A NOVEL TEMPORAL-FREQUENCY DOMAIN ERROR CONCEALMENT METHOD FOR MOTION JPEG

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Abstract Motion-JPEG is a common video format for compression of motion images with high quality using JPEG standard for each frame of the video. During transmission through a noisy channel some blocks of data are lost or corrupted, and the quality of decompression frames decreased. In this paper, for reconstruction of these blocks, several temporal-domain, spatial-domain, and frequency-domain error concealment methods are investigated. Then a novel method is proposed for recovery of channel errors with a mixture of temporal-domain and frequency-domain error concealment methods. To reconstruct the missed blocks in the proposed novel method, when two successive frames are similar, a proposed two phase block matching algorithm is performed in temporal-domain. When two successive frames are different, our proposed method reconstructs the missed block by the estimation of DC and AC coefficient, in frequency-domain. The proposed method and the other similar methods are simulated for different noise and quality factors. The results of quality measurements are indicated that in all tested video sequences, the proposed method shows higher quality in reconstruction of missed blocks.

Keywords Motion JPEG, noisy channel, error concealment, image enhancement.

چکیده Motion-JPEG یک فرمت ویدیویی متداول برای فشرده سازی تصاویر متحرک با کیفیتی عالی است، که آن از استاندارد JPEG برای فشرده سازی هر قاب تصویر، استفاده می‌شود. از آنجاییکه در انتقال از یک کانال نویزی، ممکن است بعضی از بلوک‌های تصویر، تخریب شوند، کیفیت تصویر وافشرده شده، کاهش می‌یابد. در این مقاله برای بازسازی بلوک‌های گم شده، روش‌های متعددی در حوزه‌های زمان، مکان و فرکانس مورد بررسی قرار گرفته و سپس روشی نوین بر مبنای ترکیب یک روش فرکانسی و یک روش پیشنهادی زمانی، ارائه می‌شود. در روش پیشنهادی، هنگامی که دو قاب متوالی، شبیه یکدیگر هستند، از یک روش تطابق بلوک پیشنهادی در دامنه زمان، برای یافتن بلوک تخریب شده استفاده می‌شود. هنگامی که دو قاب متوالی، متفاوت از یکدیگر باشند، یک روش بازسازی DC-AC در فضای فرکانس، برای بازسازی بلوک تخریب شده، به کار می‌رود. روش پیشنهادی با سایر روش‌های مورد بررسی، برای چند نمونه تصاویر متوالی مرسوم، برای ضرایب کیفیت و میزان نویز مختلف، مورد مقایسه قرار گرفته و نشان داده می‌شود که روش پیشنهادی، کیفیت بهتری در بازسازی بلوک‌های تخریب شده دارد.

1. INTRODUCTION

The compression is a processing that decreases the digital data by eliminating redundant data. This process depends on acquired bandwidth (BW) of data transmission, needed storage space and quality of decompressed data. The M-JPEG or Motion-JPEG format is a video compression format to compress the motion images, and it is part of JPEG compression standard [1].

Applications of M-JPEG are very wide. It is commonly used by IP based video cameras via HTTP streams by using the multipart/x-mixed-replace content type or via RTP (Real-time Transport Protocol). Therefore, some internet browsers have native support for viewing M-JPEG streams and some of them can display M-JPG streams with the help of external plugins. Some game consoles have integrated M-JPEG decompression hardware in order to play in-game video sequences. In digital still cameras, M-JPEG is often used in movie mode that allows video encoding and playback through the integrated JPEG compression hardware with only a software modification. Also, M-JPEG is frequently used in non-linear video editing systems [2].

Generally, compressed bit streams are very sensitive to channel errors. For instance, a single bit error in a coded video bit stream may cause severe degradation on image quality. Therefore, via transmission of compressed frames through a noisy communication channel, some data blocks are destroyed and so, the quality of decompressed frames in a receiver is decreased. When bit errors occur during transmission and cannot be corrected by an error correction scheme, error concealment is needed to conceal the corrupted image at the receiver [3]. Error concealment algorithms attempt to repair damaged portions of the image, using approximate information about destroyed blocks.

In this paper, a novel temporal-frequency domain reconstruction method is proposed for high quality error concealment in M-JPEG video sequences. In the section 2, M-JPEG standard elements are reviewed, then to reconstruct and enhance the quality of noisy decompressed images, several temporal-domain, spatial-domain, and frequency-domain error concealment methods are investigated, in the section 3. After that, in the section 4, a proposed method that is based on a novel mixture of temporal-domain and frequency-domain methods, is presented. Finally, the results of the proposed method and some other similar methods are compared and the quality of decompressed images under different noise and quality factors is studied, in the sections 5 and 6. The last section, presents a conclusion of the paper.

2. MOTION JPEG

Motion JPEG is a format to compress the motion images. In this format each frame of a video file is under the JPEG standard separately.

1.JPEG standard

The JPEG standard is used for compression of grayscale or colored images with 8 bits for each color. The compression is performed in three sequential steps: level shifting and DCT computation, quantization and variable-length code assignment [4]. These stages are shown in Figure1.

At the first stage, an input image is subdivided into pixel blocks of size 8×8. As each 8×8 blocks or sub-image is encountered, its 64 pixels are level shifted by subtracting the quantity 2^{n-1}, where 2^n is the maximum number of gray levels. When the JPEG system is used for images with 2^8 or 256 gray level, therefore initial sub image pixel level

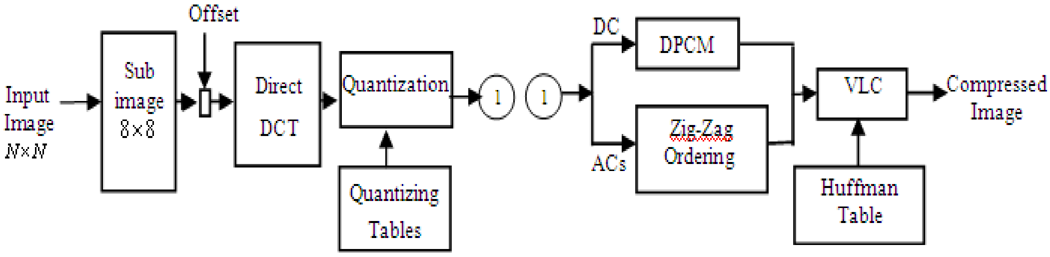

Figure1. Block diagram of the JPEG compression system.

are shifted by -2^7 (or -128) gray levels. Then Discrete Cosine Transform or DCT is applied. It transforms the array of intensity data to frequency data that indicates the intensity variation rate. With applying DCT on each block, a 8×8 matrix of frequency coefficients is created that the frequency increases when it move away from the origin.

The second stage of JPEG standard is quantization that is a principle phase that compression operation is performed there. In this phase, DCT coefficients are quantized based on the required details of image. By increasing the frequency, the human's eye sensitivity is reduced therefore the high frequency DCT coefficients can be efficiently quantized by quantization table Q_{table}. It means that many of coefficients with small values become zero. Commonly, in order to control image quality, Q_{table} is multiplied in a α quality factor that has reverse with Q_{JPEG} quality factor, and then DCT coefficients matrix are divided to αQ_{table}.

In order to compress color images by JEG standard, each color element including luminance and chrominance is compressed individually by corresponding Q_{table}.

The last stage of JPEG standard is coding. In this stage, output coefficients of quantized block are divided into two parts: (1) DC coefficient: This factor is the first element of coefficient matrix and is the most important coefficient that specifies the illumination of block average and it has a major role for image recovery. (2) AC coefficients: Other matrix entries call AC factors, that many of them have zero quantity. In order to coding them the Run-Length Coding (RLE) method is used. The DC coefficients are coded separately from the AC ones. Differential Pulse Code Modulation (DPCM) is the coding method.

2. YUV color space

The YUV model defines a color space in terms of one luma and two chrominance components. The YUV color model is used in the PAL, NTSC, and SECAM composite color video standards.

Y stands for the luma component (the brightness) and U and V are the chrominance (color) components, U and V are blue-luminance and red-luminance differences. Equations (1) and (2) show the relation between these two color spaces.

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51498 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (1)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.13983 \\ 1 & -0.39465 & -0.58060 \\ 1 & 2.03211 & 0 \end{bmatrix} \begin{bmatrix} Y \\ U \\ V \end{bmatrix} \qquad (2)$$

To get a digital signal, YUV images can be sampled in several different ways. In order to get the higher compression, YUV 420 [5] is used in this paper.

3. ERROR CONCEALMENT METHODS, PREVIOUS WORKS

The compressed bit streams are very sensitive to channel errors and therefore there are usually some missed blocks during decompression. Error concealment algorithms attempt to repair damaged portions of the image. In this section, we discuss several temporal-domain, spatial-domain, and frequency-domain error concealment techniques that are used for M-JPEG coded images, and then we propose a novel method based on a mixture of temporal-domain and frequency-domain recovery methods.

1.Spatial-domain methods

In the spatial method, after receiving the compressed frame's code from noisy channel by receiver, the frame is reconstructed. Since the missed blocks don't have any data, the information from surrounding blocks of the missed block in the same frame is used to reconstruct the missed data [6].

1) Weighted averaging

The simplest and often used method is weighted averaging. Each pixel $p(i,j)$ of a missed block is interpolated as a linear combination of the nearest pixels in the boundaries as shown in Figure 2 [7].

$$p(i,j) = \frac{d_R p_L + d_L p_R + d_B p_T + d_T p_B}{d_L + d_R + d_T + d_B} \qquad (3)$$

2) Triangular propagation

In this method, information from four surrounding blocks of the same frame is used to reconstruct the missed data as shown in Figure 3. The missed block is divided to four triangles and the values of neighbor pixels are propagated through corresponding triangles [8].

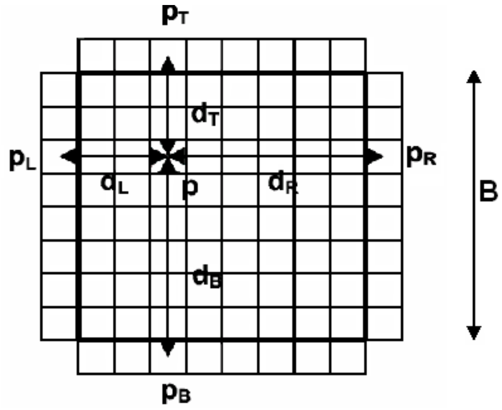

Figure 2. Weighted averaging method in spatial domain [7].

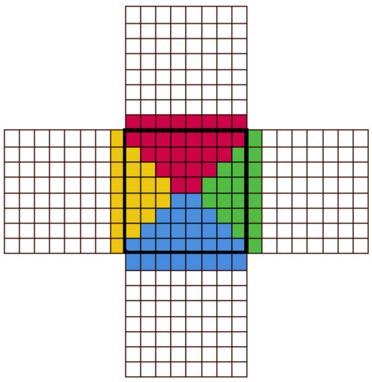

Figure 3. Triangular propagation method in spatial domain.

2.Frequency-domain methods

In frequency based methods after receiving the compressed frame's code from noisy channel, data are encoded. Before computing the inverse DCT of blocks, the missed blocks are reconstructed by neighboring blocks of the missed block in DCT domain.

1) Averaging

In the averaging method, each frequency of the missed block is replaced by the average of the four corresponding frequencies of the neighborhood blocks. If F(*i*,*j*) is the frequency of (*i*,*j*) in the missed block, then it is computed by the equation (4), where $F_U(i,j)$, $F_D(i,j)$, $F_L(i,j)$ and $F_R(i,j)$ are the corresponding frequencies in the up, down, left and right neighborhood blocks, respectively. Figure 4 shows the details.

$$F(i,j) = \frac{1}{4}\left[F_U(i,j) + F_D(i,j) + F_L(i,j) + F_R(i,j)\right] \tag{4}$$

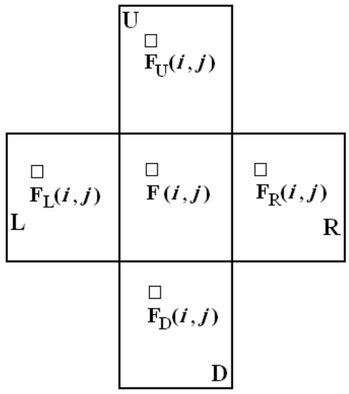

Figure 4. The averaging method in frequency-domain. The center block is missed block and F(*i*,*j*) should be replaced by information of corresponding (*i*,*j*) frequencies in the neighborhood blocks.

2) Triangular propagation

In triangular propagation method, the replacement method for missed block, according to Figure 5 is based on propagation the values of pixels from neighboring blocks.

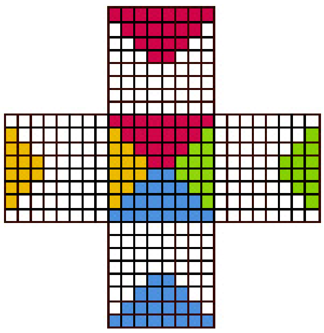

Figure 5. Triangular propagation method in frequency-domain.

3) Estimation of DC and AC coefficients

Since the DC coefficient of a block represents the average pixel value of the block, a loss of the DC coefficient will affect the brightness or color of the corresponding block. There are several ways to recover the DC coefficient when it is lost or damaged.

One estimate for the DC coefficient of a corrupted block is the simple average or median value of DC coefficients of the neighboring blocks. Taking four neighboring blocks for the DC estimate turns out to be more effective. For low-frequency AC coefficients, as illustrated in Figure6, AC coefficients of the center block that is assumed to be lost are predicted as weighted sums of DC values of surrounding blocks.

The first five low-frequency AC coefficients are estimated using the following prediction equation.

$$\begin{aligned} AC1 &= 1.13885 \times (DC4 - DC6)/8 \\ AC2 &= 1.13885 \times (DC2 - DC8)/8 \\ AC3 &= 0.27881 \times (DC2 + DC8 - 2 \times DC5)/8 \\ AC4 &= 0.16213 \times (DC1 + DC9 - DC3 - DC7)/8 \\ AC5 &= 0.27881 \times (DC4 + DC6 - 2 \times DC5)/8 \end{aligned} \quad (5)$$

DC5 coefficient is obtained as the median of the DC values of surrounding blocks. The other remained erroneous high-frequency AC coefficients are assumed to be zero [9][10][6].

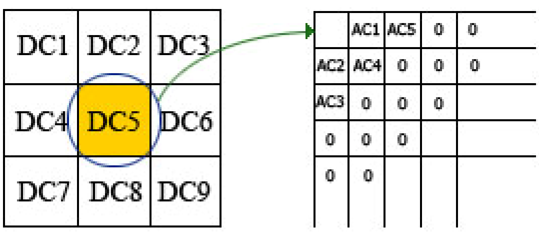

Figure 6. The Estimation of DC and AC Coefficient method in frequency-domain [9].

3.Temporal-domain methods

These kinds of reconstruction methods extract some necessary information from temporal correlation of the sequence to conceal the error. Usually, motion estimation using previous frames is performed to reconstruct the missed block.

1) Copy paste

"copy-paste" is the simplest temporal error concealment method called also" previous frame concealment" [7]. The missed blocks of one frame according to (6) are simply replaced by spatially corresponding blocks from the previous frame.

$$P_n(i, j) = P_{n-1}(i, j) \quad (6)$$

2) Optimum boundary matching

Several block matching techniques have been used in temporal-domain error concealment methods. The optimum boundary matching is one of the most popular and efficient one [9][11][12]. Since the information inside of a missed block has been lost, only the value of boundary pixels are considered for block matching. All 36 boundary pixels (8×4+4) are compared with boundary pixels of all candidate blocks in a corresponding search region of the previous frame. This method is graphically shown in Figure 7. The search region S×S is considered based on the maximum motion that is typically set to 16×16. The most similar block is selected as the best block for replacing.

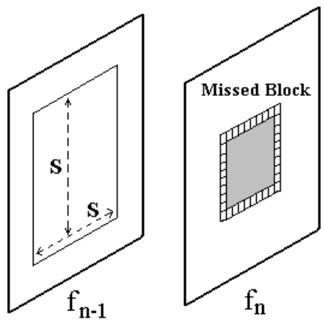

Figure 7. The optimum boundary matching method.

4. PROPOSED NOVEL METHOD

The quality of reconstructed block completely depends on video sequences. Considering two successive frame in a video sequence, two cases are possible: slow motions and sudden changes. In the first case, the frame containing a missed block and the previous frame are similar. It means that there is only a slow motion in video sequence and temporal based error concealment methods leads to the best results. On the other hand, in the second case when there is a sudden change in two successive frames, frequency based error concealment methods show higher quality. Therefore, the first stage of our proposed method is a change analyzer that tries to detect “slow motion” or “sudden change” cases in the current frame. Then a proper proposed error concealment method is used for each case.

1.Change Analzser

Change analyzer, is a simple video sequence analysis algorithm that tries to distinguish two possible cases “slow motions” and “sudden changes”. To detect these two cases, the similarity of some blocks of one frame is compared with the corresponding blocks in the previous frame via normalized cross-correlation criterion that is according to (7).

$$NCC = \frac{\sum_i ((A_i - \overline{A})(B_i - \overline{B}))}{\sqrt{\sum_i (A_i - \overline{A})^2 \sum_i (B_i - \overline{B})^2}} \quad (7)$$

In our implementation, only 9 blocks of the current frame (with dimension of 8×8 as is used in JPEG standard) that are selected randomly are compares with the corresponding blocks of the previous frame. To compute the NCC criterion, only gray level information is used and the NCC threshold value is set to 0.35. If there are at least 5 similar blocks, “slow motion” case is detected.

2.Error Concealment

In the case of “sudden changes”, our proposed method uses reconstruction by the estimation of DC and AC coefficient method that show good results, based on the equation (5). While in the case of “slow motion”, our proposed novel method finds the best matched block in the previous frame based on a proposed block matching algorithm.

1) Proposed Block Matching

Usually, computational cost is one the most disadvantages of full search blocks matching algorithms. Therefore we propose a novel two phase, coarse to fine block matching algorithm with low cost and high performance for error concealment.

At the first phase of the proposed block matching algorithm, three most similar blocks are found in a search window of 16×16 dimensions in the previous frame. For this step, in spite of the optimum boundary matching method, only 12 pixels of neighbor pixels of missed block corners are compared with available pixels in the search window as shown in Figure 8.

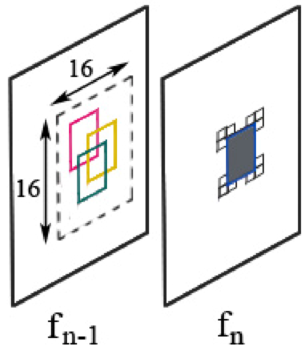

Figure 8. The selection of three most similar blocks, in the proposed method.

At the second step of our proposed block matching, the optimum boundary matching is used only for 3 similar blocks which found at the first phase. After the second phase, the missed block is replaced by the most similar ones.

This proposed two phase block matching is faster than the optimum boundary matching, because the computational cost of the first phase is lower and the other hand, the computational cost of the second phase is negligible. Our simulations which will be presented in the next section show that the proposed two phase block matching executes faster than conventional optimum boundary matching.

5. SIMULATION AND RESULTS

In this section, the simulation setup and the results are presented for three standard test video sequences including Akiyo, Tennis and Mobile [13]. The Akiyo is a video sequence without camera motion and a little difference in each frame. In the Tennis video sequence, there is a little rapid in camera motion and some of frames are different. The Akiyo and Tennis video sequence include several objects in each frame. In the Mobile video sequence, there is also a little rapid in camera motion, many objects and sharp edges. In all benchmarks, 100 frames of the tested video sequences are considered.

1.Image quality evaluation

To evaluate the results of reconstructed images, both quality and quantity measurements are considered. Visual inspection as a criterion for quality measurement and image differencing and PSNR (Peak Signal to Noise Ratio) calculations as quantity measurement are used. PSNR analysis uses a standard mathematical model to measure an objective difference between two images. It is commonly used in the development and analysis of compression algorithms, and comparing visual quality between different compression systems. PSNR is calculated by the following equation:

$$PSNR = 10 \log \frac{255^2}{MSE} \text{ dB} \quad (8)$$

$$MSE = \frac{1}{N.M} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \left[\left| f(i,j) - f^*(i,j) \right|^2 \right] \quad (9)$$

In the equation (9), *f* is the decompressed noiseless image while *f** is the reconstructed noisy image with applying the error concealment algorithm. For PSNR higher than 37dB, the quality of the reconstructed block is very high and then the difference between two images is not recognizable. The quality of reconstructed block is good when the PSNR is between 31dB to 37dB and it is acceptable when it is higher than 25dB.

2.Noise factor

To simulate a noisy channel, several blocks over entire frames of video sequence are damaged. Noise factor means the number of blocks which are damaged by noise in one hundred blocks. For example, if the dimension of one frame is 352×288 pixels, it will have 1584 blocks. For a 6% noise factor, approximately it has 9500 noisy blocks on total 100 frames of a video sequence.

3.Simulation results

Motion-JPEG compression and decompression are simulated in MATLAB environment and some experiments are done on the benchmark video sequences including Akiyo, Tennis and Mobile. Quality factors (Q) used in these tests were 25 and 50. Also, noise factors used for the channel error were 1% and 6% which are representing low and high noisy environment. The results are represented by giving average of PSNR of one hundred noisy frames and comparing with the average of PSNR of reconstructed frames with applying eight different methods including spatial averaging, spatial triangular, frequency averaging, frequency triangular, estimation of DC and AC, copy paste, optimum boundary matching and finally our proposed novel method. The total of the statistical results are indicated in Tables 1, 2 and 3. Finally, some image samples are represented.

1- Akiyo video sequence

a)Without error concealment

The average of PSNR value for one hundred noisy frames with Q=25 and 1% noise factor is 29.1482 dB and 6% noise factor is 21.9791dB, with Q=50 and 1% noise factor is 28.9185dB and 6% noise factor is 21.4683dB.

b)With error concealment

The average of PSNR values with Q=25 and Q=50, obtained by eight different methods for reconstruction of one hundred frames of the Akiyo video sequence are shown in figures 9 and 10 respectively.

2- Tennis video sequence

a)Without error concealment

The average of PSNR value of one hundred noisy frames with Q=25 and 1% noise factor is 27.8952 dB and 6% noise factor is 22.0895dB, with Q=50 and 1% noise factor is 25.3251dB and 6% noise factor is 21.728dB.

b)With error concealment

The average of PSNR values with Q=25 and Q=50, obtained by eight different methods for reconstruction of one hundred frames of the Tennis video sequence are shown in figures 11 and 12 respectively.

3- Mobile video sequence

a)Without error concealment

The average of PSNR value for one hundred noisy frames with Q=25 and 1% noise factor is 25.7182 dB and 6% noise factor is 21.0204dB, with Q=50 and 1% noise factor is 26.3238dB and 6% noise factor is 20.843dB.

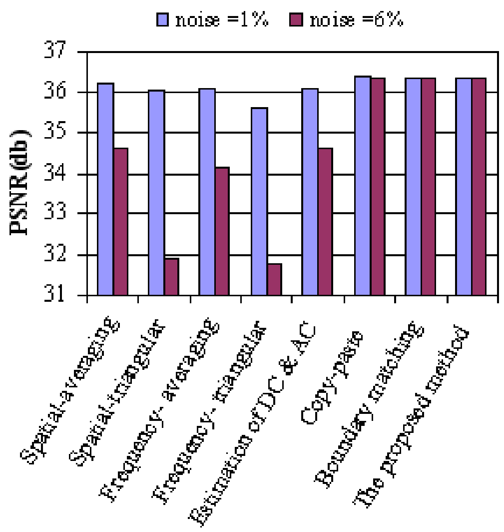

Figure 9. PSNR average values for the reconstruction of Akiyo sequence with Q=25.

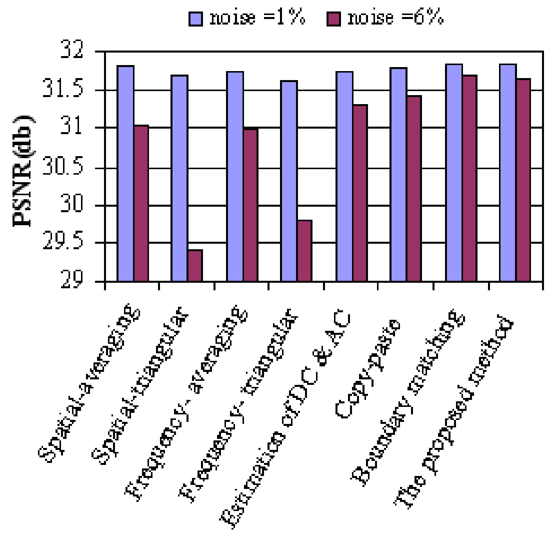

Figure 11. PSNR average values for the reconstruction of Tennis sequence with Q=25.

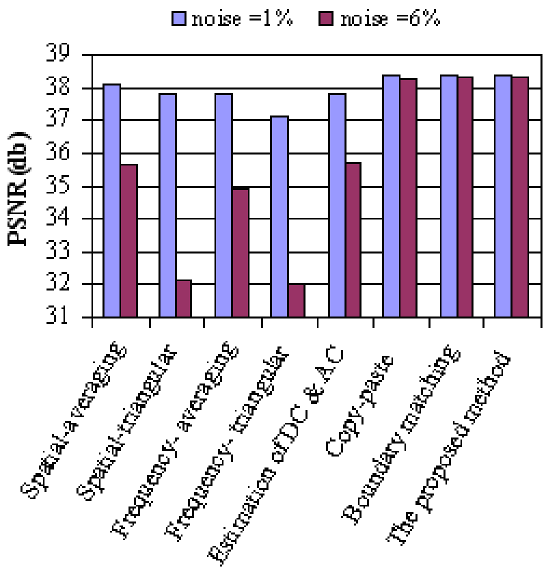

Figure 10. PSNR average values for the reconstruction of Akiyo sequence with Q=50.

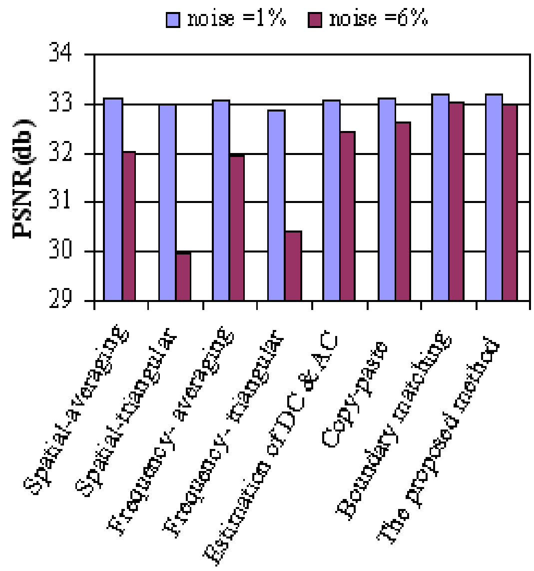

Figure 12. PSNR average values for the reconstruction of Tennis sequence with Q=50.

b)With error concealment

The average of PSNR values with Q=25 and Q=50, obtained by eight different methods for reconstruction of one hundred frames of the Mobile video sequence are shown in figures 13 and 14 respectively.

6. DISCUSSION

All of the PSNR results are presented in the Tables 1 and 2 for the noise factor 1% and 6%, respectively. Some samples of reconstruction blocks by the proposed novel method are also

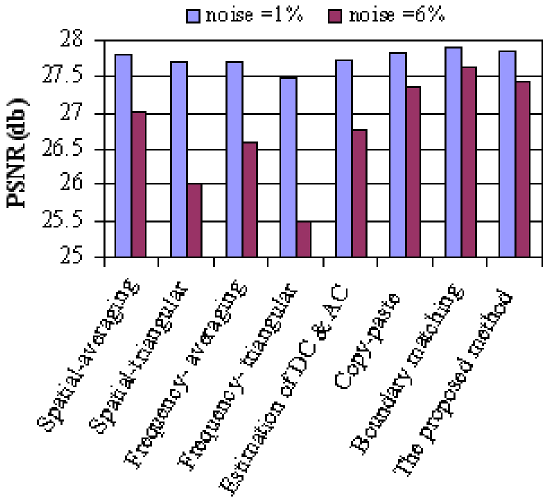

Figure 13. PSNR average values for the reconstruction of Mobile sequence with Q=25.

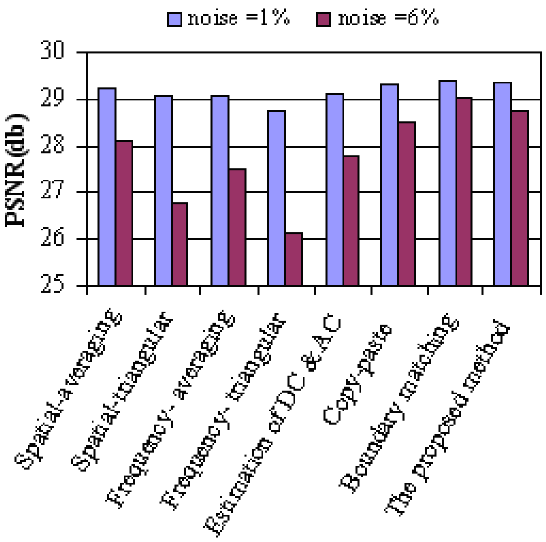

Figure 14. PSNR average values for the reconstruction of Mobile sequence with Q=50.

Figure 15. The noisy frames of Akiyo video sequence without reconstruction.

Figure 16. The reconstructed frames of Akiyo video sequence by the proposed novel method.

shown in Figures 15 to 18. Just as indicated in Tables 1 and 2, the average PSNR of hundred reconstructed frames are increased by raising the quality factor and decreased by raising the noise factor. Also, by averaging from all of the results of available reconstruction methods in Table 1, specifies that from 1% to 6% noise factors and 25 to 50 quality factors, the PSNR will be nearly 30.76dB to 32.7dB. The difference between the most and least PSNR quantities for 1% noise factor is nearly 0.57dB and in 6% noise factor is nearly 3.28dB.

The average PSNR values for the proposed method and the optimum boundary matching are close to each other, but the computational cost of the proposed method is lower, because the block matching in the proposed method needs lower computational cost. Table 3 shows the relative reduction of the execution time (including the JPG computations and the error concealment) of the proposed method respect to the optimum boundary matching, where all methods are implemented in Matlab environment.

Figure 17. The Noisy frames of Tennis video sequence without reconstruction.

Figure 18. The reconstructed frames of Tennis video sequence by the proposed novel method.

TABLE 1. Comparing the statistical results of different reconstruction method for the different video sequences with noise factor equal to 1%

Reconstruction methods (Noise factor=0.01)	Akyio		Tennis		Mobile	
	Q=25	Q=50	Q=25	Q=50	Q=25	Q=50
Spatial-weighted averaging	36.2183	38.1003	31.7937	33.1391	27.8028	29.2468
Spatial-triangular propagation	36.036	37.7735	31.6932	32.9837	27.7004	29.1017
Frequency-averaging	36.0574	37.8086	31.7466	33.0676	27.6904	29.0828
Frequency-triangular propagation	35.5934	37.1465	31.6091	32.8959	27.4662	28.7746
Estimation of DC and AC coefficients	36.0848	37.8146	31.7598	33.0869	27.7086	29.1123
Copy-paste	36.3419	38.3301	31.7701	33.136	27.8413	29.2913
Optimum boundary matching	36.339	38.3393	31.839	33.2257	27.8989	29.4034
The proposed novel method	36.3385	38.33	31.8333	33.213	27.8653	29.3499

7. CONCLUSSION

In this paper, after review of different methods for reconstruction of missed blocks, the proposed two stages method that is based on a novel mixture of temporal-domain and frequency-domain reconstruction methods is proposed. The first stage of the proposed method tries to distinguish two cases of video frames including "slow motion" and "sudden changes" by computing the similarity of some blocks of one frame with the same blocks in the previous frame by the normalized cross-correlation criterion.

In the case of "slow motion", the proposed two

TABLE 2. Comparing the statistical results of different reconstruction method for the different video sequences with noise factor equal to 6%

Reconstruction methods (Noise factor=0.06)	Akyio		Tennis		Mobile	
	Q=25	Q=50	Q=25	Q=50	Q=25	Q=50
Spatial-weighted averaging	34.6046	35.6615	31.0472	32.0426	27.0274	28.1257
Spatial-triangular propagation	31.8864	32.1562	29.4229	29.9618	26.0109	26.795
Frequency-averaging	34.1054	34.8989	30.988	31.9164	26.5854	27.5365
Frequency-triangular propagation	31.7638	32.0291	29.7955	30.4182	25.4982	26.1615
Estimation of DC and AC coefficients	34.6306	35.7247	31.3134	32.4389	26.7674	27.7902
Copy-paste	36.2951	38.2603	31.4278	32.6229	27.3542	28.5517
Optimum boundary matching	36.3085	38.3009	31.6938	33.0237	27.6392	29.0508
The proposed novel method	36.2996	38.271	31.6396	32.9784	27.4262	28.7526

TABLE 3. Percentage of execution time reduction of the proposed method respect to the optimum boundary matching

Movies	Percentage of Noise factor	Q	Percentages of execution time reduction
Akiyo	1	25	22
		50	19
	6	25	18
		50	15
Mobile	1	25	20
		50	19
	6	25	13
		50	13
Tennis	1	25	27
		50	15
	6	25	15
		50	11

phase block matching algorithm is performed in temporal-domain. In the case of “sudden changes”, our proposed method reconstructs the missed block by the estimation of DC and AC coefficient, in frequency-domain.

The proposed novel method is compared with those of some other reconstruction method including spatial averaging, spatial triangular, frequency averaging, frequency triangular, estimation of DC and AC, copy paste and optimum boundary matching methods. The simulation results for one hundred frames of three standard video sequences including Akiyo, Tennis and Mobile with different quality factor (Q) and noise factors are compared. The reconstruction results show that subjective quality of the proposed method is better than the other compared methods. On the other hand, the average PSNR values of the proposed method and the optimum boundary matching method are close to each other. For the second compared methods, the average PSNR values are improved about 1.93 dB by the proposed novel method. The investigations show that PSNR improvement is higher for monotonous frames. On the other hand, PSNR improvement is increased when quality factor (Q) is increased.

Although, the average PSNR values of the proposed method is close to the optimum boundary matching, but the computational cost of the proposed method is lower. On the other hand, the subjective quality is also higher. The computational cost of the proposed method is higher than the other compared methods, but the subjective and objective quality of reconstructed blocks is also higher, and therefore the proposed novel method is more proper for high quality Motion-JPEG applications.

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