COMPARATIVE ANALYSIS OF VARIOUS SPATIAL DOMAIN METHODS FOR IMAGE ENHANCEMENT

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Abstract : ***Image enhancement is an important step which is desirable as pre-processing step in number of applications i.e. object detection, segmentation, contrast improvement etc. Images captured i.e. SAR, Medical, natural images etc. are sometimes not clear due to noise in them, have unbalanced contrast caused by bad weather condition, low lightning, camera sensor defects etc. and need enhancement before further processing needed in segmentation, classification of images. Different types of methods have been proposed both in spatial and transform domain which are helpful in enhancement of images. Some methods which give effective results are contrast stretching, power-law or gamma correction, histogram equalization which comes in spatial domain category. In this work, a modified methods in these categories are analyzed and implemented which are effective than traditional techniques found in spatial domain. Total eight methods has been presented in which three methods are advancements in HE technique named as CLAHE, BBHE and DSIHE which preserves the contrast based on average mean and entropy value of the images. One method uses hybrid of HE and contrast-stretching first divided the input image into two halves based on mean average value. Two methods are based on gamma correction in which first method uses adaptive gamma correction along with weighting distribution. These methods can progressively increase the low intensity and avoid the significant decrement of the high intensity. Furthermore, the weighting distribution (WD) function is also applied to slightly modify the statistical histogram and lessen the generation of adverse effects. Effectiveness of the presented methods has been compared using seven different quality matrices named as MSE, PSNR, Contrast, gradient, entropy, NC and MSSIM in which four different datasets comprise of ten images each from natural scenes, medical ultrasound images, SAR and HDR are experimented. It has been found that optimal gamma correction and DSIHE methods balances the contrast than other methods in all type of images. Contrast-stretching gives effective results than the remaining methods when contrast parameter is considered. CLAHE gives effective results when gradient parameter is considered. For comparing NC values almost all methods are effective as all approaches to one but adaptive and optimal gamma correction along with contrast-stretching gives high value of NC parameter when all dataset are considered. Similarly adaptive and optimal gamma correction found effective when SAR and medical datasets are considered but for natural and HDR images optimal gamma correction and contrast-stretching found more effective than the rest.***

IndexTerms – Image Enhancement, Spatial Domain Techniques, evaluation parameters

I. INTRODUCTION

1.1 Image Enhancement

It is the process of manipulating image which is stored in digital form. The tools used in the image enhancement include many different kinds of software such as filters, image editors and other tools for changing various properties of an entire image or parts of an image.

The different devices used for Image enhancement incorporate a wide range of sorts of programming, for example, channels, image editors and different instruments for changing different properties of a whole image or parts of a image.

The absolute most essential kinds of image enhancement apparatuses basically change the difference or brilliance of a image or control the dim scale or the red-green-blue shading examples of a image. A few kinds of fundamental channels additionally permit converting a shading image to a sepia-tone image, or to high contrast image. Many sorts of image enhancement the instruments can be apply few changes all the many particularly to some specific parts of an image.

Further developed kinds of image enhancement devices likewise incorporate highlights like clearing up images that might be in poor condition, because of problematic image catch conditions, Wiener channels for genuine de-obscuring of images and other complex assets for reestablishing or maturing or different causes.

1.2 Image Enhancement Methods

Image enhancement is the improvement of digital image quality without knowing the source of degradation. Image enhancement is used to restore the images which have undergone some distortion. This distortion may be due to various reasons such as optics, some electronic issue or some environmental issues. Image enhancement can also be viewed as enhancing certain features of the image. The term image enhancement is subjective on that is enhancement for one person cannot be enhancements for other.

The aim of image enhancement is processing of an input image. The output of image enhancement is more reliable from original input image. Nowadays these techniques are applicable in many areas. Some of them are remote sensing technology, medical imaging, communication, biotech, environment science, face detection, computer vision etc. There are two types of image enhancement i.e. Frequency and spatial domain techniques.

1.3 Challenges in Image Enhancement

Followings are challenges in the image enhancement

- None of the technique we have developed is enough for removing whole noise in the image. So we have to come up with better algorithm which will enhance image.
- When we are enhancing the image then at edges we loss the pixel information. So we have to develop such technique which will enhance image all over the area equally whether it is on middle of the window or at the edges.

- Sometimes we get blurring effects when we are enhancing. This happens because during enhancement process we apply some technique to remove noisy pixel then its neighboring pixel is also affected and we get blurring effect. So we have to come up with techniques which only affect noisy pixel.

II. PROPOSED METHOD

2.1 Evaluation Parameters

In image enhancement technique quality of an image can be subjective. It may be completely different for person to person, thus as a result of this reason it's required to ascertain some parameters to match the image quality. Following area unit the matrix to inquire the standard of associate image:

(i) Mean Square Error (MSE): The MSE signifies the cumulative squared error between the input and the output image. To compute the PSNR, we first calculate the mean squared error. It is calculated by the following equation (1).

$$MSE = \frac{\sum_{M,N}[I1(\mathrm{m,n}) - I2(\mathrm{m,n})]^2}{M * N} \quad \textbf{(1)}$$

Where N and M are the number of columns and rows in the input images, respectively and I1 (m, n) is the input image, I2 (m, n) is the decompressed image.

(ii) Peak Signal-to-Noise Ratio (PSNR): Signal–to-noise ratio (SNR) is a mathematical measure of image quality. It is based on the pixel difference between two images. The SNR measure is an estimate of quality of enhanced image compared with original image. PSNR is defined by the following equation (2)

$$PSNR = 10\log_{10}\left[\frac{R^2}{MSE}\right] \quad (2)$$

The PSNR takes the signal strength into consideration. The values were used to evaluate the quality of the image. Where R represents maximum fluctuation or value in the image, its value is 255 for 8 bit unsigned number.

(iii) Structure Similarity Index Metrics (SSIM)

SSIM is full-reference image quality assessment methods; the quality of a test image is evaluated by comparing it with a reference image that is assumed to have perfect quality [31]. The goal of image quality assessment research is to design methods that quantify the strength of the perceptual similarity (or difference) between the test and the reference images.

$$SSIM(\mathrm{x,y}) = \frac{(2\mu_x\mu_y + \mathrm{C}_1)(2\sigma_{xy} + \mathrm{C}_2)}{(\mu_x^2 + \mu_y^2 + \mathrm{C}_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (4)$$

$$MSSIM(\mathrm{X,Y}) = \frac{1}{M}\sum_{j=1}^{M} SSIM(\mathrm{x}_j, \mathrm{y}_j) \quad (5)$$

Mean SSIM (MSSIM) index to evaluate the overall image quality can be given [31]:

(iv) Entropy

The entropy of a digital image is a statistical measure that expresses the randomness of gray levels (colors) and it is defined as:

$$E = \sum_{i=0}^{2^B-1} p_i \log_2 p_i \quad (6)$$

where B is the total quantity of bits of the digitized image

$p_i = \frac{ki}{m1 * m2}$, is the probability of occurrence of color i,

Ki is the frequency of occurrence of color i in the image

M1 is number of rows of the image,

M2 is number of columns of the image

(v) Average gradient

The gradient of an image measures how it is changing. The magnitude of the gradient tells us how quickly the image is changing.

(vi) Contrast

Contrast is the difference in luminance or color that makes an object distinguishable. In visual perception of the real world, contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view

(vii) Normalized Cross-Correlation

Normalized cross-correlation is used for measuring the difference between input and output image.
The formula for calculating this is as
NCC = 1/N * sum { [x(n) - mean(x)]* [(n) - mean(y)] }/ (sqrt(var(x)*var(y))
Where, The sum is taken from 1 till N.
Mean(x) is the mean of x
var(x) is the variance of x.

(viii) MSSIM (Mean Structural Similarity Index)

It is a perceptual metric that quantifies image quality degradation caused by processing such as data compression or by losses in data transmission. It is a full reference metric that requires two images from the same image capture- a reference image and a processed image. The processed image is typically compressed.

SSIM actually measures the perceptual difference between two similar images. It cannot judge which of the two is better: that must be inferred from knowing which the “original” and which has been subjected to additional is processing such as data compression.

III. IMPLEMENTION WORK

3.1 Contrast Enhancement by Adaptive-Gamma Correction using Weighting Distribution

They directly utilized cd f and applied a normalized gamma function to modify the transformation curve without losing the available histogram of statistics. Consequently, the lower gamma parameter generates a more significant adjustment. This observation led us to employ a compensated cd f as an adaptive parameter, which modifies the intensity with a progressive increment of the original trend. The proposed adaptive gamma correction (AGC) is formulated as follows:

$$T(l) = l_{\max}(l / l_{\max})^{\gamma} = l_{\max}(l / l_{\max})^{1-cdf\,(l)} \quad (1)$$

The adaptive gamma correction method can increase low intensity and decrease high intensity. Furthermore, the weighting distribution (WD) function is also applied to slightly modify the statistical histogram and lessen the generation of adverse effects [15]. The WD function is formulated as:

$$pdf_w(l) = pdf_{\max}\left(\frac{pdf\,(l) - \mathrm{pdf}_{\min}}{pdf_{\max} - pdf_{\min}}\right)^{\alpha} \quad (2)$$

where α is the adjusted parameter, $\mathrm{pdf}_{\max}$ is the maximum pdf of the statistical histogram, and $\mathrm{pdf}_{\min}$ is the minimum pdf . Based on Equation (2), the modified cd f is approximated by

$$cdf_w(l) = \sum_{l=0}^{l_{\max}} pdf_w(l) / \sum pdf_w \quad (3)$$

where the sum of pdf_w is calculated as follows:

$$\sum pdf_w = \sum_{l=0}^{l_{\max}} pdf_w(l) \quad (4)$$

Finally, the gamma parameter based on cd f of Equation (1) is modified as follows:

$$\gamma = 1 - cdf_w(l) \quad (5)$$

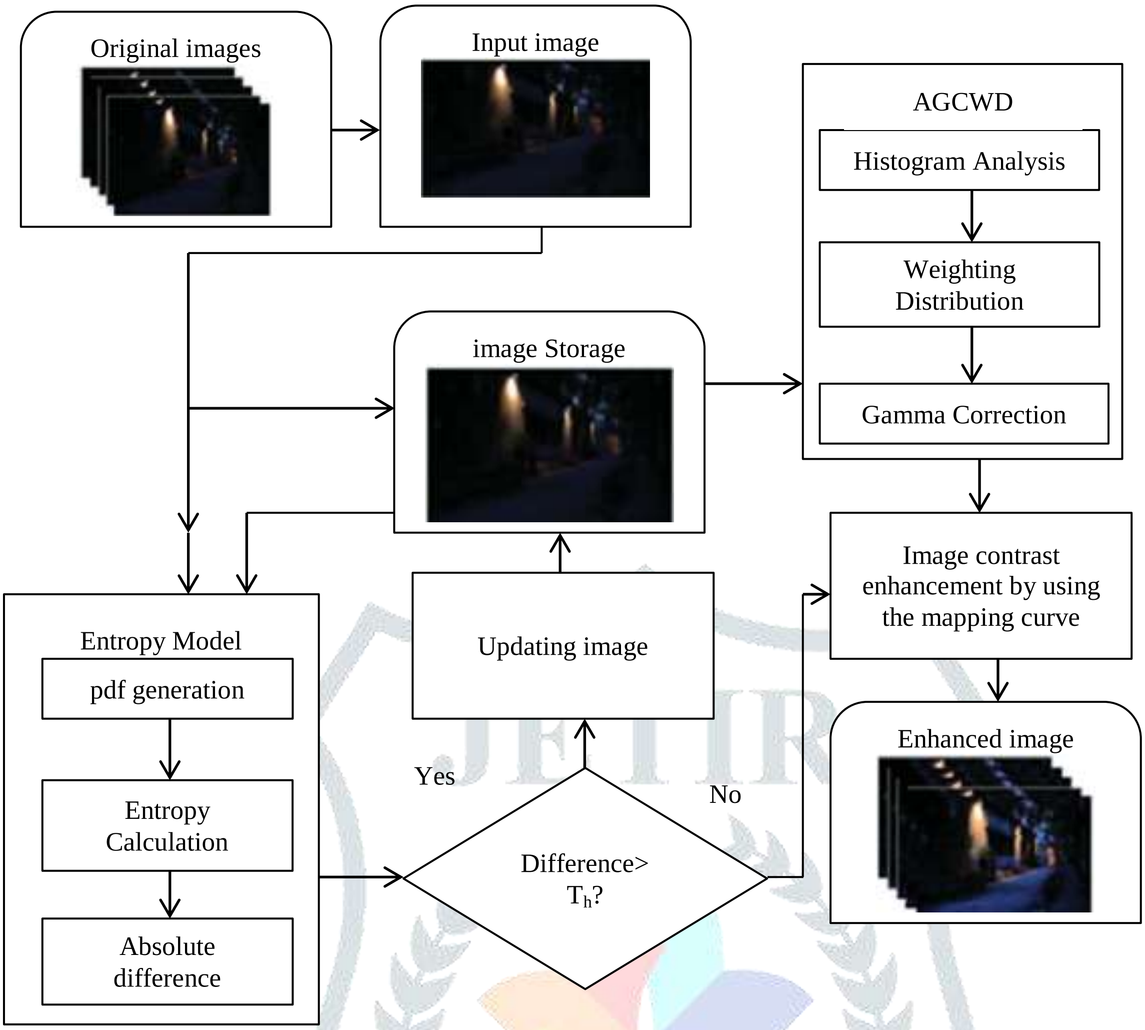


Fig 3.1 Flowchart of the TB method

At the beginning of the process, input image is directly used to generate a mapping curve for the proposed AGCWD method. Then, the entropy model can be used to measure the differences of the information content between the pixels. The information content of each image is approximated by the following entropy formula:

$$H = -\sum_{l=0}^{l\max} pdf(l)\log(pdf(l)) \quad (6)$$

3.2 Contrast enhancement using an optimal-gamma correction with weighted sum approach and brightness preservation

- **System description:** A system block diagram for contrast enhancement and brightness preservation is depicted in Figure 1. Given a colour image in the red–green–blue (RGB) space,

$$I(u,\upsilon) = \{R(u,\upsilon), G(u,\upsilon), B(u,\upsilon)\} \quad (7)$$

where (u, v) is the pixel coordinate u = 1, . . . ,U, v = 1, . . . , V and (U, V) is the image size in width-by-height. For implementation convenience, the signals are often normalized in [0 1] with 256 intervals matching the common 8-bit resolution. Each colour channel magnitudes are firstly stretched across the permitted ranges, for example, the red colour channel magnitude is stretched as

$$R(u,\upsilon) \leftarrow \frac{R(u,\upsilon) - \min\{R\}}{\max\{R\} - \min\{R\}} \quad (8)$$

where the minimum and maximum values are obtained over all pixels in the image. The green and blue channels are also stretched in the same way. This process enriches the image colour content and serves as pre-processing for contrast enhancement. After magnitude stretching, all colour signals are converted to the Hue–saturation–intensity (HSI) space. The I-signal representing the intensity or brightness is processed in the system. The extracted I-signal Iin is fed simultaneously into a compressor and an expander, both adopting the gamma correction approach with the factor γ , giving interim outputs Icp and Iex , respectively. An additional interim-enhanced image Î en is derived from the compressed and expanded images using a weighting factor α. This newly obtained image is tested for an objective function composed of maximum entropy and a penalty term depending on the brightness error between the input and the interim-enhanced image. The governing factors, γ and α are optimized for a highest objective function. The optimization is carried out using the efficient golden section search for its implementation simplicity [6].When an optimal parameter set is obtained, the interim image is reconverted to RGB from HSI as the output for display or for further processing. Method can be used for gray scale images in which grayscale image is used at the place of intensity channel as used in in HSI converted image.

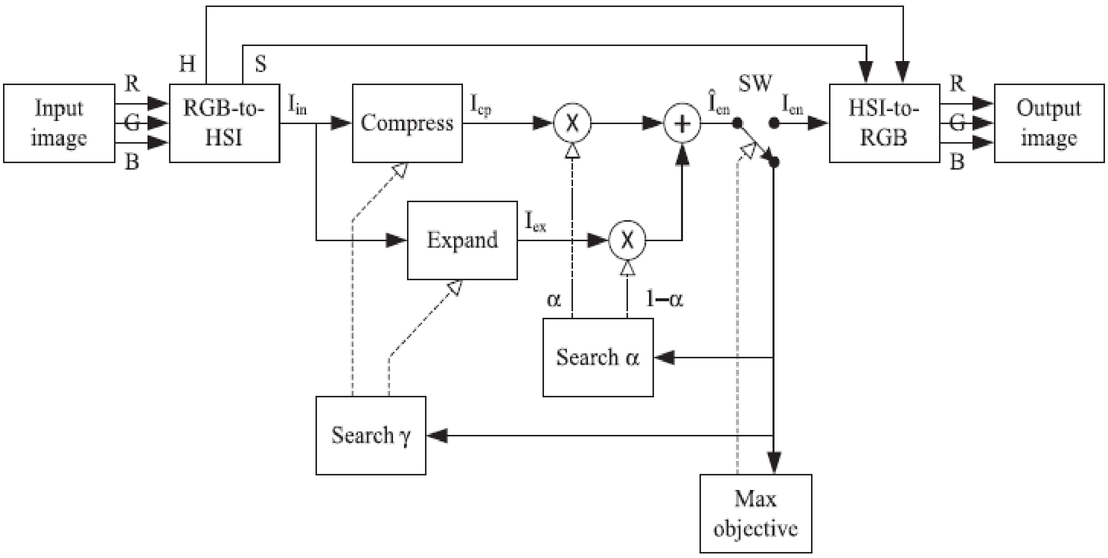


Fig 3.2 System block diagram for contrast enhancement with brightness preservation.

3.3 Histogram equalization

To enhance nature of envision, the shading image improvement approach used to upgrade the difference [23]. One of the upgrade systems is the power histogram evening out (HE) technique which extends the packed histogram into the uniform histogram. We have eight-piece dark level image of size M×N, the likelihood of event in force level I_k is approximated by

$$p_i(I_k) = \frac{n_k}{MN} \quad k = 0,1,2,3.....255 \quad \ldots (9)$$

where n_k is number of pixels which have power I_k. The force change is then computed by

$$c_k = T(I_k) = 255\sum_{j=0}^{k} p_I(I_j)$$
$$= \frac{255}{MN}\sum_{j=0}^{k} n_j \quad k=0,1,2,3,4...255 \quad \ldots\ldots. (10)$$

In this way, a Histogram Equalization image is delivered by changing each pixel esteem in the first image with power Ik into a neighboring pixel with level ck in the yield Histogram Equalization image. This kind of Normalization is an imperative procedure on image preparing on the grounds that exclusive by procedure of normalizing the image, the scope of estimations of pixel force is changed by prerequisite of calculation. The light imperfections in a image is amended for instance poor difference because of glare, are improved to get the complexity of the image the required range. So the conveyance in power is outperformed. The worldwide differentiation of the image is upgraded to a higher difference level. The higher complexity facilitates include extraction. The most regular power esteems are successfully spread out the image. Histogram evening out works better in dim scale images .Histogram leveling is when connected on shading images, the difference extending is performed on all the three groups i.e. R,G and B .Performing balance on all the three parts is autonomously may not improve the image. The impacts of histogram evening out may push undesired upshots in the event that on all shading images.

3.4 Contrast stretching

Because of low difference of images, histogram's dynamic range is low at a few levels. Differentiation extending is in this way considered to redistribute the pixel esteems somewhere in the range of 0 and 255grey level. Differentiation extending calculation utilized in straight scaling of the pixel is given as [11]:

$$I_N(x, y) = \left(I\ (x, y) - I_{Min}\right) \times \left(\frac{Id_{Max} - Id_{Min}}{I_{Max} - I_{Min}}\right) Id_{Min}, \qquad (11)$$

Here $I_N(x, y)$ = normalized pixels intensity value after contrast stretching;

$I\ (x, y)$ = pixel intensity value before contrast stretching;

I_{Min} = lowest intensity of the parent image;

I_{Max} = highest intensity of the parent image;

Id_{Min} = minimum pixel intensity in desired range;

Id_{Max} = maximum pixel intensity in desired range.

A difference extending task expect that adequate powerful ranges in the image flag, which is contrastingly not in the situation for low differentiation symbolism. Thus, from the info image, pixel force of least and greatest qualities are gotten by the strategy. Creation of a image which is reasonable for extra handling can likewise happen by applying the differentiation extending calculation.

3.5 Contrast limited adaptive histogram equalization (CLAHE)

The following stage in this is histogram equalization (HE) that has performed differentiate extending. In view of non-homogeneous property of pixel worldwide histogram adjustment [29] isn't dependable for shading cast issue is seen. Hence, the CLAHE calculation is utilized [20]. This calculation is valuable in images with dull and lighter bits. Different segments of a image has adjusted the histogram and enterprise the power standardized pixels to redistribute the delicacy esteems, by this the extraction of shrouded information and the change of nearby difference will happen. The stream procedure for CLAHE working is as in beneath.

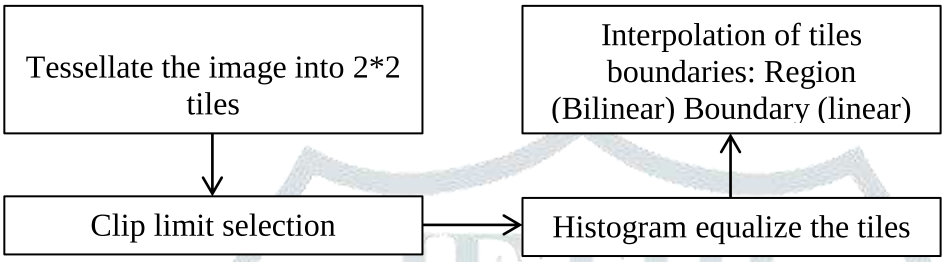


Fig 3.3 Sequence of operations in CLAHE

As indicated by Pizer et. al. [20], if indicates the recurrence of the event of pixel's force esteem that is related with a container for every conceivable power, at that point P_k is characterized as

$$P_k = n_k; \ k = 0,1,2,...,255, \tag{12}$$

here n_k is the number of pixels associated with k^{th} intensity value.

As a subsequent stage, the aggregate dissemination work (cdf) of every one of the power esteems is figured by

$$\mathrm{cdf}_{I(x,y)} = \sum_{k=0}^{I(x,y)} P_k, \tag{13}$$

here x = 1, 2, 3, . . . , M(number of rows), y = 1, 2, 3, . . . , N(number of columns). The histogram equalized image I (x, y) is given as beneath

$$I'(x,y) = (f\ loor)\left\{\frac{\mathrm{cdf}_{I(x,y)} - \mathrm{cdf}_{min}}{M \times N - \mathrm{cdf}_{min}} \times 255\right\}, \tag{14}$$

here cdf_{min} is the minimum cdf value of the corresponding section.

Subsequent to testing a few images with various blends of parameters, CLAHE task in the calculation is embraced by the accompanying strategy.

3.6 Brightness Preserving Bi-histogram Equalization (BBHE)

BBHE first deteriorates a unique image into two sub images in view of mean of the first image [36]. One of the sub images is set of tests which is equivalent to or less then the mean while the second one is the arrangement of tests more prominent than the mean. At that point the BBHE evens out the sub images autonomously in view of their separate histograms with the imperative that the examples in the previous set are mapped into the range from the base dim level to the info mean and the examples in the last set are mapped into the range from the intend to the most extreme dark level. It implies first sub image is leveled over the range up to the mean and the other sub image is adjusted over the range. Hence, the subsequent leveled sub images are limited by each other around the information mean, which has an impact of safeguarding mean brilliance.

3.7 Dualistic Sub-Image Histogram Equalization (DSIHE)

Like BBHE, dualistic sub-image HE (DSIHE) likewise breaks down the information image into two sub-images and after that evens out the histogram of sub-images independently [35]. Contrasting from breaking down a image rely on its mean dark level, the DSIHE strategy decays a image going for the amplification of the Shannon's entropy of the delivered image. For such point, the first image is deteriorated into two sub-images, being one brilliant and one dull, regarding the equivalent territory property .In [35], it demonstrates that the shine of the yield image produced by the this technique is the normal of the equivalent zone level of the image I and the center dark level of the image, i.e., L/2. The creators of [35] assert that the shine of the yield image produced by applying this strategy does not present a noteworthy move in connection to the brilliance of the first image, particularly for the vast zone of a image with similar dim levels, e.g., P with little questions in regards to extraordinary darker or brighter foundations.

IV. RESULTS AND DISCUSSION

The data which is required for additionally preparing on the normal/SDR images might be corrupted because of changes of light or legitimate enlightenment issue, and a similar image catch by camera is known as crude image.

Improved images by various strategies have been shown and are contrasted and unique information image in view of some quality and complexity parameters. The outcomes by various parameters for various techniques have been appeared beneath in table 4.1, 4.2, 4.3 and 4.4 for normal, HDR, SAR and restorative images. Medicinal ultrasound images Images are obtained from www.ultrasoundcases.info. This site contains substantial number of general ultrasound images acquired from the Gelderse Vallei Hospital in Ede, the Netherlands. Lena, peppers, vessel, primate and so forth are regular images which are taken frame MATLAB standard dataset of characteristic images. HDR images are taken from http://scarlet.stanford.edu/~brian/hdr/hdr.html which contains standard dataset for HDR images. Similarly SAR dataset has been collected from http://sipi.usc.edu/database/ database.php which have aerial SAR images in their dataset.

The quality parameters taken are MSE, PSNR, NC and MSSIM. Alongside this entropy, slope and differentiation parameters are additionally taken which gives data about spatial substance in the image.

Peak signal to noise ratio is the proportion between the most extreme intensity of a flag and intensity of undermining clamor. Since signs may have a wide unique range, PSNR is normally communicated as far as the logarithmic decibel scale. PSNR is most ordinarily used to quantify the nature of remaking of lossy pressure codecs and image reclamation strategies where the flag in these cases comprises of the first information, and the commotion is the mistake presented by pressure or rebuilding. Despite the fact that a higher PSNR for the most part demonstrates the recreation is of higher quality, now and again it may not be the situation. SSIM has been all the more as of late presented for estimating the similitude between two images giving a superior match to the human view of value. The SSIM is intended to enhance customary strategies, for example, PSNR and mean squared mistake (MSE), which are appeared to be not constantly predictable with the human view of value. SSIM is an observation based model that considers image corruption as an apparent change in auxiliary data, while likewise fusing both luminance veiling and difference covering terms. Auxiliary data is the possibility that pixels have solid between conditions particularly when they are spatially close. These conditions convey essential data about the structure of articles in the scene.

(a) (b) (c) (d) (e)

(f) (g) (h) (i) (j)

Fig 4.1 Database for natural images

(a) (b) (c) (d) (e)

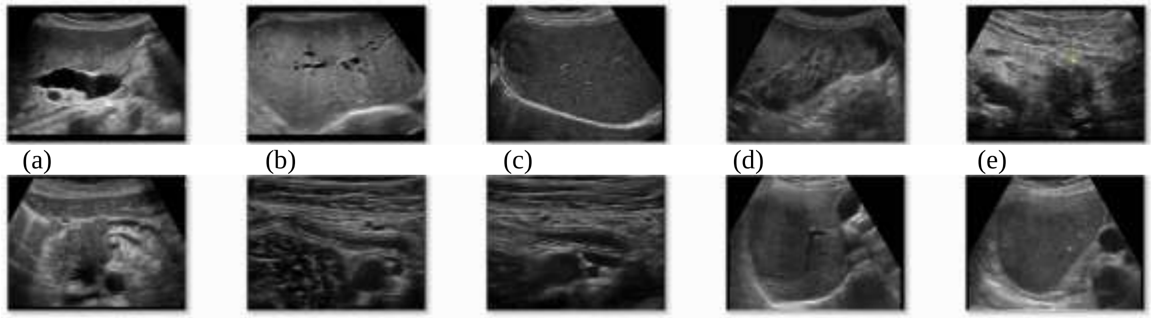
(f) (g) (h) (i) (j)

Fig 4.2 Database for HDR images

(a) (b) (c) (d) (e)

(f) (g) (h) (i) (j)

Fig 4.3 Database for SAR images

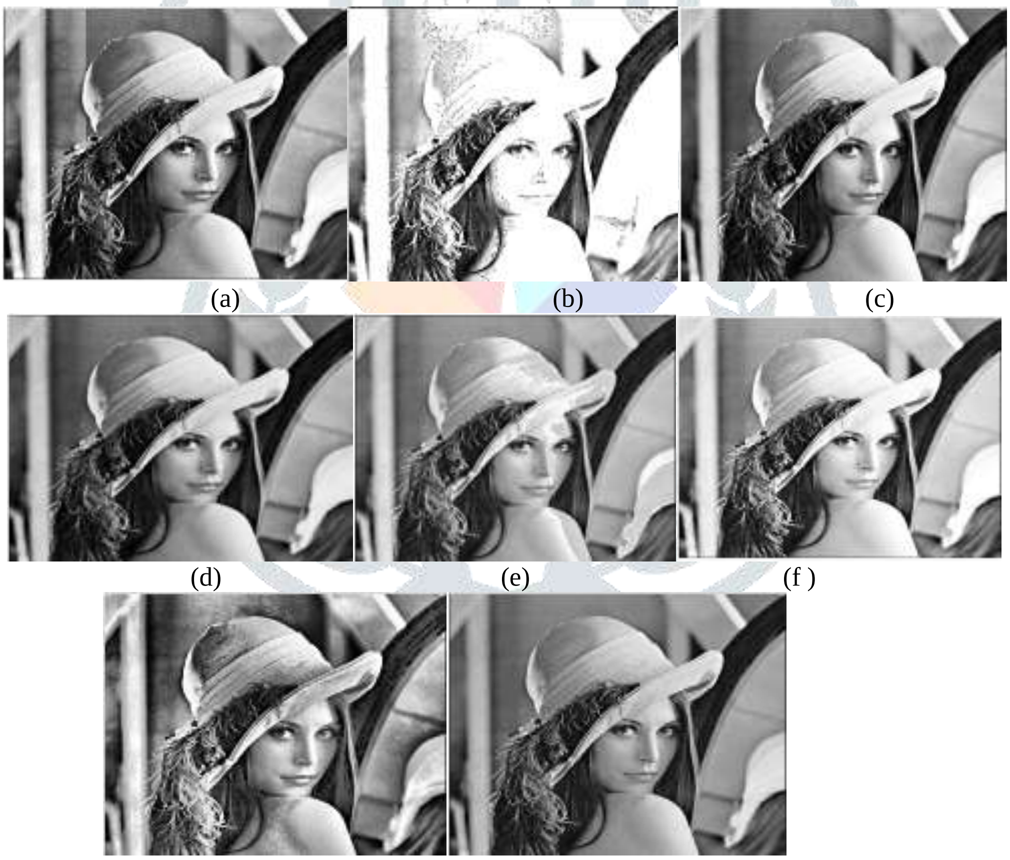


(a) (b) (c) (d) (e)

(f) (g) (h) (i) (j)

Fig 4.4 Database for medical images

4.1 Performance evaluation for natural images



(a) (b) (c)

(d) (e) (f)

(g) (h)

Fig 4.5 output obtained by applying different methods on sample natural image Fig.4.1 (e), (a) D-stretch and HE (b) BBHE (c) Histogram Equalization (d) DSIHE
(e) Contrast stretching (f) Adaptive gamma correction with weighting distribution
(g) CLAHE (h) Optimal gamma correction and weighted sum approach.

Table 4.1 Results by different parameters for different methods using natural images

Parameters / Methods	MSE	PSNR	Contrast	Entropy	Gradient	NC	MSSIM
(a)D-stretch and HE	1715.772	16.953	64.489	5.726	10.166	0.974	0.752
(b)Histogram	1584.929	17.322	64.934	6.516	9.747	0.978	0.778

Equalization							
(c)Contrast stretching	880.792	18.907	47.143	6.593	7.580	0.996	0.905
(d)CLAHE	1445.278	17.066	55.749	7.844	12.039	0.972	0.722
(e)BBHE	1344.992	16.566	29.627	3.5147	4.841	0.983	0.772
(f)DSIHE	1214.524	18.786	58.736	6.479	8.871	0.983	0.818
(g)Adaptive gamma correction with weighting distribution	2099.44	15.172	52.415	6.490	7.604	0.997	0.912
(h)Optimal gamma correction and weighted sum approach	60.470	32.969	44.119	6.668	6.227	0.998	0.983

As observed from the table 4.1, the visual quality of the output images after applying the different methods is significantly higher for optimal gamma correction and weighted sum approach. Also when compared the structured similarity and N.C the method (h) provides the best results closely followed by the Adaptive gamma correction with weighting distribution.

4.2 Performance evaluation for HDR images

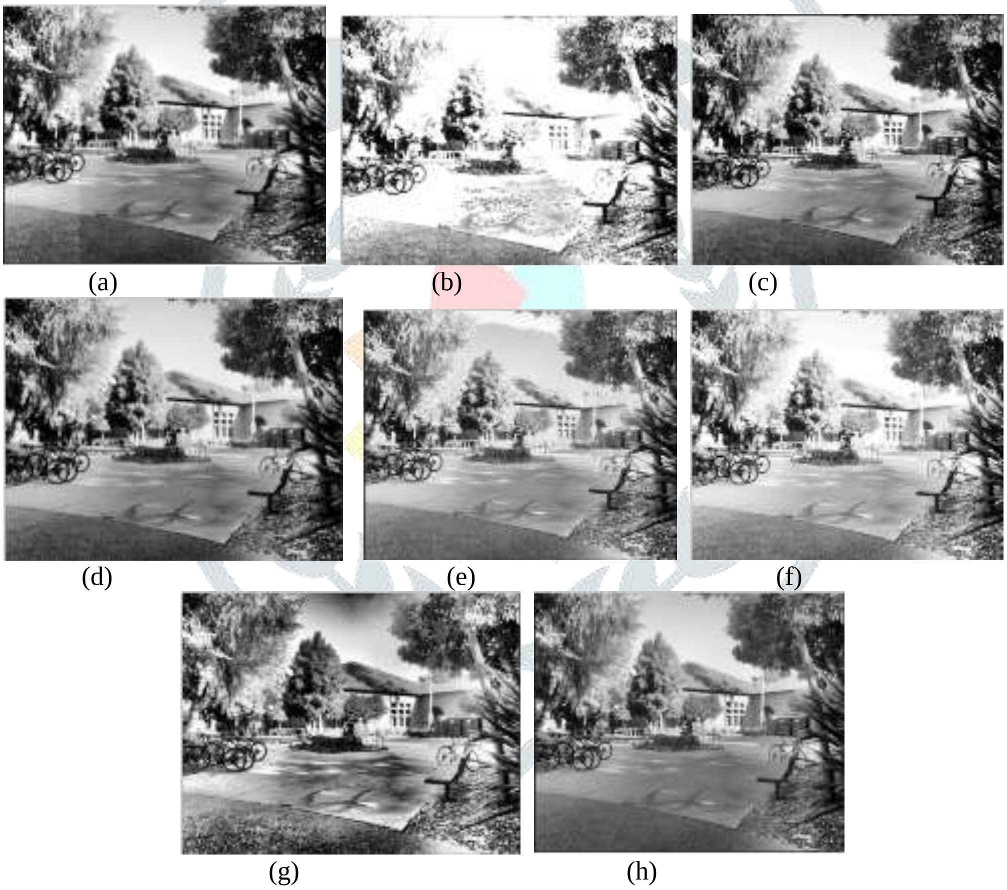


Fig 4.6 output obtained by applying different methods on sample HDR image Fig.4.2 (g), (a) D-stretch and HE (b) BBHE (c) Histogram Equalization (d) DSIHE
(e) Contrast stretching (f) Adaptive gamma correction with weighting distribution
(g) CLAHE (h) Optimal gamma correction and weighted sum approach.

Table 4.2 Results by different parameters for different methods using HDR image

Parameters / Methods	MSE	PSNR	Contrast	Entropy	Gradient	NC	MSSIM
(a)D-stretch and HE	1100.851	18.135	64.572	5.982	11.729	0.985	0.845
(b)Histogram	1002.785	18.706	63.462	7.369	11.337	0.989	0.869

Equalization							
(c)Contrast stretching	838.255	18.965	49.349	7.409	9.765	0.996	0.925
(d)CLAHE	1606.459	16.143	58.323	7.968	14.444	0.969	0.763
(e)BBHE	1529.596	15.942	29.781	4.260	6.106	0.976	0.731
(f)DSIHE	645.924	20.808	58.502	7.342	10.462	0.991	0.898
(g)Adaptive gamma correction with weighting distribution	2301.07	14.535	54.305	7.278	10.111	0.996	0.886
(h)Optimal gamma correction and weighted sum approach	21.111	35.167	43.396	7.537	8.228	0.999	0.995

As observed from the table 4.2, the visual quality of the output images after applying the different methods is significantly higher for optimal gamma correction and weighted sum approach and Contrast stretching. Also when compared the structured similarity and N.C the method (h) provides the best results closely followed by the Adaptive gamma correction with weighting distribution. Mean average contrast is more effective range to validate it. Optimal gamma correction and DSIHE methods balances the contrast than other methods.

4.3 Performance evaluation for SAR image

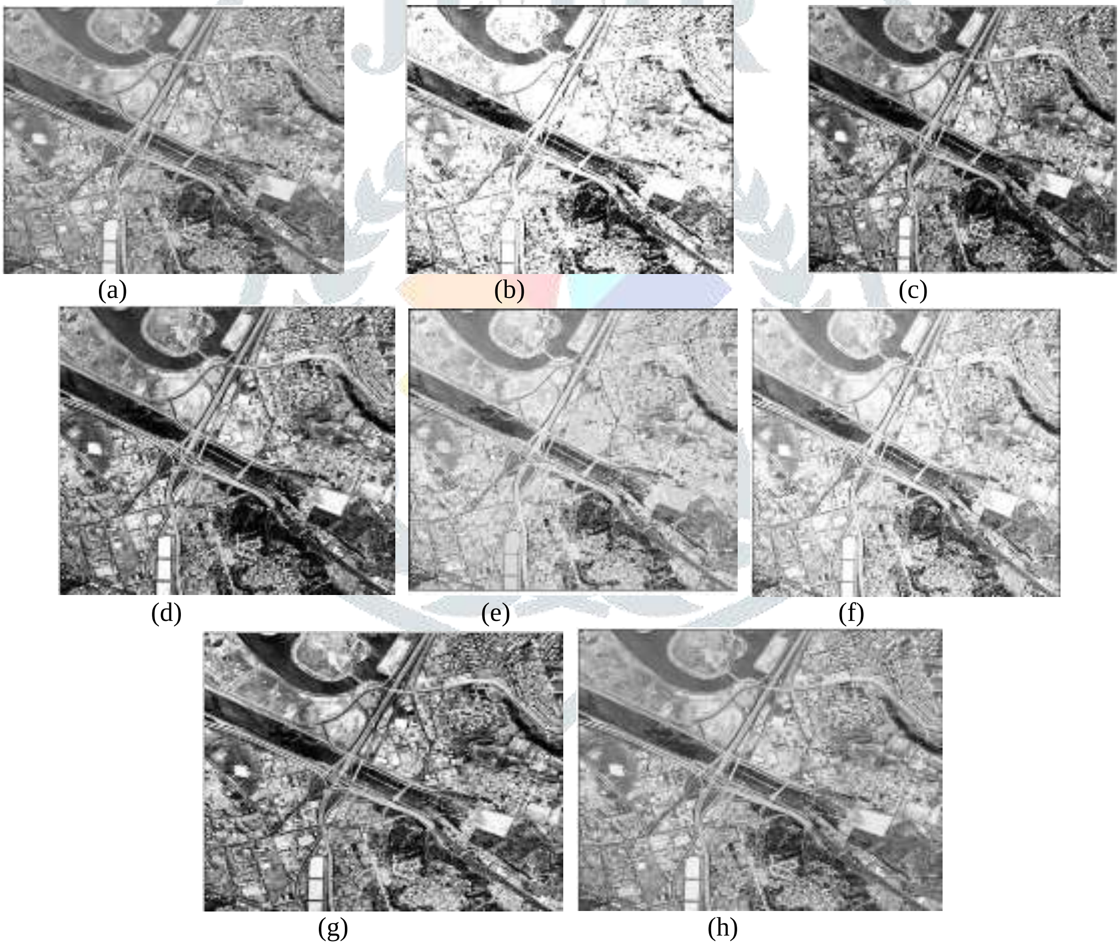


Fig 4.7 output obtained by applying different methods on sample natural image Fig.4.3 (g), (a)D-stretch and HE (b)BBHE (c)Histogram Equalization (d) DSIHE (e) Contrast stretching (f). Adaptive gamma correction with weighting distribution
(g) CLAHE (h) Optimal gamma correction and weighted sum approach.

Table 4.3 Results by different parameters for different methods using SAR image

Parameters / Methods	MSE	PSNR	Contrast	Entropy	Gradient	NC	MSSIM
(a)D-stretch and HE	4044.506	12.567	64.585	5.916	23.893	0.931	0.516

(b)Histogram Equalization	3727.28	12.935	63.593	6.465	22.934	0.939	0.542
(c)Contrast stretching	1406.947	17.058	24.106	6.441	10.082	0.998	0.821
(d)CLAHE	3795.913	12.730	61.061	7.984	25.605	0.934	0.500
(e)BBHE	954.943	18.093	25.395	3.647	9.311	0.986	0.761
(f)DSIHE	1353.513	17.310	46.672	6.426	16.518	0.979	0.724
(g)Adaptive gamma correction with weighting distribution	2102.364	15.232	33.158	6.444	11.971	0.998	0.855
(h)Optimal gamma correction and weighted sum approach	72.492	31.198	24.622	6.553	9.883	0.998	0.960

As observed from the table 4.3, the visual quality of the output images after applying the different methods is significantly higher for optimal gamma correction and weighted sum approach and BBHE. Also when compared the structured similarity and N.C the method (h) provides the best results closely followed by the Adaptive gamma correction with weighting distribution. When considered entropy or energy of the images, contrast-stretching gives effective results than the remaining methods. CLAHE gives effective results when gradient parameter is considered.

4.4 Performance evaluation for Medical image

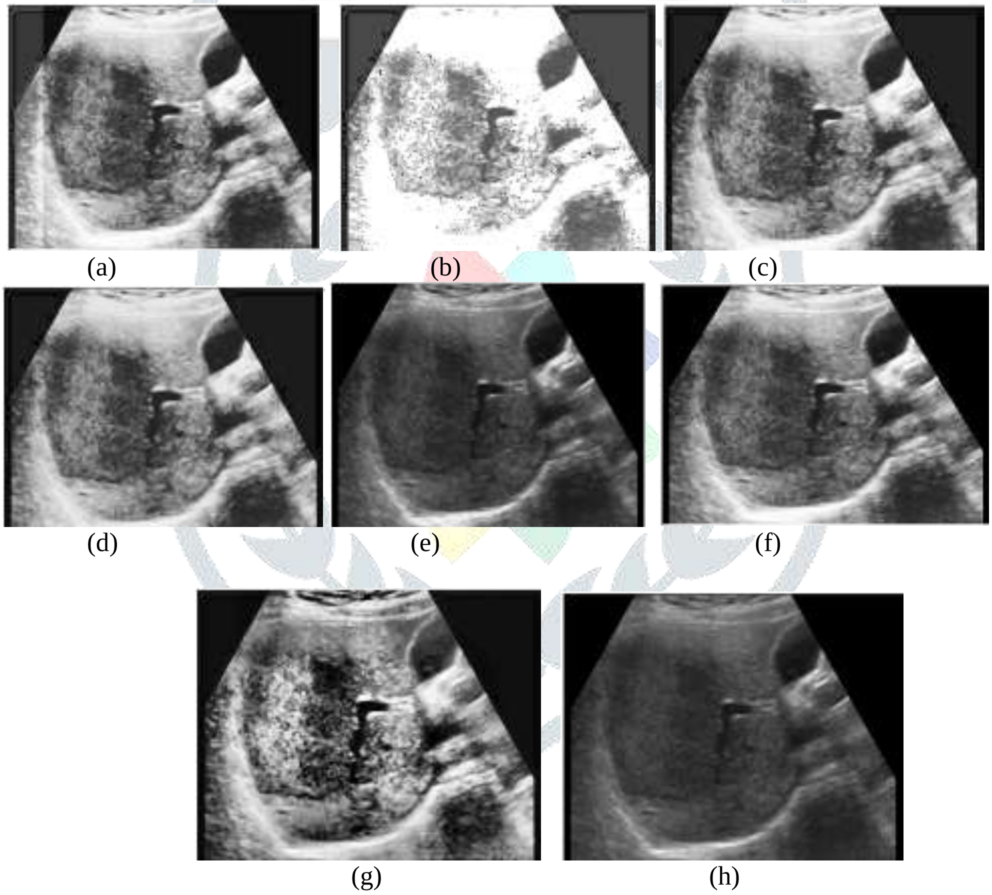


Fig 4.8 output obtained by applying different methods on sample natural image Fig.4.3 (i), (a) D-stretch and HE (b) BBHE (c) Histogram Equalization (d) DSIHE
(e) Contrast stretching (f) Adaptive gamma correction with weighting distribution
(g) CLAHE (h) Optimal gamma correction and weighted sum approach.

Table 4.4 Results by different parameters for different methods using Medical image

Parameters / Methods	MSE	PSNR	Contrast	Entropy	Gradient	NC	MSSIM
(a)D-stretch and HE	6065.79	10.45838	64.29623	5.786598	7.753934	0.962732	0.538742
(b)Histogram Equalization	6101.39	10.440	62.468	6.647	7.332	0.966	0.539

(c)Contrast stretching	254.437	24.423	39.033	6.812	5.343	0.997	0.965
(d)CLAHE	4683.07	11.743	59.943	7.708	9.772	0.945	0.482
(e)BBHE	1310.24	17.046	16.353	3.665	2.305	0.916	0.607
(f)DSIHE	4954.85	11.380	59.264	6.639	7.070	0.968	0.570
(g)Adaptive gamma correction with weighting distribution	3193.74	13.120	61.438	6.743	6.926	0.983	0.740
(h)Optimal gamma correction and weighted sum approach	42.781	32.023	31.099	6.788	4.586	0.998	0.989

As observed from the table 4.4, the visual quality of the output images after applying the different methods is significantly higher for optimal gamma correction and weighted sum approach and Contrast stretching. Also when compared the structured similarity and N.C the method (h) provides the best results closely followed by the Adaptive gamma correction with weighting distribution. When considered entropy or energy of the images, contrast-stretching gives effective results than the remaining methods. CLAHE gives effective results when gradient parameter is considered.

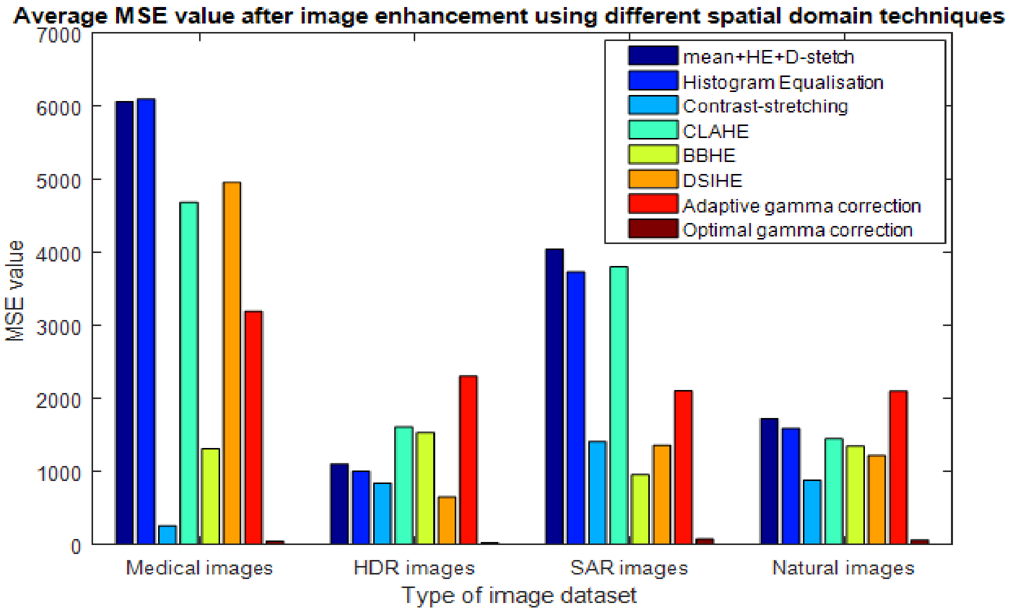


Fig 4.9 Average MSE value after image enhancement using different spatial domain techniques

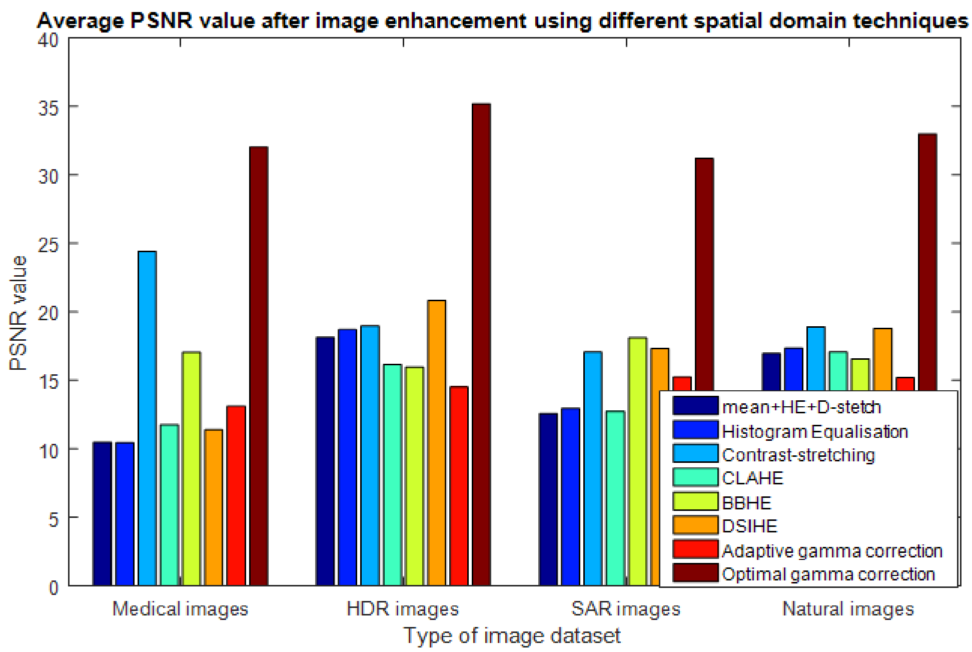


Fig 4.10 Average PSNR value after image enhancement using different spatial domain techniques

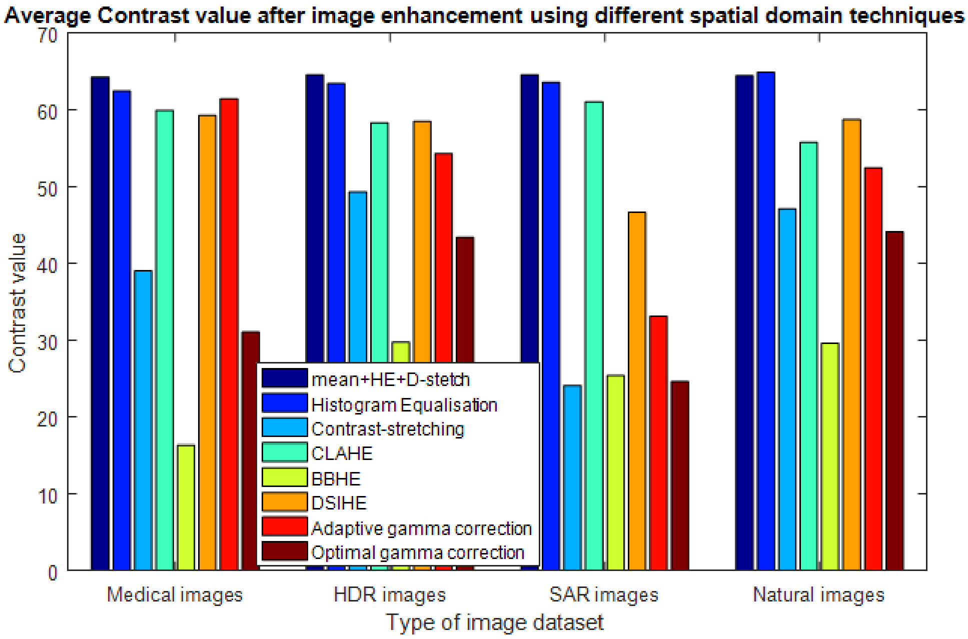


Fig 4.11 Average Contrast value after image enhancement using different spatial domain techniques

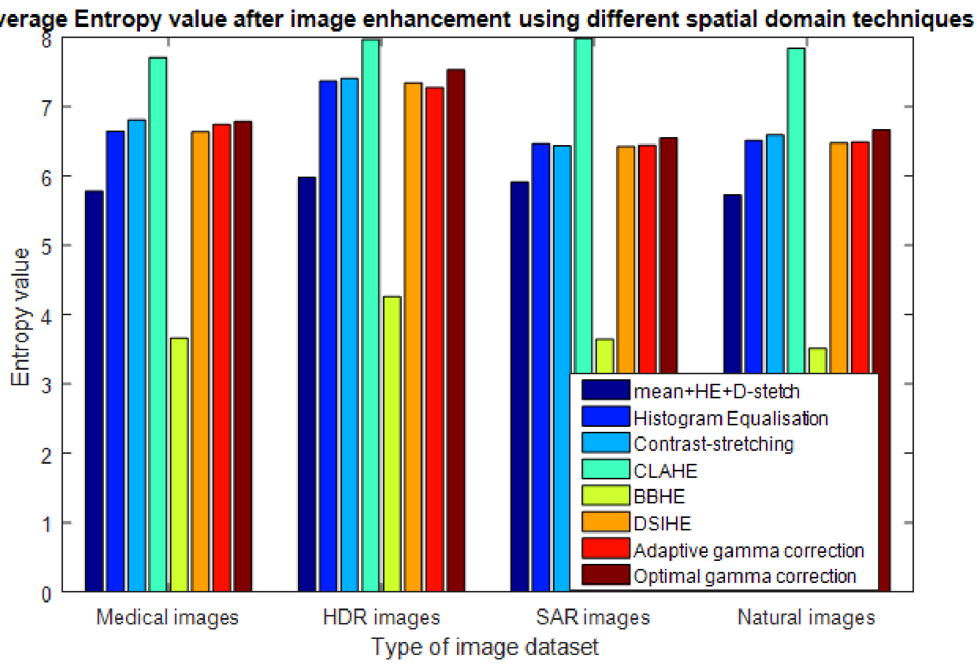


Fig 4.12 Average entropy value after image enhancement using different spatial domain techniques

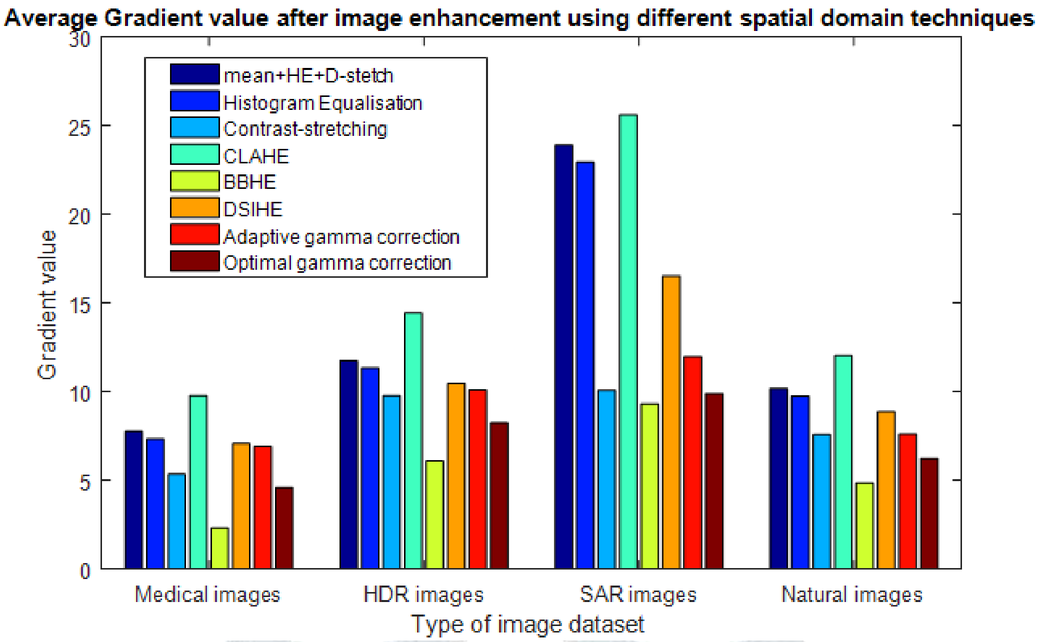


Fig 4.13 Average Gradient value after image enhancement using different spatial domain techniques

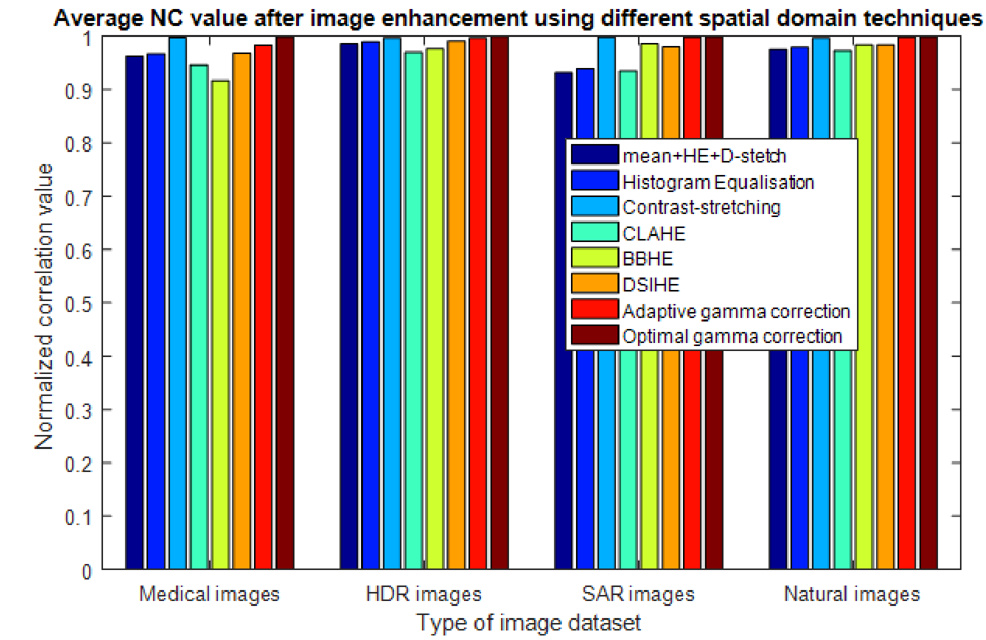


Fig 4.14 Average NC value after image enhancement using different spatial domain techniques

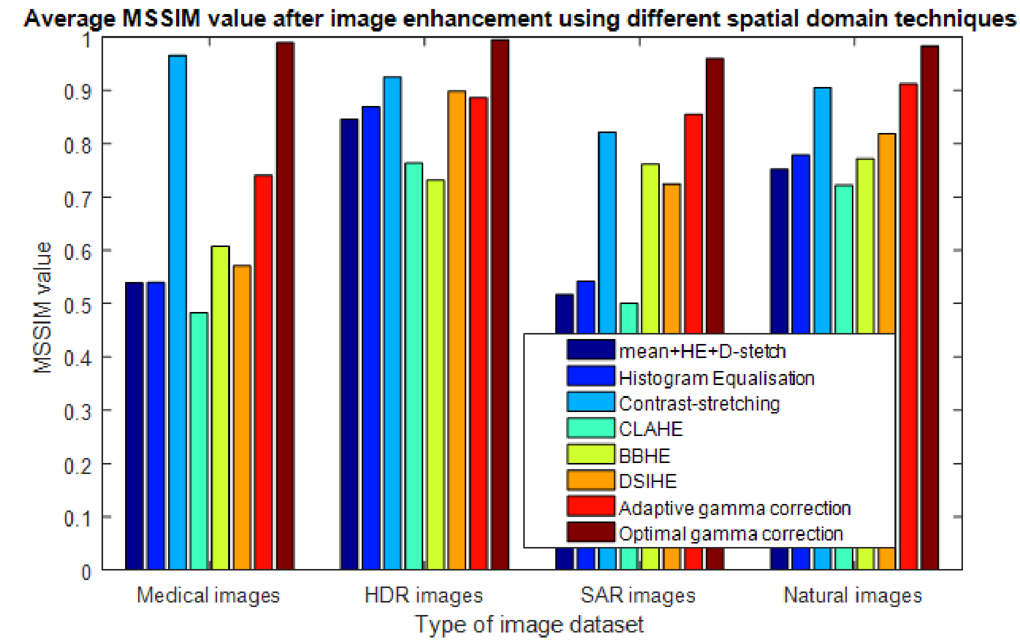


Fig 4.15 Average MSSIM value after image enhancement using different spatial domain techniques

IV. Conclusion

In this work, different spatial domain methods have been explored and implemented which are improved versions of the traditional techniques of histogram equalization, power law or gamma correction. Contrast stretching etc. first method .uses mean method which divide the image into two halves on behalf of mean value. Then histogram equalization is applied for both halves separately which are further enhanced by decorrelation stretch. Finally both halves are merged together which gives enhanced image. Second and third methods are histogram equalization and contrast stretching respectively which are effective in contrast enhancement. Fourth method is CLAHE (contrast limited adaptive histogram equalization) which is useful for images with dark and lighter portions. Fifth method is also variation of HE named as Brightness preserving Bi Histogram Equalization (BBHE) which is effective in preserving mean brightness of the image. Next method is DSIHE, Dualistic Sub-Image Histogram Equalization. DSIHE method found more effective than BBHE method in quality preservance as well as image enhancement. Last two methods used power law or also named as gamma correction to enhance the contrast of the mages. First method used adaptive gamma correction along with weighting distribution. Furthermore, the weighting distribution (WD) function is also applied to slightly modify the statistical histogram and lessen the generation of adverse effects. Last method uses an optimal gamma correction and weighted sum approach which is more effective than previous method. For performance evaluation of the presented methods, seven quality metrics has been used. When compared with PSNR indices optimal gamma correction method goves high values for all type of datasets in which HDR dataset shows higher among all datasets. Then DSIHE, BBHE methods gives mixed results on different datasets such that DSIHE found effective for HDR and natural images, contrast strectcing found effective for medical images and BBHE found effective for SAR images. Contrast is not a parameter in which high or low values can be considered as evaluation as contrast enhancement method increases the contrast of dim pixels whereas decreases the contrast for bright pixels. Therefore, mean average contrast is more effective range to validate it. Optimal gamma correction and DSIHE methods balances the contrast than other methods in all type of images. When considered entropy or energy of the images, contrast-stretching gives effective results than the remaining methods. CLAHE gives effective results when gradient parameter is considered. For comparing NC values almost all methods are effective as all approaches to one but adaptive and optimal gamma correction along with contrast-stretching gives high value of NC parameter when all dataset are considered. Similarly adaptive and optimal gamma correction found effective when SAR and medical datasets are considered but for natural and HDR images optimal gamma correction and contrast-stretching found more effective than the rest.

In this work only spatial domain methods are explored and implemented. In future work, transform domain methods especially wavelet, contour let and fusion based methods can be explored and can be compared with spatial domain techniques.

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