# Design New Biorthogonal Wavelet Filter for Extraction of Exudates from Fundus Images

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## ABSTRACT
Diabetic Retinopathy caused by leakage of blood or fluid from the retinal blood vessels and it will damage the retina. Yellow flecks are called hard exudates. Exudates are the lipid residues of serous leakage from damaged capillaries. Design new wavelet filter for extraction of exudates using fundus images. This algorithm is tested on online databases such as, STARE, DRIVE, Diarect DB0, Diarect DB1 and local database SASWADE. The proposed wavelet filter is compared with the existing symlet wavelet. The proposed algorithm got Sensitivity of 97.97 % and Specificity of 100%.

## Keywords
Wavelet Filter, Retinal Exudates

## 1. INTRODUCTION
According to world health organization (WHO), 347 million people worldwide have diabetes, more than 80% of diabetes deaths occur in different countries. WHO projects that diabetes will be the 7th leading cause of death in 2030. Diabetic Retinopathy caused by leakage of blood or fluid from the retinal blood vessels and it will damage the retina. The diabetic retinopathy is categories into two stages. First is non-proliferative diabetic retinopathy (NPDR) and second is proliferative diabetic retinopathy (PDR). According to Asha G. K. and et. al., Exudates are one of the primary signs of diabetic retinopathy, which is a main cause of blindness and can be prevented with an early screening process. In this paper, authors have attempted to detect exudates using back propagation neural network. The publicly available diabetic retinopathy dataset DIARETDB1 has been used in the evaluation process. To prevent the optic disk from interfering with exudates detection, the optic disk is eliminated. Significant features are identified from the images after preprocessing by using two methods: Decision tree and GA-CFS method are used as input to the BPN model to detect the exudates and non-exudates at pixel level. The results prove that, BPN performance with features identified by Decision tree and GA_CFS approach has outperformed the performance of BPN with all inputs. The BPN classifier best performance was found with Sensitivity of 96.97 %, Specificity of 100% and classification accuracy of 98.45% [1]. S.Kavitha and et.al. has detected hard and soft exudates in fundus image using color histogram thresholding. They have got 89.78% sensitivity, 99.12% specificity and 99.07 accuracy [2]. V. Vijaykumari and et.al. has developed a method for exudates detection in retinal image using image processing techniques. Here few methods are used for the detection and the performance of all techniques was compared [3]. P.N. JebraniSargunar and et.al. detected and classified exudates in diabetic retinopathy images by texture segmentation methods. They proposed a tool for the early detection using fuzzy c-means clustering, fractal techniques and morphological transformations. Here a accuracy of 85% is achieved [4].

## 2. METHODOLOGY
The proposed algorithm is design for extraction of exudates from fundus images Following table show the fundus image databases.

**Table 1. Fundus image database**

| Sr. No | Name of Fundus Database | Total images |
|---|---|---|
| 1 | SASWADE | 500 |
| 2 | STARE | 402 |
| 3 | DRIVE | 40 |
| 4 | Diarect DB 0 | 130 |
| 5 | Diarect DB 1 | 89 |
| 6 | HRF (Diabetic Retinopathy) | 15 |
| 7 | HRF (Glaucoma) | 15 |
| | **Total** | **1191** |

In proposed algorithm firstly, preprocessing is done by extracting the green channel and intensity transformation of image enhancement. After image enhancement apply digital image processing techniques and apply proposed wavelet filter for feature extraction of exudates. After extraction of exudates create dataset of extracted feature (area, diameter, length and thickness) and then apply K-Means clustering for classifying the data into normal and abnormal cluster.Following are the steps followed for extraction of feature from fundus images.

$$g = \frac{G}{(R + G + B)} \quad (1)$$

Here g is a Green channel and R, G and B are Red, Green and Blue respectively.Then we have use Histogram equalization function for enhancing the complementary image. :

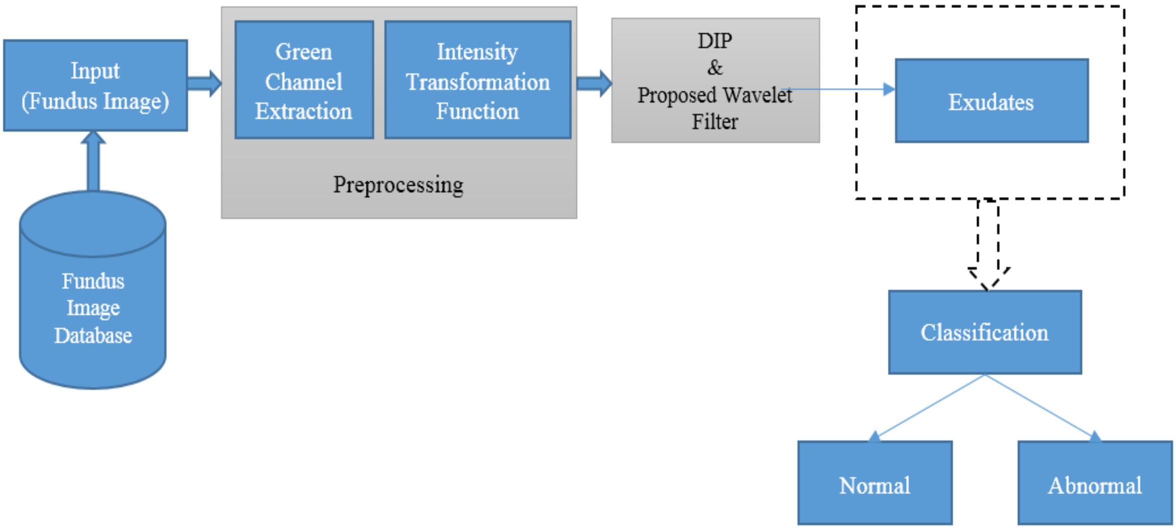


**Fig 1: Workflow for detection of exudates**

$$h(v) = \text{round}\left(\frac{\text{cdf}(v) - \text{cdf}_{\min}}{(M \times N) - \text{cdf}_{\min}} \times (L-1)\right) \quad (2)$$

Here $\text{cdf}_{\min}$ is the minimum value of the cumulative distribution function, M × N gives the image's number of pixels and L is the number of grey levels.

After using histogram equalization apply intensity-transformation function. Following is the formula for intensity transformation function.

$$s = T(r) \quad (3)$$

Where T is Transformation and r is Intensity

A multiresolution analysis of $L^2(IR)$ is a sequence of closed subspaces $V_j \subset L^2\,(IR)$ such that

$$V_j \subset V_{j+1}, \bigcap_j V_j = \{0\}, \overline{\bigcup_j V_j} = L^2(IR)(4)$$

$$f(x) \in V_0 \Leftrightarrow f\,(x \Leftrightarrow 1) \in V_0,$$

$$f(x) \in V_j \Leftrightarrow f\,(2x) \in V_{j+1} \quad (5)$$

A scaling function $\varphi \in V_0$ with unit integral exists such that $\{\varphi_{0,,k}(x) \equiv \varphi(x \Leftrightarrow k), k \in \mathbb{Z}\}$ is an orthonormal basis of $V_0$ and, consequently, the set of functions.

$$\varphi_{j,k}(x) = 2^{\frac{j}{2}}\varphi(2^j\, x \Leftrightarrow k)(6)$$

is an orthonormal basis of the space $V_j$. Since $\varphi \epsilon V_0 \subset V_1$, a sequence of complex-valued coefficients $a_k$ exists such that $\sum a_k = 1$ and

$$\varphi(x) = 2\sum_k a_k\; \varphi(2x \Leftrightarrow k\,) \quad (7)$$

Above techniques is apply for extraction exudates from fundus images.

## 2.1 Biorthogonal Wavelet

The biorthogonal wavelet transform is made-up of the decomposition process and the reconstruction process with two different wavelets Ψ and Ψ̃. Ψ is used in the decomposition process, and Ψ̃ is used in the reconstruction process. Ψ and Ψ̃ are the dual and orthogonal to each other, and this relationship is called biorthogonal. Now, there are two scale functions ϕ and ϕ̃ in the above processes, these two scale functions are also dual and orthogonal. One is used in the decomposition process, and the other one is used in the reconstruction process. Consequently, there are four filters in biorthogonal wavelet transform. They are the decomposition low-pass filter {h_n}, the decomposition high-pass filter {g_n}, the reconstruction low-pass filter {(h_n ) ̃} and the reconstruction high-pass filter{(g_n ) ̃} [5].

## 2.2 Discrete Cosine Transform (DCT)

As for discrete cosine transform (DCT), we have

$$C^T(i,j) = \begin{cases} \frac{1}{\sqrt{N}}, & j = 0, \quad i = 0,1,\dots,N-1 \\ \sqrt{\frac{2}{N}}\; cos\frac{j(2i+1)\pi}{2N}, & j = 1,2,\dots N-1, i = 0,1,\dots,N-1 \end{cases} \quad (8)$$

$$H_i(j) = \sum_{i=0}^{N-1} C^T(i,k)C(k,j)F(k), \quad i,j = 0,1,\dots,N-1. \quad (9)$$

When Equation (9) is applied to Equation (8),

$$H_i(j) = \frac{1}{N}\left[F(0) + \sum_{k=1}^{N-1} 2cos\frac{k(2i+1)\pi}{2N} cos\frac{k(2j+1)\pi}{2N}F(k)\right]. \quad (10)$$

Because of $H_i(j) = H_j(i)$, we get

$$Q(n) = Q(-n), n - 0,1,\dots,N-1. \quad (11)$$

Therefore, the frequency response of the system is

$$H(e^{j\omega}) = Q(0) + 2\sum_{k=1}^{N-1} Q(k)\cos(k\omega). \quad (12)$$

So, the system has strict zero phase characteristics and is an all phase filter.

### A. *Design of Biorthogonal Wavelet (Filter Coefficients Solver)*

The transfer function of Discrete Cosine Sequency Filter (DCSF) in DCT domain can be obtained with Equation (12):

$$H(z) = Q(0) + \sum_{k=1}^{N-1}(Q(k)z^{k} + Q(-k)z^{-k}). (13)$$

Obviously, $\boldsymbol{Q}_{1/2}$ is corresponding to the coefficients of each decomposition and reconstruction filter. Because of the strict zero-phase characteristic, we know $Q(k) = Q(-k)$.It means that coefficients of the biorthogonal wavelet transform must meet the requirement of symmetry

$$h_{2\,k-n} = h_n, g_{2k-n} = g_n, \tilde{h}_{2\,k-n} = \tilde{h}_n, \tilde{g}_{2\,k-n} = \tilde{g}_n. \quad (14)$$

**Decomposition filter:** low-frequency $Q_L(k) = h_k$, input signal $x(n)$; high-frequency $Q_H(k) = g_{k+1}$, output signal $x(n+1)$.

**Reconstruction filter:** low-frequency $Q_L(k) = \tilde{h}_k$ , input signal $x(n)$; high-frequency $Q_H(k) = \tilde{g}_{k+1}$, output signal $x(n+1)$.

Having transfer function of the system, the method for solving the coefficients of each filter is as follows:

(1) Firstly, the filter order is defined as *N*, in other words, in corresponding filters $\{h_n\},\{\tilde{h}_n\},\{g_n\},\{\tilde{g}_n\}, N = \max(n) + 1$;

(2) If $\boldsymbol{Q}_{1/2}$ is known, the filter parameter F can be obtained.

In different wavelet transforms, $\boldsymbol{Q}_{1/2}$ is corresponding to different filters $\{h_n\},\{g_n\},\{\tilde{h}_n\} and\ \{\tilde{g}_n\}$ the details are described as follows:

### B. *Design New Wavelet Filter using MATLAB*

Create a biorthogonal wavelet of type 2
Create the two filters associated with the biorthogonal wavelet and save them in a MAT-file.

Rf = [1/2 1/2];
Df = [7/8 9/8 1/8 -1/8]/2;

Add the new wavelet family to the stack of wavelet families.
Display the two pairs of scaling and wavelet functions.

We can now use this new biorthogonal wavelet to analyze a signal/image.

After extraction of exudates by proposed wavelet filter, we have calculated the area, diameter, length and thickness of exudates.

**Table 2. Feature data of exudates by proposed wavelet filter**

| Sr. No | Image | Area | Diameter | Length | Thickness |
|---|---|---|---|---|---|
| **1** | IMAGE01 | 17 | 13 | 9 | 2 |
| **2** | IMAGE02 | 22 | 15 | 11 | 2 |
| **3** | IMAGE03 | 15 | 12 | 8 | 2 |
| **4** | IMAGE04 | 25 | 16 | 13 | 2 |
| **5** | IMAGE05 | 15 | 12 | 8 | 2 |
| **6** | IMAGE06 | 17 | 13 | 9 | 2 |
| **7** | IMAGE07 | 24 | 16 | 12 | 2 |
| **8** | IMAGE08 | 12 | 11 | 6 | 2 |
| **9** | IMAGE09 | 17 | 13 | 9 | 2 |
| **10** | IMAGE10 | 15 | 12 | 8 | 2 |
| **11** | IMAGE11 | 14 | 13 | 9 | 2 |
| **12** | IMAGE12 | 22 | 15 | 11 | 2 |
| **13** | IMAGE13 | 15 | 18 | 9 | 2 |
| **14** | IMAGE14 | 25 | 16 | 15 | 2 |
| **15** | IMAGE15 | 15 | 14 | 8 | 2 |
| **16** | IMAGE16 | 11 | 13 | 9 | 2 |
| **17** | IMAGE17 | 24 | 16 | 12 | 2 |
| **18** | IMAGE18 | 16 | 11 | 6 | 2 |
| **19** | IMAGE19 | 17 | 11 | 10 | 2 |
| **20** | IMAGE20 | 17 | 12 | 7 | 2 |
| **21** | IMAGE21 | 19 | 17 | 9 | 2 |
| **22** | IMAGE22 | 28 | 15 | 11 | 2 |
| **23** | IMAGE23 | 15 | 16 | 8 | 2 |
| **24** | IMAGE24 | 23 | 16 | 13 | 2 |
| **25** | IMAGE25 | 13 | 12 | 8 | 2 |
| **26** | IMAGE26 | 17 | 13 | 9 | 2 |
| **27** | IMAGE27 | 27 | 16 | 15 | 2 |
| **28** | IMAGE28 | 13 | 11 | 7 | 2 |

## 3. RESULT

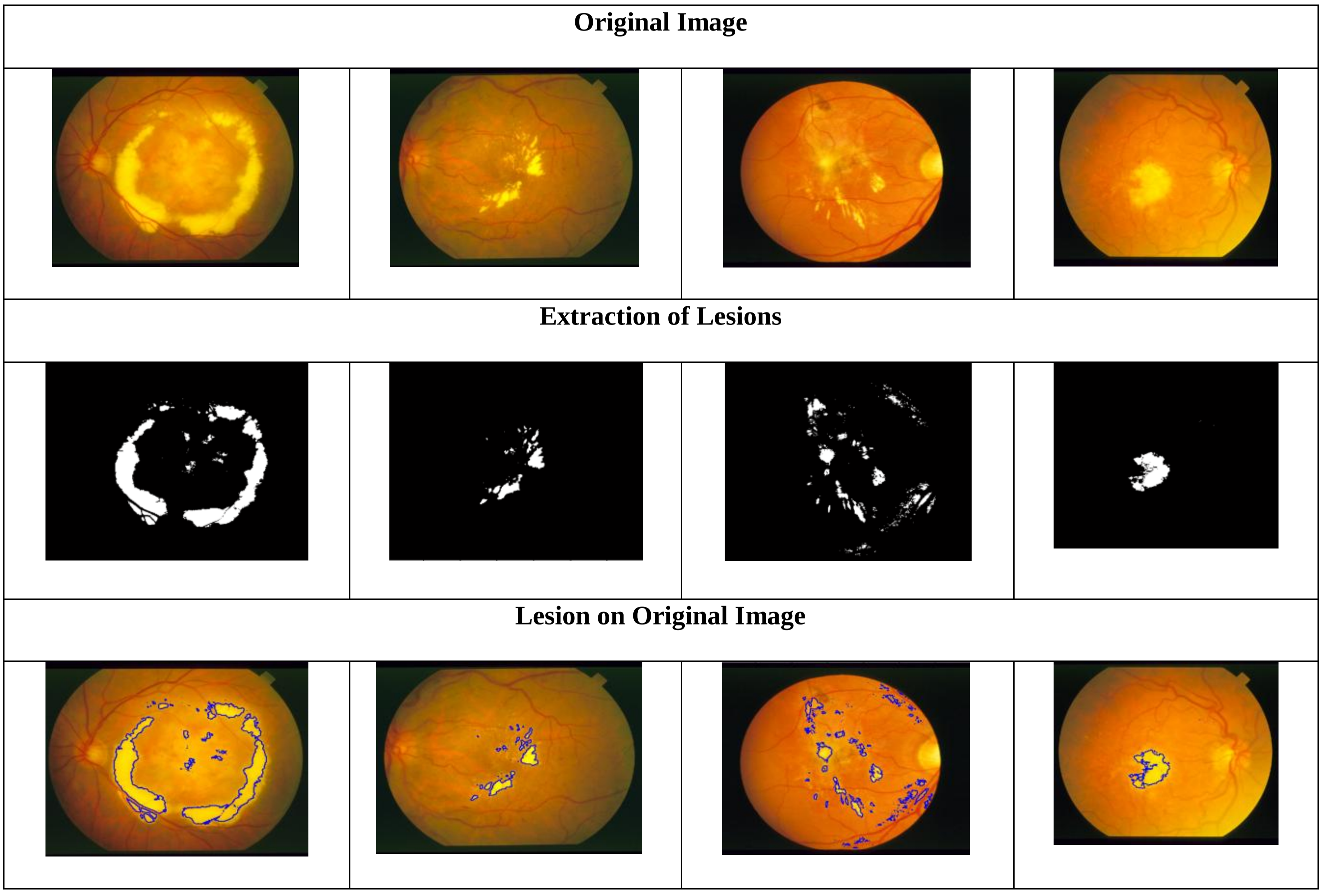


**Fig 2: Extraction of exudates by proposed wavelet filter**

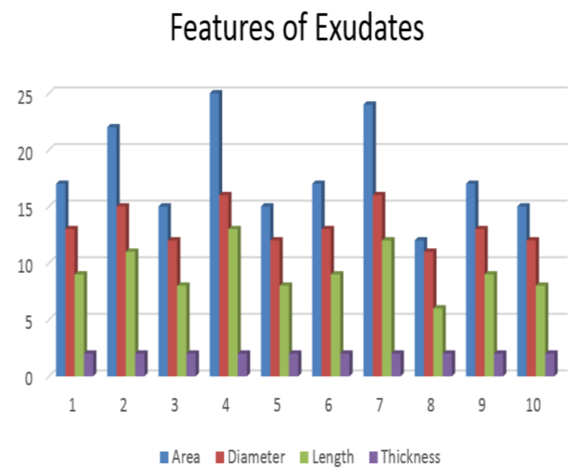


**Fig 3: Features of exudates**

After extraction of exudates features we have apply K-Means clustering on extracted feature data. Following figure shows the output of K-Means clustering.

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## 6. REFERENCES

[1] Asha G. K., et al, "Exudates Detection in Retinal Images using Back Propagation Neural Network", International Journal of Computer Applications (0975 – 8887) Volume 25– No.3, July 2011.

[2] S. Kavitha & K. Duraiswamy "Automatic Detection of Hard and Soft Exudates in Fundus Images Using Color Histogram Thresholding" European Journal of Scientific Research SSN 1450-216X Vol.48 No.3 (2011), pp.493-504.

[3] V.Vijayakumari, N. Suriyanarayanan "Exudates Detection Methods in Retinal Images Using Image Processing Techniques "International Journal of Scientific & Engineering Research, Volume 1, Issue 2, November-2010 1 ISSN 2229-5518

[4] P N Jebarani Sargunar & R Sukanesh, "Exudates Detection And Classification In Diabetic Retinopathy Images By Texture Segmentation Methods" International Journal of Recent Trends in Engineering, Vol 2, No. 4, November 2009,148

[5] Baochen Jiang, et. al, "Implementation of Biorthogonal Wavelet Transform Using Discrete Cosine Sequency Filter", International Journal of Signal Processing, Image Processing and Pattern Recognition Vol. 6, No. 4, August, 2013.

[6] http://www.diabetes.co.uk/global-diabetes/diabetes-in-india.html

[7] M. B. Patwari, R. R. Manza,Y. M. Rajput, M. Saswade, N K. Deshpande, "Calculation of Retinal Blood vessels Tortuosity by using Image processing Techniques and Statistical Techniques", International Journal of Trends in Computer Science, ISSN: 7462 – 8452, Volume 2, Issue 11, 2013.

[8] M. B. Patwari, R. R. Manza,Y. M. Rajput, M. Saswade, N K. Deshpande, "Detection and Counting the Microaneurysms using Image Processing Techniques International Journal of Applied Information Systems (IJAIS) 6(5):11-17, November 2013. Published by Foundation of Computer Science, New York, USA., ISSN : 2249-0868, Vol. 6 Number 5, October 2013.

[9] M. B. Patwari, R. R. Manza,Y. M. Rajput, M. Saswade, N K. Deshpande, "Automatic Detection of Retinal Venous Beading and Tortuosity by using Image Processing Techniques", International Journal in Computer Application(IJCA), February 2014, ISBN : 973-93-80880-06-7, Impact Factor 0.821

[10] Yogesh M. Rajput, Ramesh R. Manza, Manjiri B. Patwari, Neha Deshpande, "Retinal Blood Vessels Extraction Using 2D Median Filter", Third National Conference on Advances in Computing(NCAC-2013), 5th to 6th March 2013, School of Computer Sciences, North Maharashtra University, Jalgaon-425001 (MS) India.

[11] Yogesh M. Rajput, Ramesh R. Manza, Manjiri B. Patwari, Neha Deshpande, "Retinal Optic Disc Detection Using Speed Up Robust Features", National Conference on Computer & Management Science [CMS-13], April 25-26, 2013, Radhai Mahavidyalaya, Auarngabad-431003(MS India).

[12] M. B. Patwari, R. R. Manza,Y. M. Rajput, M. Saswade, N K. Deshpande, "Review on Detection and Classification of Diabetic Retinopathy Lesions Using Image Processing Techniques", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 2 Issue 10, October – 2013.

[13] Manjiri B. Patwari, Ramesh R. Manza, Yogesh M. Rajput, Neha K. Deshpande, Manoj Saswade, "Extraction of the Retinal Blood Vessels and Detection of the Bifurcation Points", International Journal in Computer Application(IJCA), September 18, 2013. ISBN : 973-93-80877-61-7.

[14] Manjiri B. Patwari, Dr. Ramesh R. Manza,Yogesh M. Rajput, Dr. Manoj Saswade, Dr. Neha K. Deshpande, "Personal Identification algorithm based on Retinal Blood Vessels Bifurcation", 2014 International Conference on Intelligent Computing Applications, 978-1-4799-3966-4/14 © 2014 IEEE, DOI 10.1109/ICICA.2014.51

[15] Manjiri B. Patwari,Ramesh R. Manza, Yogesh M. Rajput, Deepali D. Rathod, Manoj Saswade, Neha Deshpande, "Classification and Calculation of Retinal Blood vessels Parameters", IEEE's International Conferences For Convergence Of Technology, Pune, India.

[16] Deepali D. Rathod, Ramesh R. Manza, Yogesh M. Rajput, Manjiri B. Patwari, Manoj Saswade, Neha Deshpande", Localization of Optic Disc using HRF database", IEEE's International Conferences For Convergence Of Technology, Pune, India.

[17] Patwari Manjiri, Manza Ramesh, Rajput Yogesh, Saswade Manoj, Deshpande Neha, "Automated Localization of Optic Disk, Detection of Microaneurysms and Extraction of Blood Vessels to Bypass Angiography", Springer, Advances in Intelligent Systems and Computing. ISBN: 978-3-319-11933-5, DOI: 10.1007/978-3-319-11933-5_65. 2014.

[18] "Understanding MATLAB" By Karbhari Kale, Ramesh R. Manza, Ganesh R. Manza, Vikas T. Humbe, Pravin L. Yannawar, Shroff Publisher & Distributer Pvt. Ltd., Navi Mumbai, April 2013. ISBN: 9789350237199.

[19] "Understanding GUI using MATLAB for Students" By Ramesh Manza, Manjiri Patwari & Yogesh Rajput, Shroff Publisher & Distributer Pvt. Ltd., Navi Mumbai, April 2013. ISBN: 9789351109259.

[20] Yogesh M. Rajput, Ramesh R. Manza, Manjiri B. Patwari, "Extraction of Cotton Wool Spot using Multi Resolution Analysis and Classification using K-Means Clustering", IJCA Proceedings on National conference on Digital Image and Signal Processing, International Journal of Computer Applications (0975 – 8887) 2015.