Technical Journal, University of Engineering and Technology (UET) Taxila, Pakistan Vol. 23 No. 3-2018
ISSN:1813-1786 (Print) 2313-7770 (Online)

Role of Digital Filters in Dermoscopic Image Enhancement

U. Jamil[1], Q. Ann[2], A. Sajid[3], M. Imran[4]

[1,2,3]Computer Science Department, Government College University, Faisalabad, Pakistan
[4]University of Agriculture, Faisalabad
[1]uzma.jamil@gcuf.edu.pk

Abstract-Melanoma is a type of skin cancer. Dermoscopy helps in detection of melanoma. Death toll of melanoma patients is very high due to difficulties faced in diagnosis. Computer aided design is a way to diagnose it at early stage and hence proper treatment will lead to decreased death rate. Digital dermoscopic images are processed to diagnose and classify skin cancer. Noise present in image is a hurdle in detection of lesion. Gabor wavelets are used to highlight artifacts. Hair, reflections, shadows, skin lines and air bubbles are artifacts that are considered as noise. Noisy image can lead to wrong detection of cancer region. Image visibility can be enhanced by improving color contrast and noise removal. Image processing techniques are applied on images to remove artifacts. This paper presents comparative analysis of ten filters and six point processing techniques. De-noised image is further processed for feature extraction, segmentation and classification.

Keywords-Melanoma, Dermoscopic, Gabor Wavelet, Point Processing, Low Pass Filter, High Pass Filter, Power Law Transform, Contrast Enhancement, Adaptive Histogram Equalization, ImageIn-Painting

I. INTRODUCTION

Skin cancer is wild growth of de-structured skin cells. Melanoma is a kind of skin cancer that occurs in melanocytes. Melanocytes are melanin producing cells that are present on lower epidermis. Melanin is pigment that control color of skin and hair. Melanoma is a kind of skin cancer that is produced in melanocytes. Melanoma skin cancer has tendency to spread to other body cell and can cause death. Non-melanoma rarely have chance to penetrate rest of body cells. Hence, melanoma is most dangerous type of skin cancer as death rate is high [i].

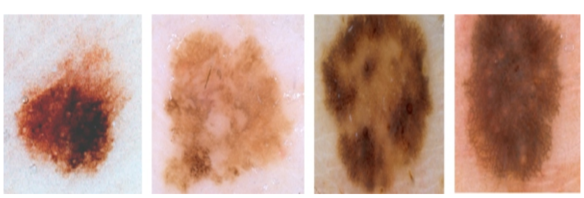


Fig. 1. Dermoscopic images of Melanoma with artifacts

Melanocytes are specific skin cells that produce a black pigment named as melanin. Melanin is responsible for skin complexion in human beings. People with fair skin tone have less melanin in melanocytes as compared to the brown one. This pigment is responsible to protect human skin from the effects of ultraviolet radiations of sun. Melanoma is due to uncontrolled growth of melanocytes. Figure 1 show how melanoma looks on human skin. Development of melanoma can be either fast or slow. Ultra violet rays are basic element that can cause melanoma.

Dermoscopy is a way to examine skin lesion [ii]. Fig. 2 show pictorial representation of dermatoscope. It aids to classify lesion based upon structure and color. There are many clinical ways to diagnose melanoma based upon features of lesion. ABCD method [iii], seven point check list [iv], three point check list [v], menzis method [vi] and CASH algorithm [vii] are widely used methods.

Fig. 2. Digital Dermatoscope

Digital images are produced as an output of Dermatoscope. Digital image is composed of pixels and dots. Digital image processing is a domain of image processing in which operations are performed on images to enhance and extract required information. Image processing is used in engineering as well as medical science for image visualization, restoration, sharpening and feature extraction. It is used to improve pictorial information so that human can analyze medical images easily. It is used to extract feature from MRI images, CT-scan images and dermoscopic images etc. Image enhancement techniques are applied on image to remove blurriness, noise and to remove sharp intensity differences in an image. Noise can affect the accuracy of an image so it is imperative to remove it before any further processing.

In dermoscopic image the artifacts could be in form of gel, sweat drops, air bubbles, hair, skin lines and poor contrast. This can alter the reality of image so it is necessary to get rid of them before segmentation. A variety of algorithms are used for artifact removal. Each technique differs from other as some use filtering and other work on value of pixel.

CAD systems based on medical knowledge try to mimic the performance of dermatologists for the detection of pigmented region [i]. Automated CAD system will take dermoscopic image as an input, processes the input and tells the user whether the patient is having melanoma or not. The first and most important phase in automatic detection is artifact removal and de-noising of dermoscopic image. A pre-processed and de-noised dermoscopic image will result in better diagnosis.

Our research paper will provide the facility to use the defined methods direct instead of testing and diagnosis the images from initial stages. The methods will be accurate enough that one can use them without any doubt and he will get the required results. It will be used by the doctors of skin cancer as they can diagnose the patients within no time. It reduces complexities in early detection. It will provide the ground base for further stages of image processing. This application will remove the noise and enhance the images so that it can be useful for the other image processing stages like image restoration, image segmentation and image classification.

There are two types of image enhancement techniques namely spatial domain and frequency domain techniques.

A. Spatial domain filtering

It is normal image space. It is combination of pixels of an image. In this domain operations are performed directly on pixels. Spatial domain processes are expressed as:

$$g(x, y) = T[f(x, y)] \quad (1)$$

Where $f(x, y)$ is the input image, $g(x, y)$ is the output image and T is some transformation function applied for enhancement, defined over some neighborhood of(x, y). The neighborhood is defined to some principles. Spatial domain techniques can be broadly categorized as point processing and mask processing. Point processing can be further categorized as gray level transformation, piece-wise linear transformation and histogram based image processing techniques. It uses pixels of image. The general form of gray level transformations is given as:

$$S = T(r) \quad (2)$$

S is the value of pixel after processing and r is value of pixels before processing [viii]. T is the transformation that maps pixel values from r into s. Image negative, log transform and power law transformation functions are used for gray level transformation.

Contrast stretching is another point processing techniques. It is used to enhance the low contrast images with poor contrast. It works by stretching the range of intensity values of pixels that is desired to enhance. The formula for contrast stretching is as follows [ix]

$$P_{out} = (P_{in} - c)\left(\frac{b-a}{d-c}\right) + a \quad (3)$$

Histogram equalization is also used for image enhancement. Mask processing is used for image smoothing and image processing.

B. Frequency domain filtering

In frequency domain processing is not performed on image rather it is applied on inverse transformation of an image. After processing, image is converted to spatial domain [x]. These filters are used for image smoothing, sharpening and artifact removal. Ideal filter, butter-worth filter and Gaussian filters are used. For smoothing low pass filters are used while for sharpening high pass filters are used. Smoothing results in blurriness because it stop high frequencies and allow low frequencies to pass through. Sharpening is used to preserve edges. It performs inverse of smoothing filters.

This paper represents critical analysis of filtering techniques and six point processing methods. It provides a detailed discussion that which filters are suitable to remove which type of artifacts. Section 2 provides work done by other researchers, section 3 explains methodology, results are discussed in section 4 while section 5 provides conclusion and at last references are provided in section 6.

II. LITREATURE REVIEW

Preprocessing is fundamental step in design of automated diagnosis. Image processing is contemporary research area. Researchers are working on image preprocessing, artifact removal, image post-processing, segmentation and classification of melanoma. A noise free image helps in better diagnosis as compared to image having artifacts surrounding lesion so it is mandatory to remove noise before going for segmentation and classification. There are two types of image enhancement techniques namely spatial domain and frequency domain techniques [i]. Focused on image pre-processing and segmentation. He used sixty-four directional filters to detect and remove artifacts. He processed RGB images to get red, blue and green components. He selected blue component because of its information description. Then he used threshold method to detect artifacts in images. Pixel could be categorized as reflection if threshold value is less than intensity value of respective pixel and if the average intensity of the surrounding pixel subtracted from intensity of pixel is still greater than threshold then it is definitely a reflection or artifact. He had used directional filters to get rid of hair. Binary mask of hair artifacts was multiplied by gray scale version of image. This would result in appearance of gaps. Moreover, neighborhood operation was performed to fill all the gaps of resultant image. In this way noise free image was obtained and could be used for segmentation. 94% accuracy was achieved by above proposed methodology.

Gabor wavelet transformation is used to remove unwanted noise from dermoscopic images. Active contour technique was used to define area for pre-processing as it defined the boundary of shape. Binary mask was obtained by converting the image to binary image. Color enhancement was obtained by linearly combining RGB values into single luminance value. Gray threshold of image was adjusted using thresholding technique. It accommodated shadows and high variations in images. Hair enhancement and removal was obtained using Gaussian filter. Image in-painting was obtained by neighborhood operation. Median filter was used to remove dark spots and smooth image is obtained as output. Median filter removed noise without de-blurring the image [ii].

Wavelet transformation is another technique for artifact removal. Image enhancement is performed using 2-dimensional Gabor filter. It spot-light hair artifacts in the image. Adaptive Otsu's thresholding method is applied to make binary mask of hairs and hair pixels are replaced by skin pixels using neighborhood operation. Illumination of image is corrected by equalizing L-channel. The color between skin and lesion pixel is adjusted by adaptive sigmoidal using cutoff value. Median filter with disc-shaped structure is applied to remove small ignorable noise.

There are two types of processing one is scalar and other is vector. In [xiii] scalar processing, RGB dermoscopic images are converted to grayscale. For vector processing, image has to be converted to l*a*b or l*u*v or HSV color space. According to his survey morphological filtering is a way to make lesion prominent in dermoscopic images and color morphological filters can be used to highlight lesion portion. Image smoothing can be achieved using anisotropic diffusion filter. Median filters are a good choice where images contain too much noise. Average filters are non-linear filters. Non-linear filter helps in keeping the edges intact without blurring it. Homo-morphic filters along with fast Fourier transform and high pass filtering is an excellent way to pre-process dermoscopic image.

The most important phase in image pre-processing is artifact removal. Filters are a good choice to remove hair, bubbles, gel, reflections and other type of noise. Filter could be mean filter, median filter, Gaussian filter and anisotropic diffusion filter. Time of computation for former three filters is independent of mask size while for anisotropic filter it is dependent upon mask size. Morphological top hat operator could be used to filter out blood vessels from dermoscopic images. Morphological closing operator could be used to detect hair and bilinear interpolation could remove hair artifacts. Moreover, morphological closing with thresholding, morphological operators with partial differential based in painting, matched filtering along with Gaussian smoothing and entopic thresholding are good ways to remove artifacts. Random transform followed by pewit operations are good for edge detection. Every discussed method had its own pros and cons [xiv].

Completed pre-processing consists of three steps [xv]. During digitization, black frames were introduced and were removed by converting RGB image to HSV and determined luminance component of HSV color space. Gaussian smoothing filter was used to get rid of lines, reflections, gel and bubbles. White top hat transform technique is used to remove hair from image and inpainting is done using neighborhood operation.

[xi] proposed a method to remove black frames and hair strands from dermoscopic images . First of all color space is changed from RGB to HSV and luminance component is used. Median filter with mask of size [3x3] is used for artifact removal. Nagao and kuwahara smoothing filters were later applied. Smoothing filters preserves the edges. Mathematical morphology operations were performed to remove black frames. Image inpainting techniques include patch-based class, sparse class, partial differential equation and early interpolation method.

Canny edge detection method is used to detect hairs, morphological operators are used to remove hair and multi-resolution coherence transport inpainting is applied to repair hair pixels [xvii].

[xviii] had worked on hair removal for dermoscopic colored images . Black frames appeared on images as a result of digitization process. Black frames were removed by converting RGB color space to HSL and considering L component. Pixel was considered as black frame if its L value is below 15. Gel, bubble, skin lines and reflections were removed by applying Gaussian filter. De-noised images was converted to gray scale and laplacian based high pass filter was applied to it. Top-hat transform was applied to cater for remaining hair. Unwanted pixels were replaced using neighborhood in-painting technique.

Median filter is used to remove noise from dermoscopic image. Then hair artifacts are removed using morphological closing operation. Median filter should be of kernel size [5x5] with the disc of diameter 3. Skin is separated from lesion by applying a histogram adjustment [xxi].

ABCD method can be used to detect Melanoma for dermoscopic images. For this purpose, first step is to pre-process dermoscopic image by removing hair artifacts. RGB images were taken as input. Color space was changed to CIE LAB. Homo-morphic filters were applied on L plane to adjust uneven illumination of image. Hair artifacts were removed by applying derivative of Gaussian along with morphological function and fast marching. He proposed a hair removing algorithm that preserves the features of image. It was able to process both dark and light colored hairs. Firstly RGB image was converted to gray-scale image. Rough hair is detected using first derivative of Gaussian filter along with matched filtering and thresholding technique. Hairs were refined using morphological edge based technique. When hair pixels were removed then empty pixels were in-painted using fast marching inpainting technique. As a result de-noised dermoscopic image was obtained without damaging texture of lesion [xxii].

A comparison of spatial domain filtering techniques is discussed in [xxiii]. Contrast enhancement is achieved using histogram equalization and tone mapping.

A comparative analysis of spatial and transformation domain filtering is presented in [xxv] and [xxvi]. Short-comings are discussed in both.

Bi-histogram equalization with alpha rooting technique is used to enhance image quality [xxvi]. According to them there are many histogram equalization techniques but they are difficult to implement and have high computational time.

Advantages and disadvantages of spatial and transformation domain filtering are discussed in [xxvii]. Another author proposed optimum wavelength based masking for contrast enhancement of medical images. Their proposed method had higher performance as compare to other techniques [xxviii].

III. Methodology

The proposed system takes dermoscopic image as input and processes it to get rid of artifacts. Hair artifacts are highlighted using Gabor wavelet transform. Point processing techniques are applied on image. Furthermore image is passed through low pass or high pass filters. Artifacts are removed using neighborhood operation. A comparison of these point processing and filters is presented in this paper.

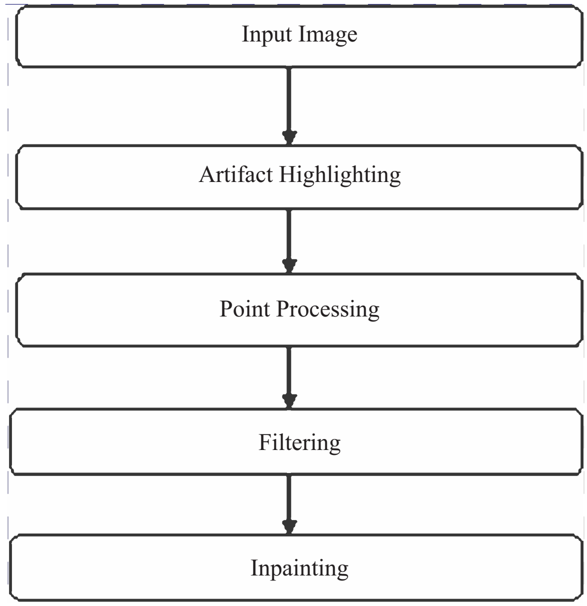


Fig. 3. Flow chart for artifact removal

A. *Input Image*

Accurate data set plays a key role in performance. Our proposed method is tested on European data set of hundred lesion skin cancer images. These images are acquired from dermoscope. These are approved by three dermatologists that its ground truth is available. Each image is RGB image with a bit depth of 24. It dimensions are 972x615 pixels having horizontal and vertical resolution of 116 dpi. After image is acquired from dermatoscope, it is saved in digital format. These are taken as input test images for further processing. Matlab R2016b 64 bit version is used as software for application development. It is handy to use and provides high quality graphical output. Its environment is easy to use. It is vastly used in digital image processing as it allows image and video as input from various digital imaging devices. Fig. 1 shows some lesion images of European data set.

B. *Artifatct highlighting*

Artifacts include gel, sweat drops, hair and skin lines. Hair is the main hurdle in post-processing of image so it is necessary to get rid of them. Gabor wavelet works for spatial domain as well as frequency domain. Gabor wavelets are used to identify corners, edges and blobs. It is used in feature extraction as it reduces the product of standard deviation to minimum in both domains. The equation for Gabor filter is:

$$g(x,y) = exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}+\varphi\right) \quad (5)$$

$$x' = x\cos\theta + y\sin\theta \quad (6)$$

$$y' = -x\sin\theta + y\cos\theta \quad (7)$$

Where sigma is standard deviation of Gaussian function, theta is the orientation; lambda is the wavelength of the sinusoidal factor, gamma is the spatial aspect ratio and psi is the phase offset. According to our proposed methodology, sigma is set to 2.8, theta is taken as 360, wavelength is set to 5, gamma is set to 0.3 and phase offset is taken as 0.

By applying Gabor filter to dermoscopic image, hair and other artifacts are highlighted.

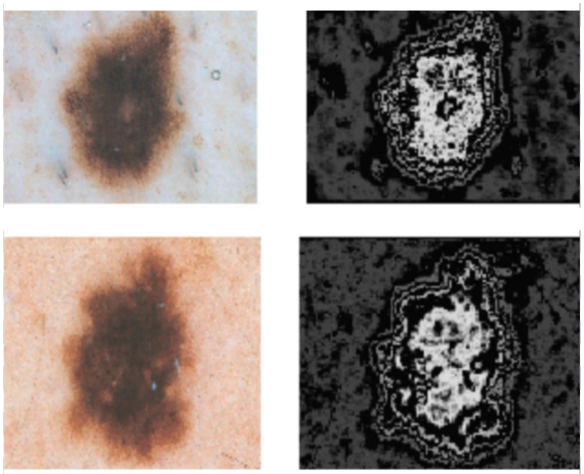


Fig. 4. Artifact highlighted using Gabor filter

C. Point Processing

We have compared six point processing techniques that are used for image enhancement. Negative of image highlights grey or white components of image. Log transformation dark pixels of image are enhanced while high intensity components are compressed relatively. It is represented by equation:

$$s = c \log(r+1) \tag{8}$$

Where's' is pixel value of output image. 'r' is pixel value of input image while 'c' is a constant.

Log of zero is infinity so '1' is added to each input pixel so that minimum value should not decrease below one.

Power law transformation is used to make image bright. Image brightness highly depends upon gamma. When gamma is greater than 1 image becomes dark and it becomes bright if gamma is less than 1. C and r are positive constants. The equation for power law transformation is

$$s = cr^{\gamma} \tag{9}$$

Contrast enhancement technique is used to adjust poor contrast. It stretches the range of intensity values. Equation for contrast enhancement is

$$P_{out} = (P_{in} - c)\left(\frac{b-a}{d-c}\right) + a \tag{10}$$

In above equation, a represents maximum pixel value in an image and b represents minimum pixel value in an image. Image has to be normalized over maximum and minimum pixel values. Here c and d represents normalized maximum and minimum pixel value.

Intensity level slicing is used to enhance features of image. It is used to brighten range of gray level values and it preserves background. Histogram equalization changes the intensity values of input image to improve contrast. Suppose 'm' is the input image whose intensity of pixels 'a' varies from 0 to L-1 where 'L' frequently refers to 256 and 'x' is normalized histogram.

$$x_a = \frac{\text{number of pixels with intensity a}}{\text{total number of pixels}} \tag{11}$$

$$a = 0, 1 \ldots L-1 \tag{12}$$

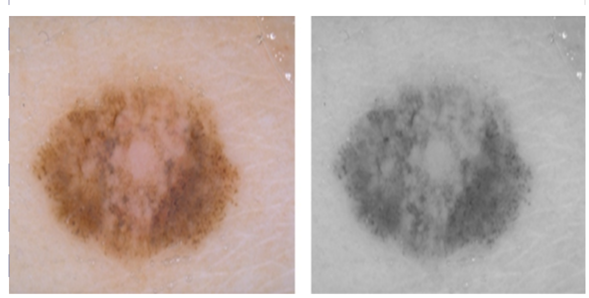
k is histogram equalized image and can be calculated as

$$k_{\{i,j\}=floor((L-1)} \sum_{a=0}^{m_{i,j}} x_a \tag{13}$$

Histogram equalization is not effective on some images as it makes those images even worse.

D. Filtering

Filtering is a way to remove noise and get enhanced image. There are two ways to filter a digital image one is spatial domain and other is transformation domain. We are providing a critical comparison of both domains. Low pass as well as high pass filters are used.



(a) (b)

Fig. 5. (a) Original image (b)Filtered image

1) Median Filter

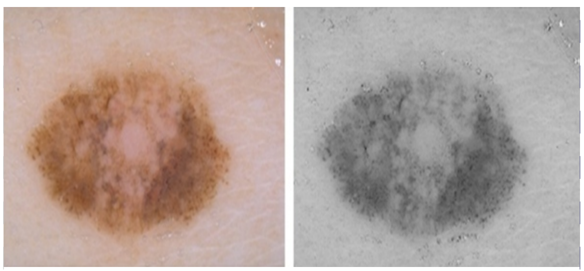
Median filter is a smoothing and edge preserving filter. It works on every pixel of whole image. It replaces pixel value with the median of neighborhood pixels. It takes a pixel and calculate median of its neighborhood pixels and replaces the selected pixel with that median value. Number of neighborhood pixels is determined by window size. It doesn't create any new value that's why it preserves edges. Figure 5 represents original image and image after applying median filter.

2) Second Derivatives - The Laplacian Filter

Image enhancement is achieved using second derivative filters. These filters respond more accurately to small details like thin lines and isolated points. It responds strongly to a line as compared to a step and is comparatively stronger for a point. The Laplacian is used as a second derivative filter. Laplacian is an isotropic filter it means it gives the same result when rotating the image and applying filter or first applying the filter and rotating the image. Its response is independent of the direction of the discontinuities in the image to which the filter is applied [30]. The Laplacian *L(x,y)* of an image with pixel intensity values *I(x,y)* is given by:

$$L(x,y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad (14)$$

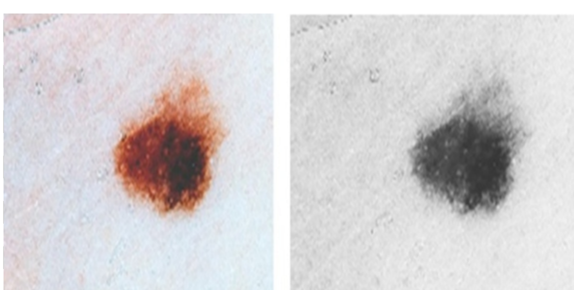
Fig. 6 represents original image and image after second derivative Laplacian filter.



(a) (b)
Fig. 6. (a)Original image (b) Laplacian image

3) Ideal low pass filter

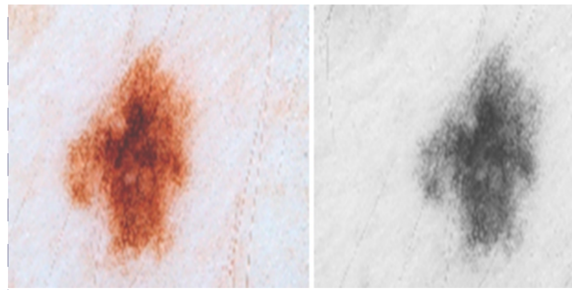
It works on a cut-off frequency. All above frequencies are assigned zero value. Low frequencies are left behind and high frequencies are filtered out. The resultant image is transformed in spatial domain to smooth the edges and remove all high frequency components. In other words, ideal low pass filter retains low frequencies from zero to a cut-off frequency and remove high frequencies. Fig. 7 represents original image and image after ideal low pass filter.



(a) (b)
Fig. 7.(a)Original image (b)Ideal low pass filtered image

4) Butterworth Lowpass Filter

The frequency response of butterworth low pass filter is nearly flat. The frequencies that are allowed to pass are called pass band and those which are stopped by filter is called stop band. In Butterworth lowpass filter, there is no sharp discontinuity in the frequencies. Butterworth lowpass filter does not show ringing and negative values.

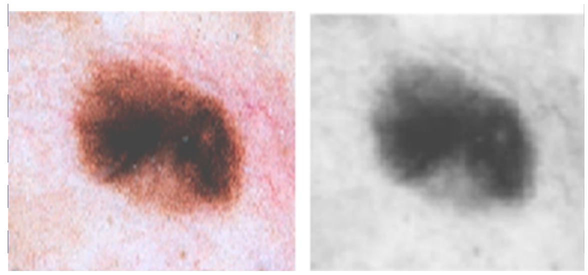


(a) (b)
Fig. 8. a) Original Image b) Image after butterworth low pass filter

5) Gaussian lowpass filter

Gaussian filter is a smoothing filter. It results in blurred image and filter out noise. The transfer function of a Gaussian low pass filter is defined as [xxxi]

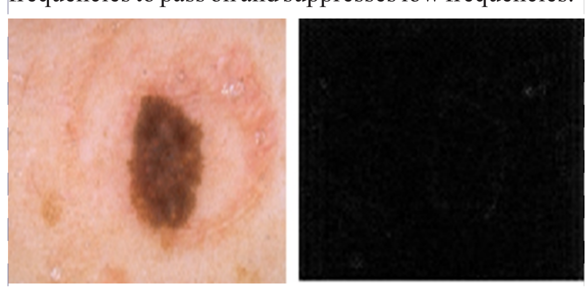
$$H(u,v) = e^{-D^2(u,v)/2D_0^2} \quad (15)$$



(a) (b)
Fig. 9. a) Original image b) Gaussian low pass filtered image

6) Ideal Highpass Filter

Highpass filters are sharpening filters. It is opposite of ideal low pass filter as it allows high frequencies to pass on and suppresses low frequencies.



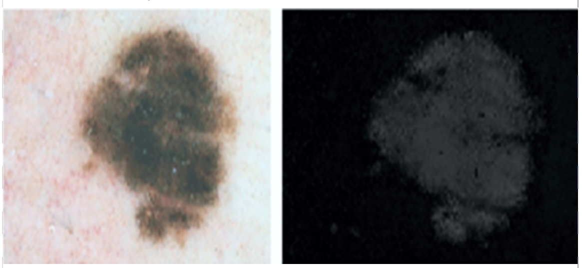
(a) (b)
Fig. 10. a) Original image b) Ideal high pass filtered image

7) Butterworth Highpass Filter

It is opposite to butterworth lowpass filter as it allows high frequencies to pass on and attenuates low frequencies. Sharpness of image is controlled by the order. It results in smooth image even for small cut off frequencies the boundaries are intact [xx]. It can be defined as:

$$H(u,v) = \frac{1}{1+[D_\circ/D(u,v)]^{2n}} \quad (16)$$

Where D_o is cut off frequency and n is is the order.

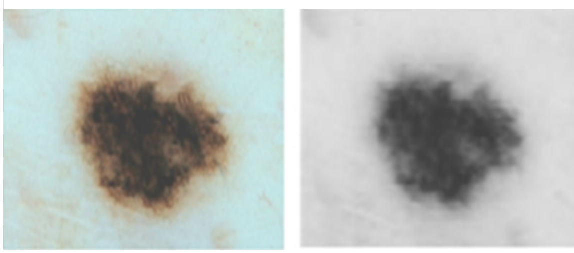


(a) (b)

Fig. 11. a) Original image b) Butterworth high pass filtered image

8) Gaussian Highpass Filter

It is a sharpening filter. It suppresses frequency components that are close to filter. Gaussian filters do not result in ringing effects.

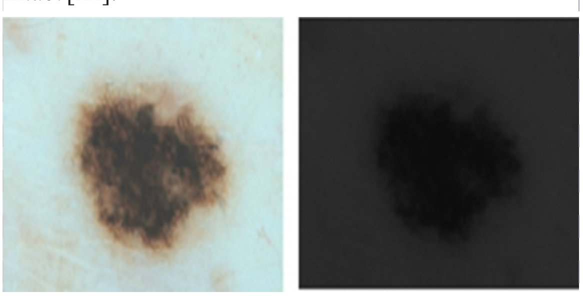


(a) (b)

Fig. 12. a) Original image b) Gaussian high pass filtered image

9) High Boost Filter

It is also a sharpening filter that amplifies high frequency components of an image. It enhances edges and removes blurriness. It is different from other high pass filters in a sense that they remove low frequency components and it keeps low frequency components intact [xx].



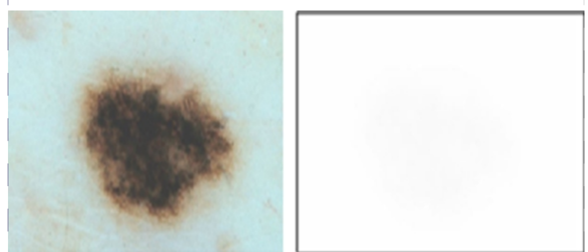
(a) (b)

Fig. 13. a) Original image b) High boost filtered image

10) Homomorphic Filter

It is used to get rid of multiplicative noise. It is used to fix non-uniform brightness in image.

Homo-morphic filtering is handy technique in image enhancement. It normalizes the brightness in image by increasing the contrast. A digital image is product of illumination and reluctance. The illumination components show gradual change while reluctance components show rapid change while performing homo-morphic filters. Therefore, by applying frequency domain filters, variation in the image intensity can be reduced while highlighting the details.



(a) (b)

Fig. 14. a) Original image b) Homomorphic filtered image

E. Inpainting

Binary mask of artifacts are obtained using OTSU's thresholding. Hair in-painting is a process to replace all the hair pixels with skin tone pixels. This will result in smooth hair free image. Neighborhood based region filling method is used for hair in-painting as discussed in [xii]. It works towards the centre of image in a radial manner. It takes average of background and estimated neighborhood. It runs in a loop to fill the entire region evenly using morphological operations [xii].

IV. Results and Discussion

Here is the numbering is assigned to the technique according to the positive result it gives to us. The top ranking is for the best and going down to the better, good, normal and worst results of image enhancement technique.

1. The best for segmentation
2. Better for segmentation
3. Good for segmentation
4. normal for segmentation
5. worst for segmentation

Filters	Negat-ive	Log trans-form	Power law tra,	Contrast stretch-ing	Intensity level slicing	histogram equaliz-ation
Low pass	2	2	1	3	5	2
Median	2	2	1	3	5	2
High pass	5	5	5	4	5	5
Seccond deriva-tive	2	1	1	2	5	1

Ideal low pass	2	3	1	3	5	2
Butter worth low pass	2	2	1	3	5	2
Gaussian low pass	2	3	1	2	5	2
Ideal high pass	4	4	4	4	5	4
Butter worth high pass	1	1	4	2	5	1
High boost	3	3	3	3	5	2
Homo morphic	5	5	5	5	5	1

V. Conclusion

We had made a comparison of morphological techniques, wavelet based techniques and digital filters for dermoscopic image enhancement.

Adaptive histogram equalization is used to enhance the contrast of an image. In this method separate histogram is computed for every section of image and then lightness is distributed over whole image. In this way, it enhances edges and local contrast and enhancement can be controlled so that noise amplification is avoided.

Power law transform makes image bright and clear as compared to other enhancement techniques. Hence it is come to know that Power Law Transformation gives the best enhanced images for low pass filter, second derivative filter, median filter, ideal low pass filter, butter worth low pass filter and Gaussian low pass filter. Moreover Gaussian filters outperformed other filters for dermoscopic image filtering.

VI. Future Work

We are providing the best enhancement technique for cancer images dataset. This will be helpful for the people who want to segment images. It is very time saving for that person because he need not to start from zero and instead our work will give it surety that this image enhancement technique is best for images mentioning the positive effects for that technique.

References

[i] K. Eltayef, Y. Li & X. Liu (2017, February). Detection of melanoma skin cancer in Dermoscopy images. *In Journal of Physics: Conference Series* (Vol. 787, No. 1, p. 012034).

[ii] Wise Geek what are melanocytes? [Online]. Available:http://www.wisegeek.com/what-are-melanocytes.htm#didyouknowout.Accessed [2017]

[iii] F. Nachbar, W. Stolz, T. Merkle, A. B. Cognetta, T. Vogt, Landthaler, G. M& Plewig (1994). The ABCD rule of dermatoscopy: high prospective value in the diagnosis of doubtful melanocytic skin lesions. *Journal of the American Academy of Dermatology*, *30*(4), 551-559.

[iv] G. Argenziano, G. Fabbrocini, P. Carli, V. De Giorgi, E. Sammarco,& M. Delfino(1998). Epiluminescence microscopy for the diagnosis of doubtful melanocytic skin lesions: comparison of the ABCD rule of dermatoscope and a new 7-point checklist based on pattern analysis. *Archives of dermatology,* 134(12), 1563-1570

[v] H. P. Soyer, G. Argenziano, I. Zalaudek, R. Corona, F. Sera, R.Talamini & P. Farro(2004). Three-point checklist of Dermoscopy. Der matology , 208(1), 27-31.

[vi] S. W. Menzies, C. Ingvar, K. A. Crotty & W. H. McCarthy (1996). Frequency and morphologic characteristics of invasive melanomas lacking specific surface microscopic features. *Archives of Dermatology,* 132(10), 1178-1182.

[vii] J. S. Henning, S. W. Dusza, S. Q. Wang, A. A. Marghoob, H. S. Rabinovitz, D. Polsky & A. W. Kopf (2007). The CASH (color, architecture, symmetry, and homogeneity) algorithm for Dermoscopy. *Journal of the American Academy of Dermatology, 56*(1), 45-52.

[viii] Equation for Grey level transforms [Online]. Available:http://www.tutorialspoint.com/dip/images/graylevel1.jpg Accessed [2017]

[ix] Contrast Stretching [Online].Available: http://www.homepages.inf.ed.ac.uk/rbf/HIPR2/stretch.html. Accessed [2017]

[x] Frequency Domain Image Enhancement Technique [Online].Available:http://www.slideshare.net/diwakerpant/frequency-domain-image-enhancement-techniques. Accessed [2017]

[xi] J. Uzma, S. Khalid, and M. U. Akram (2016), "Dermoscopic image enhancement and hair artifact removal using Gabor wavelet." Innovative Computing Technology (INTECH), 2016 Sixth International Conference on. IEEE. 279-284

[xii] J. Uzma, S. Khalid, and M. U. Akram, S. Abbas and K. Saleem, (2016). Computer based melanocytic and nevus image enhancement and segmentation, 2016 BioMed Research International.

[xiii] R. B. Oliveira, E. Ma. Z. Mercedes Filho, J. P. Papa, A. S. Pereira & J. M. R. Tavares (2016). Computational methods for the image segmentation of pigmented skin lesions: a review. *Computer methods and programs in biomedicine,* 131, 127-141.

[xiv] M. E. Celebi, Q. Wen, H. Iyatomi, K. Shimizu, H. Zhou & G. Schaefer (2015). A state-of-the-art survey on lesion border detection in Dermoscopy images. *Dermoscopy Image Analysis*, 97-129.

[xv] J. Jaworek Korjakowska, and R. Tadeusiewicz. "Determination of border irregularity in dermoscopic color images of pigmented skin lesions." *Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE*. IEEE, 2014.

[xvi] A. Sultana, I. Dumitrache, M. Vocurek& M. Ciuc (2014, May). Removal of artifacts from dermatoscopic images. *In Communications (COMM), 2014 10th International Conference on* (pp. 1-4). IEEE.

[xvii] M. T. B. Toossi, H. Pourreza, H. Zare, M. Sigari, P. Layegh & A. Azimi(2013). An effective hair removal algorithm for dermoscopy images. *Skin Research and Technology*, 19(3), 230-235.

[xviii] J. Korjakowska, Joanna, and R. Tadeusiewicz. (2013), "Hair removal from dermoscopic color images." Bio-Algorithms and Med-Systems 9.2: 53-58.

[xix] Dogra, Ayush, and P. Bhalla. (2014), "Image sharpening by gaussian and butterworth high pass filter." Biomed Pharmacol, 7(7), 07-13

[xx] High Boot Filter [Online]. Available: http://www.fourier.eng.hmc.edu/e161/lectures/gradient/node2.html. Accessed [2016]

[xxi] N. Smaoui and S. Bessassi, (2013), "A developed system for melanoma diagnosis," International Journal of Computer Vision and Signal Processing, 3(1), 10-17.

[xxii] Q. Abbas, I. F. Garcia, M. Emre Celebi, & W. Ahmad, (2013). A feature-preserving hair removal algorithm for dermoscopy images. *Skin Research and Technology,* 19(1), e27-e36.

[xxiii] Singh, Gursharn, and Mittal Anand. "Various Image Enhancement Techniques-A Critical Review." (2014).

[xxiv] P. Agrawal, V. Chourasia, R. Kapoor & S. Agrawal, (2014). A Comprehensive Study of the Image Enhancement Techniques. *International Journal of Advance Foundation and Research in Computer (IJAFRC)*, 1, 85-89.

[xxv] S. S. Bedi, and Khandelwal Rati. "Various image enhancement techniques-a critical review." *International Journal of Advanced Research in Computer and Communication Engineering* 2.3 (2013).

[xxvi] Patel, R. Tilak, and D. Avinash, (2014). "Image Enhancement Using Frequency and Spatial Technique Using Alpha Rooting with Bi-Histogram Equalization." International Journal of Advanced Research in Computer Science 5(5).

[xxvii]Nguchu, B. Alexander. (2016), "Critical Analysis of Image Enhancement Techniques. International Journal of Electrical and Electronics Research, 4(4), (23-33).

[xxviii]Daniel, Ebenezer, and J. Anitha. (2016), "Optimum wavelet based masking for the contrast enhancement of medical images using enhanced cuckoo search algorithm." Computers in biology and medicine 7(1), 149-155.

[xxix] Laplacian Low Pass Filter [Online]. Available: http://www.homepages.inf.ed.ac.uk/rbf/HIPR2/log.html. Accessed [2017]

[xxx] Gaussian Low Pass Filter [Online] Available: http://www.research.ijcaonline.org/volume109/number14/pxc3900999.pdf. Accessed [2017]

[xxxi] S. Khalid, B. Sabir, S. Jabbar and N. Chilamkurti, (2017), "Precise shape matching of large shape datasets using Hybrid Approach", Journal of Parallel and Distributed Computing, Elsevier 110, 16-30.

[xxxii]S. Khalid, S. Sajjad, S. Jabbar and H. Chang, (2017), "Accurate and efficient shape matching approach using vocabularies of multi- feature space representations", Journal of Real- Time Image Processing, 13(3), 449-465.