A Block-Based Barni Watermarking Method for Improved Robustness under Video Compression Attacks

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***Abstract* — The Barni method has been proposed in the literature for watermarking still images. In our previous work, we have extended this method to work for image sequences (video). However, it was found that this extended frame-based version fails under video compression attacks. In this paper, we present a block-based version to improve robustness against such attacks.**

***Index Terms* — Watermarking, Barni method, Video Compression.**

I. Introduction

In recent years, there has been a significant increase in the distribution of videos (image sequences) in digital format. Because of the ease in which such videos can be copied and modified, this has created a pressing need for the development of video copyright protection methods. Digital video watermarking has been proposed as a viable solution to this problem.

In digital video watermarking, copyright protection information are embedded in the frames in the form of a watermark. The frame must not be visibly degraded by the presence of this watermark. Another main requirement of watermarking for copyright protection applications is robustness. Thus, the watermark must be resistant to unauthorised detection and decoding. In addition, the watermark must be tolerant to normal video processing techniques (e.g. compression), as well as to intentional attacks (attempts to destroy or remove the watermark).

There are many digital video watermarking techniques reported in the literature, see [1], [2]. They can be classified according to a number of different criteria. One such criterion is the domain in which the watermark is embedded. In this context, there are two main categories: spatial domain techniques, e.g. [3][4], and frequency-domain techniques, e.g. [5], [6].

Another classification of digital image watermarking techniques is based on whether the original image is needed in the watermark extraction process or not. If the original image is *not* needed to recover the watermark from the watermarked image, then the technique is called complete (also referred to as blind or oblivious), otherwise it is called incomplete (non-blind or nonoblivious).

The Barni method [5] has been proposed in the literature for watermarking still images. In [7] we have extended this well-known method to work for image sequences (video). However, it was found that this extended frame-based version fails under video compression attacks. In this paper, we present a block-based version to improve robustness against such attacks.

The paper is organized as follows. Section II briefly describes the Barni method for watermarking still images. Section III describes the frame-based Barni method for watermarking video. Section IV presents the proposed block-based Barni method for watermarking video. Section V presents and discusses the results. Finally, Section VI gives some concluding remarks.

II. Barni Method for Still Images

The Barni method is a complete robust frequency domain method. In this method, the watermark $\mathbf{X}=\{x_1,x_2,x_3,\ldots,x_N\}$ consists of a pseudo random sequence of length N. Each value x_i is a random real number with a normal distribution having a zero mean and a unity variance.

In the watermark embedding step, the discrete cosine transform (DCT) of the original image **D** is computed and the DCT coefficients are recorded into a zigzag scan, such as that used in the JPEG compression algorithm. The coefficients from the $(L+1)^{th}$ to the $(L+N)^{th}$ are taken to form the vector of original coefficients $\mathbf{V}=\{v_1, v_2, v_3,\ldots, v_N\}$. Note that the first L coefficients are skipped to achieve perceptual invisibility of the watermark. The vector $\mathbf{V'}=\{v_1',v_2',v_3',\ldots,v_N'\}$ of watermarked DCT coefficients is computed according to the following rule:

$$v_i' = v_i + \alpha|v_i|x_i\,, \qquad (1)$$

where α is called the scaling factor or the watermarking strength. The watermarked DCT coefficients are then reinserted in the zigzag scan and the inverse DCT is performed to obtain the watermarked image **D'**.

Given a possibly corrupted watermarked image **D***, the DCT is applied, the DCT coefficients are re-ordered into a zigzag scan and the coefficients from the $(L+1)^{th}$ to the $(L+N)^{th}$ are selected to generate a vector **V***.

Since the original image is not available (as this is a complete method), it is impossible to recover the watermark itself. Instead, the correlation between the recovered watermarked coefficients **V***, which may already have been corrupted, and the original watermark **X** is taken as a measure of the watermark presence. This correlation measure is given by:

$$C(\mathbf{X},\mathbf{V}^*) = \frac{\mathbf{X}\cdot\mathbf{V}^*}{N} = \frac{1}{N}\sum_{i=1}^{N} x_i \cdot v_i^* . \qquad (2)$$

This correlation is then compared to a predetermined threshold T to decide if the watermark **X** is present or not. The threshold can be computed using this equation:

$$T = \frac{\alpha}{3N}\sum_{i=1}^{N}\left|v_i^*\right| . \qquad (3)$$

Typical values of the parameters of this method are $N = L = 1000$ and $\alpha = 0.2$.

III. Frame-Based Barni Method for Video

In [7] we have presented three different ways of extending the Barni method to work for video. The three methods are:

1) **Repeated Watermark:** this method uses the Barni algorithm to embed the same watermark in each frame of the sequence.
2) **Different Watermark:** this method uses the Barni algorithm to embed a different (unique) watermark in each frame of the sequence.
3) **Divided Watermark:** this method generates a long watermark, divides it into short watermarks, and then uses the Barni method to embed each short watermark in a different frame of the sequence. The recovery system will then try to recover the long watermark from these smaller parts.

Note that all the above methods can be described as *frame-based*. This means that the DCT is taken for the whole frame and the watermark is embedded in this frame DCT. For brevity, this paper will concentrate on the *repeated watermark* method, although the same analysis can be carried out for the other two methods. Thus, hereafter, the term *frame-based method* will be used to refer to the *frame-based repeated watermark Barni method*.

IV. Proposed Block-Based Barni Method for Video

This paper proposes a *block-based* Barni method. In this method, each frame **D** of the sequence is *divided* into *blocks* $\mathbf{D}_i$ of size $B\times B$ and the DCT is taken for each block *individually*. The watermark **X** of length N is then *divided* into *smaller sub-watermarks* $\mathbf{X}_i$ of length N_s each. Each sub-watermark is then embedded into the DCT of a *different* block of the frame.

In the extraction process, a watermarked, and possibly corrupted, vector $\mathbf{V}_i$* of length N_s is extracted from the DCT of each watermarked, and possibly corrupted, block $\mathbf{D}_i$*. The extracted vectors are assembled to form a vector of watermarked coefficients **V*** of length N.

The idea behind this method is that the block-based embedding and extraction processes are *matched* to the block-based coding process utilized by most video compression standards. Thus, this match may result in improved robustness against such attacks.

V. Results and Discussion

Two test image sequences were utilized for generating the results. Both of them are of the CIF (Common Intermediate Format) format with a luma of 352×288, chromas of 176×144, and a frame rate of 30 frames/s. Each sequence contains 300 frames. The two sequences were chosen for their varied characteristics. The first sequence “Foreman” has medium motion content with one scene change, whereas the second sequence “Table” has high motion content and many scene changes.

Unless otherwise stated, the results were generated using the luma components of sequences. For the frame-based Barni method, the parameters were set to $N = L = 1000$ and $\alpha= 0.2$. For the block-based Barni method, the parameters were set to $B = 8$, $N_s = 1$, $N = 1000$, $L = 10$, and $\alpha = 0.2$. This means that each frame will be divided into 1584 blocks of size 8×8. The 1000-elements watermark will be divided into 1000 sub-watermarks with 1 element each. Each sub-watermark will be embedded into a different block.

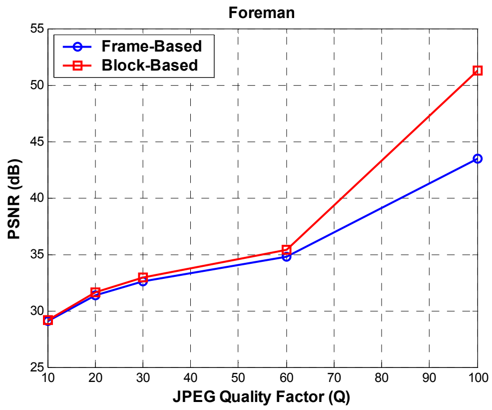
A. Performance under JPEG Compression

Although JPEG compression applies mainly to still images rather than video, some applications may apply JPEG compression to individual frames of video (motion JPEG).

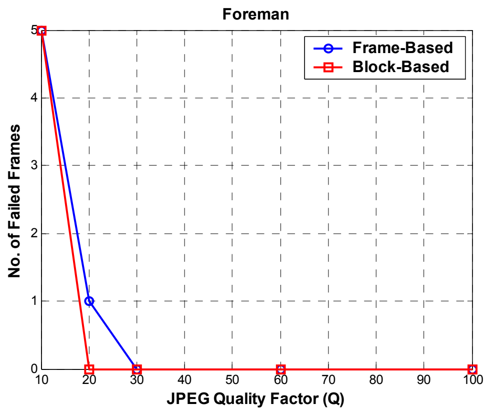
In this attack, the watermarked sequence will be compressed using different compression ratios by varying the JPEG quality factor (Q). This factor has a range from 1 to 100. The lower the Q, the higher is the compression ratio and, consequently, the lower is the quality of the decoded sequence.

Fig. 1 compares between the frame-based and block-based Barni methods when applied to “Foreman” under JPEG attack. Fig. 1(a) shows the objective quality of the watermarked sequence, in terms of the average Peak Signal to Noise Ratio (PSNR) in dB. Fig. 1(b) shows the robustness against JPEG attack in terms of the number of frames that fail the detection test (i.e. with correlation less than the detection threshold).

It is clear that the proposed block-based method provides a watermarked sequence with better objective quality while providing similar robustness to the frame-based method. Similar results have also been obtained with the “Table” sequence.



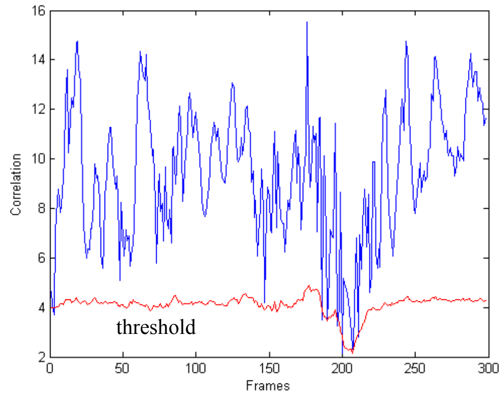
(a) PSNR measure



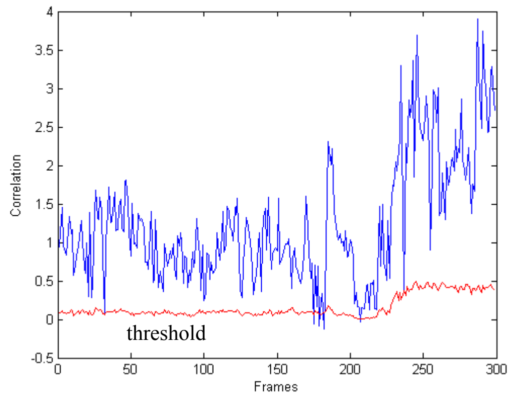
(b) Number of failed frames

Fig. 1 Comparison between frame-based and block-based Barni methods when applied to Foreman under JPEG attack

In general, both methods have good robustness against JPEG compression attacks. The quality factor Q has to be reduced to a very low value (Q=10) for the methods to start failing the detection of watermarks in some frames. This is illustrated in Fig. 2 which compares the detection performance of the two methods when applied to “Foreman” under a JPEG attack with Q=10. The blue curve in both subfigures shows the correlation measure of (2) on a frame-by-frame basis, whereas the red curve shows the detection threshold of (3). When the blue correlation curve goes below the red threshold curve, then this indicates that the method has failed to detect the presence of the watermark in that particular frame. It is clear that the two methods have comparable robustness.



(a) Frame-based



(b) Block-based

Fig. 2 Correlation measure of frame-based and block-based Barni methods when applied to Foreman under JPEG attack with Q=10

Note that at this low Q the watermarked sequence is of low quality, as can be seen in Fig. 3. Thus, even if the attack manages to fail the method, the resulting low quality sequence will not be useful for the attacker.

(a) original (b) frame-based (c) block-based

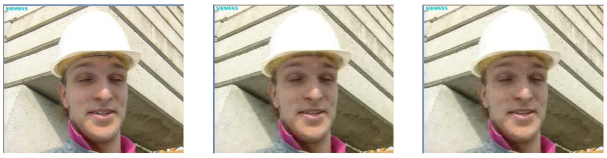
Fig. 3 Subjective quality of watermarked Foreman with JPEG quality Q=10

B. Performance under H.263 Video Compression Attack

A more relevant attack for video watermarking is the video compression attack. This paper investigates the performance under the H.263 compression attack [8].

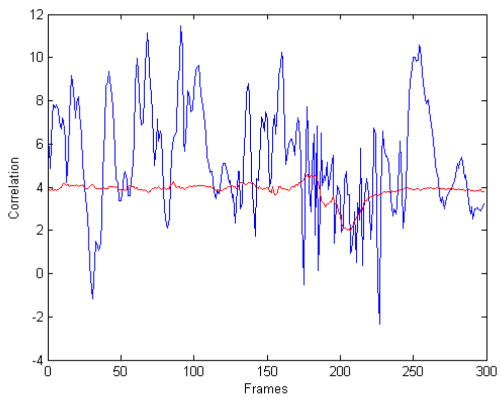
In this attack, the watermarked sequence will be compressed to different bitrates by varying the quantization parameter (*QP*) of the H.263 encoder. This parameter has a range from 1 to 31. The higher the *QP*, the lower is the bitrate and, consequently, the lower is the quality of the decoded video.

Fig. 4 shows the subjective quality of a selected frame from the watermarked “Foreman” when H.263 compressed with *QP*=20. It can be seen that the proposed block-based method provides similar quality at slightly lower bitrate. Put in another way, for the same bitrate the block-based method will provide a slightly better quality.

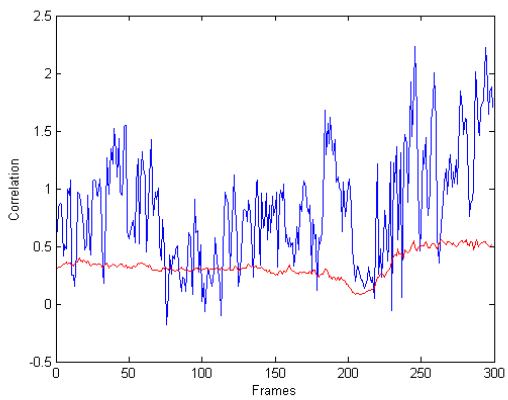


(a) original (b) frame-based (185 kb/s) (c) block-based (179 kb/s)

Fig. 4 Subjective quality of watermarked Foreman under H.263 compression with *QP* = 20.



(a) Frame-based (185 kb/s)

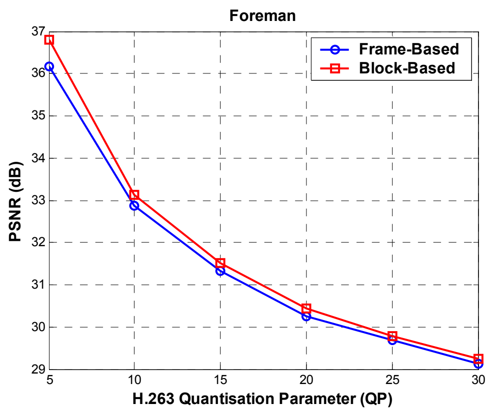


(b) Block-based (179 kb/s)

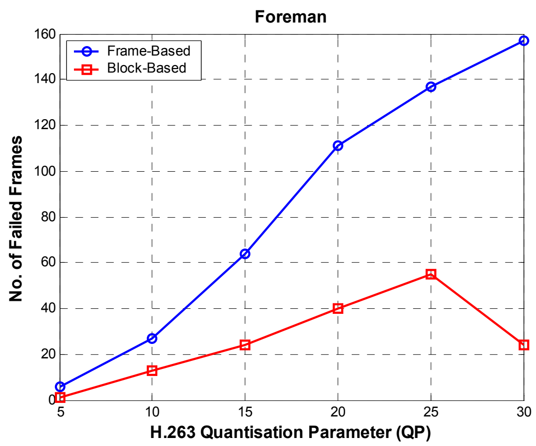
Fig. 5 Correlation measure of frame-based and block-based Barni methods when applied to Foreman under H.263 attack with *QP*=20.

Fig. 5 compares the detection performance of the two methods when applied to “Foreman” under an H.263 attack with *QP*=20. It is clear that the proposed block-based method has more robustness as it fails the detection process at a smaller number of frames.

This is further illustrated in Fig. 6 which compares between the frame-based and block-base Barni methods when applied to “Foreman” under H.263 attack with different *QP*s. It is immediately evident from Fig. 6(b) that the proposed block-based method provides more robustness to H.263 attack as it fails less frames compared to the frame-based method. This improved robustness is more apparent at high values of *QP* (i.e. at low bitrates). In addition to this improved robustness, the proposed block-based method also provides a watermarked sequence with a slightly better objective quality, as evident from Fig. 6(a). Similar results have also been obtained with the “Table” sequence.



(a) PSNR measure



(b) Number of failed frames

Fig. 6 Comparison between frame-based and block-based Barni methods when applied to Foreman under H.263 attack

By comparing Fig. 1(b) and Fig. 6(b) it can also be observed that the H.263 compression attack is much more severe than the JPEG compression attack. This is apparent in the higher number of failed frames under the H.263 compression attack.

VI. Conclusions

A block-based Barni watermarking method was proposed.

Simulation results under JPEG compression attack showed that the proposed block-based method provides a watermarked sequence with better objective quality than that provided by the frame-based method. In terms of robustness, both methods were found to provide good robustness against this attack. The JPEG quality factor Q has to be reduced to a very low value for the methods to start failing the detection of watermarks in some frames. At such low Q values, the watermarked sequence is of low quality and may not be useful for the attacker.

Simulation results under H.263 video compression attack showed that this attack is much more severe than the JPEG compression attack. In general, it was found that the proposed block-based method provides more robustness to H.263 attack as it fails less frames compared to the frame-based method. This improved robustness is more apparent at high values of QP (i.e. at low bitrates). In addition to this improved robustness, the proposed block-based method also provides a watermarked sequence with a slightly better objective quality.

VII. Acknowledgement

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VIII. References

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