Artifacts Removal of Compressed Digital Images by Linear Enhancement and Filtering

Shanty Chacko, F. T. Josh, J. Jayakumar

***Abstract**: Digital images that are compressed by JPEG compression schemes are affected by compression artifacts. The blocking artifacts and the ringing artifacts are the commonly seen compression artifacts. These artifacts need to be removed when we decompress the image for various applications. The objective of this work is to remove these artifacts without degrading the image. These compression artifacts can be reduced by low pass filtering of compressed mages. Low pass filtering of images cause loss of information whereby the images get blurred or the clarity of images get reduced. In this work, compressed image is first enhanced using linear enhancement technique and the resulting enhanced image is filtered using Gaussian type filter. The enhanced artifacts are removed more effectively when filtering is done in the enhanced image domain. After the removal of compression artifacts the linear enhancement is removed by the inverse of the transform which is used for linearly enhancing the image. After the removal of artifacts images will be of good quality which can be used in application areas like analysis medical image, analysis of satellite image, remote sensing and product inspection in industry.*

***Index Terms**: Blocking artifacts, Block DCT, Image enhancement, Ringing artifacts.*

I. INTRODUCTION

The digital images are compressed to reduce the image size so that its storage space requirement will be much lesser compared to the original image. Also, the band width required for transmitting a compressed image will be much smaller compared to the original digital image. The two dimensional Discrete Cosine Transform is applied to sub images or blocks to compress the digital images into the standard JPEG form.

When the digital images are compressed using the above transform, the image quality will be degraded due to the visual compression artifacts. The break of correlation between the adjacent sub images or blocks will result in blocking artifacts. Also, while coding the image, high frequency components present in the image will be lost which will cause ringing artifacts. Researchers have done lots of research in this area to reduce the artifacts and thereby to improve the image quality, when the compressed images are used for various applications. The theory of projection on to convex sets is a technique used by researchers [1], [3] to remove the artifacts which are caused by the image compression; but it requires lot of computation because of which not suitable for real time applications. Wavelet transform technique [2], [3] is also used by the researchers for removing the visual artifacts and found to be useful. In Adaptive filters [6], filter weights are adaptively changed in accordance with the image features and the technique is found to be very useful for removing the compression artifacts. A. Zakhor [5] proposed an iterative technique in the transformed domain to suppress the artifacts in the compressed image. In [7], [8], weighted averaging of pixels is used in spatial domain and these weights decide the filtering strength. Weighted sums of symmetrically aligned pixels of adjacent sub images can be used [7] to reduce the discontinuity at the borders of sub images. Adaptive fuzzy filters [8] and Adaptive bilateral filter uses the averaging technique within a window depending on the image characteristics and features. Filtering strength and window size can be varied [4] in the filtering operation to achieve better quality image. In 3D spatial filter [9], negative of the compressed image is used for the filtering operation to remove compression artifacts. Total Variation minimization technique is also used by researchers in various applications to remove the compression artifacts.

A simple, yet very effective technique is proposed in this work in which the compressed image is first enhanced using piecewise linear enhancement technique, and the resultant enhanced image is filtered using Gaussian type low pass filter. When the compressed images are linearly enhanced, artifacts are also enhanced along with other image features. This enhanced compression artifacts are suppressed by Gaussian type low pass filter. After the filtering is done, piecewise linear enhancement is removed by the inverse transform and hence the artifacts removed image is recovered. The linear enhancement technique and the filtering technique used in this work is discussed in section 2 ,flow chart and algorithms are given section 3, the result is discussed and compared in section 4 .The article is concluded in section 5.

II. LINEAR ENHANCEMENT AND FILTERING OF COMPRESSED IMAGE

Image enhancement is the technique used to change an image into a form which is more suitable for some specific application. Images can be enhanced in spatial domain or in frequency domain. Some of the commonly used image enhancement techniques are given in [10]. Image filtering itself is an image enhancement technique by its definition. In this work, the equation used for image enhancement is depicted in (1).

$$I_e(x,y) = A * I(x,y) + B \qquad (1)$$

where I_e represent enhanced image, I represent image before enhancement, x and y represent pixel location (row number and column number), and A and B are constants. A Gaussian type low pass filter (window size of 5X5) is applied to the image which is already enhanced using Piecewise linear enhancement

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technique. The function used for filtering is given in (2).

$$I_f(i,j)=\frac{\sum e^{-(I_e(u,v)-I_e(i,j))^2/(\sigma^2)} * I_e(u,v)}{\sum e^{-(I_e(u,v)-I_e(i,j))^2/(\sigma^2)}} \qquad (2)$$

where I_f represents the filtered image and I_e represent unfiltered image. The row number and column number of the images are represented by the alphabets 'i' and 'j' respectively. 'u' and 'v' represent row and column numbers respectively of the pixels within the window of size 5X5 surrounding the pixel $I_e(i,j)$ with the pixel $I_e(i,j)$ at the centre of the window, and σ is a parameter which decides filtering strength. In this filter, σ value of 100 is used. Once filtering is done, linear enhancement is removed by the inverse transform equation given in (3).

$$I_r(x,y)=\left(I_f(x,y)-B\right)/A \qquad (3)$$

where I_r represents the recovered image after removing the enhancement. It has been observed that the image quality is improved by a large extent compared to the image which is filtered directly without enhancement. The peak signal to noise ratio is used here to measure the image quality.

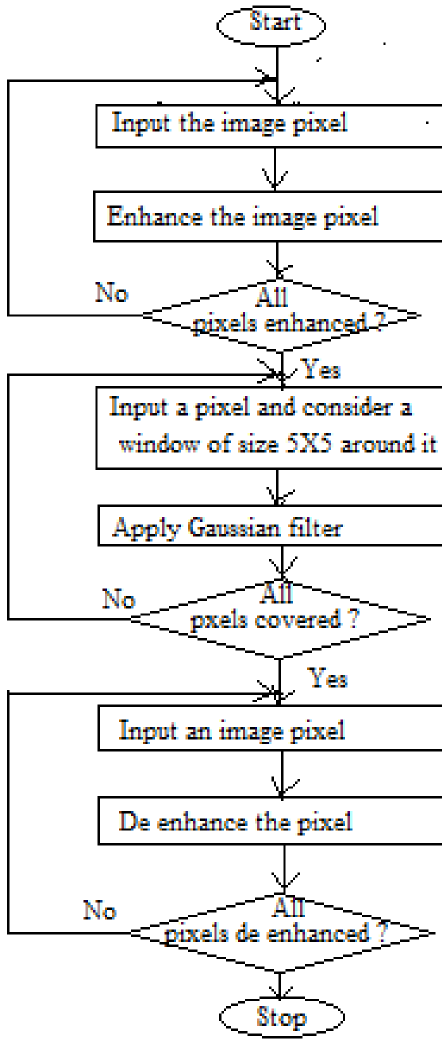
It has also been observed that when the value of 'A' in the linear enhancement function is varied, the peak signal to noise ratio (PSNR) value of the restored image is also varied. The PSNR value reaches a maximum value when the value of 'A' reaches 'an optimum value named as A_{opt}.

III. ALGORITHM AND FLOW CHART

Algorithm

Step1: Get the first pixel of the compressed image.
Step2: Enhance the image pixel by applying the equation 1.
Step3: Continue the process till all the pixels are enhanced.
Step4: Extent the image at the top and bottom by two rows by simply repeating the top and bottom rows
Step5: Extent the image at the left and right by two columns by simply repeating the left most and right most columns.
Step6: Consider a window of 5X5 around each pixel and apply Gaussian filter
Step7: Get each pixel of filtered image.
Step8: Deenhance the filter by applying equation 3.
Step9: Continue the de enhancement process till all the pixels are de enhanced.

Flow Chart



The first part of the flowchart deals with the enhancement of each of the image pixels, the second part deals with image filtering and the third part deals with deenhancement of each of the image pixels. Gaussian type low pass filter with a window size of 5X5 is used for the image filtering operation.

IV. RESULT AND DISCUSSIONS

MATLAB software is used to implement the enhancement and the filtering of compressed image. PSNR value [15] is measured and used to compare the quality of the filtered images. Various standard compressed images are used for linear enhancement and filtering. The PSNR values obtained when filtering is done on linearly enhanced images are tabulated in Table 1 and the same is compared with PSNR values obtained when filtering is done without enhancement. It can be seen that the PSNR values are much more when filtering is done after enhancement.

Table 1 -Comparison of PSNR Values between Gaussian filtered compressed images with and without enhancement

Image	**Compression Ratio in %**	**Gaussian Filter**	**Gaussian Filter with enhancement**	A_{opt}
Lena	91.40	31.13	34.29	7
Lena	86.30	31.49	38.62	31
Barbara	86.20	25.26	29.64	6.3
Barbara	81.70	25.51	36.93	32
Pepper	91.49	31.53	33.85	5.1
Pepper	85.56	32.07	37.13	25
Bridge	81.95	24.79	27.78	8.2
Bridge	74.00	25.27	33.46	14
Crowd	87.32	29.21	33.21	6.8
Crowd	82.96	29.58	38.72	20
Boat	88.40	28.05	31.68	6.8
Boat	82.26	28.43	36.60	22
Zelda	93.10	33.93	36.35	8.0
Zelda	88.62	34.25	40.10	40
Trucks	86.08	27.68	30.04	9.2
Trucks	78.53	27.89	34.30	16
Couple	87.60	27.29	31.52	8.0
Couple	81.93	27.60	36.85	24
Clown	90.01	29.74	34.11	9.2

Compressed Boat image, Filtered Boat image without enhancement, and filtered Boat image with enhancement are shown in Figure 1(a), I(b) and 1 (c) respectively. Improvement in quality is clearly visible in the figure. Similarly, results obtained when other standard images are used, are displayed in Figures 2-9.


Figure. 1 (a)


Figure. 1 (b)


Figure. 1 (c)

Fig. 1 (a) Compressed Boat image (b) Filtered Boat image (c) Boat image filtered after linear enhancement.


Figure. 2 (a)


Figure. 2 (b)


Figure. 2 (c)

Fig. 2 (a) Compressed Cameraman image (b) Filtered Cameraman image (c) Cameraman image filtered after linear enhancement.


Figure. 3 (a)


Figure. 3 (b)


Figure. 3 (c)

Fig. 3 (a) Compressed Lena image (b) Filtered Lena image (c) Lena image filtered after linear enhancement.


Figure. 4(a)


Figure. 4(b)

Figure. 4(c)

Fig. 4(a) Compressed Barbara image (b) Filtered Barbara image (c) Barbara image filtered after linear enhancement.

Figure. 5 (a) **Figure. 5 (b)**

Figure. 5 (c)

Fig. 5 (a) Compressed Pepper image (b) Filtered Pepper image (c) Pepper image filtered after linear enhancement.

Figure. 6(a) **Figure. 6(b)**

Figure. 6 (c)

Fig. 6 (a) Compressed Bridge image (b) Filtered Bridge image (c) Bridge image filtered after linear enhancement.

Figure. 7(a) **Figure. 7(b)**

Figure. 7(c)

Fig. 7(a) Compressed Crowd image (b) Filtered Crowd image (c) Crowd image filtered after linear enhancement.

Figure. 8(a) **Figure. 8(b)**

Figure. 8(c)

Fig. 8(a) Compressed Zelda image (b) Filtered Zelda image (c) Zelda image filtered after linear enhancement.

Figure. 9(a) **Figure. 9(b)**

Figure. 9(c)

Fig. 9(a) Compressed Trucks image (b) Filtered Trucks image (c) Trucks image filtered after linear enhancement

The result obtained is also compared with other techniques which are commonly used for removing the compression artifacts. The PSNR values obtained when Gaussian filtering is done on enhanced image is compared with the PSNR values obtained when Adaptive bilateral filter, Directional Fuzzy filter and Total Variation Minimization techniques are used. The comparison of PSNR values are given in Table 2. It can be observed that PSNR value obtained is more when Gaussian filtering is done on linearly enhanced image compared to other techniques used for artifacts removal.

Table 2- Comparison of PSNR Values between Gaussian filter on image with enhancement (GFE), Adaptive bilateral filter (ABF), Directional Fuzzy Filter (DFF) and Total Variation Minimization (TVM) Technique

Image	Compression Ratio	GFE	ABF	DFF	TVM
Lena	91.40	34.29	33.84	32.79	29.66
Barbara	86.21	29.64	29.39	28.18	21.77
Pepper	91.50	33.85	33.14	32.38	29.58
Bridge	81.95	27.78	27.54	26.82	23.10
Crowd	87.32	33.21	32.52	31.36	27.94
Boat	88.40	31.68	31.30	30.27	26.63
Zelda	93.10	36.35	35.89	35.06	33.10
Trucks	86.08	30.04	29.81	29.08	26.46
Couple	87.60	31.52	31.13	29.95	26..33
Clown	90.01	34.11	33.64	31.58	29.09

V. CONCLUSION

Restoration of compressed image is an important area of research. Compressed images are affected by compression artifacts like blocking artifact and ringing artifacts. In this article a new technique to remove compression artifacts from compressed image is discussed. Compressed image is first linearly enhanced using linear enhancement technique before being filtered by the Gaussian filter. After the filtering operation, linear enhancement is removed by the inverse transform. This technique is found to be very effective in removing the artifacts without causing blurring or without degrading the image. The quality of the restored image is measured using PSNR values and these are compared with PSNR values obtained using other existing techniques. It has been observed that the above technique perform better than other existing techniques.

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