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Image Enhancement by Histogram Specification Using Multiple Target Images

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Abstract— Shape and characteristics of the histogram plays a major role in finding the quality of an image. Histogram Specification is an image enhancement technique, where the histogram of the input image is transformed to a pre-specified histogram derived from a high resolution image, called target image. In this paper, the classical histogram specification technique is extended by using a target image which is obtained by fusing multiple high resolution images. A set of Quality Metrics were identified to assess the quality of the output enhanced image.

The paper addresses the following issues:

- a) Effect of varying the number of target images on the quality of the output enhanced image
- b) Role of using different methods of fusion on the quality of the output enhanced image
- c) Category of the target image on the quality of the output enhanced image. If the input image is from a forest, whether in order to obtain an enhanced image, all target images has to be selected from the forest category
- d) Effect of preprocessing of target image on the quality of the output enhanced image.

Keywords—Histogram Specification, Image Fusion, Quality Metrics

I. INTRODUCTION

Histogram modeling techniques provide sophisticated methods of modifying the dynamic range and contrast of an image by altering each individual pixel, such that its intensity histogram assumes a desired shape. Histogram specification, or histogram matching, is a basic histogram modeling technique that transforms one histogram into another by remapping the pixel values to control the relative frequency of their occurrence. Histogram specification employs a simple monotonic, nonlinear mapping which re-assigns the intensity values of pixels in the input image such that the target and output image histograms resembles each other as much as possible[1]- [3]. A large number of research work is done for image enhancement using histogram specification technique [4]-[7]. Most of the work uses a single image as the target image. In this paper, we have proposed an enhancement

technique based on Histogram Specification, where multiple target images are fused to obtain a single target image. Large number of research work is proposed [8]-[9]. For pixel and window based image fusion. The window based fusion method using spatial frequency and visibility used in our paper is similar to the one proposed by Maruthi and Sankarasubramanian [8]. In this paper an additional feature Entropy is also used for fusion. Study is made to show the effect of varying parameters such the number of target images fused, nature of target images, method of target fusion and dependence on the category of target image on the output enhanced image by Histogram Specification.

II. HISTOGRAM SPECIFICATION

Many applications require a desirable shape of the histogram. The objective of Histogram Specification (HS) is to generate an output image that has a specified desirable histogram. Histogram Specification algorithm is also called Histogram matching. The classical Histogram Specification algorithm is given in Appendix - 1.

The target image must be an image with wide range of grey values, high resolution and noise free. Since it is only the histogram that is required from the target image, it can be obtained by fusing multiple target images used in the histogram specification algorithm for enhancing the input image. Hence, the target image can be a single image or an image obtained by fusing multiple target images having desired histogram shape.

III. IMAGE FUSION

Image fusion is a process of combining images which results in a single image having complementary information from the source images which is otherwise not available in a single image. Hence we fuse multiple images to obtain the desired histogram which otherwise is not available from a single image.

The fusion process in the proposed method is carried out by window based fusion where features are calculated on sub windows of the input images. The features chosen are several characteristic properties of the image like Entropy (high information content), Spatial Frequency (high activity level) and Visibility (clarity).

A. Entropy (En)

Image entropy is an important parameter for measuring information content of an image. Higher value of entropy in the fused image means higher information content [10]. Let $H[i]$ is the number of pixels of intensity i , then Probability Density Function (PDF) is $p[i]$, Entropy is given as,

$$En = - \sum p[i] \log_2 p[i] \quad (1)$$

B. Spatial Frequency (SF)

Spatial frequency measures the overall activity level in an image. For an $M \times N$ image block F , with gray value $F(m, n)$ at position (m, n) , the spatial frequency is defined as

$$SF^2 = RF^2 + CF^2 \quad (2)$$

Where RF and CF are the row frequency, defined as,

$$RF = \sqrt{\frac{1}{MN} \sum_{m=1}^M \sum_{n=2}^N (F(m, n) - F(m, n-1))^2}$$

$$CF = \sqrt{\frac{1}{MN} \sum_{n=1}^N \sum_{m=2}^M (F(m, n) - F(m-1, n))^2}$$

C. Visibility (V)

Visibility is a measure of how clearly an image can be viewed.

$$V = \sum_{m=1}^M \sum_{n=1}^N \frac{|F(m, n) - \mu|}{\mu^{\alpha+1}} \quad (3)$$

μ is the mean intensity value of the image and α is a visual constant which varies from 0.6 to 0.7.

Image Fusion rule:

For each sub window of size $(n \times n)$ of the input images, the feature values are calculated and the elements of the window having a higher value of feature are used to form the corresponding window of the fused image. The sub window is slid by single pixel over the entire image to form the fused image.

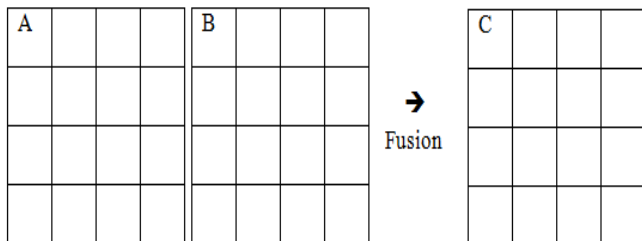


Figure 1. Window Based Image Fusion

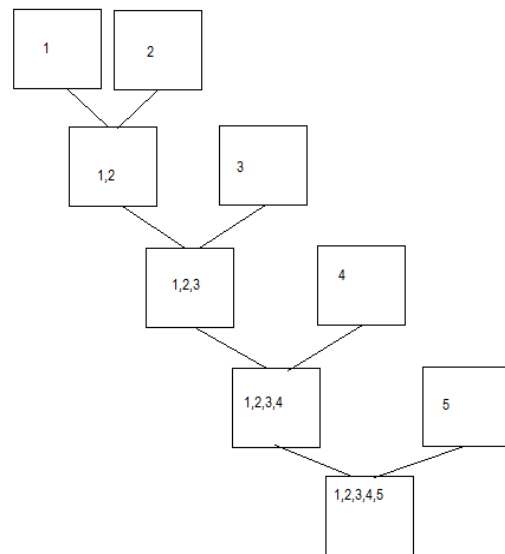


Figure 2. Block diagram of Target Image Fusion

IV. EXPERIMENTAL STUDY

The objectives of the experiments are as follows:

- Study with multiple target images
- Study with different methods of fusion
- Study with preprocessed target image(s)
- Study with target images from various categories

Five set of target images are selected based on their histogram and visual appearance. The images are fused hierarchically and each of the intermediate fused images is used to specify the histogram. The fusion of the target image is based on the method described in section 3. The output images obtained are subjected to quality metrics analysis for comparative study of enhancement techniques. The targets are then pre processed using Histogram Equalization. The outputs are subjected to quality assessment. To study the effect of dependence of the category of target images, images of forest, habitation, rocks and water body are chosen. All the enhanced images so obtained are subjected to quality assessment

V. QUALITY METRIC (QM)

Quality assessment of images aims at quantification of image quality by means of quality metrics. In this paper, we have used objective measurement of quality parameters such as MSE [11], MAE, PSNR [11], SC [12], MD [12], UQI, SSM [11], MSSM [12], Contrast and AMBE [2]. These parameters are used to measure the quality of the enhanced image with respect to the original image. The details of the quality parameters are given in Appendix - 2.

VI. RESULTS AND CONCLUSION

Quality assessment of enhanced images shows that histogram specification with target images of same category fused with T3 and T2 gives comparatively better result. Study, further shows that changes in the sequence of target images to be fused, change in image features for fusion, change in image categories affects the quality of the enhanced image. The results are shown from Table 1 to Table 7.

The Quality Metrics used for the enhancement (described in section 5) indicates that the enhancement is better when it has low values for MSE, MAE, SC, MD and AMBE and high values for PSNR, UQI, SSM and Contrast. Study with single target images show that the enhancement is better with target T3 and T2 where as it is comparatively poorer with target T4 and T5.

A. Study with Multiple Target Images

The enhancement is better when targets T3 and T2 are fused where as it is of low quality when T4 and T5 are fused. This indicates that the quality of enhancement does not depend on the number of target images but on the quality of the target image (Fig. 5-6 and Tables 2-3).

B. Study with different method of Target image fusion

The Quality Metric values show that the enhancement is better with the target images generated using window based fusion, and visibility as the image attributes (Fig. 5, 7, 8 and Tables 2, 4, 5).

C. Study with Preprocessed Target Images

When the target images are preprocessed using histogram equalization prior to the specification, the output enhanced image almost gave same values for different number of target images. This is because once the target image is equalized, it reaches saturation and addition of any number of target images does not affect the final enhanced image (Fig. 9 and Table 6).

D. Study of Target image from various categories

When targets of different categories are used for enhancement, the Quality Metrics indicates that the enhancement is independent of the category. The Enhancement by fused image of habitation, rock and water is better than the enhancement by fused image of T1, T2 and T3 which are from the same category. Hence, to enhance an image of forest, the target images need not be essentially from the same category (Fig. 10 and Table 7)

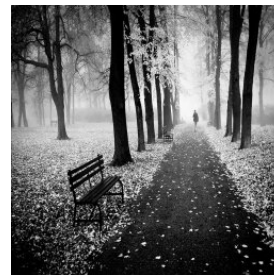


(a)

(b)



(c)



(d)



(e)



(f)



(g)



(h)



(i)

Figure 3. Image data base used for the present study (a) Input image, (b)Target T1, (c) Target T2, (d) Target T3, (e) Target T4 (f) Target T5, (g) Habitation, (h) Rock, (i) Water body



(a)

(b)



(c)

(d)

Figure 5. Enhancement by targets fused by Entropy as attribute,(a) Enhancement by target T1 and T2, (b) Enhancement by target T1,T2 and T3, (c) Enhancement by target T1, T2,T3 and T4, (d) Enhancement by target T1, T2, T3, T4 and T5



(a)

(b)



(c)

(d)



(e)

Figure 4. Enhancement by Single Target (a) Enhanced by T1, (b) Enhanced by T2, (c) Enhanced by T3, (d) Enhanced by T4, (e) Enhanced by T5



(a)

(b)



(c)

(d)

Figure 6. Enhancement by targets fused in different order by Entropy as attribute (a) Enhancement by target T3 and T1, (b) Enhancement by target T3,T1 and T2, (c) Enhancement by target T3, T1,T2 and T4, (d) Enhancement by target T3, T1, T2, T4 and T5

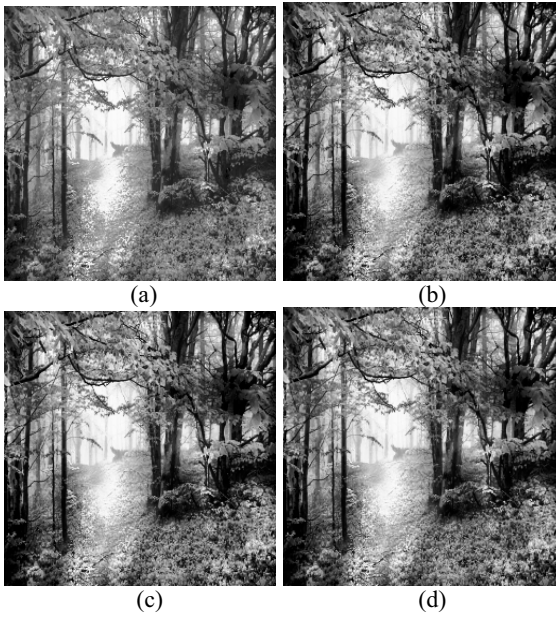


Figure 7. Enhancement by targets fused by Spatial Frequency as attribute. (a) Enhancement by target T1 and T2, (b) Enhancement by target T1, T2 and T3, (c) Enhancement by target T1, T2, T3 and T4, (d) Enhancement by target T1, T2, T3, T4 and T5

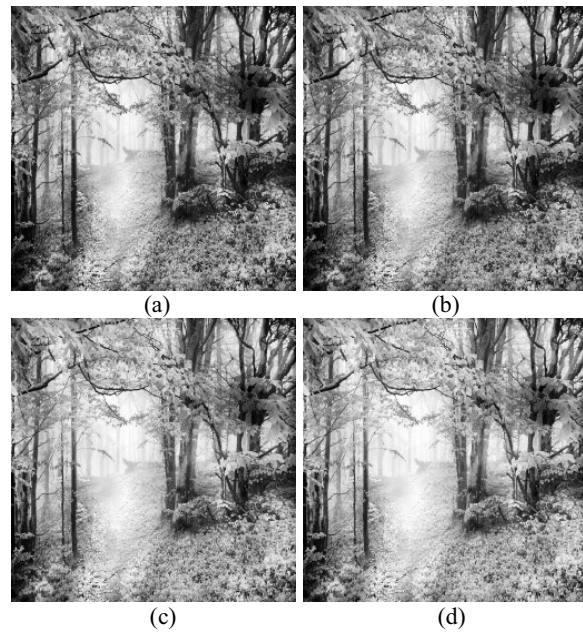


Figure 9. Targets enhanced by Histogram Equalization and fused by Entropy as attribute. (a) Enhancement by target T1 and T2, (b) Enhancement by target T1, T2 and T3, (c) Enhancement by target T1, T2, T3 and T4, (d) Enhancement by target T1, T2, T3, T4 and T5

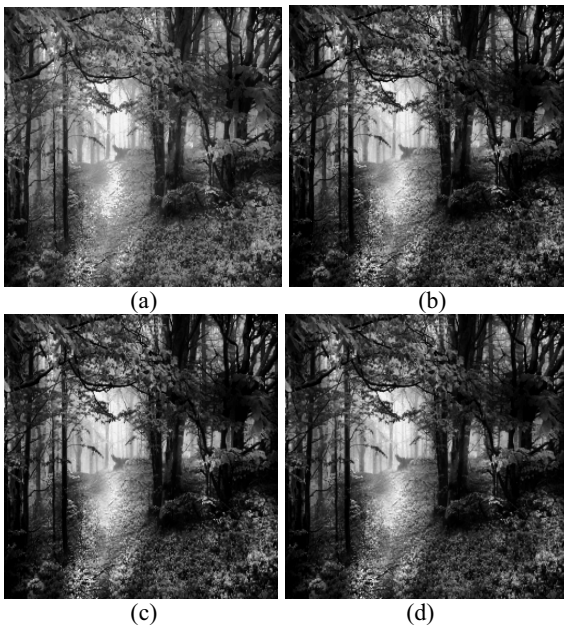


Figure 8. Enhancement by targets fused by Visibility as attribute. (a) Enhancement by target T1 and T2, (b) Enhancement by target T1, T2 and T3, (c) Enhancement by target T1, T2, T3 and T4, (d) Enhancement by target T1, T2, T3, T4 and T5

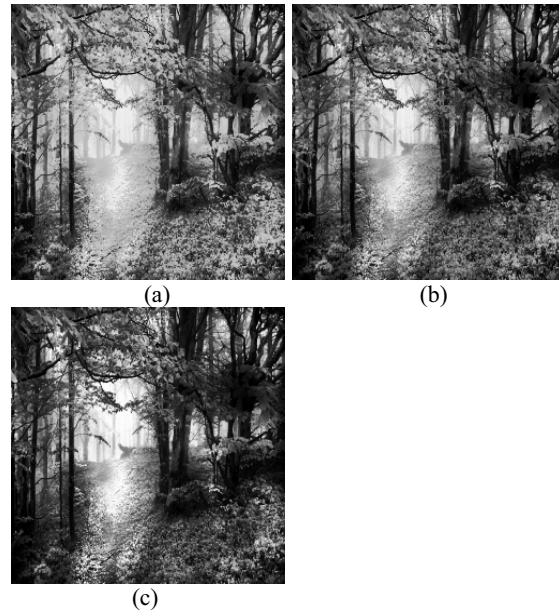


Figure 10. Targets fused by Visibility as attribute (a) Enhancements by Habitation, (b) Enhancement by Habitation and Rock, (c) Enhancement by Habitation, Rock and Water

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A. Appendix-I

1) Algorithm Histogram Specification

Read input image and the target image

Find the histogram of input and target image, and

$$p_x(i) \quad p_z(i)$$

Find histogram equalization mapping of the input image,

$$F_x(j) = \sum_{i=0}^j p_x(i)$$

Find histogram equalization mapping of the target image,

$$F_z(j) = \sum_{i=0}^j p_z(i)$$

$$F_x(l)$$

Build Lookup table, for each grey level l in find the corresponding $F_z(j)$ level j such that $F_z(j)$ best matches

$$F_x(l)$$

$$|F_x(l) - F_z(j)| = \min_k |F_x(l) - F_z(k)|$$

Enter value in the look up table as,

$$lookup(l) = j$$

The output image is obtained from the above created look up table.

B. Appendix-II

1) Quality Metric

a) Mean Squared Error (MSE)

MSE quantifies the global difference between a enhanced image and an original image; hence MSE is a full-reference metric and is defined as follows:

$$MSE = \frac{1}{N} \sum_{i=0}^{N-1} (x_i - y_i)^2 \quad (4)$$

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:

$$MAE = \frac{1}{MN} \sum_{m=1}^M \sum_{n=1}^N |x(m, n) - \hat{x}(m, n)| \quad (5)$$

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, respectively.

c) Peak Signal to Noise Ratio (PSNR)

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

$$PSNR = 20 \cdot \log_{10} \left(\frac{255}{MSE} \right) \quad (6)$$

d) Structural Correlation (SC)

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

$$SC = \sum_{j=1}^M \sum_{k=1}^N [F(j, k)]^2 / \sum_{j=1}^M \sum_{k=1}^N [\hat{F}(j, k)]^2 \quad (7)$$

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:

$$MD = \text{Max} (|x(m, n) - \hat{x}(m, n)|) \quad (8)$$

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 $x = \{x_i \mid i=1, 2, \dots, N\}$ and $y = \{y_i \mid i=1, 2, \dots, N\}$ are the original and the test image (enhanced), respectively. The proposed quality index is defined as

$$UQI = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \cdot \frac{2\bar{x}\bar{y}}{x^2 + y^2} \cdot \frac{2\sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2} \quad (9)$$

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

g) *Structural Similarity (SSIM)*

SSIM measures the image similarity and higher

Value indicates greater image similarity and is defined as

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

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.

Mean Structural Similarity (MSSIM)

MSSIM is the average of SSIM values over all windows to compute the overall image quality and is defined as follows:

$$MSSIM(x, y) = \frac{1}{M \times N} \sum_{M, N} SSIM_{(x, y)} \quad (11)$$

h) *Absolute Mean Brightness Error (AMBE)*

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

$$AMBE = |\mu_p - \mu_o| \quad (12)$$

i) *Contrast*

Contrast measures the clarity with which objects or regions in the image can be identified. It is estimated by the value of the standard deviation of pixel intensities in the image,

$$Contrast, \sigma = \frac{1}{mn} \sqrt{\sum_{i=1}^m \sum_{j=1}^n [f(i, j) - M]^2} \quad (13)$$

Where m and n are the height and width of the image and M is the global mean.

TABLE I. QM FOR ENHANCEMENT BASED ON SINGLE TARGET

Parameters									
Input File Name	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Contrast
Input, Target1	5001.850	63.431	11.139	4.211	128.000	0.315	0.613	63.432	59.219
Input, Target2	1450.170	28.931	16.517	2.404	80.000	0.769	0.772	28.931	52.617
Input, Target3	3392.108	36.949	12.826	3.277	101.000	0.593	0.596	36.950	71.988
Input, Target4	7007.582	91.340	9.675	4.998	117.000	0.630	0.632	81.340	47.672
Input, Target5	2725.494	48.975	13.776	3.157	94.000	0.754	0.576	48.975	46.407

TABLE II. MULTIPLE TARGET IMAGES FUSED BY ENTROPY

Parameters	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Contrast
Input File Name									
Input, Target 1+2	3612.770	53.907	12.552	3.5900	111.000	0.6732	0.6756	53.907	54.674
Input, Target1+2+3	3670.850	52.160	12.483	3.600	104.000	0.647	0.650	52.160	58.574
Input, Target1+2+3+4	4853.134	63.073	11.271	4.138	110.000	0.621	0.623	63.073	57.169
Input, Target1+2+3+4+5	4579.894	60.706	11.522	4.0224	109.000	0.627	0.629	60.706	57.669

TABLE III. MULTIPLE TARGET IMAGES FUSED BY ENTROPY IN DIFFERENT ORDER

Parameters	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Contrast
Input File Name									
Input, Target3+1	4061.625	54.274	12.044	3.770	108.000	0.622	0.625	54.274	60.959
Input, Target3+1+2	3723.595	52.710	12.421	3.623	104.000	0.646	0.648	52.711	58.414
Input, Target3+1+2+4	4883.228	63.301	11.244	4.150	109.000	0.620	0.622	63.301	57.131
Input, Target3+1+2+4+5	4594.281	60.776	11.509	4.028	109.000	0.626	0.628	60.776	57.720

TABLE IV. MULTIPLE TARGET IMAGES FUSED BY SPATIAL FREQUENCY

Parameters	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Contrast
Input File Name									
Input, Target 1+2	4173.71	57.327	11.926	3.847	122.000	0.640	0.642	57.327	57.837
Input, Target1+2+3	3962.242	47.245	12.151	3.660	117.000	0.590	0.593	47.245	69.158
Input, Target1+2+3+4	4292.539	50.175	11.804	3.817	119.000	0.578	0.581	50.175	69.630
Input, Target1+2+3+4+5	4206.855	50.656	11.891	3.795	119.000	0.587	0.590	50.656	68.143

TABLE V. MULTIPLE TARGET IMAGES FUSED BY VISIBILITY

Parameters									
Input File Name	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Contrast
Input, Target 1+2	1340.488	26.379	16.858	2.324	102.000	0.773	0.776	26.379	53.466
Input, Target1+2+3	934.710	4.996	18.424	1.699	93.000	0.777	0.780	4.996	57.591
Input, Target1+2+3+4	1019.356	6.075	18.048	1.761	93.000	0.766	0.769	6.075	58.746
Input, Target1+2+3+4+5	840.826	4.064	18.884	1.634	93.000	0.790	0.793	4.064	56.189

TABLE VI. MULTIPLE TARGET IMAGES (ENHANCED BY HISTOGRAM EQUALIZATION) FUSED BY ENTROPY

Parameters									
Input File Name	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Contrast
Input, Target 1+2	6568.547	70.348	9.956	4.821	120.000	0.529	0.532	70.348	66.926
Input, Target1+2+3	6612.467	71.519	9.927	4.845	119.000	0.535	0.538	71.518	65.416
Input, Target1+2+3+4	6567.340	70.633	9.957	4.827	120.000	0.532	0.535	70.633	66.541
Input, Target1+2+3+4+5	6492.651	69.677	10.007	4.794	121.000	0.530	0.533	69.677	67.321

TABLE VII. QM FOR ENHANCEMENT BY HS USING TARGETS FROM VARIOUS CATEGORIES

Parameters									
Input File Name	MSE	MAE	PSNR	SC	MD	UQI	SSM	AMBE	Contrast
Input, Habitation	4487.680	55.232	11.610	3.917	104.000	0.584	0.587	55.232	64.438
Input, Habitation+ Rock	2118.094	31.623	14.871	2.736	98.000	0.693	0.696	31.623	61.343
Input, Habitation+ Rock + Water	1969.389	21.893	15.187	2.491	115.000	0.680	0.683	21.893	66.090