

A method for estimating PSNR of coded pictures by use of embedded invisible markers

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Abstract

We propose a scheme to estimate PSNR of coded pictures with embedded invisible markers as an objective picture quality measurement method that does not use reference pictures. The PSNR of the decoded picture is estimated as follows. The invisible markers are embedded into WHT coefficients of the original picture using spread-spectrum processing. The markers are detected in the decoded picture, and the false detection rate is translated into PSNR. Picture degradation and the influence to coding efficiency by embedding markers is very small, so that this scheme is applicable to high-quality video transmission.

1. Introduction

Automatic picture quality assessment methods without reference pictures have been studied for the purpose of quality monitoring of digital video transmission. They include NRRR methods. However, as NR methods don't use information of the original picture, it is difficult to highly improve the estimation accuracy. RR can provide better accuracy, but it requires additional control lines, and the transmission delay for reference information can be critical for real-time monitoring.

The purpose of this study is to provide an automatic quality monitoring method that gives accurate assessment of picture quality without any additional control lines.

Our method utilizes invisible marker signals embedded into the picture. The receiver side calculates the false detection rate for the markers, which is then translated into PSNR.

In the following, after explaining the method of embedding and detecting markers, the relationship between degradation (MSE) and the false detection rate (FDR) is derived. Next, computer simulation experiments show that this scheme provides highly accurate estimation of PSNR while the degradation by markers and the influence on coding efficiency is negligibly small.

2. Embedding and detecting of invisible markers

Figure. 1 shows the overview of the proposed method.

2.1. Embedding of markers on the transmitter side

On the transmitter side, prior to encoding, invisible markers are embedded by a data-hiding method using spread spectrum, in the same way with digital watermarking. First, the picture is multiplied by a PN sequence, and then Walsh-Hadamard Transform (WHT) is performed on each macroblock. Some of the transform coefficients are modified to embed markers. Here, WHT is used instead of FFT or DCT in order to reduce the computational load.

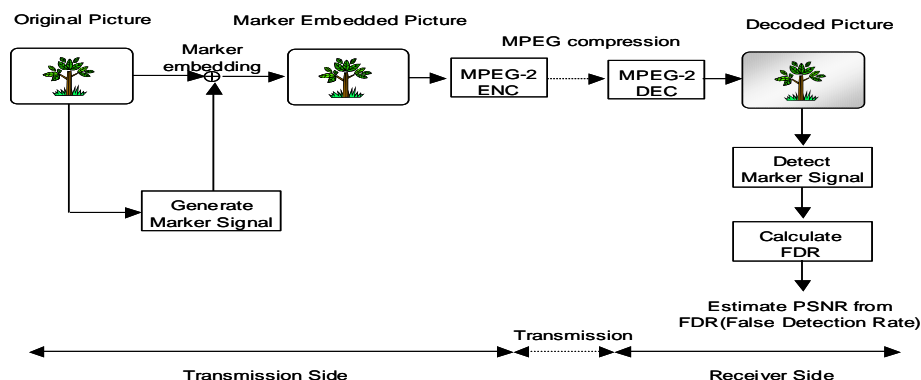


Figure. 1: Overview of the proposed method.

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2.2. Detecting of markers and estimation of PSNR on the receiver side

Next, the picture with embedded markers is encoded and transmitted to the receiver side. As the marker signals degrade by the coding noise, some of the markers are falsely detected on the receiver side. By detecting all the markers, the false detection rate (FDR) is derived. Referring to a PSNR-FDR table obtained beforehand, we estimate the PSNR of the received picture from FDR.

2.3. Derivation of PSNR-FDR curve

This sub-section derives the relationship between PSNR and FRD by theoretical modeling. Let s_0 denote the frequency where a marker is embedded, $X_{SS}[s_0]$ the frequency component after spread spectrum (multiplication by a PN sequence) and embedding of a marker, and $X'_{SS}[s_0]$ the frequency component after spread spectrum on the receiver side. Then the degradation of the frequency component $E_{SS}[s_0]$ is

$$E_{SS}[s_0] = X_{SS}[s_0] - X'_{SS}[s_0] \quad (1)$$

Let $p_e(x)$ denote the probability density function of $E_{SS}[s_0]$. It can be represented by a Laplacian distribution with the variance σ_e^2 .

$$p_e(x) = \frac{1}{\sqrt{2}\sigma_e} \exp\left(-\frac{\sqrt{2}}{\sigma_e} |x|\right) \quad (2)$$

When M represents the step size for embedding markers, the condition for an embedded marker to be correctly detected is $|E_{SS}[s_0]| \leq M/2$.

Therefore, the false detection rate will be

$$FDR = 1 - \int_{-M/2}^{M/2} p_e(x) dx = \exp\left(-\frac{M}{\sqrt{2}\sigma_e}\right) \quad (3)$$

Now, σ_e^2 can be an estimate of MSE because the degradation has been through spread spectrum processing.

$$MSE \approx \sigma_e^2 \quad (4)$$

From Eq.(3) and (4) we obtain

$$\frac{1}{MSE} \approx 2 \left[\frac{\ln(FDR)}{M} \right]^2 \quad (5)$$

PSNR can be derived from MSE in Eq.(5). Thus, we can estimate PSNR from FDR and the parameter M, which is shared between the transmitter and the receiver sides.

3. Computer simulation experiments

The following experiments show the accuracy of PSNR estimation by the proposed method, as well as the degradation of the original picture due to embedding markers. Simulation parameters are shown in Table. 1.

3.1. PSNR-FDR curve

False detection rate (FDR) for markers and PSNR was calculated for each decoded picture, to derive PSNR-FDR curve (Figure. 2). The line in this figure was obtained as a regression curve that conforms to Eq.(5). Thus, the value of this curve is the PSNR estimated from FDR, and the shorter the distance between each point and the curve is, the higher the estimation accuracy is. As Figure. 2 shows, this regression curve does not depend on the kind of picture or bit rate, so it can be utilized to estimate PSNR only from FDR for various kinds of pictures and bit rates.

Table. 2 shows the PSNR of the marker-embedded picture on the transmitter side and the error in PSNR estimation on the receiver side. The errors are represented by the mean absolute error [dB] and variance. The proposed method estimates PSNR with the average error of about 1[dB], while the degradation due to embedding of markers is being kept invisible (over 49dB). This degradation is negligible compared to coding noise.

Table. 1: Parameters for simulation experiments

Test Sequences	Cheerleaders, Flamingoes, Green leaves, Marching in Mobile and Calendar, Soccer Action
Picture Size	704(H)x480(V)
Picture Format	NTSC 4:2:2, 30fps
Codec	MPEG-2 Test Model 5
Bitrate	5,10,20,40 Mbps
Picture Quality Measure	PSNR (average of 30frames)
Blocksize	16x16
Marker Intensity M	M=300

Table. 2: Estimation accuracy and degradation of original pictures

	PSNR of marker-embedded picture[dB]	Estimation Accuracy [dB]	
		MAE	Variance
Cheer	49.18	1.230	2.415
Fla	49.12		
Green	49.16		
March	49.16		
Mobile	49.10		
Soccer	49.10		

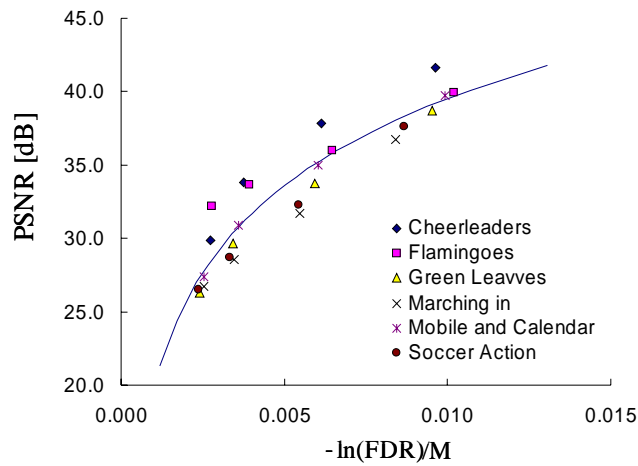


Figure. 2: Relationship between $\ln(\text{FDR})/M$ and PSNR

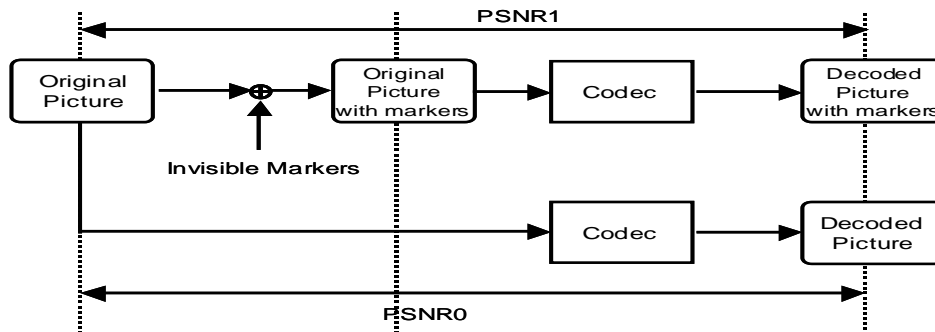


Figure. 3: Definition of PSNR0 and PSNR1

Table. 3: Influence of coding efficiency

bitrate[Mbps]	Cheer		Soccer	
	PSNR0 [dB]	PSNR1 [dB]	PSNR0 [dB]	PSNR1 [dB]
5	29.77	29.74	26.59	26.43
10	33.87	33.68	28.75	28.72
20	38.12	37.63	32.40	32.32
40	42.50	41.12	37.94	37.58

3.2. Influence on coding efficiency

The embedded marker signals can be considered random noise upon the original picture, so that the entropy of the picture can increase a little, giving rise to the possibility of decreasing coding efficiency. The following experiment shows the influence of embedded markers upon coding efficiency.

We compared the coding efficiency of marker-embedded pictures with that of the original pictures, by calculating PSNR (average of 30 frames) of decoded pictures. Table. 3 shows results using the pictures Cheerleaders and Soccer. Here, PSNR0 and PSNR1 are defined as described in Figure. 3. As the decrease in PSNR by embedding markers is very small compared to the coding degradation itself, we can conclude the influence of embedded markers on coding efficiency is negligible.

4. Conclusion

We have proposed a scheme to estimate PSNR where invisible marker signals are embedded in pictures. This scheme utilizes the relationship between PSNR of the decoded picture and the false detection rate (FDR) for the markers. The receiver side can estimate PSNR of the decoded picture only by obtaining FDR. As picture degradation by embedded markers and the influence on coding efficiency is negligibly small, this scheme can be applied to a high-quality video transmission such as contribution and primary distribution.