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MEDICAL IMAGE ENHANCEMENT BY FILTERS AND EDGE APPROACHES: REVIEW

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ABSTRACT

Medical image enhancement improves the quality and facilitates diagnosis This thesis investigates seven methods of medical image enhancement by exploiting useful edge information Since edges have higher perceptual importance the edge information based enhancement process is interesting However determination of edge information is not an easy job In enhancement methods have limitations such as i Less effective for medical images containing wide range of anisotropic and directional features. Enhancement techniques have been widely used in the field of medical image processing, where the subjective quality of images is important for human interpretation and diagnosis. Various enhancement algorithms have developed to apply medical imaging problems. Since edges are higher perceptual importance, the primary objective of this thesis work is to develop and analyze edge information based methods to enhance the medical images.

Keywords: Medical image, Enhancement, edge method, edge enhancement

INTRODUCTION

Image enhancement is a process so that the enhanced image is more suitable than the original image for a specific application. Medical image enhancement is necessary (Yang 2010 and Li Yang 2010) if the original is not a good candidate for subsequent processing. In many cases, enhancement improves the quality of the image and facilitates diagnosis (Sundaram 2011, Li Yang 2010, Tay 2010 and Peng 2007).

Image enhancement is the process to improve an image, so that it looks subjectively better (Yu 2012). However, subjective quality of an image depends largely on the sharpness and explicitness of edges. The lack of sharpness is due to wrong focus of imaging equipment, motion blur, etc. Sharpness directly related to human sight properties and visibility. Emphasizing the edges there by enhancing sharpness provide better visibility. Among the various techniques, edge information based enhancement methods

(Karen 2011, Bhutada 2011, Zhiguo Gui 2011, Eltoukhy 2010, Phan 2009, Peng 2007 and Akram 2009) are successful due to their promising results. The similarity and dissimilarity between the edge information based enhancement methods are tabulated in Table 1.1

Table 1.1 Comparison of Edge Information based Enhancement Methods

uthor Year	Technique used to obtain edge information	nhancement/ Application	Noise control	Multiscale and multidirection
Karen, 2011	Nonlinear Masking	Mammogram	No	No

Eltoukhy 2010	Detail coefficients of Curvelet transform	Mammogram	No	Yes
Phan 2009	Directional Filter Bank	Cardiac Vessels	Yes	Yes
Peng 2007	Detail coefficients of Contourlet Transform	Retinal	No	Yes
Akram 2009	Detail coefficients of Wavelet Transform	Blood Vessels	No	Yes
Bhutada 2011	Wavelet and Curvelet Transforms	Natural Images	Yes	Yes
Zhiguo 2011	Fuzzy based method	Natural Images	Yes	No
Methods in this thesis	2D filters, Wavelet, Contourlet, and directionlet transforms	Mammogram, CT, Retinal, Chest Xray, ultrasound	Yes	Yes

These methods have their own advantages and limitations along with applications. Karen (2011) method much influenced by noise due to local window and there is no noise control in Eltoukhy (2010), Peng (2007) and Akram (2009). The methods (Bhutada 2011, Phan 2009) treat the noise separately where as Zhiguo (2011) did not include fuzzy edges in the enhancement process. In order to overcome these limitations, algorithms are developed to deal the noise in multiple scales (scale multiplication) and incorporate the same in the enhancement process (contrast enhancement) itself. The drawbacks and techniques to overcome the drawback of existing methods summarized in Table 1.2. This thesis analyzes one or more techniques to overcome these limitations.

Table 1.2 Drawbacks in Enhancement Process

Sl. No	Drawbacks	Developed Techniques/approaches to deal
1.	Low contrast	(i) Improve the contrast by increase the background to foreground ratio Applying two level contrast enhancement process
2.	Enhancement in the uneven illumination	Illumination parameter is regularized
3.	Less noise control (noise sensitivity)	Scale multiplication in multiscale representation to improve the noise control
4.	Using of isotropic edge feature	Using of anisotropic edge features given by anisotropic transform like Contourlet, directionlet
5.	Limited number of directions	Using of Multidirectional transform

More over the methods in this thesis are applied to two or more image types. However, determination of reliable edge information is not an easy task due to three following important reasons (i) Noise sensitivity (ii) Illumination dependent (iii) Limited number of directions. While detecting edges, noise also pronounces. Therefore, successful determination of edge information in an image and uses it for efficient enhancement process lead to better-quality images. Conventional edge determination algorithms such as Roberts, Prewitt, Sobel and Fri-Chen, are very sensitive to fine structure of edges and face difficulty in distinguishing the weak edge from noise. To combat with noise, pre-smoothing algorithm devised such as Marr and Hildreth (1980) and they combine Gaussian smoothing while estimating gradients. They are more effective in higher noise conditions at the cost of dislocated and suppressed weak edges (Rakesh 2004 and Mitra Basu 2002). Thus, there is a need for tradeoff between the level of smoothing and the accuracy of estimated edge location. Difference of Gaussian (DoG) kernels ensure optimal tradeoff as in Canny Edge Detection (CED) (Canny 1986), but the tradeoff is sensitive to category of edge (sharp or smooth) and signals to noise ratio. Hyperbolic tangent (HBT) function also provides good tradeoff (Saravanakumar 2006) and has the advantage of better localization than DoG.

In particular, when the smoothing parameter is greater than one, the localization and detection performances of DoG are degraded, but HBT perform well. This thesis intends to use HBT function in edge determination purpose. Ideally, edge filters must obtain the filter responses at any arbitrary position and orientation. Steerable filter is a class of filters, can be tuned to detect edge features at any possible orientation (Felice 2004, Mathews 2004, Simoncelli 1996, Freeman 1991, Burt 1981). Steerable filter can also used as directional filters in the second stage of the Contourlet implementation (Yue 2007, Cunha 2006 and Do 2005) to gather local geometrical feature and their orientation. In addition to these gradient edge filters, non-linear derivative scheme is also applied to detect edges. (Olivier 2010).

In images, edges are typically located along smooth curves that are key features in visual perception. In order to process the filtering on two dimensional (2D) image data, one dimension (1D) filter is operated row and column wise. Therefore, separable 1D filter has blurred regions in diagonal orientations and limited directions. To remove such effect 2D non-separable filters are used (Yuichi 2009 and Do 2005). The 2D constrained least square filter designs for better regularization (Markus 1996) and edge extraction filter (Sanjit 2001 and Lim 1990) is also found in the literature.

Multiresolution technique (MRT) (i.e.) Wavelet transform (WT) is the good choice for effective edge information detection (Mallat 1981). MRT has a collection of functions that are used to decompose signals into various frequency components at an appropriate resolution for a range of spatial scales through directional features. Their coefficients are proportional to the gradient and the modulus of this gradient vector at various scales corresponds to multi scale edges (Sylvain 2010, Mallat 2009, 1981). By incorporating the multiscale edge information, noise suppressed efficiently. A modulus maximum is computed to combine multiscale and multidirectional edges from the decomposition sub bands of wavelet transform (Mallat 2009). To detect the edge features and noise suppression scale multiplication technique is used (Paul Bao 2005).

An adaptive fusion of scale information for edge preservation also proposed (Bhutada 2011). Gabor wavelets are commonly used for extracting local features and Simplified Gabor Wavelets (SGW) established improved performance in edge features detection (Wei Jiang 2009 and Wing 2008). Some of the MRT based edge determination algorithms are also found in the literature. A general way of wavelet based edge detection method is described(Muhammad 2008). An algorithm, which combines local filtering and multiscale analysis to detect edge, ridge and curvilinear objects, was proposed (Sylvain 2010). A Shearlet approach based edge detection analyzes is given (Sheng Yi 2009). A wavelet based multi scale version of edge detection for lips extraction was successful (Guan 2008). Due to multiresolution property of these techniques provides efficient multiscale and multi directional edge information.

Local contrast enhancement attempts to increase the appearance of large-scale light-dark transitions (i.e.) Unsharp Masking (USM) increases the appearance of small-scale edges. Good local contrast gives natural look to an image. Increase the contrast of the interested structures is one of the main approaches in enhancement algorithm. Adaptive mammographic image enhancement using first derivative and local statistics is proposed (Kim 1997), in which the local information well utilized for enhancement process. While determining the edge information of the interested structure, the noise effect also improves. Classical USM bring out the information along with noise. USM is a common image sharpening method in which the filter has the effect of masking edges and fine detail in the image crisper. Laplacian of Gaussian (LoG) based USM is a widely used image sharpening enhancement algorithm. Image sharpening improves the contrast by adding the scaled edge information near the boundaries of objects in an image (Konstantinos 1999). Kim (2008) presented statistical based on feature noise adaptive unsharp masking for local enhancement.

Sharpening is an important process in images to increase the contrast between bright and dark regions to bring out boundary features. Sharpening enhancement should lead to a better-looking image. Sharpening enhancement interpreted as addition of missing higher frequency components in the frequency domain. It only enhances the details already present and improves the steepness of edges. Zhiguo (2011) discusses a fuzzy logic based image-sharpening algorithm. Image smoothing and sharpening based on nonlinear diffusion equation also an interested work presented (Dai Fang 2008). Though these methods improve the contrast by sharpening process, they are influenced by the noise effect (Kim 2008). Even though sharpening methods are simple and have many applications, they still have problems (Karen 2011). Undesirable distortions in uniform areas and consequently, some artifacts appear in the output image due to the usage of linear high pass filter. Approaches are available to control the noise effect by smoothing operation at the cost of dislocation and loss of edge information. Therefore, increase in contrast near the interested structures and without (or) reduced noise effect is problem. Due to multiscale characteristics MRT based enhancement algorithms overcome this problem.

Although there are many wavelet based enhancement algorithms presented, some of them are important. Fu (2000) proposed wavelet-based histogram equalization enhancement of gastric sonogram images. Sakellaropoulos (2002) proposed an adaptive wavelet-based enhancement for mammogram images. An integrated wavelet for enhancement of microcalcifications in digital mammography was also successful (Heinlein 2003). Yong (2006) proposed a nonlinear multiscale wavelet diffusion for speckle suppression and edge enhancement in ultrasound Images. Microcalcification detection algorithm using adaptive contrast enhancement on wavelet transform and neural networks discussed (Kang 2006). Scharcanski (2006) described a denoising and enhancing digital mammographic images for visual screening algorithm. Algorithm to segment retinal vessels using the 2-D Morlet wavelet and neural network have explained in Ghaderi (2007). Subramanyam (2008) used a stochastic resonance wavelet transform based algorithm to enhance the ultrasound images. Mammographic images enhancement and denoising for breast cancer

detection using dyadic wavelet processing is also dealt (Mencattini 2008). Wavelet based blood vessel enhancement and segmentation that provides fruitful results presented in Akram (2009). In addition, a medical image enhancement algorithm based on wavelet transform described (Yang 2010). Edge preserved image enhancement using adaptive fusion of images denoised by wavelet is proposed (Bhutada 2011). Isotropic and limited directivity are the drawbacks of common separable WT.

In images, edges are the key features in visual perception and they are typically located along smooth curves (i.e. contours) owing to smooth boundaries of physical objects (Abràmoff 2010, Yuichi 2009 and Peng 2007). Therefore, anisotropic transforms such as Curvelet, Contourlet with more directions are developed to use in medical imaging. Retinal images are analyzed using curvelet Transform and multi structure elements morphology by reconstruction (Mohammad 2011). Edge preserved image enhancement using adaptive fusion of images denoised by wavelet and curvelet transform is presented (Bhutada 2011). Breast cancer diagnosis in digital mammogram using multiscale curvelet transform is proposed (Eltoukhy 2010). Curvelet transform based retinal blood vessels extracted by Esmaeili (2009) and (2012). Though curvelet transforms are popular, their computation effort is high. An efficient pan-sharpening method via a combined adaptive PCA approach and Contourlets is proposed (Shah 2008). Peng (2007) presented a general enhancement of retinal image by the contourlet transform. Directional filter bank are used to enhance the retinal vessel (Phan 2009). Though Contourlet based approach improves the contrast of retinal image, it has artifacts due to shift-variance. Shift invariant version of Contourlet (i.e.) non- sub sampled Contourlet (NSCT) is also employed in enhancement process (Zhen 2011 and Yuxin 2009).

In general, enhancement methods have limitations such as (i) Less effective for medical images containing wide range of anisotropic features and directions (ii) Noise influence. In order to deal these limitations, there is a need to develop enhancement algorithms based on techniques that are able to obtain the effective edge information along with the suppressed noise effect. Therefore, efficient edge structures, which aid the methods, lead to success of the enhancement algorithm.

Computed Tomography (CT) image enhancement: CT is an important radiological diagnosis method which allows better visualization of different soft tissue regions. Even though, CT provide every part of the human body, CT are subject to a variety of imperfections due to quantum noise, scattering by the patient, beam hardening and nonlinear partial volume effects. In addition, distribution of gray levels reduces the overall contrast and the texture differences between individual organs have serious visualization problem. In order to achieve good quality images and radiologists to complete proper diagnoses, image-processing algorithms are used.

Resolving the High Frequency (HF) components in low contrast structures is one of the most common tasks performed by interpreting CT (Ching 2008 and Ching 2009). However, while detecting the HF components, the noise also enhanced. Pre smoothing is a well-known process that controls the noise effect, but smoothing the noise without blurring is challenging work. In addition, enhancing the HF component without amplifying noise is still an active research area (Li Yang 2010, Shcherbinin 2010 and Konstantinos 1999). This thesis examines a two-dimensional least square hyperbolic secant square filter, which is used to sharp the CT images.

Microscopic blood smear image enhancement: Analysis of microscopic medical images is an important interdisciplinary problem involving both physician and computer scientist. Many digital microscopy images suffer from poor illumination, due to factors related to the light path between the camera and the microscope (Qiang 2008). In order to compensate uneven illumination and enhance the edges of image for further processing there is a need for enhancement algorithms. This will aid the automatic process of screening the images, in particular detection and recognition. It helps diagnosing and managing a large number of diseases either automatically/semi automatically or manually. In order to extract the edge information from non-uniform weak illumination images, different algorithms were proposed (Arandiga 2010, Wanpeng 2008, Arandiga 2008, Saravanakumar 2006 and Desolneux 2001). Blood is an unusual connective tissue because it is normally in liquid form. One of the important active areas of research is the counting of blood cells, recognition of blood cells etc. There are large numbers of literatures dedicated to differential blood counts, blood particles segmentation, blood classification and other related medical issue found in some sample works from (Habibzadeh 2011 and Wei Xiong 2010). The ability to resolve fine picture detail is of paramount importance in medical imaging systems for viewing small tissue, bone structure and anatomy in chest X-ray images is still research issue (Ming Zeng 2012). This thesis investigates a method to enhance the edge of uneven illuminated blood smear image and low contrast chest X ray image using wavelet based edge similarity. The developed method measures the similarity of homogeneous and non-homogeneous regions using regularization parameter and wavelets to discriminate the edges in the uneven illuminated region. The weight of the regularized parameters is estimated by minimum mean square method.

Mammogram image enhancement: Breast cancer has become a significant health problem and early detection is the primary solution for improving breast cancer prognosis. Screening is done through mammogram, ultrasound and magnetic resonance imaging. Although mammogram is an effective method for detecting breast cancer, interpretation of such mammograms requires skill and experience by a trained radiologist. Thus, computer aided analysis can act as a second reader before the final decision.

Image processing algorithms play an important role mammogram analysis, especially in enhancement the abnormal area of mammogram. Mammogram image enhancement improves the appearance of images, to eliminate noise or error, or to accentuate certain features in an image. In screen film mammography, film serves as the medium for both image acquisition and display. Screen film mammography has limited detection capability for low contrast lesions in dense breasts. Among the various mammographic suspicious regions, two of them very important (i) Cluster of micro calcifications (ii) Spiculated masses. Microcalcifications are tiny calcium specks, most of the time, they are not a sign of cancer, but they can be cancerous. A spiculated mass is a cluster of barbed tissue that is one of the primary indicators of cancer. Rather than a smooth lump, a spiculated mass has spicules or thin, elongated pieces of tissue sticking out from its perimeter.

Many research works have presented on mammograms for its contrast enhancement and for identification of image features like cluster of microcalcification and masses associated with breast cancer (Mini 2011, Sundarm 2011, Dhawan 1986 and Gordon 1984). Kim (1997) proposed a method for mammographic image enhancement using first derivative and local statistics. The Contrast Limited Adaptive Histogram Equalization (CLAHE) introduced by Zuiderveld (1994) has given very good results in the case of image contrast enhancement, but it is not suitable for mammogram images containing fine details. Moreover, a histogram modified Local contrast enhancement (Sundaram 2011) and nonlinear unsharp masking method (Karen 2011) are proposed recently. In addition to common enhancement algorithms, wavelet based enhancement algorithms are also found in literature (Mencattini 2008, Papadopoulos 2008, Sampat 2008,
Scharcanski 2006, Heinlein 2003, Sakellaropoulos 2002 and Rangayyan 1997). Though image processing in wavelet domain is popular, isotropy characteristics and limited directions are main drawbacks. Therefore,

anisotropic transforms as if curvelets is used (Eltoukhy 2010). The significances of anisotropic DT and its applications are discussed in (Vladan Velisavljevic 2006, 2009). Although, varieties of contrast enhancement algorithms are present in the literature, dealing with images having fine details such as mammogram is still a research issue. In this thesis investigates two different algorithms, which efficiently enhance the mammogram using anisotropic features by NSCT and directionlet transform. In the first method, NSCT uses a 2D hyperbolic tangent edge directional filter as the directional filter bank to collect the efficient edge information whereas in the second method, directionlet transform is used to do the same. In both algorithms, the directional and scaled edge information that obtained from NSCT and DT decomposition are combined to enhance the mammogram. The stepwise procedure as follows

Step 1: Decompose the input image into subbands (scales and directions) Step 2: The inter scale subbands coefficients are multiplied.
Step3: Incorporate the scaled information and directional information. Step 4: Use them in the enhancement process.

Retinal image enhancement: The retina is the unique region of the human body where the vascular conditions are observed directly. Optic fundus photography technique has become a common procedure to diagnose vascular and nonvascular pathology and duly indicate many eye diseases. The assessment of the characteristics of the vessels plays an important role in a variety of medical diagnoses and treatment. The main structures of retinal image are optic disc (OD) and vascular network. Automatic analysis techniques instead of manual observation/measurements have been widely used. However, it is difficult to extract the vessels automatically because of its low contrast. One of the difficulties in image capture of the ocular fundus is image quality, which is affected by factors such as medial opacities, defocus, or presence of artifact.

There is a wide range of vessels widths in retinal images, from less than one pixel to more than ten pixels. The small vessels, which are of less than two pixels widths, are generally low contrast. Enhancement of vessel's contrast before extraction greatly improves the performance of vessel extraction algorithm. Retinal images play an important role in diagnosing many eye diseases. However, images are often noisy, uneven illumination and low contrasted. Techniques improving contrast and sharpness and reducing noise are therefore required to aid the human interpretation or automatic analysis of the retinal images. Joshi (2008), Peng (2007), Grisan (2006), Foracchia (2005) and Lin (2003) signify retinal image enhancement and its applications. Histogram equalization has been shown to be inappropriate for retinal images (Peng 2007). Unsharp masking-based enhancement is partly effective but is not capable of handling uneven illumination (Joshi 2008). A local normalisation of each pixel to zero mean and unit variance aims to compensate lighting variation and enhancing local contrast but also introduces artifacts due to amplification of noise (Peng 2007). This thesis examines an enhancement algorithm uses locally operated nonlinear function on high pass subbands of NSCT, which is able to control the noise effect by scale multiplication.

Analyzing the retinal images plays important role in detection of some diseases in early stages. Retinal blood vessels act as the detecting tool for many diseases in early or later stage, in particular the states of retinal blood vessels inside the OD is important, but, extracting blood vessels in OD region is not an easy task. Thus enhancing the details of the retinal vasculature is essential (Jian 2008). There are many practical algorithms to detect the OD (Hung 2012, Aliaa 2008, Foracchia 2004 and Lalonde 2001).

Tracing of OD boundary is also important step in retinal image analyzes for diagnose (Esmaeili 2012, Gopal Datt 2011, Arturo 2010, Bock 2010, Muramatsu 2009 and Nyul 2009). In order to find the vascular tree in retinal image (Carmen 2010), particularly vasculature in and around the OD region, many algorithms are in the literature (Keith 2011, Harihar 2007 and Michael 2006). A method for detecting and analyzing the optic nerve head also reported in (Muramatsu 2009). Enhancement followed by retinal feature extraction approach also proposed (Mohammad 2011).

In this contest, exact and accurate localization of the OD centre, tracking of OD boundary and enhancement of retinal vasculature found within the rim of OD are important in screening many retinal diseases. This new work entails a unique OD localization strategy locating the centre of the OD with NSCT decomposition. The next stage of rim boundary is traced by employing the region growing techniques. The mask of the OD is obtained using NSCT based edge detection, operated with morphological dilation and erosion. The vessels within the OD are enhanced by two new methods. First method uses two levels of varied parameters of adaptive histogram equalization (AHE) and second method uses CT based edge along with morphological operators. This is the first to take the initiative step of combining all the three jobs of OD centre localization, boundary tracking and the retinal vasculature enhancement. The significance of this new approach is fully automatic and able to process three important retinal image algorithms in a single chain of image processing algorithms. The performance measures are calculated and they are found to be better and fruitful.

Ultrasound image enhancement: The medical use of ultrasound has expanded enormously, due to the following facts as (i) safe, (ii) real-time visualization of moving structures, (iii) suitable for many clinical applications and (iv) inexpensive. However, ultrasound is also subject to a number of inherent artifacts that compromise image quality and impair diagnostic utility. The most important degradation, which arises from coherent wave interference, gives a granular appearance to homogeneous region of tissue. Speckle noise reduces image contrast and makes it difficult to identify abnormal tissues that indicate disease. Another source of noise is 'clutter', which arises from beam forming artifacts, reverberations and other acoustic phenomena. Clutter consists of spurious echoes seen within structures, confused with real objects. Another potential source of thermal is noise in deep-lying regions. All these sources of noise affect the ability of the radiologist to recognize essential tissue anomalies. Therefore, noise reduction improves the visibility and progress towards effective diagnosis. This thesis aims to analyze an enhancement algorithm for visual improvement of ultrasound images. An ultrasound (US) is a noninvasive medical test that helps physicians to diagnose and treat medical conditions. Although there are many advantages of using ultrasound as an imaging modality, they are hampered by contrast effect (Tay 2010 and Paul 1997) either in error or as an effect of image acquisition. Due to small contrast differences between foreground and background, human vision strains to achieve better focus and weak identification of sharp edges are felt as lack of details. Sharpening is an important image enhancement method to increase the contrast between bright and dark regions to bring out boundary features (Zhiguo 2011). In particular, more research work on US image sharpening has published (Subramanyam 2008, Tsubai 2007, Jun 2006, Yong 2006 and Tsubai 2004) and still a research focus (Al-Kindi 2011 and Tay 2010).

In this research methods are considered to enhance (i) low contrast retinal images (ii) furry regions of ultrasound images (iii) low contrast mammogram image (iv) edges in blood smear image (v) edges in chest X ray

(vi) CT for good quality visual perception. This thesis investigates seven new algorithms to enhance these medical images by exploiting useful edge

information. Wavelet transforms, Non-sub sampled contourlet transform (NSCT), directionlets (DT) and regularized two-dimensional (2D) high pass (HP) filters obtain this edge information. In particular, NSCT and directionlet transform provides anisotropic edge features in their sub bands. From the decomposed high pass sub bands, the multiscale and multidirectional edge features are combined in a suitable method. In order to prove the ability of these algorithms, this thesis also examines the applications such as vessel extraction and vasculature enhancement in retinal images, detection of microcalcification and enhancement of spiculated masses in mammogram images. The seven enhancement algorithms are as follows.

1. Sharpening Enhancement of CT and Retinal Images using 2D Hyperbolic Secant Square Filter
2. Blood smear image and Chest X ray image edge enhancement based on Wavelet similarity
3. Directionlet based mammogram image enhancement
4. Enhancement of mammograms by contourlet using Hyperbolic Tangent directional filter
5. Contourlet based ultrasound image enhancement
6. Contourlet based retinal image enhancement
7. Contourlet based Vasculature enhancement method for Optic Disc region and mammogram

The conceptual contributions are tabulated in Table 1.3

Table 1.3 Conceptual Contributions of Developed Methods

Sl.No	Technique / method	Conceptual Contribution
1.	2D Hyperbolic Secant Square Filter (HBSS)	Least square design of 2D HBSS Edge detection using of HBSS 2D HBSS based unsharp masking

Sl.No	Technique / method	Conceptual Contribution
2.	Wavelet based similarity measure	(i) Measuring the similarity using wavelet and detect weak edges in illumination varying conditions (ii) Illumination regularization parameter with least squarely estimated weights.
3.	Directionlet based enhancement	(i) Resolving of anisotropic features with various directions and use it for enhancement (ii) The directional anisotropic features in homogenous and non-homogenous are separated and combined by scale multiplication.
4.	Hyperbolic Tangent directional edge filter based Contourlet	(i) Design of 2D Hyperbolic Tangent based directional edge filter (ii) Use it in second stage of contourlet transform (iii) The contourlet coefficients are combined by scale multplication
5.	Contourlet followed by shearing operator for ultrasound image enhancement	Contourlet coefficients which are operated by shear matrix are combined to enhance the furry regions of ultrasound
6.	Contourlet Coefficients with nonlinear operator for retinal image enhancement	Enhance the retinal images by improving the background to foreground ratio using nonlinear differential operator.
7.	Contourlet with	Using morphological operators along with

Sl.No	Technique / method	Conceptual Contribution
	morphological operators for retinal image Optic disc enhancement	contourlet coefficients to enhance the vessels inside the optical disc

Each algorithm has independent approach/method, test images, experimental results, evaluation methods, performance comparison and application.

CONCLUSION

This effective edge features are used to enhance the medical images to overcome the limitations such as (i) Less effective for wide range of anisotropic and directional features (ii) Noise influence due to high pass characteristics. In many cases, enhancement improves the quality of the image and facilitates diagnosis. Enhancement measure (EME), Structural similarity measure (SSIM), image quality indices and Figure of merit are used as performance evaluation parameters. The tests are performed on images obtained from standard database such as DRIVE, STARE, MESSIDOR, MIAS, BramhimRAD and PHIL

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