A New Deblocking Filter for Digital Image Compression

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Abstract:

Nippon Steel has devised a filter for removing distortions generated by digital image compression of block bases such as in MPEG videos. Since conventional deblocking filters use low-pass filters, they have the disadvantage of removing not only block distortions but also high-pass components included in the original image. The filter proposed is capable of removing the block distortions by making use of human visual sense characteristics, while conserving existing high-pass components to the maximum extent possible. In addition, the filter's very simple structure allows use with any hardware and software, making it possible to easily realize deblocking. The filter is also suitable for incorporation into LSIs.

1. Introduction

1.1 Significance of digital image compression

There is much interest in the technology of digital image compression, which has already been applied to the digital (still) camera, digital video disc (DVD), communication satellite (CS) digital broadcasting, and many other fields. Why is the "compression" technology so needed? The reason is the enormous amount of information involved in images. The amount of information of one uncompressed still image is 100 or 1000 times as much as the amount of information of one text page, which is comprised of characters only. Furthermore, the amount of information of moving pictures for one second would be several dozen times the amount of information of one still image.

It is not easy to handle such enormous volumes of information even with the present high level technologies for storage and transfer. If they are not compressed, huge storage media and vast-capacity transfer lines would become necessary. Either of these is too expensive, or, for example in the case of wireless transfer, it is impossible to realize. Thus, compression technology becomes necessary that is capable of highly efficient compression unrealizable by conventional analogue technology. This is why the technology of digital image compression has attracted interest as a practical technology.

1.2 International standard of digital image compression

The technology of digital image compression has developed and has spread along with the progress of international standardization. For example, the still image, tele-conferencing, video phones, Video CD, DVD and digital satellite broadcasting respectively use compression in compliance with the international standard called JPEG (Joint Photographic Experts Group)[1], ITU-T Recommendation H.261[2] and H.263[3], MPEG-1[4], and MPEG-2[5]. And now, the image compression method with high compression ratio and various functions called MPEG-4 is being standardized and discussed for application to portable multimedia terminals, Internet television, and others. Hereafter, these technologies of digital image compression will be applied to still wider fields and become much more widespread.

The international standard methods mentioned above have common characteristics, in which the image is divided into small rectangular areas (blocks) and processed in block bases. However, when increasing the compression ratio in block base, visual inferiority of image quality, called blocking distortion, will appear in the decoded image. This blocking distortion is a significant problem which must be solved in the process of expanding the technology of digital image compression. This report will propose and illustrate a new filter to remove this blocking distortion.

2. Occurrence and Removal of Blocking Distortion

2.1 Occurrence of blocking distortion

The digital image is represented as a collection of pixels. Digital image compression represents the digital image with a smaller data sequence than the original image data, by processing various calculations on these pixel values (see **Fig. 1**). While there are diverse methods in digital image compression, the most common

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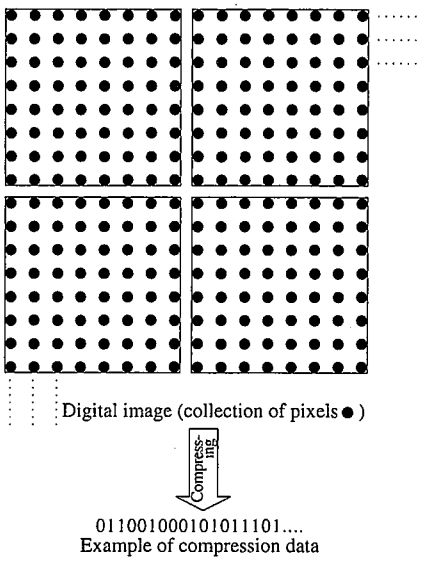


Fig. 1 Compression of a digital image

one is the method of dividing the image into rectangular blocks of 8×8 or 16×16 pixels, as shown in the broken lines of **Fig. 1**, and compressing each of those blocks. In these methods, however, at higher compression ratios, discontinuity occurs on the block boundaries of the image after decoding, and the shape of the blocks will appear more clearly. This is blocking distortion. As an example, **Photo 1(a)** shows the original image before compression, and **Photo 1(b)** shows the decoded image[*1] after compression with MPEG-4. In **Photo 1(b)**, significant blocking distortion is noticed in the face, jacket, and background.

2.2 Removal of blocking distortion by conventional methods

Various compression methods have been proposed to remove such blocking distortion, but whichever compression method is used, it is necessary to filter the decoded image for totally removing the blocking distortion. The filter conventionally used for that deblocking is a low-pass filter. This low-pass filter is applied to the area around discontinuous (edge) parts, and the blocking distortion is removed by smoothing this discontinuity. However, when using this method to remove blocking distortion, it is necessary to filter the image very strongly, resulting in removing not only blocking distortion but also high-frequency components essentially present in the original image, and in making the decoded image totally blurry. This is a disadvantage of this method.

2.3 Removal of blocking distortion by proposed method

The deblocking filter proposed in this report differs from conventional methods that use low-pass filters, and is capable of removing blocking distortion without blurring the decoded images. The basic principle of the proposed method is to use human visual sense characteristics, whereby "a linear edge" is visually outstanding even if the magnitude of the edge (difference between pixel values of both sides of the edge) is small. One of the reasons the blocking distortion is a visual eyesore and becomes a problem is that blocks consist of horizontal and vertical lines, so that linear edges occur around block boundaries and, because of the characteristics mentioned above, they are outstanding even if their magnitudes are small. In this proposed method, therefore, the blocking

*1 compression condition: Common Image Format (CIF), 10 Hz, 48 kbps, Q = 16 fixed

(a) Original image

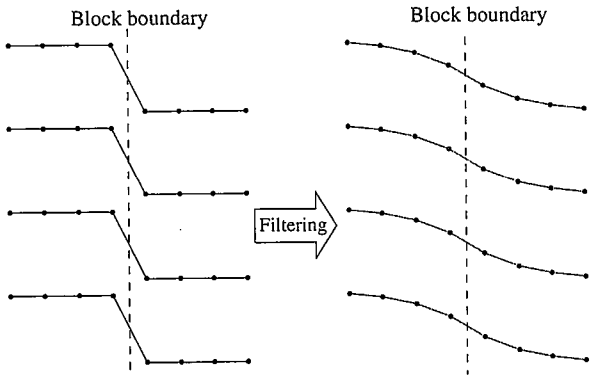
(b) Decoded image after MPEG-4 compression

(c) Decoded image debloked by proposed method

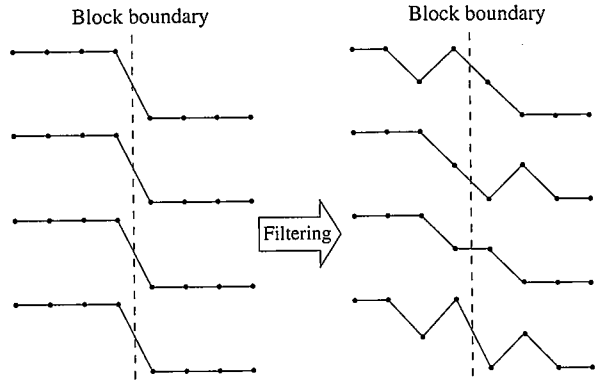
Photo 1 Simulation result

distortion is removed on the basis of visual characteristics by randomly disarranging the linearity of edges on the block boundaries and avoiding the matching conditions which cause those characteristics to appear.

Figs. 2 (a) and **(b)** illustrate the difference between the conventional methods using low-pass filters and the proposed method. In **Fig. 2**, the left side represents a decoded image including the blocking distortion, and the right side represents an image after filtering. The positions of dots in vertical direction show pixel values, and the lines connecting those dots show the variance of pixel values on each scanned line of a decoded image. The vertical broken line shows the existence of block boundaries. **Fig. 2 (a)** shows removal of the blocking distortion using the conventional method, where the low-pass filter is applied to the area around a block boundary and the edge existing on the block boundary of each line is smoothed and thus the blocking distortion is removed. In this case, the same processing is applied to each line and there is no difference between those lines. On the other hand, in the proposed method shown in **Fig. 2 (b)**, the various processings are randomly applied to each line and the linearity of edges on the block boundary is disarranged. As this processing is not low-pass filtering, the high-frequency components of an original image are conserved well.



(a) Deblocking by a low-pass filter



(b) Deblocking by a filter of proposed method

Fig. 2 Comparing a proposed deblocking method with a conventional deblocking method

3. Deblocking Filter Using Visual Sense Characteristics

3.1 Detail of proposed method

Fig. 3 shows details of the proposed method. **Fig. 3** illustrates one of the lines shown in **Fig. 2 (b)**. Indexes n-1, n, n+1, and n+2 represent the positions of pixels, and X_n represents the pixel value at position n. Further, the block boundary exists between position n-1 and position n.

Repeating the following processing on the block boundary of each scanned line and scanning the image not only in a horizontal direction but also in a vertical direction makes it possible to remove the blocking distortion.

Assuming the difference between two pixel values over the block boundary is D_n, it is represented by the expression $D_n = X_n - X_{n-1}$ and the magnitude of the edge on the block boundary is represented as $|D_n|$ (an absolute value of D_n). Where this magnitude $|D_n|$ is greater than a threshold, this edge is assumed as the one essentially existing in the original image, and the following processing will not be done. Where the magnitude $|D_n|$ is less than a threshold, it is assumed that the blocking distortion exists at that position and the following processing will be done.

Define the value proportional to D_n as a correction value Δ for removing the blocking distortion ($\Delta = D_n$, for example). This Δ value is added to the pixel value of position n-2 or n-1 and is subtracted from the pixel value of position n or n+1. At this time, pseudo-random numbers are used to select these positions. That is to say, one of four patterns shown in **Table 1** is selected according to the value of the pseudo-random number generated, and each value shown in the table is added to the pixel value of associated position (**Fig. 3** shows an example where pattern 1 is selected). In this case, to select a random pattern in each line on the same

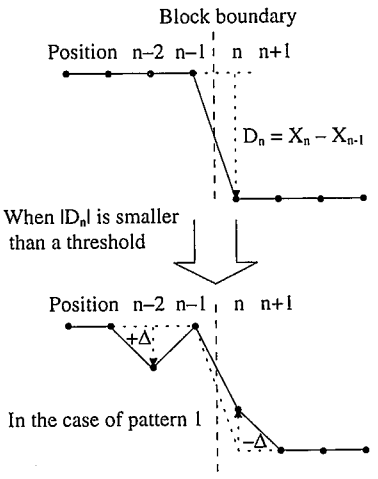


Fig. 3 Detail of the process proposed

Table 1 Possible patterns of correction values

Position	n-1	n-2	n	n+1
Pattern 1	+Δ	0	-Δ	0
Pattern 2	0	+Δ	0	-Δ
Pattern 3	0	+Δ	-Δ	0
Pattern 4	+Δ	0	0	-Δ

block boundary, it is necessary to use pseudo-random numbers which have adequate randomicity*2.

As all processing mentioned above can be done with the combination of simple operations and the amount of processing needed is less, any use of hardware and software makes it possible to easily achieve deblocking and it can be incorporated into the LSIs of MPEG video decoders.

3.2 Simulation results and features of proposed method

Photo 1 (c) shows the simulation results when a deblocking filter of this proposed method is applied. As this photo shows, the proposed method can remove the blocking distortion on the chest of a jacket and the wall of a background without blurring the decoded image. On the other hand, it is not as efficient for the blocking distortion of stronger edges such as that surrounding eyes and arms. Although this could be improved by using a larger Δ value mentioned above, a comparatively small Δ value is used in **Photo 1 (c)** because the use of too large Δ value may cause the added pattern value to look like noise. To compensate for this point, it is possible to use this proposed method combined with other methods for effectiveness with strong edges. But **Photo 1 (c)** shows an example of extremely high compression ratio, so in applying a compression ratio that is not so high the proposed method would demonstrate sufficient effectiveness.

4. Conclusion

This report describes a filter which can remove blocking distortion without losing the high-frequency components of an original image. Nippon Steel proposed this deblocking filter as a reference method for deblocking filters for MPEG-4 in the MPEG Brazil meeting in November 1996, and it was compared and evaluated with various other methods in the MPEG Bristol meeting in April 1997[6,7]. Finally, the other method, which is extremely complex and is highly effective for deblocking was adopted as a reference deblocking filter for MPEG-4. However, our proposed method, which is simple and requires less processing, is considered valuable in actual applications.

Hereafter we will advance a more detail discussion of incorporating the filter into hardware aiming for the completion of MPEG-4 standardization in December 1998, and we plan to install it in products of the Semiconductor Division that relate to image compression.

*2 Furthermore, if the proposed method is applied to a moving picture image, the pseudo-random numbers should be initialized at the beginning of processing each picture comprising the moving picture and are in different points of time sequence, but at the same physical position so that the same pattern is selected for each associated position.

References

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