Comparison of Different Diabetic Retinopathy Detection Algorithms with a Proposed One Using Neural Network and DWT

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Abstract— Diabetic Retinopathy (DR) is the retinal disorder arises on diabetic patients and in many cases it may lead to vision loss. The early retinal examination is essential to avoid Diabetic Retinopathy and there are different types of detection methods are available to recognize DR. This paper presents a comparison of different Diabetic retinopathy detection methods and proposes one based on DWT and neural network. The proposed method is developed by extracting image's feature points by using Discrete Wavelet Transform (DWT) and applying this feature points to neural network to classify the images into 5 stages- Normal, mild NPDR, Moderate NPDR, Severe NPDR and PDR. The experiment result shows that proposed method is give better output as compared to existing methods.

IndexTerms—Diabetic Retinopathy, DWT, Neural Network, Retinal image.

I. INTRODUCTION

The Diabetic Retinopathy is the retinal disease arises on diabetic patients. It damages the small blood vessels present in retina which may result in leaking fluid and distorting vision [1-3]. After 10 years of diabetes about 20% of patients develop serious visual impairment and it becomes more affected and danger with age. According to the study, the early finding of retinopathy stage can lower the danger of vision loss by 40% [4,5].

There are four different stages of diabetic retinopathy. The condition of DR may increases from no or mild retinopathy to a much more severe stage. The explanation of Different stages is given as [6-9]:

(a) Mild nonproliferative diabetic retinopathy: it is the first stage of DR. In this stage the retina's small blood vessels are started to swell which is called microaneurysms.

(b) Moderate nonproliferative diabetic retinopathy: in this stage the swelling increases and the blood vessels started to distort.

(c) Severe nonproliferative diabetic retinopathy: in this stage the many blood vessels are blocked due to which blood supply to retina areas are deprived.

(d) Proliferative diabetic retinopathy: it is the last and most dangers stage in which new fragile blood vessels of retina can begin to grow. This new vessels can leak blood and pull on the retina as they grow which causes of vision loss. The retinal image of normal and DR affected image is shown in fig. 1.

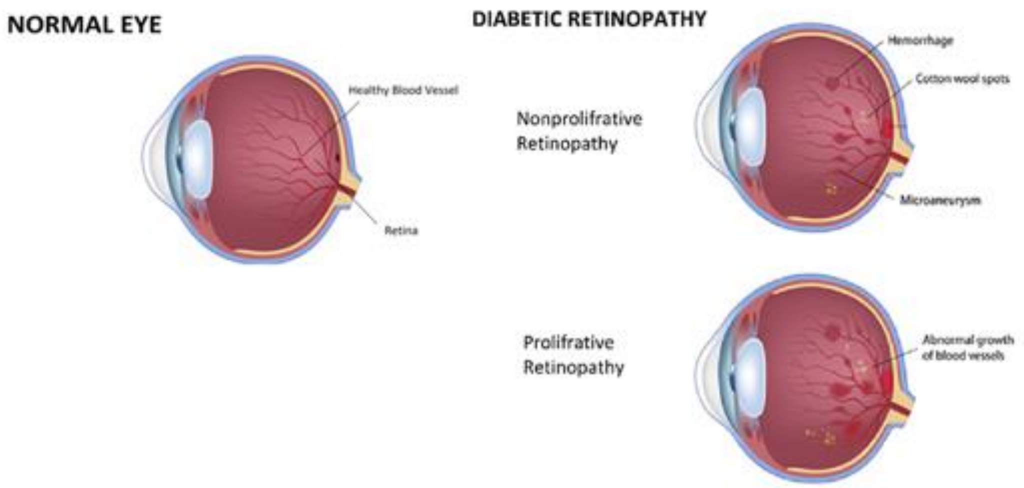

Figure 1. Retinal image

The early identification of diabetic retinopathy can effectively decrease the risk of visual loss. For the detection process the digital image processing technique become more popular [10-12]. In this paper we propose digital image processing technique based on DWT and Neural Network for automatic identification of Diabetic retinopathy. We also compared the proposed method with well known DR detection methods.

II. Related work

An extensive study of related research works has been made. A brief overview of the existing DR identification technique using different digital image processing technique is reported here:

Ren F et. al [13] propose an ensemble based adaptive over-sampling machine learning algorithm for overcoming the class imbalance problem in the false positive reduction, and they use Boosting, Bagging, Random subspace as the ensemble framework to improve microaneurysm detection.

Neto et al. in [14] presented an unsupervised coarse segmentation approach for vessel detection with an average accuracy of 87%. They incorporated multiple concepts, i.e., mathematical morphology, curvature, and spatial dependency, with the coarse-to-fine method to accurately define thin and elongated vessels from vessel pixels. However, the algorithm was unsuccessful in the determination of the vessel diameter and was also found to be less satisfactory at segmenting vessel structures on low contrast images.

Sarathi et. al [15] presented a real-time approach for OD segmentation, in which the disc boundary was extracted after the removal of vessels using a region growing adaptive threshold and ellipse fitting methods. This method is tested on standard databases - MESSIDOR and DRIVE with an accuracy of 91%.

An adaptive threshold approach was applied by Issac et al. in [16] for disc and cup segmentation. Color features, e.g., mean and standard deviation, were computed from the fundus image and then applied for the subtraction of background parts of the OD and OC. Finally, OD and OC boundaries were extracted from the red and green channels. The authors reported an accuracy of 92%. However, their scheme was tested on a small dataset and failed on low contrast images.

Detail analysis of detection of DR by fundus images is presented by Khademi et.al [17] for scientific studies. A new approach for routine DR detection by using DWT is proposed which extract texture feature from testing fundus images and compare it with training images. The method was experimented in 38 normal and 48 abnormal images with 79% of Specificity, 85.4% of sensitivity and 82.2% of accuracy.

The identification of diabetic retinopathy stage based on convolution neural network (CNN) has been developed by García et. al [18]. Extracting the features from fundus pictures, using image processing technique, and then they are apply to CNN model which classify the images into different DR stages. This method improves the performance of classification with the specificity of 93.65% and accuracy of 83.68%.

III. Proposed System

This paper proposes an automatic DR identification technique by using DWT and neural network. It involve following steps:

(1) Data collection: The testing database of 112 retinal images (38 normal and 74 abnormal) and the training database of 466 retinal images (101 normal and 365 abnormal) are created. These images are collected from three different hospitals: Aashirwad Laser & Phaco Eye Hospital Bilaspur, Luthra Hospital Bilaspur and Shri Mahadevam Multispeciality Hospital Raipur.

(2) Preprocessing: The query image and all the images of training Database are resized into 256×256 and converted into gray image [19,20].

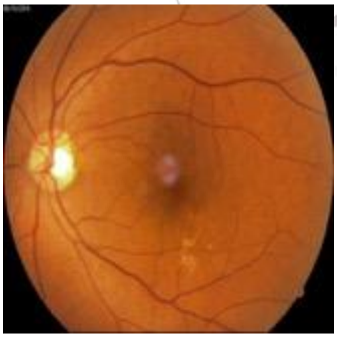

Figure 2. Sample Query Image

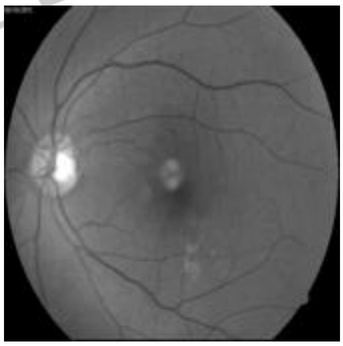

Figure 3. Gray Imgae

(3) Feature Extraction: In the next step the DWT is applied on the gray images. DWT is the multi resolution characterization of an image that decode constantly from low to high resolution [21,22]. It divides the image into low and high frequency element. The high frequency has the information of corner elements and the low frequency is again divided into high and low frequency elements. In the case of two dimensional applications, for each level of decomposition, DWT firstly implement in the vertical direction which is followed by the DWT in the horizontal direction. After the first level of decomposition, there are 4 sub-bands: LL, LH, HL, and HH (Approximation, Horizontal, Vertical and Diagonal band respectively) [23,24].

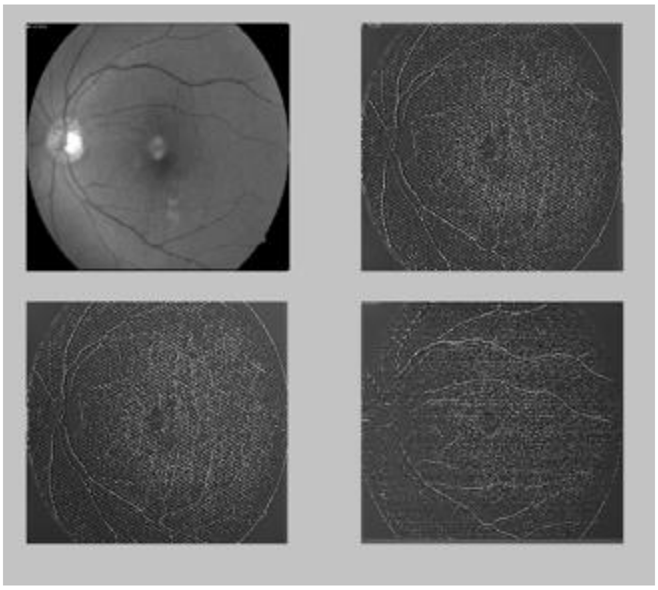

Figure 4. DWT Decomposition of Query Image

The feature Points: energy, mean, Standard deviation and skewness of all decomposed images are calculated by using following formulae [25,26]:

Energy: $$E = \frac{1}{N}\sum_{k,l}(P_{k,l})^2$$

Mean: $$M = \sum_{N}^{l=1}\frac{1}{N}P_{kl}$$

Standard deviation: $$\sigma = \sqrt{\left(\frac{1}{N}\sum_{N}^{l=1}(P_{kl} - M)^2\right)}$$

Skewness $$S = \sqrt{\left(\frac{1}{N}\sum_{N}^{l=1}(P_{kl} - M)^3\right)}$$

Where P is the intensity of the pixel located at row k and column l and N is the total number pixel.

(4) Classification using neural network: Neural Network is the processing system which is modeled to simulate the way of human brain analyzing the information or data [27, 28]. They are generally used for classification and pattern recognition work. In this work Probabilistic Neural Networks (PNN) are used to perform classification process. It is a one type of multi-layered feed forward neural network in which parzen widow and non-parametric function is used to approximate probability distribution function (PDF) of each class. The structure of PNN is shown in fig. 5.

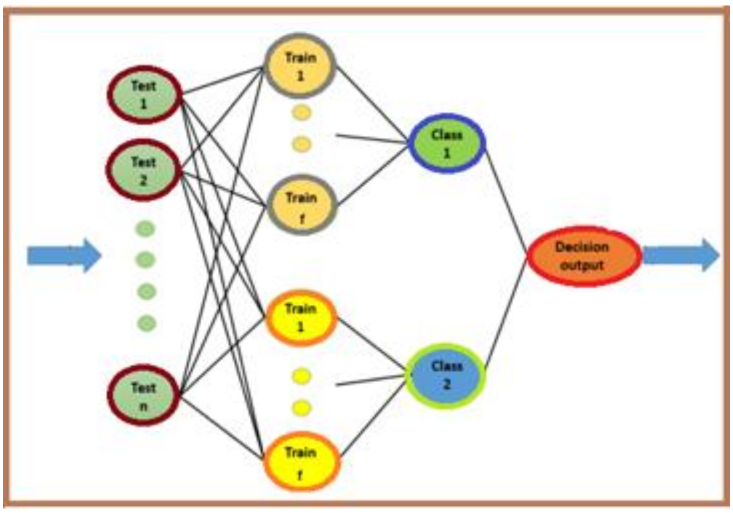

Figure 5. The Structure of PNN

PNN is comprises of four layers namely Input Layer, Pattern Layer, Summation Layer and Output Layer. All the feature points of query and database images are in PNN from input layer which is further transmitted to the next layer which is pattern layer. Given an input, pattern layer computes the distance between the training feature points and testing feature points and produces different points to indicate the relatedness between testing and training data [29]. The Radial Basis Function (RBF) is applied to estimate the probability distribution function N (Iab , µab) for training data a on class b:

$$P_{ab}(\vec{M}) = \frac{1}{(2\pi)^{\frac{D}{2}}\,\mu^{D}} \exp\left[\frac{-(\vec{M}-\vec{I}_{ab})^{T}(\vec{M}-\vec{I}_{ab})}{2\mu^{2}}\right] \qquad (5)$$

Where, M is the input testing points and I is the training data, D denotes the dimension, µ is the smoothing parameter and Iab is the neuron vector. After that the different feature points of different inputs are combined by the summation layer to produce the net output on the basis of probabilities [25]. Assume f is the total of training examples and W is the weights vector, then the probability of M belongs to class b is:

$$P_{a}(\vec{M}) = \sum_{b=1}^{f} W_{ab} P_{ab}(\vec{M}) \qquad (6)$$

At the last stage of PNN the data is fed into the output layer which transfers the data as a result to the outside world. The sum for each classes are compare and the maximum possible probabilities are search by using transfer function and produces one for that class and zero for other [30, 31]. If the number of class is represented by c then the output can be represented as:

$$Output = \arg\max(P_{a}(\vec{M})), \text{ for a= 1,2……c} \qquad (7)$$

The flowchart of the proposed methodology is shown in fig. 6.

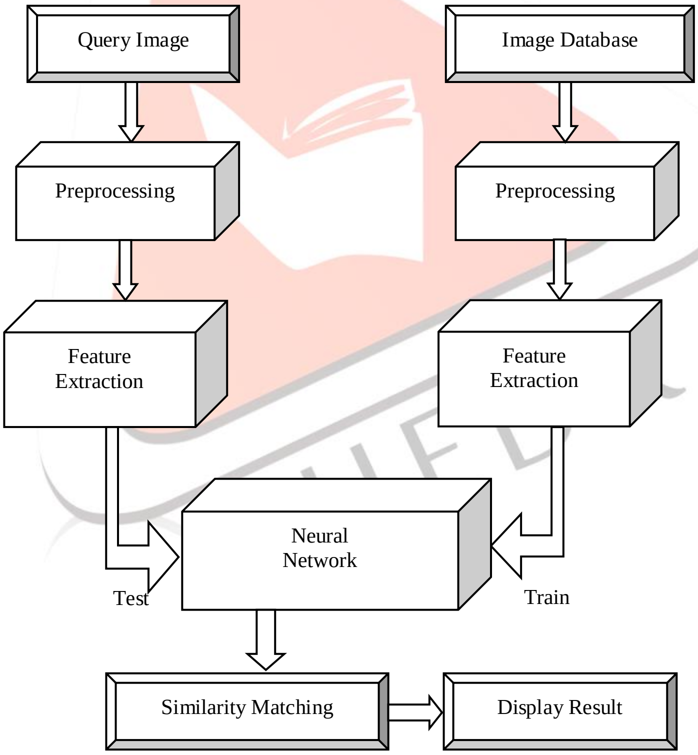

Figure 6. Flowchart of the proposed methodology

IV. RESULTS AND DISCUSSION

The proposed system is developed on MATLAB R2016b and evaluated for 112 testing database and 466 training database. The overall classification result of testing database using ANN-DWT is represented in table 1 with the comparison of Human Observer.

Table 1. Classification Results

	Total	Normal cases	Diabetic retinopathy cases				Missed images
			Mild	*Moderate*	*Severe*	*PDR*	
Human Observer	112	38	31	28	11	4	--
ANN-DWT Detection	112	36	29	26	9	4	8

To measure performance of the system the value of accuracy using true positive (TP), true negative (TN), false positive (FP) and false negative (FN) is computed by following formula [32]:

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN}$$

Table 2. Accuracy of the Proposed System

TP	TN	FP	FN	Accuracy
68	36	2	8	92.86%

To check the usability of proposed system, it was compared with some well known DR detection methods [13-18] in terms of accuracy as shown in Table 3.

Table 3. Comparison Results of the Proposed Method against other DR Detection Methods

Author	Dataset	Number of images	Accuracy
Ren F et. al [13]	e-optha	148	84.41
Neto et al. [14]	DRIVE, STARE	60	87
Sarathi et.al [15]	Private dataset	63	92
Issac et al. [16]	MESSIDOR, DRIVE. local dataset	1384	91
Khademi et. al [17]	local dataset	86	82.2
García et. al [18]	EyePACS	35126	83.68
Our Method	Private dataset	578	92.86

From these results it could be simply observed that the proposed system give better performance than other systems in terms of accuracy obtained and the accuracy is the important parameter as it represents the effectiveness of the detection works. The average performances of all the methods are plotted as graph figure 7.

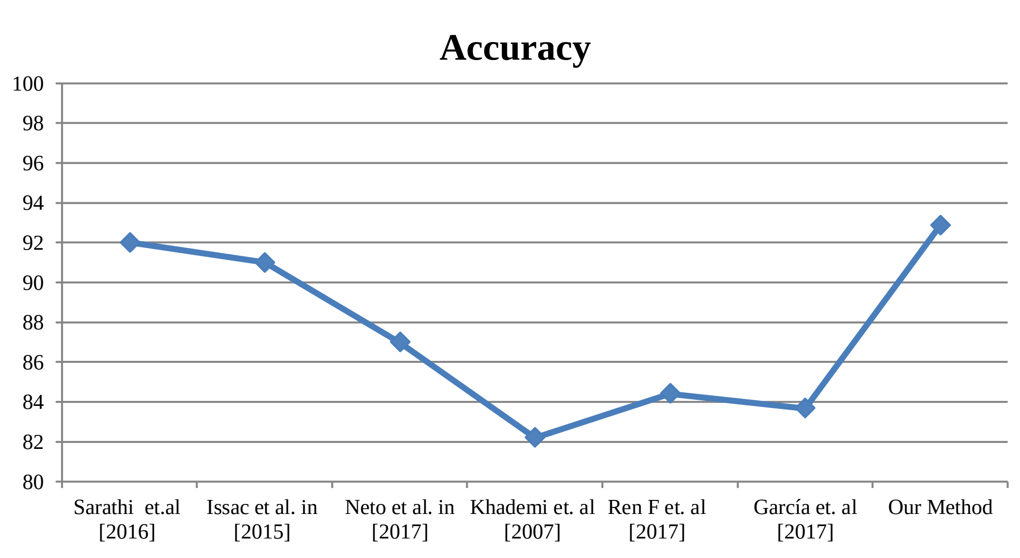

Figure 7. Performance Comparison Chart of Existing Systems with Proposed System

V. Conclusion

The initial identification and proper treatment of Diabetic retinopathy can decrease the growth of this disease and prevent vision loss. The DR identification method presented in this paper is the combination of discrete wavelet transforms (DWT) and Neural Network. The neural network has improved the efficiency and accurate classification capability of the system while the DWT has reduced complex computation work and the analysis time. Also, the method was compared with some well known DR detection techniques and the comparison result shows that the proposed method has outperforms other systems in terms of accuracy. As this method is implemented in Matlab software, it can be applicable freely in numbers of real time applications.

VI. Acknowledgment

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References

[1] Wild S., Roglic G., Green A., Sicree R., king H, "Global Prevalence of Diabetes," DIABETES CARE, vol. 27, issue 5, 2004.
[2] Nikita Kashyap, Dr. Dharmendra Kumar Singh and Dr. Girish Kumar Singh, "Review of Digital image processing techniques for detection of diabetic retinopathy," International Journal of Emerging Technologies and Innovative Research, ISSN: 2349-5162, Vol. 6, Issue 3, pp. 559-563, March-2019.
[3] Klonoff DC, Schwartz DM. "An economic analysis of interventions for diabetes", Diabetes Care 2000, 23: 390-404. M. Rema and R. Pradeepa. "Diabetic retinopathy: An Indian perspective". Indian journal of medical research. 125(3), 2003.
[4] Kim Ramasamy & Rajiv Raman & Manish Tandon, "Current State of Care for Diabetic Retinopathy in India," Curr Diab Rep: Springer Science and Business Media New York, 2013, DOI 10.1007/s11892-013-0388-6.
[5] Nikita Kashyap and Dr. Dharmendra Kumar Singh, "Color Histogram Based Image Retrieval Technique for Diabetic Retinopathy Detection," International Conference for Convergence in Technology (I2CT), pp. 799-802, 2017, DOI: 10.1109/I2CT.2017.8226238.
[6] ChandakkarP., VenkatesanR., Li B., Li H., "Retrieving clinically relevant diabetic retinopathy images using a multi-class multiple-instance framework," Proc. SPIE 8670, Medical Imaging, Computer-Aided Diagnosis, 2013, Doi:10.1117/12.2008133.
[7] R. Sivakumar, G. Ravindran, M. Muthayya, S. Lakshminarayanan and C. U. Velmurughendran, "Diabetic Retinopathy Classificatio," IEEE International Conference on Convergent Technologies for the AsiaPacific Region, Vol. 1, pp. 205 – 208, 2003.
[8] Habashy S., "Identification of Diabetic Retinopathy Stages using Fuzzy C-means Classifier," International Journal of Computer Applications, Vol. 77 (9), 0975 – 8887, 2013.
[9] D. Siva Sundhara Raja, S. Vasuki, "Screening Diabetic Retinopathy in Developing Countries using Retinal Images," Applied Medical Informatics Original Research, Vol. 36, issue 1, pp. 13-22, 2015.
[10] Nikita Kashyap, Dharmendra Kumar Singh and Girish Kumar Singh, "Mobile Phone Based Diabetic Retinopathy Detection System Using ANN-DWT," 4th IEEE UPCON Conference on Electrical, Computer and Electronics, pp. 463-467, 2017, DOI:10.1109/UPCON.2017.8251092.
[11] K.Wanjale, Tejas Borawake and Shahideep, "Content Based Image Retrieval for Medical Image Techniques and Storage Methods Review Paper," International Journals of Computer Application, Vol. 1 (19), 2012.

[12] Chaitali Desai, Shivani Gupta, Shirgaon, Priyanka, “Diagnosis of Diabetic Retinopathy using CBIR Method,” International Journal of Computer Applications Proceedings on National Conference on Role of Engineers in National Building, 12-15, 2016.
[13] Ren F., Cao P., Li W., Zhao D., Zaiane O., “Ensemble based adaptive over-sampling method for imbalanced data learning in computer aided detection of microaneurysm,” Computer Medical Imaging Graph, Vol. 55, pp. 54–67, 2017.
[14] Neto, L.C.; Ramalho, G.L.; Neto, J.F.R.; Veras, R.M.; Medeiros, F.N., “An unsupervised coarse-to-fine algorithm for blood vessel segmentation in fundus images,”. Expert System with Applcation. Vol. 78, pp. 182–192, 2017.
[15] Sarathi, M.P. Dutta, M.K. Singh, A. Travieso, C.M., “Blood vessel inpainting based technique for efficient localization and segmentation of optic disc in digital fundus images,” Biomedical Signal Processing. Vol. 25, pp. 108–117, 2016.
[16] Issac A., Parthasarthi M.,Dutta M.K., “An adaptive threshold based algorithm for optic disc and cup segmentation in fundus images,” In Proceedings of the IEEE 2nd International Conference on Signal Processing and Integrated Networks (SPIN). Vol. 19(20), pp. 143–147, 2015.
[17] Khademi and S. Krishnan, “Shift-invariant discrete wavelet transform analysis for retinal image classification,” Medical and Biological Engineering and Computing, vol. 45, issue 12, pp. 1211–1222, 2007.
[18] García G., Gallardo J., Mauricio A., López J., Del Carpio C., “Detection of diabetic retinopathy based on a convolutional neural network using retinal fundus images,” In Lecture Notes in Computer Science, Proceedings of the Artificial Neural Networks and Machine Learning—ICANN. vol. 10614, pp. 635–642, 2017.
[19] Kauppi, T., Kalesnykiene, V., Kamarainen, J., Lensu, L., Sorri, I., Raninen, A., Voutilainen, R., Uusitalo, H.,Kalviainen, H. and Pietila, J., “Diaretdb1: Diabetic retinopathy database and evaluation protocol,” Procdeeings of medical image understanding and analysis (MIUA), pp. 61-65, 2007.
[20] Winder RJ, Morrow PJ, McRitchie IN, Bailie JR, Hart PM, “Algorithms for digital image processing in diabetic retinopathy,” Computer Med Imaging Graph, vol. 33, pp. 608-622, 2009.
[21] Kalyanasundaram. K., Sanoj, “Content based Image Retrieval using Wavelet based Multi-resolution Analysis,” International Journal of Computer Applications (0975 – 8887), vol. 40, No. 6, 2012.
[22] Abràmoff M., Reinhardt J., Russell S., Folk J., Mahajan J., Niemeijer M., and Quellec G., “Automated Early Detection of Diabetic Retinopathy,” Ophthalmology, vol. 117, issue 6, pp. 1147–1154. doi: 10.1016/j.ophtha.2010.03.046, 2010.
[23] Kashyap N. and Sinha G. R., “Image Watermarking Using 2-Level DWT,” Advances in Computational Research, vol. 4, No.1, pp. 42-45, 2012.
[24] Kashyap N. and Sinha G. R. “Image Watermarking Using 3-Level DWT,” I. J. Modern Education and Computer Science, Vol. 3, pp. 50-56, 2012.
[25] Nikita Kashyap, Dr. Dharmendra Kumar Singh and Dr. Girish Kumar Singh, “A Novel Approach for Detecting and Grading Diabetic Retinopathy using Wavelet Transform and Artificial Neural Network,” International Journal of Research in Electronics and Computer Engineering (IJRECE), Vol. 7, Issue 2, pp. 100-104, 2019.
[26] Nikita Kashyap, Dr. Dharmendra Kumar Singh and Dr. Girish Kumar Singh, “Color Histogram- and Smart phone-Based Diabetic Retinopathy Detection System,” Engineering Vibration, Communication and Information Processing. Lecture Notes in Electrical Engineering, Springer. Vol. 478, 669-678, 2019, DOI: https://doi.org/10.1007/978-981-13-1642-5_58, ISBN: 978-981-13-1641-8 (PRINT), ISBN: 978-981-13-1642-5 (ONLINE).
[27] Al-Jarrah, Mohammad & Shatnawi, Hadeel, “Non-proliferative diabetic retinopathy symptoms detection and classification using neural network,” Journal of Medical Engineering & Technology, vol. 41, pp. 1-8, 2017, Doi: 10.1080/03091902.2017.1358772.
[28] A. Kwasigroch, B. Jarzembinski and M. Grochowski, “Deep CNN based decision support system for detection and assessing the stage of diabetic retinopathy,” International Interdisciplinary PhD Workshop (IIPhDW), pp. 111-116, 2018, doi: 10.1109/IIPHDW.2018.8388337.
[29] Jagadish Nayak, P Subbanna Bhat, Rajendra Acharya U, Lim Choo Min, Manjunath Gupta, “Automated Identification of Different Stages of Diabetic Retinopathy using digital fundus images,” Journal of Medical Systems, USA, 2007.
[30] Preetika D’Silva, P. Bhuvaneswari, “Content Based Medical Image Retrieval using Artificial Neural Network,” IJSTE - International Journal of Science Technology & Engineering, Vol. 1, Issue 11, ISSN (online): 2349-784X, 2013.
[31] Sonam Solkar, Lekha Das, “A New Approach for Detection and Classification of Diabetic Retinopathy Using PNN and SVM Classifiers,” IOSR Journal of Computer Engineering (IOSR-JCE), Vol. 19, Issue 5, Ver. I, PP 62-68, 2017, e-ISSN: 2278-0661, p-ISSN: 2278-8727.
[32] R. Priya and P. Aruna, “Diagnosis of diabetic retinopathy using machine learning techniques,” ICTACT Journal on soft computing, vol. 03, Issue 04, ISSN: 2229-6956, 2013.