Restoration of Image Deteriorated by JPEG Compression

Norio Iijima, Tsutomu Shohdohji, and Yasushi Hoshino
Department of Systems Engineering, Faculty of Engineering
Nippon Institute of Technology
Gakuendai 4-1, Miyashiro-Machi, Saitama 345-8501, Japan

Abstract

JPEG (Joint Photographic Experts Group) algorithm is widely used in imaging system. When image data are highly compressed by JPEG, the image is deteriorated. Deterioration of false contour and mosquito noise is mainly felt. In the restoration, false contour area is extracted and is smoothed by fitting method of least squares algorithm. Improved result is obtained, compared with the former method proposed by us.

Introduction

Now, multi-media technologies become a topic frequently and the related technologies such as computer, digital camera, digital video, internet, etc., are advancing very fast. Multi-media are based on digital data of video, image, sound, and character.[4]

Modern image compression technology offers a possible solution. State-of-the-art techniques can compress typical images from 1/10 to 1/50 their uncompressed size without visibly affecting image quality. But compression technology alone is not sufficient. For digital image applications involving storage or transmission to become widespread in today's marketplace, a standard image compression method is needed to enable interoperability of equipment from different manufacturers.

A standardization effort known by the JPEG has been working toward establishing the first international digital image compression standard for continuous-tone (multilevel) still images, both monochrome (gray-scale) and color.[5]

When image data are highly compressed by JPEG, the image is deteriorated. Deterioration of false contour and mosquito noise is mainly felt. These deterioration have a bad influence on subjective estimation of image quality. Therefore, we need to improve the image quality in high compression. We propose a fitting algorithm utilizing a method of least squares to improve the image quality of compressed-reconstructed image.

Overview of JPEG Compression System

Figures 1 and 2 show the key processing steps which are the heart of the DCT-based modes of operation. These figures illustrate the special case of single-component (gray-scale) image compression. We can grasp the essentials of DCT-based compression by thinking of it as essentially compression of a stream of 8 x 8 blocks of gray-scale image samples.

Color image compression can then be approximately regarded as compression of multiple gray-scale images, which are either compressed entirely one at a time, or are compressed by alternately interleaving 8 x 8 sample blocks from each in turn.

The following equations (1) and (2) specify the ideal functional definitions of the 8 x 8 FDCT (forward DCT) and the 8 x 8 IDCT (inverse DCT).[2, 5]

FDCT:

$$F(u,v) = \frac{1}{4} \times C(u)C(v)\left[\sum_{x=0}^{7}\sum_{y=0}^{7} f(x,y) \times \cos\frac{(2x+1)u\pi}{16}\cos\frac{(2y+1)v\pi}{16}\right] \qquad (1)$$

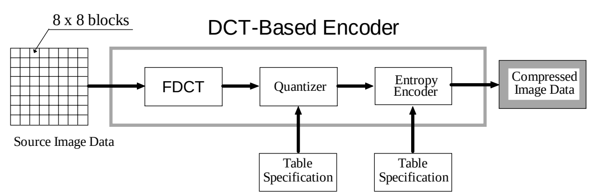


Figure 1. DCT-based encoder processing steps[5]

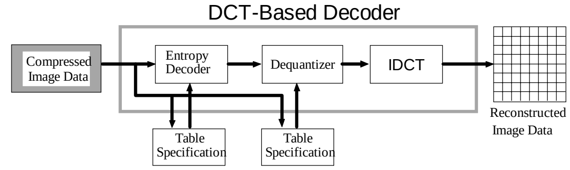


Figure 2. DCT-based decoder processing steps[5]

IDCT:

$$f(u,v) = \frac{1}{4}\left[\sum_{u=0}^{7}\sum_{v=0}^{7} C(u)C(v)F(u,v) \times \cos\frac{(2x+1)u\pi}{16}\cos\frac{(2y+1)v\pi}{16}\right] \qquad (2)$$

where

$$C(u), C(v) = 1/\sqrt{2} \text{ for } u, v=0;$$
$$C(u), C(v) = 1 \text{ otherwise.}$$

The DCT is related to the discrete Fourier transform.

Restoration Method (Part I)

The main deterioration by JPEG are false contours and mosquito noises, or the noise around binary image of character. We developed the algorithm which discriminates the area from the type of the deterioration and then restores particularly striking noises of the false contour and the noise around characters. The diagram of this algorithm is shown in Figure 3.

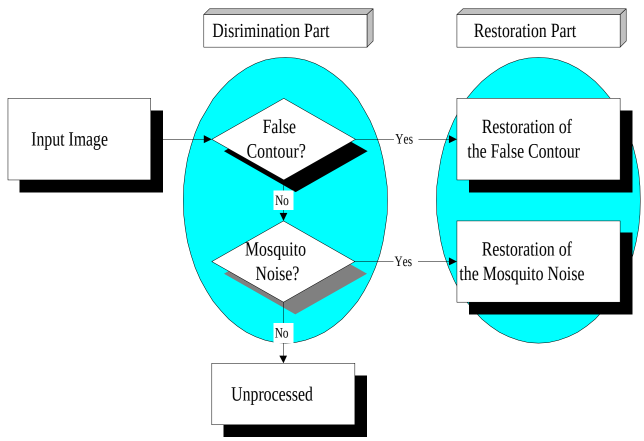


Figure 3. Flow chart of restoration algorithm[4]

The algorithm is carried out the discrimination of false contour, mosquito noise and other area, and in false contour area, averaging is operated and in restricted case of binary image, in mosquito noise area, the sub matrix of the area is replaced by most matched binary pattern. It is found that a quality of restored images is greatly improved by our algorithm. This algorithm is suitable for the high compressed image. We called this method the old restoration method.

Restoration Method (Part II)

The reconstruction of the image was enabled to some degree with the restoration method that we already reported.[4] Now, we propose the new restoration method. The reason why we develop it is that there is room for improvement in the old restoration method. Next, we explain the new restoration algorithm by the following steps:

Step 1: Several points are selected out of those area, after false contours are judged by the old restoration method.

Step 2: We compute six unknown parameters $a_1, \ldots, a_6$ of the following function by 2-dimensional method of least squares using the gray-level values in the coordinate value of those points.

$$f(x, y) = a_1x^2 + a_2y^2 + a_3xy + a_4x + a_5y + a_6 \qquad (3)$$

Step 3: We calculate the gray-level values of all pixels of the image by using equation (3).

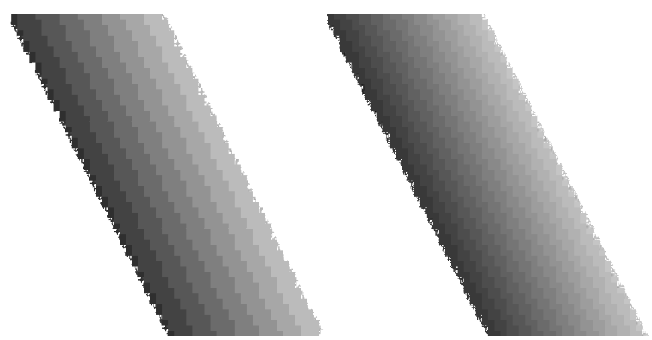
This algorithm is effective especially to false contours.

Results and Discussion

We carried out the computer experiment as follows.

First of all, we prepare the original images that showed in figures 4 and 7 (these images are different in the luminance), and confirmed the effect of the new restoration method. Figures 5 and 8 show the JPEG compression images with two different compression rate. Second, we restore the deteriorated images to the near original images (see figures 6 and 9) by our smoothing algorithm. Adequate results were obtained as shown in figures 10-13.

Figure 4. Original image 1; (50-200 of a 256-step gray-level)



(a) *(b)*

Figure 5. These images are a part of the JPEG compression image. (a) JPEG DCT at 0.267[bit/pixel] (b) JPEG DCT at 0.347[bit/pixel]

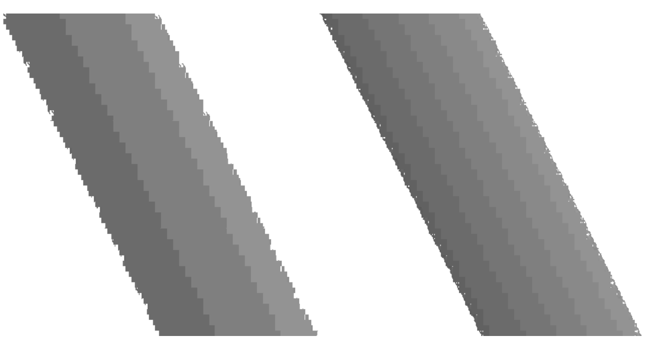
Finally, we applied our smoothing algorithm to a deteriorated image (see figure 15, we showed a typical example of the natural image for figure 14.), and obtained satisfactory results (see figure 16).

There are many studies about the reconstruction of deteriorated image.[1,3] Adding improvement to our smoothing algorithm, we want to apply it to the color images and the image containing many mosquito noises. Further computational experiments will be made in the near future.

(a) (b)

Figure 6. Restored images of the JPEG compression images by our method

Figure 7. Original image 2; (100-150 of a 256-step gray-level)



(a) (b)

Figure 8. These images are a part of the JPEG compression image. (a) JPEG DCT at 0.160[bit/pixel]; (b) JPEG DCT at 0.213[bit/pixel]

(a) (b)

Figure 9. Restored images of the JPEG compression images by our method

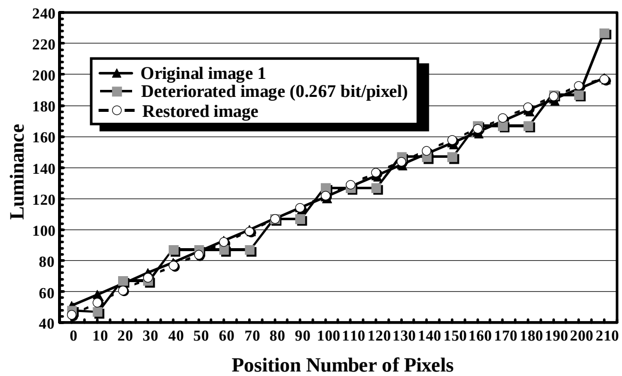


Figure 10. Computational results for original image 1 (case 1)

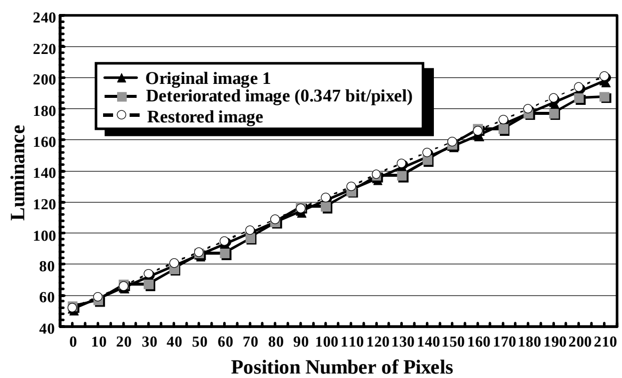


Figure 11. Computational results for original image 1 (case 2)

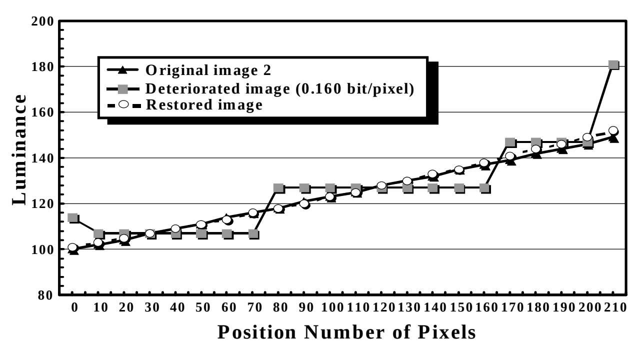


Figure 12. Computational results for image 2 (case 1)

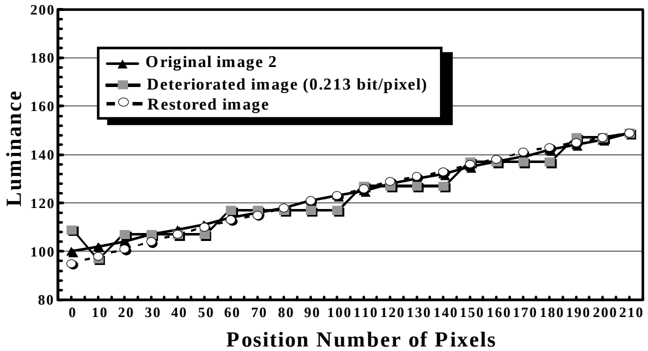


Figure 13. Computational results for image 2 (case 2)

Figure 14. Original image 3

Figure 15. JPEG DCT at 1.163[bits/pixel]

References

1. T. Jarske, P. Haavisto and I. Defe'e, "Post-Filtering Methods for Reducing Blocking Effects from Coded Images," *Proceedings of IEEE International Conference on Consumer Electronics*, pp. 218-219, 1994.
2. W. B. Pennebaker and J. L. Mitchell, *JPEG Still Image Data Compression Standard*, Van Nostrand Reinhold, NY, 1993.
3. B. Ramamurthi and A. Gersho, "Nonlinear Space-Variant Postprocessing of Block Coded Images," *IEEE Transactions on Acoustics, Speech, and Signal Processing*, Vol. ASSP-34, No. 5, pp.1258-1268, 1986.
4. T. Shimojo and Y. Hoshino, "Restoration of Images Deteriorated by High Compression in JPEG Algorithm," *Proceedings of International Congress on Advances in Non-Impact Printing Technologies(NIP12)*, pp. 120-124, 1996.
5. J. K. Wallace, "The JPEG Still Picture Compression Standard," *Communications of the ACM*, Vol. **34**, No. 4, pp. 31-44, 1991.

Figure 16. Restored image

Biography

Norio Iijima is a graduate student of Prof. Hoshino, Nippon Institute of Technology, Japan. He received a BE degree in Systems Engineering from Nippon Institute of Technology in 1997. He is now studying image processing.

Tsutomu Shohdohji is an Associate Professor of Operations Research at Nippon Institute of Technology. He received a BE and ME degrees in Management Science from Aoyama Gakuin University, Japan, in 1973 and 1975 respectively. He is a member of the Institute for Operations Research and the Management Sciences and the Information Processing Society of Japan. His recent publications have appeared in international proceedings and journals. He is now interested in image processing and operations research.

Hoshino Yasushi is a Professor of Nippon Institute of Technology. He gained BS, MS and Dr. Eng. degrees from the University of Tokyo, 1970, 1972, and 1984 respectively. After he gained MS degree, he joined Electrical Communication Laboratories of NTT and developed LED printer firstly, high speed laser printer, color laser printer by using ultra elliptical laser beam scanning, photo-induced toning technology and ion flow printing. He moved to Nippon Institute of Technology in 1994. He published more than 20 papers and several papers also in IS&T's Journal. He attended almost all NIP congresses.