-hat transformation | | |
| | Gray level-based | | |
| | Feature Extraction | Optical Disc Location | | |
| | Artery-vein ratio (AVR) | | |
| | Tortuosity Indexes | | |
| | Texture feature: Amplitude-Modulation Frequency-Modulation (AM-FM) | | |
| Narasimhan et al. [20] | Regression classifier | The use of grey-level and variant moments can provide the accuracy of the CAD-RH system reaching above 90% | VICAVR |
| | Pre-processing | Conversion to green channel, Morphological opening, mean filtering | | |
| | Segmentation | Top-hat transformation | | |
| | Feature Extraction | Gray level-based | | |
| | Classification | The variation in moments | | |
| | Support Vectore Machine (SVM) for determined the vessel or non vessel Menentukan AVR ratio | | |
| Noronha et al. [21] | Pre-processing | Conversion to green channel | The system of CAD-RH has a good performance, with the accuracy above 90%, unfortunately the sensitivity is still lower than accuracy. | DRIVE |
| | Adaptive Histogram Equalization (AHE) Median Filtering | | |
| | Top-hat transformation for disappear the background | | |
| | Segmentation | 2D-Matched filter, for vessel detection | | |
| | Radon transformation, extracting the | | |
| Authors | Method | Analysis | Dataset |
|---------|--------|----------|---------|
| Manikis et al. [22] | Pre-processing - Classification: Clinician, refers to AVR, Conversion to green channel, CLAHE, Edge-preserving anisotropic diffusion filter | The performance of CAD-RH system has poor performance for parameter sensitivity, which is still below 80%, | DRIVE, STARE |
| | Segmentation: Region-based, Hessian-based and Otsu thresholding | | |
| | Feature Extraction: Size-based filtering, Pruning small branches, Vessel width estimation | | |
| | Classification: Optical Disc Detection, Statistical analysis | | |
| Irshad et al. [23] | Pre-processing - Classification: Support Vector Machine | The proposed CAD-RH system can provide good performance, with an accuracy of 90%, for classification of vessel artery-veins, and RH classification. | INSPIRE-AVR, VICAVR, a local dataset |
| | Segmentation: 2-D Gabor wavelet | | |
| | Feature Extraction: Profile based features, Optical disc, Arteri-veins ratio (AVR) | | |
| | Feature Selection: Wilcoxon test | | |
| Abbasi et al. [13] | Pre-processing - Classification: Support Vector Machine | The comparison of SVM, ANN, NB and Decision Tree algorithms shows that SVM performs better than others, with AUC values in good category [24] | - |
| | Segmentation: 2-D Gabor wavelet - Multilayered thresholding | | |
| | Feature Extraction: Optical disc, Arteri-veins: Texture and color-based, Arteri-veins ratio (AVR) | | |
| | Classification: Klasifikasi artei-veins: SVM, Artificial Neural Network (ANN), NB and Decision Tree Grading of Hypertensive Retinopathy based AVR | | |
| Khitran et al. [25] | Pre-processing - Segmentation: Conversion to green channel, 2D-Gabor wavelet filter - Multilayer thresholding | The system of CAD-RH, able to provide good performance, both for arterial veins classification and RH classification, which indicated by accuracy > 95% | VICAVR, DRIVE |
| | Feature Extraction: Arteri-veins: Texture and color-based, Optical disc, Arteri-veins ratio (AVR) | | |
| | Classification: Arteri-veins: Hybrid support vector machine and naive bayesian classifier Grading of Hypertensive Retinopathy based AVR | | |
| Triwijoyo et al. [26] | Pre-processing - Segmentation: Convert to grayscale - Resize 32x32 pixel - Convert to CSV Format | The proposed of CAD-RH system provides excellent performance with the accuracy of 98.6% | DRIVE |
| | Feature Extraction: Convolutional Neural Network (CNN) | | |
| | Classification | | |
| Triwijoyo et al. [27] | Pre-processing - Segmentation: 2D-Gabor wavelet filter - Iterative otsu thresholding | The proposed of CAD-RH system can be used for the initial diagnosis of RH disease | DRIVE, STARE |
| | Feature Extraction: Optical disc, Arteri-veins ratio (AVR) | | |
| | Classification: Convolutional Neural Network and Boltzmann Machines | | |
| Cavallari et al. [28] | Pre-processing - Segmentation: Otsu Thresholding - Vessel diameter - Tortuosity Index | The proposed of CAD-RH system can be used to diagnose RH for level 1 and level 2 | - |
| | Feature Extraction: Mean dimension fractal (box-counting) | | |
| | Classification: Statistical Analysis | | |
| Wiharto et al. [8] | Pre-processing - Segmentation: Conversion to green channel | | STARE |

| **Authors** | **Method** | **Analysis** | **Dataset** |
|-------------|------------|--------------|-------------|
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| | Segmentation: Region-based, Hessian-based and Otsu thresholding | | |
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| | Feature Extraction: Optical disc, Arteri-veins: Texture and color-based, Arteri-veins ratio (AVR) | | |
| | Classification: Klasifikasi artei-veins: SVM, Artificial Neural Network (ANN), NB and Decision Tree Grading of Hypertensive Retinopathy based AVR | | |
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| | Feature Extraction: Arteri-veins: Texture and color-based, Optical disc, Arteri-veins ratio (AVR) | | |
| | Classification: Arteri-veins: Hybrid support vector machine and naive bayesian classifier Grading of Hypertensive Retinopathy based AVR | | |
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| | Feature Extraction: Optical disc, Arteri-veins ratio (AVR) | | |
| | Classification: Convolutional Neural Network and Boltzmann Machines | | |
| Cavallari et al. [28] | Pre-processing - Segmentation: Otsu Thresholding - Vessel diameter - Tortuosity Index | The proposed of CAD-RH system can be used to diagnose RH for level 1 and level 2 | - |
| | Feature Extraction: Mean dimension fractal (box-counting) | | |
| | Classification: Statistical Analysis | | |
| Wiharto et al. [8] | Pre-processing - Segmentation: Conversion to green channel | | STARE |
| Authors                  | Method                                           | Analysis                                                                 | Dataset                  |
|-------------------------|--------------------------------------------------|--------------------------------------------------------------------------|--------------------------|
| Syahputra et al. [10]   | CLAHE, Median Filtering, Conversion to grayscale | The accuracy of the resulting system is still below 90%, and the use of toxicity does not provide significant additional performance | LOCAL                    |
|                         | Subtraction to exclusion of background          |                                                                          |                          |
|                         | Thresholding, Dimention Fractal, Lacunarity     |                                                                          |                          |
|                         | RandomForest                                    |                                                                          |                          |
| Pre-processing          | Conversion to green channel, CLAHE, Morphological Close Background Exclusion |                                                                          |                          |
|                         | Segmentation                                    |                                                                          |                          |
|                         | Feature                                          |                                                                          |                          |
|                         | Extraction                                       |                                                                          |                          |
|                         | Classification                                   |                                                                          |                          |
| Faheem et al. [29]      | Match filtering, Circular Hough Transform, Invariant Moment, Gray-level information, Optical disc, Arteri-veins ratio (AVR) | The performance of the proposed CAD-RH system is better than a number of existing studies, with accuracy reaching 93.9% | DRIVE                    |
|                         | Segmentation                                     |                                                                          |                          |
|                         | Feature                                          |                                                                          |                          |
|                         | Extraction                                       |                                                                          |                          |
|                         | Classification                                   |                                                                          |                          |
| Chetia & Nirmal [1]     | Conversion to green channel, Complement the image CLAHE, Background Exclusion | The CAD-RH system is proposed with reference to tortuosity, so it can be used for initial diagnosis | DRIVE VICAVR            |
|                         | Segmentation                                     |                                                                          |                          |
|                         | Feature                                          |                                                                          |                          |
|                         | Extraction                                       |                                                                          |                          |
|                         | Classification                                   |                                                                          |                          |
|                         | -                                               |                                                                          |                          |
|                         | Pre-processing                                   |                                                                          |                          |
|                         | 2-D Gabor wavelet, Arteri-veins ratio (AVR), Statistical Moments, Mean, Standard Deviation, and Relative Smoothness of the vessel pixels intensity | The proposed CAD-RH system has relatively poor performance, compared to a number of other studies, where accuracy is still relatively low, namely 81.3% | Ophthalmology department of AFIO, Pakistan |
|                         | Feature                                          |                                                                          |                          |
|                         | Extraction                                       |                                                                          |                          |
|                         | Classification                                   |                                                                          |                          |
|                         | Support Vector Machine                            |                                                                          |                          |
|                         | Pre-processing                                   |                                                                         |                          |
|                         | 2-D Gabor wavelet, Otsu Thresholding              |                                                                          |                          |
|                         | Feature                                          |                                                                          |                          |
|                         | Extraction                                       |                                                                          |                          |
|                         | Classification                                   |                                                                          |                          |
|                         | Support Vector Machine                            |                                                                          |                          |
|                         | Pre-processing                                   |                                                                         |                          |
|                         | 2-D Gabor wavelet, Arteri-veins ratio (AVR), Capturing images, and Statistical Moments | The proposed CAD-RH system is able to provide excellent performance with accuracy and sensitivity above 95% | INSPIRE-VR VICAVR AVRDB  |
|                         | Feature                                          |                                                                          |                          |
|                         | Extraction                                       |                                                                          |                          |
|                         | Classification                                   |                                                                          |                          |
|                         | Support Vector Machine                            |                                                                          |                          |
|                         | Pre-processing                                   |                                                                         |                          |
|                         | Conversion to green channel, AHE, 2-D Gabor wavelet, Morphological Thinning, Optical disc, Arteri-veins ratio (AVR) | The proposed CAD-RH system can be used for RH diagnosis at level 2 and 4, with accuracy performance more than 95% | INSPIRE-VR VICAVR AVRDB STARE AVRDB |
|                         | Feature                                          |                                                                          |                          |
|                         | Extraction                                       |                                                                          |                          |
|                         | Classification                                   |                                                                          |                          |
3. Discussion

A number of studies on CAD-RH emphasize the use of arterial viens ratio (AVR) as an indicator in the process of diagnosis of hypertensive retinopathy. The large number of studies using AVR parameters indicate that these parameters are very important in making decisions about hypertension retinopathy diagnosis. AVR parameters can be used to indicate whether or not there is a narrowing of the arteries, if there is a narrowing it can be ascertained hypertension retinopathy. Diagnosis of hypertensive retinopathy, in addition to focusing on AVR parameters, a number of studies also used several other parameters, such as tortuosity, cotton wool spots and papilledema. The use of tortuosity, which is by looking at the curvature that occurs in blood vessels. The tortuosity parameter is generally measured using faractal dimension analysis. Cotton wool spots parameters were analyzed by checking whether there was a condition of cotton wool spots on the retina of the eye.

The development of the CAD-RH model, one of the stages is classification. The classification stage is done to determine several things, namely determining the type of artery veins or veins, and determining whether or not there is RH. The classification for determining blood vessels is usually done when using AVR diagnosis parameters. Classification algorithms are used more using algorithms with black-box approaches, such as SVM, ANN and NB. The use of a black-box approach algorithm is generally able to provide accuracy performance that is relatively better than non-black-box, as shown in Abbasi et.al's study [35], and strengthened in the research of Wiharto et al. [12]. The weakness of the black-box approach classification algorithm is the process that is not understood by clinicians, so clinicians only get results. This is different if using a non-black-box approach, the process in the classification algorithm can be understood by clinicians, so clinicians can assess the process.

The other difference from a number of CAD-RH studies is the variation in the use of blood vessel segmentation methods. The segmentation method used in the research is single or multiple algorithm. The aim of the variation of segmentation method conducted to obtain better CAD-RH performance. The process of segmentation is always preceded by the process of image improvement, image improvement made by the majority using CLAHE. Image improvement process is carried out on green channel image components, because the green channel retina image component has good quality compared to red and blue channels. In the CAD-RH model the most widely used segmentation method is a combination of Gabor wavelet filter and thresholding process. The thresholding process uses the otsu thresholding method. The combination of methods can provide better performance compared to other methods, such as Hessian-based vascular segmentation, which is only able to provide 93.71% accuracy for DRIVE datasets, and 93.18% for STARE [22].

The segmentation method used in CAD-RH, is dominated by the use of thresholding methods, edge detection, region-growing and combinations. In the CAD-RH models, there are a little research that use clustering segmentation methods [36]–[39], even the review results shown in Table 1 do not use clustering algorithms. There is not much use of clustering methods in segmentation nor is there any reason in a number of studies in CAD-RH. When referring to the research conducted by Thilagamani et al. [40] , clustering method is an effective method in image segmentation, it is also supported by the many uses of clustering algorithms for image segmentation, especially for the case of white blood cell image [41]. This can be used as a special study, namely the comparative study of clustering algorithms for retinal image segmentation.
4. Conclusion

The CAD-RH model that has been done focuses more on the constriction of blood vessels, which is by measuring the AVR ratio. The use of AVR parameters makes CAD-RH development focused on the methods used for segmentation and classification of arterial vein vessels, besides the classification methods used to determine the presence or absence of hypertensive retinopathy. The studies that have been conducted have focused on the use of region-based, edge detection, thresholding-based or combination of them. The combination of segmentation methods used varies greatly, it shows that there has not been a comprehensive review that has been done before, which can be used as a reference in the selection of methods. Another thing that has not been done in the previous research on the CAD-RH, is that no one has used clustering segmentation method, so it opens up the opportunities for advanced research to conduct a comprehensive study of clustering methods for segmentation of retinal images.

References

[1] S. R. Nirmala and S. Chetia 2017 Retinal blood vessel tortuosity measurement for analysis of hypertensive retinopathy in 2017 International Conference on Innovations in Electronics, Signal Processing and Communication (IESC) (India: Shillong) pp. 45–50
[2] C. Solomon and T. Breckon 2011 Fundamentals of Digital Image Processing A Practical Approach with Examples in Matlab, 1st ed. Garsington Road, Oxford, (UK: Wiley-Blackwell)
[3] W. Burger and M. J. Burge 2008 Digital Image Processing An Algorithmic Introduction Using Java, 1st ed. Hagenberg, (Austria: Springer)
[4] S. E. Umbaugh 2010 Human and Computer Vision Applications with CVIPtools, 2nd ed. (Boca Raton: CRC Press)
[5] P. Sharma and J. Suji 2016 A Review on Image Segmentation with its Clustering Techniques Int. J. Signal Process. (Image Process. Pattern Recognit) vol. 9 no. 5 pp. 209–218
[6] S. Kusumadewi, S. Hartati, A. Harjoko, and R. Wardoyo 2006 Fuzzy Multi-Attribute Decision Making (Fuzzy MADM), 1st ed. (Yogyakarta, Indonesia: Graha Ilmu)
[7] R. Jensen and Q. Shen 2008 Computational Intelligence and Feature Selection: Rough and Fuzzy Approaches. (USA: IEEE Press)
[8] W. Wiharto, E. Suryani, and M. Y. Kipti 2018 Assessment of Early Hypertensive Retinopathy using Fractal Analysis of Retinal Fundus ImageTEKOMNIKA Telecommun. Comput. Electron. Control vol. 16 no. 1 pp. 445–454
[9] N. Popovic, M. Radunovic, J. Badnjar, and T. Popovic 2018 Fractal dimension and lacunarity analysis of retinal microvascular morphology in hypertension and diabetes Microvasc. Res., vol. 118 pp. 36–43
[10] M. F. Syahputra, I. Aulia, and R. F. Rahmat 2017 Hypertensive retinopathy identification from retinal fundus image using probabilistic neural network in International Conference on Advanced Informatics, Concepts, Theory, and Applications (ICAICTA) (Indonesia: Denpasar) pp. 1–6
[11] H. R. Marateb and S. Goudarzi 2015 A noninvasive method for coronary artery diseases diagnosis using a clinically-interpretable fuzzy rule-based system J. Res. Med. Sci., vol. 20 no. 3 pp. 214–223
[12] W. Wiharto, H. Herianto, and H. Kusnanto 2018 A Tiered Approach on Dimensional Reduction Process for Prediction of Coronary Heart Disease vol. 11 no. 2 pp. 487–495
[13] U. G. Abbasi and M. U. Akram 2014 Classification of blood vessels as arteries and veins for diagnosis of hypertensive retinopathy in 10th International Computer Engineering Conference (ICENCO) (Egypt: Giza) pp. 5–9
[14] L. Ayub et al. 2016 Differentiation of blood vessels in retina into arteries and veins using neural network in 2016 International Conference on Computing, Electronic and Electrical Engineering (ICE Cube) (Pakistan: Quetta) pp. 301–306
[15] D. Ortiz et al., 2012 System Development for Measuring the Arterious Venous Rate (AVR) for the Diagnosis of Hypertensive Retinopathy in Andean Region International Conference (Ecuador Cuenca) pp. 53–56

[16] D. Ortiz et al., 2010 Support system for the preventive diagnosis of Hypertensive Retinopathy in 32nd Annual International Conference of the IEEE EMBS (Argentina Buenos Aires) pp. 5649 – 5652

[17] S. Irshad, M. Salman, M. U. Akram, and U. Yasin 2014 Automated detection of Cotton Wool Spots for the diagnosis of Hypertensive Retinopathy in Cairo International Biomedical Engineering Conference (CIBEC) (Egypt: Cairo) pp. 121–124

[18] M. U. Akram, A. Khan, and K. Iqbal 2010 Retinal Images: Optic Disk Localization and Detection in Image Analysis and Recognition vol. 6112, (Berlin, Heidelberg: Springer Berlin Heidelberg) pp. 40–49

[19] C. Aguero, V. Joshi, S. Nemeth, P. Soliz, and S. Barriga 2014 Detection of hypertensive retinopathy using vessel measurements and textural features in Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE pp. 5406–5409

[20] K. Narasimhan, V. C. Neha, and K. Vijayarekha 2012 Hypertensive Retinopathy Diagnosis from Fundus Images by Estimation of Avr Procedia Eng vol. 38 pp. 980–993

[21] K. Noronha, K. T. Nayya, and K. P. Nayak 2012 Support system for the automated detection of hypertensive retinopathy using fundus images in International Conference on Electronic Design and Signal Processing (ICEDSP) (India: Manipal) pp. 7–11

[22] G. C. Manikis et al. 2011 An image analysis framework for the early assessment of hypertensive retinopathy signs in The 3rd International Conference on E-Health and Bioengineering - EHB (Romania: Iaşi) pp. 1–6

[23] S. Irshad, M. Ahmad, M. U. Akram, A. W. Malik, and S. Abbas 2016 Classification of vessels as arteries verses veins using hybrid features for diagnosis of hypertensive retinopathy in IEEE International Conference on Imaging Systems and Techniques (IST) (Greece: Chania) pp. 472–475

[24] F. Gorunescu 2011 Data Mining Concepts, Models and Techniques, Intelligent Systems Reference Library (Berlin, Heidelberg: Springer)

[25] S. Khitran, M. U. Akram, A. Usman, and U. Yasin 2014 Automated system for the detection of hypertensive retinopathy in 4th International Conference on Image Processing Theory, Tools and Applications (IPTA) (Paris, France) pp. 1–6

[26] B. K. Triwijoyo, W. Budiharto, and E. Abdurachman 2017 The Classification of Hypertensive Retinopathy using Convolutional Neural Network. “Procedia Comput. Sci. vol. 116 pp. 166–173

[27] B. K. Triwijoyo and Y. D. Pradipo 2017 Detection of Hypertension Retinopathy Using Deep Learning and Boltzmann Machines J. Phys. Conf. Ser., vol. 801 pp. 1–7

[28] M. Cavallari, C. Stamile, R. Umeton, F. Calimeri, and F. Orzi 2015 Novel Method for Automated Analysis of Retinal Images: Results in Subjects with Hypertensive Retinopathy and CADASIL BioMed Res. Int., vol. 2015 pp. 1–10

[29] M. R. Faheem and Mui-zzud-Din 2015 Diagnosing Hypertensive Retinopathy through Retinal Images Biomed. Res. Ther., vol. 2 no. 10

[30] S. Irshad and M. U. Akram 2014 Classification of retinal vessels into arteries and veins for detection of hypertensive retinopathy presented at the Cairo International Biomedical Engineering Conference (CIBEC) (Egypt: Giza) pp. 133–136

[31] A. Tariq and M. U. Akram 2010 An automated system for colored retinal image background and noise segmentation in 2010 IEEE Symposium on Industrial Electronics and Applications (ISIEA), (Malaysia: Penang) pp. 423–427

[32] B. Shabbir, M. Sharif, W. Nisah, M. Yasmin, and S. L. Fernandes 2016 Automatic Cotton Wool Spots Extraction in Retinal Images Using Texture Segmentation and Gabor Wavelet J. Integr. Des. Process Sci. vol. 20, no. 1, pp. 1–12
[33] S. Akbar, M. U. Akram, M. Sharif, A. Tariq, and S. A. Khan 2018 Decision support system for detection of hypertensive retinopathy using arteriovenous ratio *Artif. Intell. Med.*, pp. 1–10

[34] S. Akbar, M. U. Akram, M. Sharif, A. Tariq, and U. ullah Yasin 2018 Arteriovenous ratio and papilledema based hybrid decision support system for detection and grading of hypertensive retinopathy *Comput. Methods Programs Biomed* vol. *154* pp. 123–141

[35] Z. Arabasadi, R. Alizadehsani, M. Roshanzamir, H. Moosaei, and A. A. Yarifard 2017 Computer aided decision making for heart disease detection using hybrid neural network-Genetic algorithm *Comput. Methods Programs Biomed.*, vol. *141* pp. 19–26

[36] N. E. A. Khalid, N. M. Noor, and N. M. Ariff 2014 Fuzzy c-Means (FCM) for Optic Cup and Disc Segmentation with Morphological Operation *Procedia Comput. Sci.*, vol. *42* pp. 255–262

[37] N. Dhanachandra, K. Manglem, and Y. J. Chanu 2015 Image Segmentation Using K -means Clustering Algorithm and Subtractive Clustering Algorithm *Procedia Comput. Sci.*, vol. *54* pp. 764–771

[38] N. Dhanachandra and Y. J. Chanu 2017 A Survey on Image Segmentation Methods using Clustering Techniques *Eur. J. Eng. Res. Sci.*, vol. *2* no. 1, pp. 15–20

[39] M. Lalitha, M. Kiruthiga, and C. Loganathan 2013 A Survey on Image Segmentation through Clustering *Algorithms Int. J. Sci. Res. LISR* vol. *2* no. 2 pp. 348–358

[40] S. Thilagamani and N. Shanthi 2011 A Survey on Image Segmentation Through Clustering *Int. J. Res. Rev. Inf. Sci.*, vol. *1* no. 1 pp. 14–17

[41] N. H. Harun, A. S. A. Nasir, M. Y. Mashor, and R. Hassan 2015 Unsupervised Segmentation Technique for Acute Leukemia Cells Using Clustering Algorithms vol. *9* no. 1 pp. 253–259