

DATA HIDING AIDED ROBUST H.263+ TRANSMISSION

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ABSTRACT

When transmitting a digital video over a noisy channel, the visual quality decreases severely due to the channel errors. Utilization of data hiding for this problem provides a reserve information about the video to the receiver while unchanging the transmitted bit-stream syntax; hence, improves the reconstruction video quality without significant extra channel utilization. The proposed complete error resilient video codec utilizes imperceptible embedded information for combined detection, resynchronization and reconstruction of the transmission errors and lost data. In order to conceal channel errors on intra-coded frames of a video sequence, a spatial domain error recovery technique, which hides edge orientation information of a block, and a resynchronization technique, which embeds bit-length of a block into other blocks are combined, as well as some parity information about the hidden data. The inter-coded frames are basically recovered by hiding motion vector information into the next frames. The simulation results show that the proposed approach performs superior to conventional approaches for concealing the errors in binary symmetric channels, especially for higher bit-rates and error-rates.

Keywords: data hiding, error concealment, H.263+

1. INTRODUCTION

Transmission of video signals over noisy wireless channels may cause inevitable errors that might severely degrade the visual message. Error concealment techniques can be classified into 3 major groups with the following properties [1]: an interaction between the encoder and decoder, as a re-send signal, or post-processing operations at the decoder to recover lost information, or leaving some extra redundancy at the encoder to minimize the reconstruction error. All these approaches can be merged together by hiding some imperceptible information to be useful during error concealment. In this way, hidden information is not only transmitted through a secret channel from encoder to decoder, "sending back" some lost information, but also alleviates some burden on post-processing. Moreover, the extra hidden information and its small visual loss might be equivalent to decreasing the source bit-rate for obtaining the same visual quality and utilizing error control codes as a result of the bit savings at the encoder.

This radical approach in video error concealment is a result of steganography, a new technique for making imperceptible modifications on the media, mostly utilized for copyright protection and other security-based applications [2,3]. Recently, error resilient video transmission has become a new application area for data hiding, as some novel concealment methods are proposed [4-10]. These methods are examined in the next section.

It should be emphasized that the hidden information can be transmitted with a very small bit-rate overhead in the bit-stream. The standard receivers unaware of such hidden information will be unaffected and decode the bit-stream, successfully (i.e. backward compatibility between the bit-streams and conventional decoders). Obviously, the price, one pays for this additional gain, is an increasing complexity at the decoders and a small loss in visual quality.

The main motivation of this research is to demonstrate the advantages of data hiding over conventional methods in error concealment problem for video transmission. None of the previous approaches has proposed a complete video codec with detection, synchronization and recovery (reconstruction) capabilities together based on data hiding and tested under noisy channel conditions. In our simulation results, the performance comparisons are given for a number of sequences under various channel conditions at different bit-rates.

2. RELATED WORK ON ERROR CONCEALMENT BY DATA HIDING

All state-of-the-art standardized video codecs are block-based, consisting of intra- and inter-coded frames. In these systems, the conventional approaches conceal errors by either reconstructing the lost block with the smoothness property of the intensities in an intra-coded frame, or estimating a lost motion vector from block motion vectors of its spatio-temporal neighbors to compensate for the lost block in an inter-coded frame [1]. Except for the damage of any header information in the bit-stream, the bit-errors usually destroy the data only in a single block or sometimes in all the blocks within the rest of the row of macroblocks (slice). In case of such synchronization losses, the reversible variable-length coding is the only solution with limited capabilities in some recent standards.

The error concealment methods utilizing data hiding technology can be broadly classified into 3 approaches: detection of errors [4,5], resynchronization after detected errors [6] and reconstruction of the intensities for the lost blocks [7-10].

Error detection schemes based on data hiding either hide the parity check codes of the macroblocks [4] or modify DCT coefficients according to their frequency location [5]. In [4], the LSB of the sum all non-zero DCT coefficients is hidden to the next frame as a parity to detect errors. As a different approach, the value of a DCT coefficient is forced to become even (or odd), according to its DCT frequency, indexed in zig-zag order [5].

The synchronization loss within a slice can be recovered by hiding the bit-length value of each macroblock (in binary form) into another slice [6]. Hence, if the video codec is able to detect an error in a slice, the recovered macroblock lengths are utilized to decode the bit-stream block-by-block in a reverse order from the end of slice [6]. In this approach, the detection performance is limited with video codec capabilities.

Finally, methods for the reconstruction of intensities can be examined for intra- and inter-coded frames, separately. In case of still images (intra-coded frames), finding a “good summary” for the intensity information of the lost block is the critical point. Block intensity information is approximated by using either edge-direction information [7] or a low-quality coded (high compression) version [8]. It is shown that interpolation of lost intensities along a major edge gives much superior results against well-known bilinear interpolation approach at the decoder [11]. Instead of trying to find the edge direction of a lost block from its neighbors in a suboptimal manner at the decoder [11], hiding the quantized direction information into another block at the encoder is preferred [7].

For inter-frame error concealment, motion vector of a block is obviously the most valuable information. Instead of trying to estimate the lost motion vectors (MVs) by replacing them with the average/median of the MVs from spatial/temporal adjacent blocks, as in conventional approaches [1], motion vector information is simply hidden into other blocks/frames [9,10]. In order to minimize the number of bits to hide, the modula-2 addition of the motion vector bit-streams for all slices in one frame [9] or consecutive frames [10] is hidden into motion vectors [9] or DCT coefficients [10] of the next frame.

All the attractive properties of error concealment using data hiding can be merged in order to obtain a system that is capable of jointly detecting, resynchronizing and recovering errors in video sequences. A novel method to enhance error resilience properties of ITU H.263+ codec using hidden information is explained in the next section.

3. PROPOSED METHOD

In the proposed method, the data is always embedded into the frames by *even-odd signaling* [2] of the DCT coefficients. This approach gives maximum capacity with minimum robustness, which is acceptable for our application.

In order to achieve successful error concealment, the exact location of the error, i.e. damaged block, should be detected as a first step. After detecting the damaged block, synchronization must be established back in order to prevent the propagation of the error to the other blocks. The final step is the reconstruction of the intensities for the damaged block to finalize error concealment. Therefore, the three main issues for successful error concealment are error detection, resynchronization and reconstruction (recovery) of the damaged block.

3.1. Concealment of intra-coded frame errors

Following the previous approaches [4-10], both edge-direction information [7] and macroblock bit-length values [6] are necessary to solve all 3 problems. While bit-length value (8-13 bits, determined according to the bit-rate) is hidden to a previous block for resynchronization, quantized edge-direction information (4 bits) is embedded into the upper block to be used in case of damage. Prior to embedding edge orientation, the block is tested for being classified as an *edge block* by computing the gradient magnitude and this single bit is also stored to select bilinear interpolation for smooth block recovery. During decoding, the system is also not allowed to decode bits more than the number that is dictated by the hidden value in the previous block. Finally, edge-direction and bit-length values used together to help detecting bit-errors (Fig.1).

Although, the hidden bits are enough to detect an error as an inconsistency between a block and its hidden data, they do not determine whether the block or the hidden data has been corrupted by the channel errors. This is the fundamental problem for error detection by using hidden information, which is mostly neglected in the

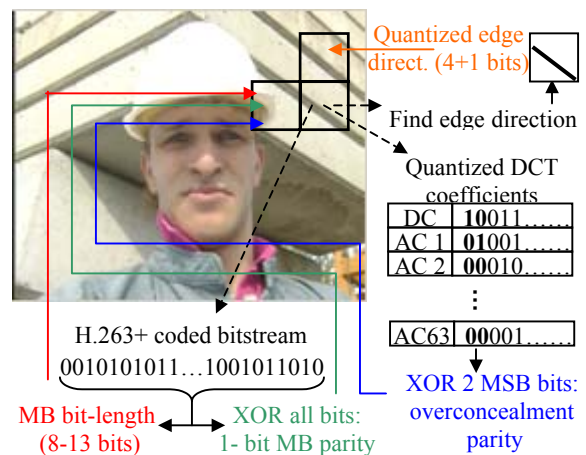


Figure 1. Hidden data for error concealment for intras

previous methods. Hence, a single-bit parity of the macroblock bit-stream is used to verify the reliability of that data. In case of a conflict between the block and the hidden data, this single-bit parity is used to resolve the conflict (Fig.1).

After successful error detection, another important problem is to “measure” the visual damage at a block before recovery, since it is possible to have a small visual error in the block, undetected by the codec itself, but “successfully” detected by the proposed system. The edge-direction based recovery technique tries to reconstruct the block, which has a very small visual degradation, while discarding all the available information. Obviously, the reconstruction quality usually turns out to be worse than the available erroneous block.

We denote this situation as *overconcealment* and it is avoided by using the modulo-2 sum of 2-bit MSBs of the current block coefficients. It is assumed that in case of visually unacceptable errors, the 2-bit MSBs are changed and this change can be detected by 2-bit parity information hidden in the previous block (Fig.1). Note that the whole idea is not to conceal the erroneous block, if there is not sufficient visual loss.

3.2. Concealment of inter-coded frame errors

The motion vector of the current block is the strictly necessary information during inter-frame recovery and this data should be hidden into other blocks.

Following [9,10], in the proposed approach, bit-stream of the differential Huffman coded MVs of each row are modulo-2 summed to obtain the parity bits. These bits, as well as their bit-length, are embedded into the motion compensated residual DCT coefficients of the next frame (see Fig.2).

In addition, that the block is coded in which mode could not be known at the decoder, when all the data about the block is lost. So, the mode of the block should also be hidden. In the proposed approach, it is represented with maximum 2 bits. Obviously, if there are errors in blocks at different rows, then the parity information is not useful anymore.

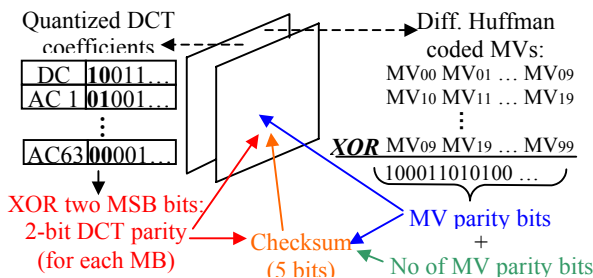


Figure 2. Hidden data for error concealment for inter-codes

Similar to intra-coded frame cases, the main problems still exist for the inter-coded frames. In this case, a similar problem to overconcealment exists. Here, one should decide whether to add the motion compensated

residual error on motion-based prediction. If a visually significant error is detected in the motion compensated error bit-stream, the decoded coefficients are not used to reconstruct the current block. Visual significance of the error is again tested by 2-bit MSBs of the DCT coefficients.

On the other hand, in order to find the location of error, all the hidden data is protected by a checksum (5 bit). This gives the opportunity to comprehend the reliability of hidden data (Fig.2).

3.3. The Algorithm

An overview block diagram of the algorithm is given in Fig.3 and Fig.4 for intra- and inter-coded frames, respectively. In both versions, there are consecutive error detection stages. The internal error detection mechanism of H.263+ is used in both inter-and intra-coded versions. For the errors invisible to the codec, the major test for intra-coded frames is synchronization and parity check, whereas the inter-coded version controls the checksum information. While the intra-coded case checks overconcealment before deciding on any reconstruction, the inter-coded approach checks the significant errors on the residual DCT coefficients.

Apart from this overview, there are also some minor details about the proposed algorithm, such as checking continuously the reliability of the hidden data or using edge information to check errors, if the hidden data for synchronization is not available.

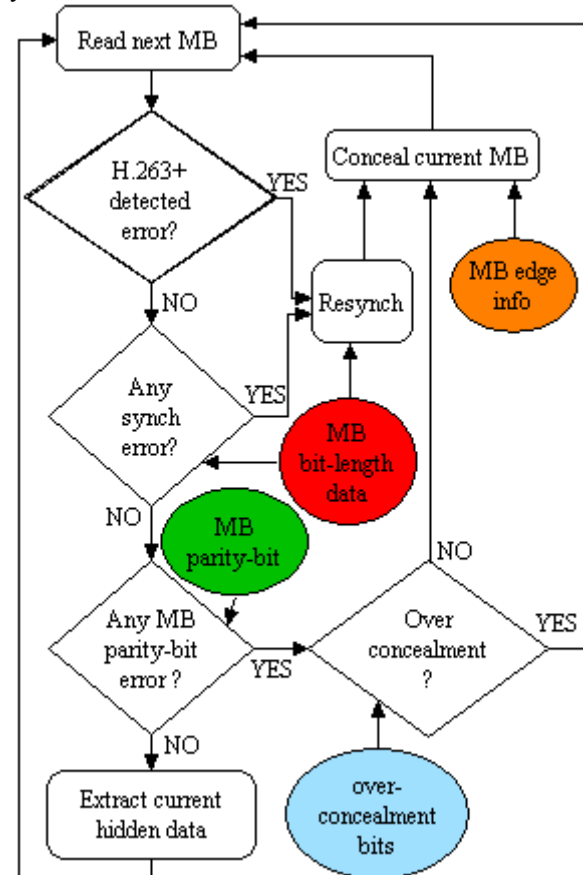


Figure 3: Block diagram of the proposed algorithm for intra-coded frames (shaded ellipses show hidden data).

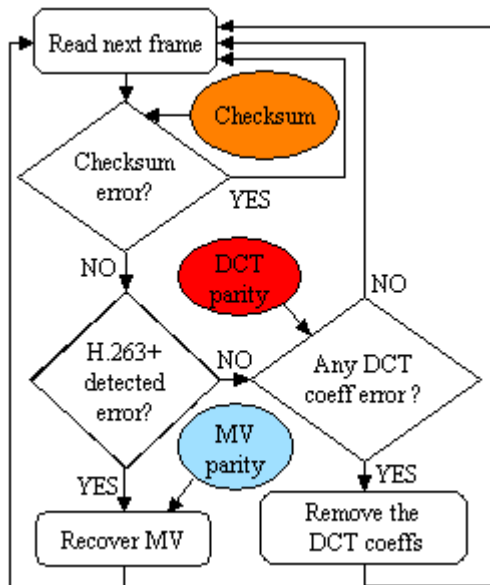


Figure 4. Block diagram of the proposed algorithm for inter-coded frames (shaded ellipses show hidden data).

4. SIMULATIONS

During experiments a binary symmetric channel (BSC) is simulated for different Bit Error Rates (BER). Using a fully encoder-decoder pair, input data is first compressed with a baseline H.263+ encoder and at the same time, the hidden info is embedded into the bit-stream; then this bit-stream is passed through a BSC, and finally, the erroneous bit-stream is decoded using a modified H.263+ decoder, capable of error concealment using hidden data. During the simulations, *Foreman* and *Carphone* sequences (first 90 frames and QCIF size) are utilized. The visual reconstruction quality is determined in terms of Peak Signal-to-Noise ratio (PSNR).

Some sample frames from the *Foreman* and *Carphone* sequences are shown in Fig. 5 and Fig. 6, respectively. In both figure, (a) is the original and (b) is the compressed frame, and (c) corresponds to data hidden frame after compression. Finally, (d) and (e) are the damaged and concealed frames. Note that the damaged sequences are obtained using the error resilience properties of H.263+ baseline codec, in which the error reconstruction is simply achieved by replacing a lost block from the same location in previous frame.

The results of simulations are summarized in Tables 1 and 2. In these tables, PSNR after compression and data hiding are presented for 3 different bit-rates. For these rates, the bit-streams are passed through BSC randomly for 100 times and the resulting average PSNRs for the damaged and concealed sequences are given.

The PSNR vs. frames plot is also shown in Fig.7 for *Carphone* sequence for BERs 10^{-5} and 10^{-4} and bit-rates 150Kb/s and 750Kb/s. From these tables and Fig.7, it is clear that the performance of the proposed algorithm improves for higher error rates (BER= 10^{-4}) and an average improvement of about 5dB is achieved for this BER over the conventional methods. For the simulated bit-rates, data hiding causes about 1dB loss. On the

other hand, the performance of the proposed algorithm gets better, as the encoding bit-rates increases. For BER= 10^{-5} , there is an average 4dB improvement moving from 150Kb/s to 750 Kb/s.

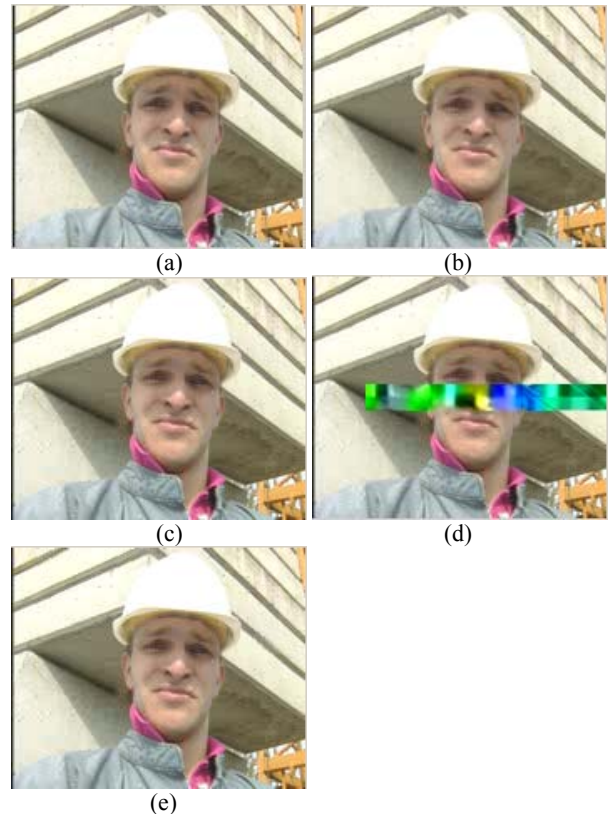


Figure 5. Sample frames for *Foreman*, (a) original 45th frame, (b) compressed as an intra frame at 350 Kbit/sec, (c) data hidden, (d) damaged, (e) concealed by the proposed method.

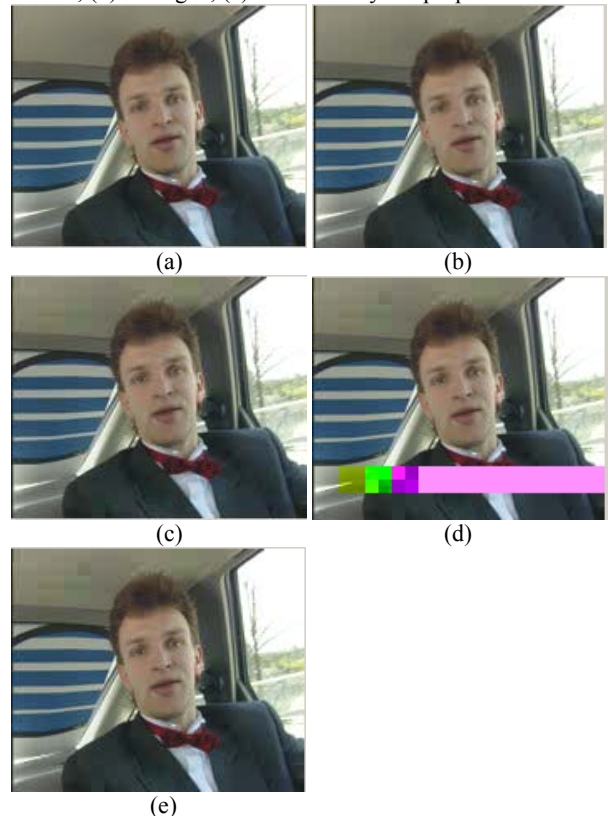


Figure 6. Sample frames for *Carphone*, (a) original 0th frame, (b) compressed as an intra frame at 350 Kbit/sec, (c) data hidden, (d) damaged, (e) concealed by the proposed method.

5. CONCLUSIONS

A novel video error concealment method is proposed, jointly achieving detection, resynchronization and recovery using data hiding. The system combines different types of hidden information in order to obtain better reconstruction quality. Simulations on video sequences indicate a significant improvement against conventional techniques.

The reason of observing better performance at higher bit-rates is due to finding enough number of non-zero coefficients to hide the required data for inter-coded frames. In order to improve the performance for lower bit-rates, the algorithm should be modified to use bit-planes other than LSB-plane for data hiding. Obviously, the proposed system shows its resilience to errors at higher error-rates, compared to baseline codec. More sophisticated versions of the same codec are expected to decrease the performance gap between the proposed method.

It should be noted that all the blocks do not have the same characteristics from reconstruction point of view. The simulations show that blocks without a major single

edge (such as highly textured areas) cannot be interpolated successfully via edge-based interpolation. The major drawback for error concealment using data hiding is due to the fundamental dilemma for finding the location of the error. Using a number of extra parity bits partially solve these problems, since these solutions come along with the assumptions on the locations of bit-errors (i.e. bit-errors should be as far away as possible). Utilization of more sophisticated error detection mechanisms (e.g. CRC), instead of simple parity bits may solve this problem, while increasing the number of bits to hide.

Simulations for comparing the proposed system against utilization of error control codes after source coding, giving with the same visual quality, which is obtained after data hiding, is left as a future work. Such a comparison will show the real benefit of data hiding for robust video transmission.

6. ACKNOWLEDGEMENTS

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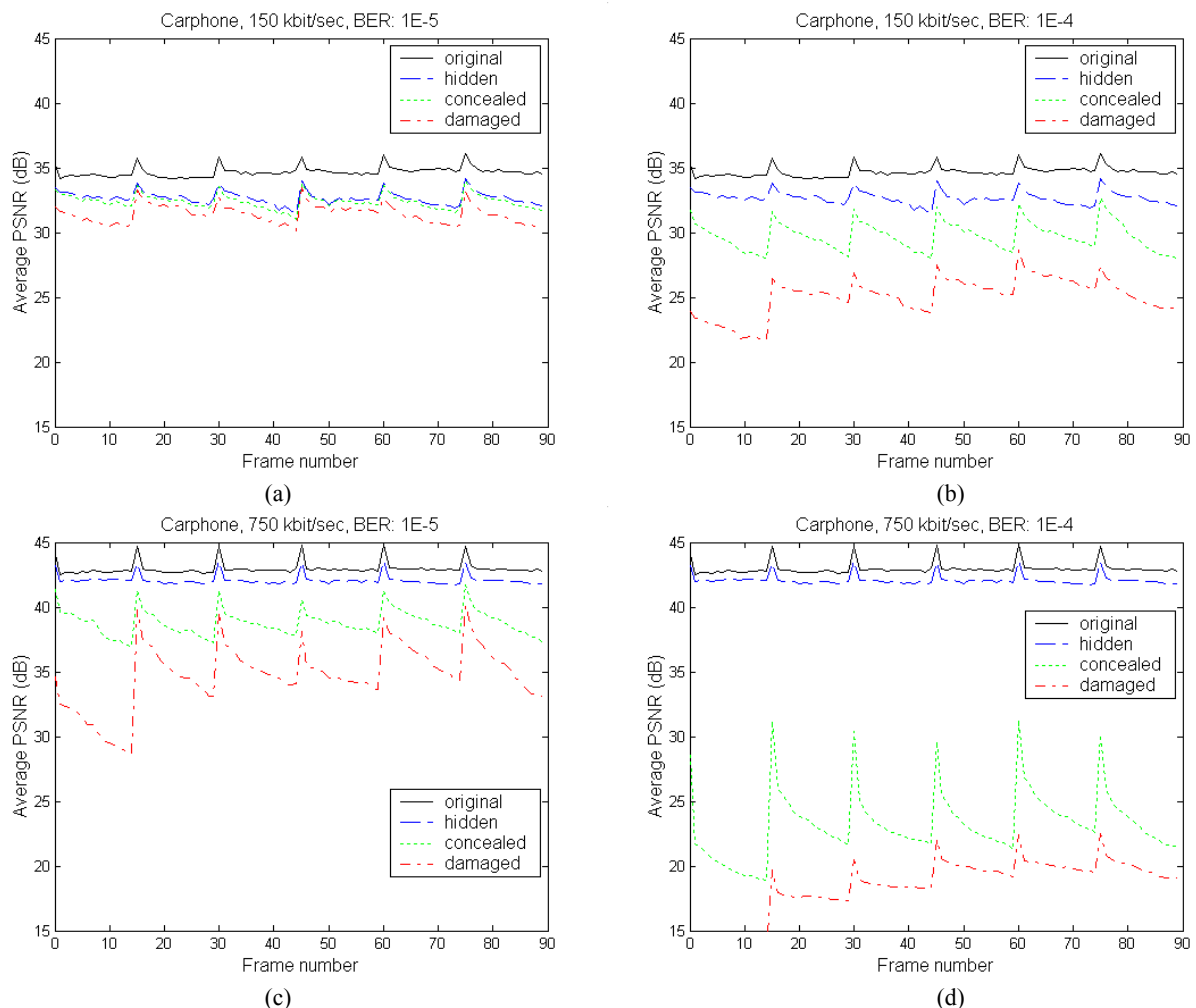


Figure 7. PSNR vs. frames for *Carphone*, (a) $BER=10^{-5}$, rate=150 Kbit/sec, (b) $BER=10^{-4}$, rate=150 Kbit/sec, (c) $BER=10^{-5}$, rate=750 Kbit/sec, (d) $BER=10^{-4}$, rate=750 Kbit/sec.

Average PSNR (dB)	Bit rate: 750 kbit/sec			Bit rate: 350 kbit/sec			Bit rate: 150 kbit/sec			
	Y	U	V	Y	U	V	Y	U	V	
Compressed	41.51	43.64	45.40	37.11	40.43	42.13	33.14	37.97	39.20	
Compressed + data hiding	40.96	42.91	44.59	36.48	40.25	41.57	31.96	37.68	38.91	
BER: 1E-4	Damaged	18.45	21.01	21.07	21.58	24.37	24.32	24.15	27.69	27.75
	Concealed	21.61	27.19	26.83	26.93	33.28	33.80	29.05	35.68	36.56
BER: 1E-5	Damaged	31.88	36.27	37.17	33.07	37.37	38.20	30.76	36.32	37.26
	Concealed	36.94	41.70	43.12	35.40	39.92	41.17	31.73	37.60	38.79

Table 1. Average PSNR values for *Foreman* sequence for different bit-rates and BERs.

Average PSNR (dB)	Bit rate: 750 kbit/sec			Bit rate: 350 kbit/sec			Bit rate: 150 kbit/sec			
	Y	U	V	Y	U	V	Y	U	V	
Compressed	42.96	45.11	45.52	38.75	42.35	42.55	34.68	40.00	39.90	
Compressed + data hiding	42.08	44.49	44.93	37.53	41.85	41.91	32.67	39.26	39.23	
BER: 1E-4	Damaged	18.31	21.39	21.52	22.15	25.57	25.75	25.08	29.93	29.87
	Concealed	23.23	29.60	29.91	28.42	35.92	36.09	29.71	37.25	37.27
BER: 1E-5	Damaged	34.73	38.68	39.08	34.39	38.98	38.96	31.42	37.85	37.78
	Concealed	38.79	43.71	44.18	36.62	41.70	41.74	32.39	39.14	39.12

Table 2. Average PSNR values for *Carphone* sequence for different bit-rates and BERs

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