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Enhancement of Aerial and Medical Image using Multi resolution pyramid

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***Abstract*— Image enhancement has been an area of active research for decades. Most of the studies are aimed at improving the quality of image for better visualization. An approach for contrast enhancement utilizing multi-scale analysis is introduced. To show the effects of image enhancement, quantitative measures should be introduced. In this paper, we examine the effect of global and local enhancement using multi resolution pyramids. We identify a set of quality metric parameters for comparative performance analysis and use it to assess the enhanced output image for a number of image enhancement algorithms using pyramids**

Keywords: Image pyramids, Enhancement methods, Quality parameters for image enhancement

I. INTRODUCTION

Image enhancement is used to improve the appearance of an image and make it easier for visual interpretation, understanding, and analysis of imagery. Some of the basic image enhancement techniques are used to modify the appearance of an image to highlight certain features while suppressing others.

Commonly used image enhancement techniques fall into two categories: (1) Global enhancement (2) Local or Adaptive Enhancement.

This paper describes the following:

a) Different types of image pyramids such as Gaussian, Laplacian, Mean, Sub Sampling, Ratio and Contrast Pyramid

b) Global and local enhancement techniques such as Histogram Equalization, Adaptive Histogram Equalization and Contrast Limited Adaptive Histogram Equalization using pyramids

c) Use of pyramids for image enhancement

d) Experimental study and results

II. MULTI-RESOLUTION PRINCIPLE FOR IMAGE ENHANCEMENT

A pyramid consists of a set of low pass or band pass copies of an image, each copy representing pattern information of a different scale. An image pyramid does contain all the information needed to reconstruct the original image [1].

A. Gaussian Pyramid

The Gaussian pyramid is a sequence of images in which each member of the sequence is a low pass filtered version of its predecessor [1].

To construct the Gaussian Pyramid levels: REDUCE [2]

$$g_l = \sum_{m=-2}^{m=2}\sum_{n=-2}^{n=2} w(m,n)\, g_{l-1}(2i+m, 2j+n)$$

To Expand the Gaussian levels: EXPAND [2]

$$g_{l,n}(ij) = \sum_{m=-2}^{m=2}\sum_{n=-2}^{n=2} w(m,n) \bullet g_{l,n-1}\left(\frac{i-m}{2}, \frac{j-n}{2}\right)$$

B. Laplacian Pyramid

Laplacian pyramid of an image is a set of band pass images and it can be obtained by calculating the difference between low pass images at successive levels of a Gaussian pyramid [3].

To construct the Laplacian levels [3]:

$$L_l = g_l - EXPAND(g_{l-1})$$

$$= g_l - g_{l-1,1}$$

C. Ratio of Low Pass Pyramid (ROLP)

ROLP is another pyramid in which at every level the image is the ratio of two successive levels of the Gaussian pyramid [1][4]

$$R_i = G_i / EXPAND[G_{i+1}]\, for 0 \le i \le N-1$$

D. Contrast Pyramid

Contrast pyramid is similar to the ratio of low pass pyramid approach. Contrast itself is defined as the ratio of the difference between luminance at a certain location in the image plane and local background [1] [4]

E. Mean Pyramid

Mean pyramid levels are calculated by calculating the average of pixels within a window size.

F. Sub Sampling Pyramid

A pyramid hierarchy can be generated by repeatedly sub sampling the original image data

II. GLOBAL AND LOCAL ENHANCEMENT METHODS

Histogram processing methods are global processing, in the sense that pixels are modified by a transformation function based on the gray-level content of the entire image. An example of this is Histogram Equalization. Sometimes, we may need to enhance details over small areas in an image, which is called a local or adaptive enhancement.

In this paper, Histogram Equalization (HE), a global enhancement method and Adaptive Histogram Equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE), two adaptive enhancement methods are implemented using pyramids and their performance is studied using quality parameters.

A. Histogram Equalization

Histogram equalization causes a histogram with closely grouped values to spread into an equalized histogram. When automatic enhancement is desired, histogram equalization is a good approach because the results from this technique are predictable and the method is simple to implement.

B. Adaptive Histogram Equalization(AHE)

In adaptive histogram equalization, the main idea is to take into account histogram distribution over local window and combine it with global histogram distribution [5]

C. Contrast Limited Adaptive Histogram Equalization. (CLAHE)

CLAHE is an adaptive contrast enhancement method. It is based on AHE, where the histogram is calculated for the contextual region of a pixel. The pixel's intensity is thus transformed to a value within the display range proportional to the pixel intensity's rank in the local intensity histogram [6].

CLAHE is a refinement of AHE, where the enhancement calculation is modified by imposing a user-specified maximum, i.e., the clip level, to the height of the local histogram, and thus on the maximum contrast enhancement factor.

Algorithms for the enhancement methods are described in Appendix - 1

III. IMAGE ENHANCEMENT ALGORITHM BASED ON PYRAMID STRUCTURE

The idea behind enhancement technique is to bring out the details in the image that are obscured, or to highlight certain features of interest in an image. The image is first decomposed into its pyramid representation. The samples at each level are then subjected to an enhancement method. The final enhanced image is then obtained by summing the levels of the processed pyramid.

IV. QUALITY METRICS FOR IMAGE ENHANCEMENT

In this paper, we have proposed objective measurement of quality parameters. The parameters are MSE, MAE, PSNR, SC, MD, UQI, SSM, Entropy and AMBE [7] [8] [9] [10] used to measure the quality of the enhanced image with respect to the original image. The detail derivation of the quality parameters are given in Appendix - 2.

V. EXPERIMENTAL STUDY

In this paper, following studies are conducted:

a) Study of global and local enhancement methods

b) Study of multi resolution pyramids

c) Enhancement of a set of input images using different pyramids

d) Study of quality of output enhanced images using quality metric parameters

e) Finding a suitable enhancement method and the corresponding pyramid that gives the best result

Two input images, one satellite image and one medical image are considered for the study. The input images are initially used to construct the various pyramid levels. Each level of the pyramid is then subjected to enhancement algorithms and reconstructed to give an enhanced image. The enhanced image is then used for quality assessment.

Input images can be referred in figure 1

VI. RESULTS & DISCUSSION

Results based on Study of Image Enhancement using Pyramids: From the study it is seen that the enhancement of images using pyramid gives a higher value of entropy i.e., higher information content in the image than the one without pyramid.

Table-I Appendix-4 shows a comparison of Entropy values using ‘Gaussian Pyramid’ and ‘No Pyramid’.

Study of best suitable enhancement techniques: Study shows that most of the quality parameters respond well for CLAHE method. The corresponding results with aerial images are shown in Table-II to Table-VI of Appendix-3A.

For medical image, quality parameters respond well for CLAHE method using Laplacian, Ratio and Contrast Pyramids. The corresponding result is shown in Table-II to Table-IV of Appendix-3B. Gaussian, Mean and Sub sampling pyramid on the other hand, respond well for HE method as shown in Table-I, Table-V, and Table-VI of Appendix -3B

VII. CONCLUSION

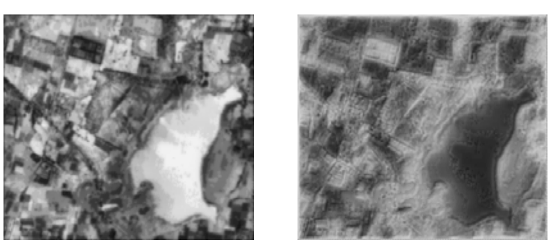
In this paper, image enhancement using multi resolution image pyramid is studied. It is seen that the entropy (image information content) is considerably increased with the use of pyramids.

The algorithm CLAHE (Contrast Limited Adaptive Histogram Equalization) is proved to be a better enhancement method in comparison to HE (Histogram Equalization) and AHE (Adaptive Histogram Equalization).

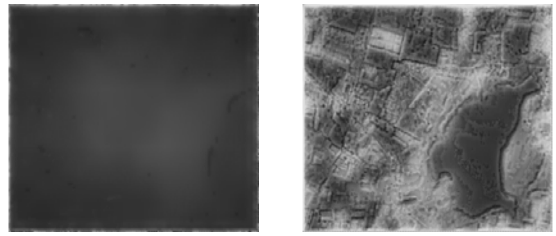
FUTURE WORK

The future work would involve using new adaptive enhancement methods and an extensive study with images from different categories such as multispectral, multitemporal, multisensor and medical image from different modalities

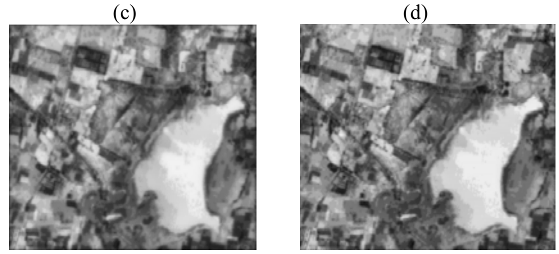
Figure 1. Input Images (a) Aerial & (b) Medical



(a) (b)



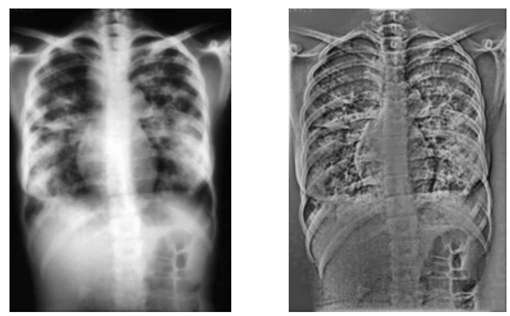
(c) (d)



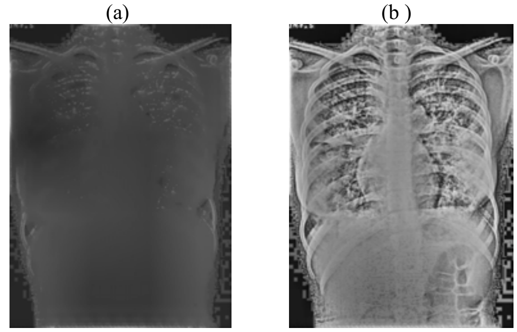
(e) (f)

Figure 2. Output Images

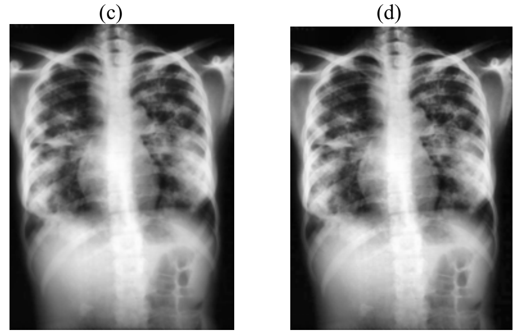
Results of CLAHE-Aerial Image for Gaussian, Laplacian, Ratio, Contrast, Mean, Subsampling Pyramids (a-f)



(a) (b)



(c) (d)



(e) (f)

Figure 3. Results of CLAHE-Medical Image for Gaussian, Laplacian, Ratio, Contrast, Mean, Subsampling Pyramids (a-f)

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APPENDIX – 1 ALGORITHM

I HISTOGRAM EQUALIZATION (HE)

STEPS: Manual input NIL

1) Compute the histogram of the input image, Hist [i] Where Hist[i] → Number of pixels with gray level i for each i=0,1,2,…,L-10,1,2,…,L-1 → Allowable gray levels in the digital image

2) Compute the cumulative histogram, $CumHist[j] = \sum_{i=0}^{j} Hist[i]$

3) Build an output mapping, that is, a look-up table LUT[i] = (L-1) * CumHist[i] / (M * N) Where M → the image height or the number of rows in the digital image, N → the image width or the number of columns in the digital image. Apply the output mapping obtained to each of the pixels in the input image to obtain the image enhanced by HE

II. ADAPTIVE HISTOGRAM EQUALIZATION (AHE)

STEPS: Manual input N

Divide the input image into an NxN matrix of sub-images

Compute the mapping from histogram equalization (HE) of each of these sub-images

For each pixel in the input image, do the following :

3.1) If the pixel belongs to an internal region (IR), then

(a) Compute four weights, one for each of the four nearest sub-images, based on the proximity of the pixel to the centers of the four nearest sub-images (nearer the center of the sub-image, larger the weight)

(b) Calculate the output mapping for the pixel as the weighted sum of the HE mappings for the four nearest sub-images using the weights computed above.

3.2) If the pixel belongs to an border region (BR), then

(a) Compute two weights, one for each of the two nearest sub-images, based on the proximity of the pixel to the centers of the two nearest sub-images

b) Calculate the output mapping for the pixel as the weighted sum of the HE mappings for the two nearest sub-images using the weights computed above.

3.3) If the pixel belongs to a corner region (CR), the output mapping for the pixel is the HE mapping for the sub-image that contains the pixel.

Apply the output mapping obtained to each of the pixels in the input image to obtain the image enhanced by AHE

III CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION. (CLAHE)

STEPS: Manual input N, CL (actual clipping level)

1) Divide the input image into an NxN matrix of sub-images

2) For each sub-image do the following

2.1) Compute the histogram of the sub-image

2.2) Calculate the nominal clipping level, P from the actual clipping level, C using the binary search.

2.3) For each gray level bin in the histogram do the following

(a) If the histogram bin is greater than the nominal clip level P, clip the histogram to the nominal clip level P

(b) Collect the number of pixels in the sub-image that caused the histogram bin to exceed the nominal clip level P.

2.4) Distribute the clipped pixels uniformly in all histogram bins to obtain the Renormalized clipped histogram.

2.5) Equalize the above histogram to obtain the clipped HE mapping for the sub-image

3. For each pixel in the input image, do the following

3.1) If the pixel belongs to an internal region (IR), then

(a) Compute four weights, one for each of the four nearest sub-images, based on

The proximity of the pixel to the centers of the four nearest sub-images (nearer the center of the sub-image, larger the weight).

(b) Calculate the output mapping for the pixel as the weighted sum of the clipped HE mappings for the four nearest sub-images using the weights computed above.

3.2) If the pixel belongs to an border region (BR), then

(a) Compute two weights, one for each of the two nearest sub-images, based on the proximity of the pixel to the centers of the two nearest sub-images

(b) Calculate the output mapping for the pixel as the weighted sum of the clipped HE mappings for the two nearest sub-images using the weights computed above.

3.3) If the pixel belongs to a corner region (CR), then the output mapping for the pixel is the clipped HE mapping for the sub-image that contains the pixel.

4. Apply the output mapping obtained to each of the pixels in the input image to obtain the image enhanced by CLAHE

APPENDIX - 2 QUALITY METRICS

a) Mean Squared Error (MSE)

MSE quantifies the global difference between a enhanced image and an original image. It is defined as follows:

$$MSE = \frac{1}{N}\sum_{i=0}^{N-1}(x_i - y_i)^2 \quad (1)$$

Where x_i the *i*th pixel of the original image, and y_i is the *i*th pixel of the enhanced image and n is the total size of the image.

b) Mean Average Error (MAE)

MAE measures the average magnitude of the errors and is defined as follows:

$$MAE = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N} \left| x(m,n) - \hat{x}(m,n) \right| \quad (2)$$

Where $x(m,n)$ and $\hat{x}(m,n)$ denote the samples of original image and enhanced image, respectively. M and N are number of pixels in row and column directions, respectively.

c) Peak Signal to Noise Ratio (PSNR)

PSNR is used to measure similarity of the fused image is defined as

$$PSNR = 20.\log_{10}\left(\frac{255}{MSE}\right) \quad (3)$$

d) Structural Correlation (SC)

SC estimates the similarity of the structure of two images and is defined as follows:

$$SC = \sum_{j=1}^{M}\sum_{k=1}^{N}[F(j,k)]^2 / \sum_{j=1}^{M}\sum_{k=1}^{N}[\hat{F}(j,k)]^2 \quad (4)$$

Where F (j, k) and $\hat{F}(j,k)$ denote the samples of original image and enhanced image, respectively. M and N are number of pixels in row and column directions, respectively

e) Maximum Difference (MD):

MD measure which takes the maximum of the difference between original and enhanced image and is defined as follows

$$MD = Max\left(\left| x(m,n) - \hat{x}(m,n) \right| \right) \quad (5)$$

Where $x(m,n)$ and $\hat{x}(m,n)$ denote the samples of original image and enhanced image, respectively. M and N are number of pixels in row and column directions

f) Universal Quality Index (UQI)

UQI measures image similarity across distortion types. Distortions in UQI are measured as a combination of three factors; Loss of correlation, Luminance distortion and Contrast distortion. Let x = {xi │ i= 1, 2… N} and y= {yi │i=1, 2… N} are the original and the test image (enhanced), respectively. The proposed quality index is defined as

The first component is correlation coefficient between x and y, the second component measures mean luminance between x and y and third component measures how similar the contrasts of the images are.

h) *Absolute Mean Brightness Error (AMBE)*

AMBE measures the deviation of the processed image mean from the input image mean and is defined as

$$AMBE = \left| \mu_p - \mu_o \right|$$

i) Entropy

A measure of the amount of information that can be derived from the image .Value of entropy as 8 for an image having uniform histogram where P(u) = number of pixels Di of each gray level i / number of pixels D in the image

$$Entropy, \quad E = -\sum_{u=0}^{255} P(u) \log_2 P(u) \qquad (8)$$

APPENDIX-3A

QUALITY METRICS FOR ENHANCEMENT (AERIAL IMAGE-ENTROPY OF ORIGINAL IMAGE-3.169)

$$UQI = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \cdot \frac{2\overline{x}\overline{y}}{\overline{x}^2 + \overline{y}^2} \cdot \frac{2\sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2} \qquad (6)$$

g) *Structural Similarity (SSIM)*

SSIM measures the image similarity and greater value indicates greater image similarity and is defined as

$$Qo = 4\sigma_{xy}\overline{x}\overline{y} \Big/ (\overline{x}^2 + \overline{y}^2)(\sigma_x{}^2 + \sigma_y{}^2),$$

$$SSIM\ (x, y) = [l(x, y)]^{\alpha} \cdot [c(x, y)]^{\beta} \cdot [s(x, y)]^{\gamma} \qquad (7)$$

Where x and y are the enhanced and original image to operate on, l(x, y) is the luminance comparison, c(x, y) is the contrast comparison, and s(x, y) is the structure comparison

TABLE I. GAUSSIAN PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	**218.920**	**2.710**	**24.728**	0.945	**110**	**0.983**	**0.983**	**2.710**	7.797
AHE	3207.965	2.814	13.068	0.878	188	0.704	0.705	2.814	7.826
CLAHE	1365.811	4.056	16.777	**0.871**	171	0.891	0.891	4.056	**7.858**

TABLE II. LAPLACIAN PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	8018.726	**12.370**	9.089	0.976	227	**0.248**	**0.252**	**12.370**	7.711
AHE	8211.945	14.169	8.987	0.992	235	0.225	0.229	14.169	**7.750**
CLAHE	**7180.606**	14.012	**9.570**	**0.590**	**197**	0.153	0.159	14.012	7.078

TABLE III. RATIO PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	3973.654	9.694	12.138	1.288	157	**0.511**	**0.522**	9.694	**7.496**
AHE	3140.911	9.855	13.160	1.260	151	0.430	0.445	9.855	7.365
CLAHE	**3053.968**	**0.280**	**13.282**	**1.081**	**138**	0.494	0.509	**0.280**	7.323

TABLE IV. CONTRAST PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	13034.563	112.759	6.980	3.720	157	0.255	0.317	112.759	4.078
AHE	13014.729	112.616	6.987	3.718	161	**0.289**	**0.342**	112.616	5.093
CLAHE	**3807.721**	**57.123**	**12.324**	**0.277**	**128**	0.162	0.214	**57.123**	**5.391**

TABLE V. MEAN PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	3873.564	10.395	12.249	1.305	157	**0.427**	**0.439**	10.395	**7.519**
AHE	3009.806	10.837	13.345	1.283	152	0.316	0.334	10.837	7.407
CLAHE	**2917.120**	**4.980**	**13.481**	**1.008**	**152**	0.385	0.402	**4.980**	7.313

TABLE VI. SUBSAMPLING PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	2687.215	17.042	13.838	1.594	91	0.517	0.522	17.042	7.847
AHE	2721.025	19.505	13.784	1.611	117	0.483	0.489	19.505	**7.893**
CLAHE	**1342.817**	**13.524**	**16.851**	**1.397**	**79**	**0.628**	**0.634**	**13.524**	7.629

APPENDIX 3B

QUALITY METRICS FOR ENHANCEMENT (MEDICAL IMAGE-ENTROPY-7.710)

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	2851.257	23.657	13.581	1.713	93	0.522	0.528	23.657	7.592
AHE	3182.547	27.988	13.103	1.784	125	0.474	0.480	27.988	**7.866**
CLAHE	**1249.422**	**12.769**	**17.163**	**1.381**	**80**	**0.646**	**0.653**	**12.769**	7.542

TABLE I. GAUSSIAN PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	**218.920**	**2.710**	**24.728**	0.945	**110**	**0.983**	**0.983**	**2.710**	7.797
AHE	3207.965	2.814	13.068	0.878	188	0.704	0.705	2.814	7.826
CLAHE	1365.811	4.056	16.777	**0.871**	171	0.891	0.891	4.056	**7.858**

TABLE II. LAPLACIAN PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	5829.577	14.917	10.474		242	**0.487**	**0.490**	14.917	7.550
AHE	6029.361	20.196	10.328	1.082	240	0.469	0.472	20.196	**7.681**
CLAHE	**5798.202**	**1.532**	**10.497**	**0.785**	**232**	0.355	0.359	**1.532**	7.190

TABLE III. RATIO PYRAMID

Parameters / Enhancement methods	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Entropy
HE	**225.072**	**2.701**	**24.608**	0.945	**110**	**0.983**	**0.983**	**2.701**	7.798
AHE	3194.441	2.734	13.086	0.876	188	0.704	0.706	2.734	7.825
CLAHE	1371.886	4.085	16.758	**0.869**	171	0.890	0.890	4.085	**7.860**

APPENDIX 4

COMPARISON OF ENTROPY VALUE WITH AND WITHOUT USING PYRAMIDS

TABLE-1 EXAMPLE: GAUSSIAN PYRAMID

Parameters / Enhancement Methods	Entropy value without pyramids	Entropy value Gaussian pyramid
HE	3.167	7.797
AHE	7.757	7.826
CLAHE	7.263	7.858