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Research Article

An Efficient Method to Detect Diabetic Retinopathy Using Gaussian-Bilateral and Haar Filters with Threshold Based Image Segmentation

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Abstract: A digital imaging technique is utilized in almost all the fields. Based on image processing concept image particle shape can be analyzed in detail. Nowadays, in eye clinics, imaging of the eye fundus with modern technology is in high demand because of its worth and expected lifetime. Eye fundus imaging is considered a non-invasive and painless route to screen and monitor the micro vascular distinction of diabetes and diabetic retinopathy. In general, Optic Disc (OD) signifies the creation of the optic nerve. It is the point where the axons of retinal ganglion cells gain nearer. The Optic Disc is an access point of major blood vessels which provides the retina. In this study a method is introduced to automatically detect the position of the OD in digital retinal fundus images. The OD detection algorithm is based on the identical expected directional pattern of the retinal blood vessels. In this study two types of filters are proposed, one is Gaussian based bilateral filter, to reduce/eliminate the noise of the fundus images and another is a Haar filter to detect the diabetic retinopathy in the fundus images. The most excellent method to segment the images is thresholding based connected component pixels. The results have been taken from many diabetic retinopathy images. In this study for implementation efficient image filtering was used and named as OpenCV 2.4.9.0 and cvblobslib to accomplish successful result. In future development, the fovea detection will be applied.

Keywords: Bilateral filter, connected component pixels, diabetic retinopathy, digital image processing, fundus images, Haar filter, optic nerve

INTRODUCTION

Diabetes is growing at an unprecedented rate in India. Data from the International Diabetes Federation (IDF'S) Diabetes atlas reveals that it is the country with the maximum number of people with diabetes. At present, 40.9 million of Indian people have diabetes and by the year of 2035 it will increase to an alarming figure of 85 million. Besides these above figures, many of them are in the vulnerable stage of being affected with diabetes-Impaired Glucose Tolerance (IGT), which is considered as the pre-diabetic state of dysglycemia. It is connected with insulin resistance and greater degree of cardiovascular pathology threat. In India, up to 14-22% of the people is categorized as pre-diabetic and if left uncheck these people can become diabetic within a decade.

When the retina of the eye is impaired due to abnormal blood flow related to diabetes mellitus, it is called diabetic retinopathy. It is so threatening that it can even cause severe loss of vision. In certain cases, blood vessels swell and fluid are leaked. However, in other cases the surface of the retina will develop abnormal new blood vessels. Diabetic retinopathy typically involves both eyes and for good vision healthy nourished retina required.

When diagnosed with diabetes patients are asked to go through constant eye examination, involving a complete retinal evaluation. This is done in order to rule out the presence of diabetic retinopathy. And if signs of it are detected, the patient is treated accordingly. Initially, changes in the vision may not be noticed but over time diabetic retinopathy can lead to loss of vision.

One of the alarming disabling chronic diseases and the leading cause of preventable blindness in the world is Diabetic Retinopathy (DR). In 2009, it was found to be the fourth most frequently managed chronic disease in general practice. The estimation can go as high as the second most frequent disease by the year 2030. Worldwide diabetes is a huge threat and the global diabetic patients are estimated to rise from 171 million in 2000 to 366 million in 2030.

Screening programs can help achieve early diagnosis of diabetic retinopathy. Without indication of decreased vision the DR will affect up to one third of people.

Diabetes is considered to be a major threat for cardiovascular diseases and causes abnormalities in the

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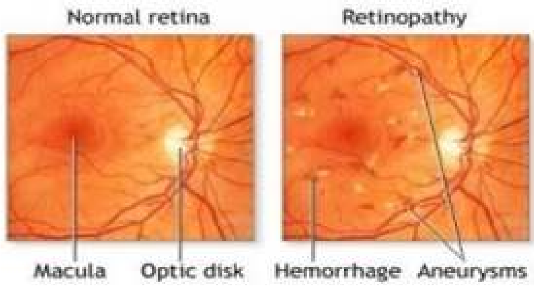

Fig.1: Non-proliferative diabetic retinopathy

retina (diabetic retinopathy). There may be no visible signs during the initial stage of diabetic retinopathy but as the disease advances, the number and severity of abnormalities becomes conspicuous. Micro aneurysms which represent the local enlargements of the retinal capillaries are the initial noticeable abnormalities. When the micro aneurysms are ruptured it can cause hemorrhages and hard exudates may become visible after sometime. The weakened blood vessels leaks lipid formations which are called hard exudates. The blood vessels may become even more blocked as retinopathy progresses causing micro infarcts (soft exudates) in the retina. As the blood flow is hindered more and more it leads to severe deficiency of oxygen. This further leads to the growth of new weak vessels.

The Neovascularization is identified series of eyesight destructive situation and may direct to deadly consequences such as unexpected defeat in visual insight or still enduring blindness. Figure 1 shows Non-proliferative diabetic retinopathy i.e., micro aneurysms, hemorrhages, hard exudates, soft exudates and neovascularization.

Constant examination is mandatory after detecting diabetic retinopathy. Fundus image examination involves medical experts which is why broad screening cannot be performed. Automated image processing technique must be evolved for the screening which demands top notch quality databases for algorithm evaluation.

Color retinal images of a patient obtained from digital fundus camera are used by ophthalmologists for the diagnosis of diabetic retinopathy. After extensive analysis, the present study is undertaken in order to develop an automatic system for the extraction of normal and abnormal features in color retinal images.

Digital image processing: Manipulation of digital images through a digital computer is called digital image processing. It concentrates mainly on images to develop a computer system that can execute processing on an image. A digital image is the input of that system and the system further process that image utilizing effective algorithms. And thus gives an image as an output. Adobe Photoshop can be considered as an example for processing digital images.

LITERATURE REVIEW

An automatic Binary Mask is a technique used to analyze the end results of the required channels as explained by Hashim *et al*. (2013). This provides an idea about the retinal image which is developed. The Intensity component can be utilized to hold back the blood vessels in the retina in the further process (Hashim *et al*., 2013).

Diabetes Retinopathy takes place as the whole retina gets affected. It also affects the whole eye sight. For this type of technique which yields precise result digital imaging is used. The rating cost of the screening process is decreased with retinopathy detection (Faust *et al*., 2012).

The exudates from the images are eliminated by methods such as Recursive Region Growing Segmentation, a micro-aneurysm and hemorrhage with the help of non-dilated pupils. Adaptive concentration with be provided later. The result is that many morphological operators are used productively (Akara *et al*., 2008).

Color images were used by Zhang *et al*. (2014) in order to identify the diabetics. In this study, Non-Invasive approach is mainly used. With the help of Diabetic Retinopathy and the color, notable features, Tongue Segmentation is recorded cautiously and different images for Tongue are demonstrated. No proliferative Diabetic Retinopathy is applied to the tongue effectively (Zhang *et al*., 2014).

A good arrangement in the position of the image is provided by the online optic disc detection method. In order to detect the optic disc, adaptive Morphological technique is used. In this study, Cascade classifier method is proposed. It detects both face and eye. The detection performance accomplished is 94.4% as the author implemented with OpenCv with C++ (Claudio *et al*., 2013).

Diabetic Retinopathy (DR) Detection is done with the help of Image processing technique as expounded by Patil and Chaudhari (2012). The color fundus photographs images detect hemorrhages and micro-aneurysms, hard exudates and cotton-wool spots with the image enhancement technique. The Digital Image Processing technique (DIP) engages the alteration of digital data. The clarity of the image, sharpness and noise reduction can be accomplished with this method (Patil and Chaudhari, 2012); Region of interest is also measured here. Upcoming detecting works can be calculated by Retinopathy Online Challenge. Cross-section analysis can be done with the use of image processing technique (Lazar and Hajdu, 2013).

Before the segmentation process (Kaur and Sinha, 2012) used color normalization to perform the difference in the respective colors and satisfy it. For the correction, Contrast-Limited Adaptive Histogram equalization is usually applied to the fundus image and it also composes contrast in that particular image. In order to compete that component of vessel to be removed in a green channel image morphological filters are used. Based on limited thresholding the vessels and non-vessels pixels are applied co-occurrences matrix in gray-level images (Kaur and Sinha, 2012).

Automatic exudates detection is demonstrated by Tripathi *et al*. (2013) which can be followed for fundus images. It can be dependent on the Differential Morphological Profile i.e., DMP. In order to mathematically determine the effort of the proposed work that it must gain its proper improvement in the quality of an image, the internet source DIARETDB1 Database is entirely utilized (Tripathi *et al*., 2013).

Facilitating the complexity in hallucination is the main impediment. Corresponding to the arrangement of blood vessels and imagery dispensation methods they conversed. And an algorithm called Fuzzy C-Means algorithm. And similar to image section and categorization of c-mean algorithm two methods were used (Habashy, 2013).

Major ladder like flush picture improvement, figure calculation, set of finest and familiar morphological operatives are the main components of the algorithm. The compassion, specificity and prognostic rate are then computed by the algorithm. Developing the outcome of recognition of pale and tiny hemorrhages is future (Joshi *et al*., 2009).

An improved technique that detects the irregularity in retina using the picture dispensation techniques is expounded by author M. Patil and are related to the morphological dealing out system. In order to observe the harshness of diabetic retinography these two ways are used. In clinical orthalmology, prospect retinal vascular digital picture examination plays a vital role (Chandrashekar, 2013).

For the Diabetes Retinopathy, the remarkable improvement of the automated system has become a very good detection component. In an advance phase called Proliferative Retinopathy it ends in leakage of the blood. In this type of method medical Image camera is commonly used (Amrutkar *et al*., 2013).

In this study, difficulty of selecting feature is prepared by the microarray gene expression data. Analysis of the wavelet power spectrum is done. So selecting a feature is absolutely dependent on the Haar wavelet power spectrum. This technique is easy, quicker and robust designed for various data types and also for the top genes. Results regarding genes will be chosen and examined by the gene expression data (Subramani *et al*., 2006).

Digital image processing segmentation through rotating filtration technique is performed for upcoming process. Filters like High pass, Laplacian and Soble are used to provide blood vessels a picture which seems to be unique. Soble filter output picture provide extra white pixels linked to the blood vessels. Gaussian filter give the highest and the best outcome. This proposed work is used to remove the retina blood vessels mechanically (Badawy *et al*., 2013).

PROPOSED METHODOLOGY

Gaussian-bilateral filters: Each pixel in the image is affected by a given filter during filtering images and is thoroughly a parallelizable process. Both filtering and application of the filter are independent in respect to other neighbor pixels. Often an image is made up of millions pixels making it a good candidate for parallelization.

Transformation that involves up-sampling and interpolation of images is called image up-scaling. Interpolation filters by their low-pass nature result in blurry edges in an image. While preserving the fidelity of sharp edges it is advisable to be able to blow up images. Linear high-pass edge preservation algorithms are common but are very transparent to noise which is considered to be a drawback. Edge preservation is traded for noise suppression in up-scaling noisy images and vice versa.

Use of bilateral filters for noise-suppressing and edge-preserving image scaling is what we propose in this study. Since bilateral filters are non-linear filters with influence functions in both spatial axes and pixel intensity, while preserving edges it can smooth out images. A laplacian edge enhancing filter, a scaling kernel with a bilinear interpolation filter and a cascade of a bilateral edge-preservation filter is the image scaling algorithm.

Haar wavelet filter: Haar Wavelet Filter is one of the simplest wavelet transform and also it is one of the sequences of function. It is a compression process. The system of functions considered by Haar system on (0, 1) consists of the subset of Haar wavelet filter defined as:

$$\text{Haar\_Filter (t)} = \begin{cases} 1 & 0 \le t < 1/2 \\ -1 & 1/2 \le t < 1 \\ 0 & \text{otherwise} \end{cases}$$

The scaling function Filter (t) can be described as:

$$\text{Filter (t)} = \begin{cases} 1 & 0 \le t < 1 \\ 0 & \text{otherwise} \end{cases}$$

Single level Haar wavelet transform: In Haar Wavelet transform is a 2-element matrix (x (1), x (2)) into another 2-element matrix (y (1), y (2)) by the relation, the equation can be followed as:

$$\begin{pmatrix} y(1) \\ y(2) \end{pmatrix} = \text{Ortho\_Matrix} \begin{pmatrix} x(1) \\ x(2) \end{pmatrix}$$

Here, Ortho_Matrix is donated as Orthonormal Matrix. The Orthonormal Matrix described as:

$$\text{Ortho\_Matrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

Two level Haar wavelet transform: The 2-Level Haar Wavelet Transform x and y becomes 2×2 matrix and it is defined by the relation. The transformation can be carried out, at first pre-multiplying the columns of x by Ortho_Matrix (Orthonormal Matrix) and then post-multiplying the rows of the result by Ortho_Matrix^T:

$$y = \text{Ortho\_Matrix}.x.\text{Ortho\_Matrix}^T$$

$$x = \text{Ortho\_Matrix}^T.y.\text{Ortho\_Matrix}$$

To compute the transformation of an complete breast image, first to divide the breast image in to 2×2 blocks and apply the equation:

$$y = \text{Ortho\_Matrix}.x.\text{Ortho\_Matrix}^T$$

Image segmentation is a fundamental step in various advanced method of multi-dimensional signal processing and it purposes. Haar wavelets functions are generated from a One-Dimensional function by its deletions and translations. The Haar transform forms the simplest compression process of this kind.

Connected component pixels: Algorithmic application of graph theory is a connected-component Pixels where subsets of connected components are uniquely marketed based on a given heuristic. Segmentation and Connected-component Pixels are different and should not be confused.

In computer vision connected-component Pixels is used to identify connected regions in binary digital images. Color images and data with higher-dimensionality can also be processed. Connected component Pixels can function on a variety of information when incorporated into an image recognition system or human-computer interaction interface. Blobs may be counted, filtered and tracked and blob extraction is commonly done on the resulting binary image from a threshold step.

Though blob extraction and blob detection are connected, blob extraction is unique from blob detection.

Working process for connected component pixels: The main part of this proposed study Connected Component Pixels, it is well known working circumstances are scanning fundus images pixel-by-pixel from top to bottom and also left to right approach in regulate to recognize connected pixel regions. The region of neighboring pixels shares the same set of intensity values I_V. Binary or gray-level images process connected component pixels and various measures of connectivity are attainable.

The image is scanned by the connected components pixels operator by moving along a row till it comes to a position P (where P stands for the pixel to be labeled at any stage in the scanning process) for which Iv = {1}. When this is true, it look at the four neighbors of P which have already been encountered in the scan i.e., the neighbors (i) to the left of P, (ii) above of P and (iii and iv) the two upper diagonal terms. The pixel of P takes place as described below and based on this information:

```
IF (All FOUR Neighbors are Zero)
        P = New_Pixel
Else IF (Only One Neighbor Has Iv = {1})
        P = New_Pixel+1
Else If (More THAN One Neighbors Have Iv = {1})
        P = P+1
THEN
MAKE Sure P and P+1 are Equivalences
```

The equivalent pixel pairs are arranged into equivalence classes and a unique pixel is allocated to each class after the scan is done. And as an ultimate step, a second scan is made through the image, during which each pixel is substituted by the pixel allocated to its equivalence classes. The pixels might be of a range of gray-levels or colors for display.

RESULTS AND DISCUSSION

Fundus camera image qualities with dimensions 545×564 (i.e., Width is 545 pixels and Height is 564 pixels) have been utilized for simulation. Fundus Image bit depth is 24 pixels and Image type is PNG file. OpenCV 2.4.9.0 and cvblobslib libraries are utilized for simulating the fundus images. Originally developed by Intel and now supported by Willow Garage the OpenCV is an open source C++ library for image processing and computer vision. For both commercial and non-commercial use it is free. It is primarily aimed at real time image processing and is a library of many inbuilt functions. Now, developing advanced computer vision applications does not require great effort because the OpenCV has several hundreds of image processing and computer vision algorithms (Referred Date: 28.07.2014, http://opencv-srf.blogspot.in /2010/09 /what-is-opencv.html).

Based on cvblobslib, the OpenCVBlobsLib is a library written in C++. When dealing with "zones" with homogeneous features in an image, it allows for gathering information, filling, labeling and filtering. To enhance the performance it uses OpenCV and PThread. With big images and many blobs, the used algorithm is very efficient. It can become even faster exploiting the multi-core architecture of modern CPUs. The CvBlobsLib is a library to present related component labelling of binary images, obtained at the OpenCVWiki page and utilized for blob extraction. To

Table 1: Setting of hue, saturation, value (brightness) of the fundus images

```
char* sCTypes [NUM_COLOR_TYPES] = {"Black", White",
"Grey", "Red", "Orange", "Yellow", "Green","
                    Aqua", "Blue", "Purple", "Pink"};
uchar cCTHue [NUM_COLOR_TYPES] = {0, 0, 0, 0, 20,
                  30, 55, 85, 115, 138, 161};
uchar cCTSat [NUM_COLOR_TYPES] = {0, 0, 0, 255, 255,
                  255, 255, 255, 255, 255, 255};
uchar cCTVal [NUM_COLOR_TYPES] = {0, 255, 120,
                  255, 255, 255, 255, 255, 255, 255, 255};
```

Table 2: Operation in gaussian-bilateral filter

```
Image = cvLoadImage ("c:/Fundus_Image_1.png",1);
int height, width, step, channels, stepr, channelsr, temp = 0;
uchar *data, *datar;
IplImage *originalThr = cvCreateImage (cvSize (image->
                       width, image->height), 8, 1);
displayedimage = cvCreateImage (cvSize (image->
                            width, image->height), 8, 3);
frame_copy = cvCreateImage (cvSize (image->

        width, image->height), IPL_DEPTH_8U, image->
                      nChannels);
cvCopy (image, frame_copy, 0);
test = cvCreateImage (cvSize (image->width, image->height),
                                              8, 1);
cvSmooth (image, image, 20, 30, 0, 0);
```

Table 3: Operation in Haar filter

```
datar = (uchar *) test->imageData;
for (i = 0; i< (height); i++)
{
   for (j = 0; j< (width); j++)
   {
      uchar H = *(uchar*) (data + i*step + j*3 + 0);
        // Hue
      uchar S = *(uchar*) (data + i*step + j*3 + 1);
        // Saturation
      uchar V = *(uchar*) (data + i*step + j*3 + 2);
        // Value (Brightness)

Determine what type of color the HSV pixel

int ctype = getPixelColorType (H, S, V);
if (((data [i*step+j*channels+2]) >
(120+data [i*step+j*channels]))     &&
                      ((data [i*step+j*channels+2]) >
(120+data [i*step+j*channels+1])))
{
       datar [i*stepr+j*channelsr] = 255;
} else {datar [i*stepr+j*channelsr] = 0;}
}
```

Table 4: Connected components pixels operation

```
blobs = CBlobResult (test, NULL, 0);
blobs.Filter (blobs, B_INCLUDE, CBlobGetArea(),
B_GREATER_OR_EQUAL, 50);
printf ("%d", blobs.GetNumBlobs());
cvMerge (test, test, test, NULL, displayedimage);
for (i = 0; i<blobs.GetNumBlobs(); i++)
{
currentBlob = blobs.GetBlob(i);
CvRect r = currentBlob->GetBoundingBox();
CvPoint p1, p2; p1.x = r.x*1; p2.x = (r.x+r.width)*1; cvRectangle
(frame_copy, p1, p2, CV_RGB (0, 235, 255), 3,
                                          8, 0);
currentBlob->FillBlob (displayedimage, CV_RGB (255, 0, 0)); }
```

open a color image, these implementations used the OpenCV libraries and change it to a grayscale and then thresholding to change it to a black and white (binary) image.

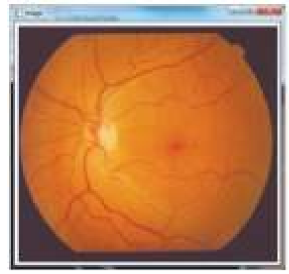

Fig. 2: Original fundus image

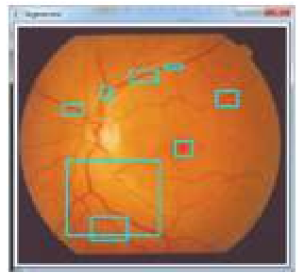

Fig. 3: Segmented image

Fig. 4: Intermediate image

Fig. 5: Detected image

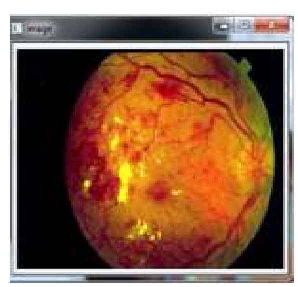

Fig. 6: Original fundus image

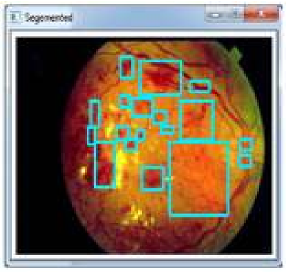

Fig. 7: Segmented image

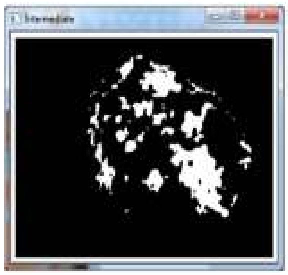

Fig. 8: Intermediate image

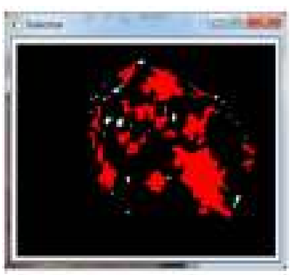

Fig. 9: Detected image

Table 1 showa setting of Hue, Saturation, Value (Brightness) of the fundus images.

Table 2 Represents main operation in Gaussian-bilateral Filter, Loads an image from the specified file and returns the pointer to the loaded image. Table 3 represents the major procedure in Haar Filter and also gives types of color in HSV pixel. Table 4 gives procedure about connected components pixels operations.

Figure 2 to 5 gives Simulated Micro aneurysms detected result and Fig. 6 to 9 provides simulated output of hemorrhages detection result in fundus image.

CONCLUSION

Today, the number of people with Diabetes is rising at an unprecedented rate. It is also considered to be a major risk for cardiovascular diseases. Micro vascular complication caused by diabetes called as Diabetic retinopathy is so risky that it can even lead to blindness. At early stages of diabetic retinopathy typically have no visible signs. But as time passes by, the number and severity of abnormalities exacerbates. Typically, it starts with small changes in retinal capillaries and micro aneurysms are the first detectable abnormalities. These micro aneurysms represent local enlargements of the retinal capillaries. Hemorrhages can happen due to ruptured micro aneurysms. Detecting diabetic retinopathy effectively is a massive challenge. The first and foremost process in developing automated screening systems for diabetic retinopathy is the Optic Disc (OD) detection. Therefore, to match approximately the direction of the vessels at the OD vicinity, an easy matched filter is proposed. After extensive research, the bilateral Gaussian and Haar filter are the two types of filter proposed in this study. First is Gaussian based bilateral filter, which is to reduce/eliminate the noise of the fundus images and another is a Haar filter to detect the diabetic retinopathy in the fundus images. Thresholding based connected component pixels is the most efficient method to segment the images. Results have been obtained from many diabetic retinopathy images. In this study, OpenCV 2.4.9.0 and cvblobslib were used for implementing efficient image filtering and to achieve successful result. The fovea detection will be applied for future development.

REFERENCES

Akara, S., U. Bunyarit and B. Sarah, 2008. Automatic exudates detection from non-dilated diabetic retinopathy retinal images using fuzzy C-means clustering. Comput. Med. Imag. Grap., 32: 720-727.

Amrutkar, N., Y. Bandgar, S. Chitalkar and S.L. Tade, 2013. Retinal blood vessel segmentation algorithm for diabetic retinopathy and abnormality detection using image subtraction. Int. J. Adv. Res. Electr. Electron. Instrum. Eng., 2(4).

Badawy, S., A.S. El-Sherbeny, A. El Saadany and M.A. Fkirin, 2013. K7. Retinal blood vessel image segmentation using rotating filtration to help in early diagnosis and management diabetic retinopathy. Proceeding of the 30th National Radio Science Conference, Egypt.

Chandrashekar, M.P., 2013. An approach for the detection of vascular abnormalities in diabetic retinopathy. Int. J. Data Min. Techn. Appl., 2: 246-250.

Claudio, A.P., A.S. Daniel, C.M. Aravena, C.I. Perez and T.J. Verdaguer, 2013. A new method for online retinal optic-disc detection based on cascade classifiers. Proceeding of the IEEE International Conference on Systems, Man and Cybernetics (SMC, 2013), pp: 4300-4304.

Faust, O., A.U. Rajendra, E.Y.K. Ng, K.H. Ng and J.S. Suri, 2012. Algorithms for the automated detection of diabetic retinopathy using digital fundus images: A review. J. Med. Syst., 36(1).

Habashy, S.M., 2013. Identification of diabetic retinopathy stages using fuzzy C-means classifier. Int. J. Comput. Appl., 77(9).

Hashim, F.A., N.M. Salem and A.F. Seddik, 2013. Preprocessing of color retinal fundus images. Proceeding of the 2nd International Japan-Egypt Conference on Electronics, Communications and Computers (JEC-ECC), pp: 258-261.

Joshi, M.S., P. Rekha and H. Aravind, 2009. Automated detection and quantification of haemorrhages in diabetic retinopathy images using image arithmetic and mathematical morphology methods. Int. J. Recent Trends Eng., 2(6).

Kaur, J. and H.P. Sinha, 2012. Automated detection of diabetic retinopathy using fundus image analysis. Int. J. Comput. Sci. Inform. Technol., 3(4): 4794-4799.

Lazar, I. and A. Hajdu, 2013. Retinal microaneurysm detection through local rotating cross-section profile analysis. IEEE T. Med. Imaging, 32(2).

Patil, J.D. and A.L. Chaudhari, 2012. Tool for the detection of diabetic retinopathy using image enhancement method in DIP. Int. J. Appl. Inform. Syst., 3(3).

Subramani, P., R. Sahu and S. Verma, 2006. Feature selection using Haar wavelet power spectrum. BMC Bioinformatics, **7**: 432.

Tripathi, S., K.K. Singh, B.K. Singh and A. Mehrotra, 2013. Automatic detection of exudates in retinal fundus images using differential morphological profile. Int. J. Eng. Technol., 5(3): 2024-2029.

Zhang, B., B.V. Kumar and D. Zhang, 2014. Detecting diabetes mellitus and nonproliferative diabetic retinopathy using tongue color, texture, and geometry features. IEEE T. Bio-Med. Eng., 61(2): 491-501.