VIDEO QUALITY ANALYSIS USING A WATERMARKING TECHNIQUE

R. Lancini, F. Mapelli and S. Saviotti

CEFRIEL – Politecnico di Milano
Via R.Fucini, 2 - 20133 – Milano - ITALY
E-mail: {rosa, mapelli}@cefriel.it

ABSTRACT

In this paper we present a novel technique to evaluate the quality of a video in a digital TV environment. This can be done without any information about original video. The idea is based on the use of a reference signal embedded in the video. To obtain this a semi-fragile technique is proposed. In the embedding phase the watermark is inserted in the hybrid domain by quantization approach. In the extraction phase the watermark is read in the received video. The extracted watermark is compared with the inserted one and its quality is evaluated. Using the value obtained the video quality is computed. The results show that the proposed algorithm provides a good estimation for the video quality for MPEG compression in a wide range of bit-rates.

1. INTRODUCTION

In the last few years a lot of TV broadcasters are moving from analog to digital TV. This approach has a lot of advantages but also new problems to face. One of the most important is the evaluation of the quality of the signal transmitted and received [1]. In the analog TV this problem is solved embedding some test signals in the parts of the frame that are not visible to the end-user – e.g. blank lines. This signals provide a good approximation of the frame quality because the main lost of quality is due to transmission errors – which can be considered constant for each single frame.

The assumptions for analog signal cannot be applied in the same way to digital TV [1]. First of all there are not blank lines: the digitalized signal does not contain any "invisible" part. Moreover the main lost of quality is due to compression and transcoding operations, which are highly non-linear also in the same frame. The typical standard used for digital TV is MPEG2 which works splitting frames in macroblocks and blocks. Each block has its own features and it is coded independently from the other. This produces the non-linearity. These problems prevent the use of test signal only in particular part of the frame.

Figure 1 - Watermark example.

In this paper we follow a novel approach to provide quality estimation for digital TV – i.e. MPEG2 coded video. The idea is similar to the one proposed for analog TV: the use of test signal. Instead being embedded only in few parts of the frame we hide this signals in the whole frame using a watermarking technique. Different approaches and applications are proposed in [2-7]. The basic idea is to use a semi-fragile algorithm [8]: higher is the compression worse is the watermark. The watermark is inserted by a quantization operation in the block based DCT domain.

Some issues must be taken into account. First of all the algorithm should be fast. Then the watermarked image must have a high quality – at least 48-49 dB – in order to not damage the video more than the higher bit-rate compression – about 40Mbps. Lastly we need to follow also quality change and not only a global estimation on the whole video.

2. WATERMARK INSERTION

In this section we present our algorithm to insert the test signal in the original video. The algorithm should be as simple as possible in order to reduce the computational cost. The idea is to hide a signal – e.g. an image – in the original video, after the compression and transmission we extract the watermark and evaluating its quality we are able to esteem the video quality. To achieve this goal we choose as a watermark an image defined using two bits per pixels – i.e. each pixel is defined with 4 gray levels. An example of watermark is shown in Figure 1.

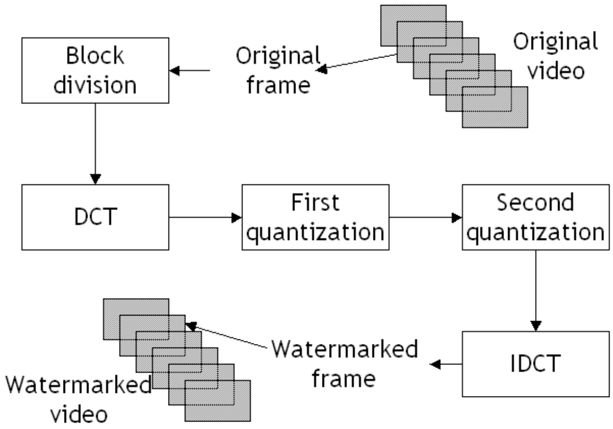

Figure 2 - Insertion algorithm.

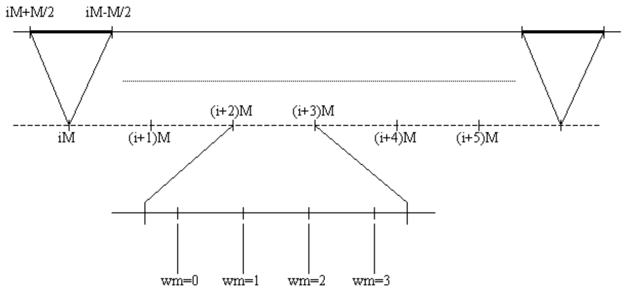

Figure 3 - Quantization levels.

The watermark insertion is performed before any other operation without any knowledge on the following processing: the best choice is to embed the signal in the original uncompressed frame. Figure 2 shows the main phases of the algorithm, which are analyzed briefly. To develop our algorithm we consider the typical standard coder, so we consider these issues:

- the most important component is the luminance;
- usually the compression is block based: frames are anlyzed splitting them in blocks;
- a transform (DCT) is used.

The watermark is inserted in each frame in the same way. Taking into account these considerations we insert the test signal only in the luminance component. The main advantage is the reduction of the computational cost. Moreover the human eye has higher sensitivity to the luminance than to the crominance.

The watermarking algorithm works in the hybrid domain: the luminance is divided in blocks of 8x8 pixels, than each block is transformed in the frequency domain using the DCT.

In each block we modify a single sample using a quantization approach to hide a pixel of the watermark – i.e. the watermark size in pixel is exactly the size of the frame in blocks. In this way we fix the value of the sample and we are able in the extraction phase to identify the variation and estimate the loss of quality. In order to preserve a high quality this step involves two different quantizations.

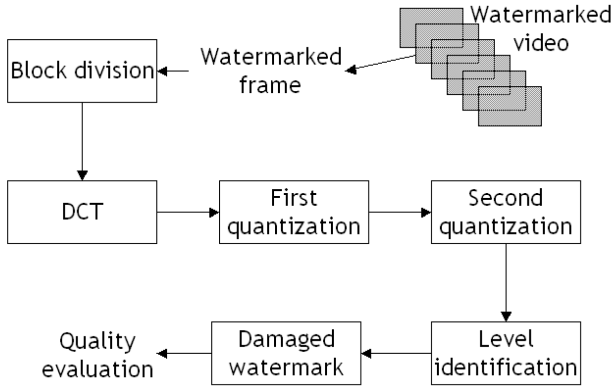

Figure 4 - Watermark extraction phase.

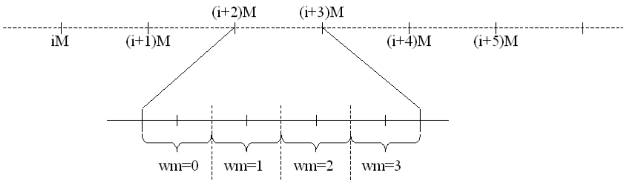

Figure 5 - Identification of the value for the watermark pixel.

The first quantization identifies a first interval in which the sample will be. Than the second one sets the value depending on the watermark. The process is depicted in Figure 3. *M* represents the first quantization step, while in each interval of size *M* the value is chosen depending of the value of the watermark pixel *wm*={0,1,2,3}. The first quantization, which dependes on *M*, is the one that cause the most important lost in quality.

At the end of this process the watermarked blocks are anti-transformed using IDCT and restored in their original position. In this way we obtain the watermarked frame.

3. WATERMARK EXTRACTION

In this phase we identify the watermark inserted by analyzing the same samples marked in the insertion phase. Figure 4 shows the extraction phase.

The video is analyzed frame by frame considering only the luminance, because the watermark is embedded in this component. The luminance is split in blocks of size 8x8 pixels. Each block is transformed using the DCT and the same sample selected in the insertion phase is considered. We use a approach similar to the one used in the insertion: quantizing the value of the sample we decide the value of the watermark pixel. This step is depicted in Figure 5.

Once extracted all the pixel values we are able to reconstruct the damaged version of the watermark *W'*. Then it is compared with the original watermark inserted in order to determine its quality W_q, using the PSNR:

$$W_q = PSNR(W, W') = 10\log_{10}\left(\frac{\max(W)}{(W - W')^2}\right).$$

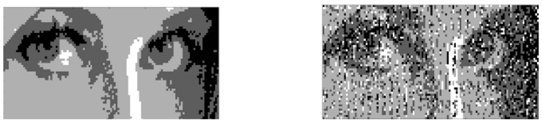

Figure 6 - Embedded (left side) and extracted (right side) watermark.

4. QUALITY EVALUATION

This section presents the last phase of the algorithm: the evaluation of the video quality by using the watermark quality.

We noticed that the watermark extracted from a single frame is too much damaged, and it does not allow the correct estimation. In order to improve the performance of our algorithm the watermark is the mean of the watermarks extracted from *N* consecutive frames. An example of watermark extracted from *N*=12 frames MPEG1 compressed to 8Mbps is in Figure 6.

This approach reduces the granularity– i.e. we are not able to measure the quality of a single frame – but improve the estimation. It must be taken into account that in general is not useful to have the quality of each single frame but the general trend.

We have to analyze how to perform the estimation. The proposed approach is quite simple: we esteem the video PSNR *Vq* from the watermark PSNR *Wq* using a linear estimator:

$$V_q = a \cdot W_q + b;$$

where *a* and *b* are two parameters that we determined experimentally. To evaluate the parameters we use a many different videos, compressed to different bit-rates and compare the extracted W_q with the PSNR computed between the compressed and the original versions. In this way we obtain *a*=1.27 and *b*=19.53.

5. TESTS

In this section we present performed tests and obtained results. To test our algorithm we use sequences with different characteristics – i.e. different compression complexity. They are about 10 seconds long in PAL format. The results are focused on the MPEG-2 compression because this application is mainly intended for digital TV, which uses this standard. We have to grant a high quality after the watermark insertion. In fact we need to be able to evaluate the video also for low level of compression (up to 40Mbps). For this reason we choose our parameter to obtain a minimum PSNR of 49dB.

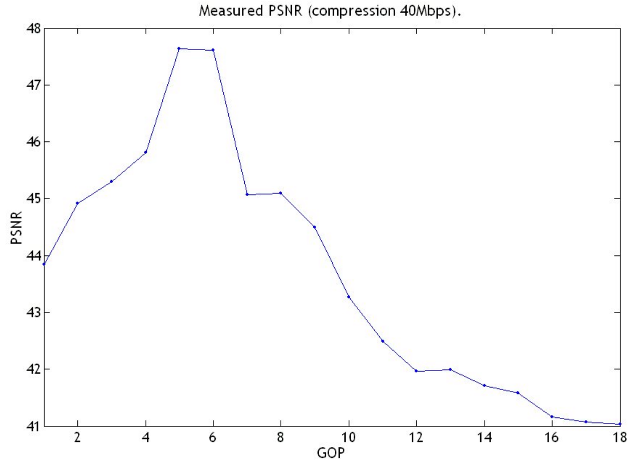

Figure 7 - Example of measured PSNR (MPEG2 40Mbps).

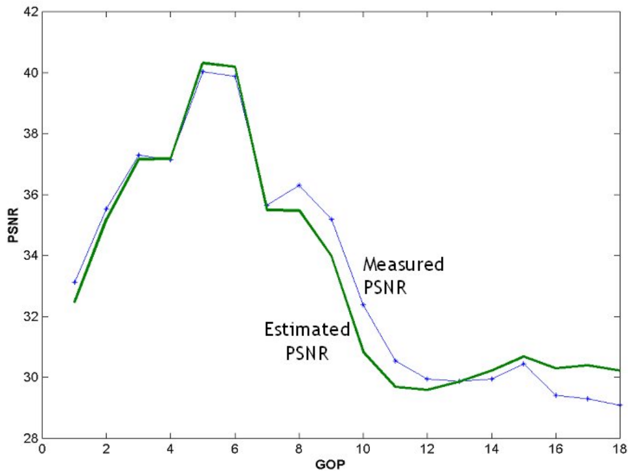

Figure 8 - Estimation example (MPEG2 8Mbps).

Figure 7 shows, as an example, the PSNR computed for MPEG2 compression at 40Mbps for a test sequence – it represents a F1 race with a scene change. Each point represents the average value in a group of 12 frames. It is noticeable that we have high variation in PSNR – due to a scene change – which allows us to test the response of our estimation. Figure 8 shows an example of estimation. The watermarked video is compressed to 8Mbps. Then we extract the mean watermark of each group of frame. The last step is the estimation of the PSNR of the video, using the PSNR of the watermark. The obtained result is compared with the measured PSNR (at 8Mbps).

Analyzing this graph we can see that however some minor variations are not seen the main trend is well approximated. Moreover it can be noticed that the esteem worsen when the quality is lower. Both these effects can be explained taking into account the watermarking strategy. The watermark has a lower resolution – only 4 levels - compared to the original video – 256 levels per channels - so it cannot follow exactly the same trend, but only the main modification. Moreover the watermark is embedded has a small noise in the video, so more the video is compressed more the noise tends to be reduced, and the estimation worsen.

Bit rate	Measured PSNR	Estimated PSNR
40 Mbps	42,22 dB	42,01 dB
30 Mbps	40,60 dB	40,42 dB
20 Mbps	38,05 dB	37,94 dB
10 Mbps	33,08 dB	34,19 dB

Table 1 - Results for high bit-rates, considering 2 frames for the estimation.

Bit rate	Measured PSNR	Estimated PSNR
10 Mbps	35,32 dB	35,41 dB
8 Mbps	33,68 dB	33,88 dB
6 Mbps	32,27 dB	32,07 dB
4 Mbps	30,64 dB	29,96 dB

Table 2 - Results for lower bit-rates, considering 12 frames for the estimation.

The tables contain the results obtained estimating the PSNR for two different cases. These values are the average computed on all considered sequences. In Table 1 we report the results for high bit-rate compression with short GOP (2 frames IB – typical in production phases). The estimation is performed considering 2 frames for the PSNR estimation. In this case the variance of the estimation error is about 0.4. This value is computed considering the error computed for a single estimation – i.e. for each single GOP.

Table 2 shows the results obtained for lower bit-rates. In this case the compression uses a GOP of 12 frames, and we consider 12 frames for the PSNR computation. In this case the variance for the error estimation is about 0.6.

We test also higher bit-rates using 12 frames for estimation. The results are slightly better than Table 1, this is mainly due to the better estimation of the watermark obtained from a higher number of frames.

The results showed that the estimation value is very close to the real one, obviously the higher the bit-rate the better the estimation. The maximum error is about 1dB.

More tests are performed using more than 12 frames for the estimation. The results are slightly better than in table 1 and 2. This advantage is paid with a lost in granularity.

6. CONCLUSIONS AND FURTHER RESEARCH

In this paper we presented a watermarking technique for automatic estimation of video quality without using the original video signal. The watermark is embedded by using a quantization approach in the block based DCT. The proposed approach was tested mainly for MPEG2 compression which is highly used in digital TV studios. The results showed that we are able to estimate the quality with a quite good approximation.

Compared with other techniques [2-7] we can operate on a wider range of bit-rates without any modification to algorithm or parameters.

For the future we are working to implement a different estimation process in order to improve the performance and the efficiency for lower bit-rates. Moreover we are moving to different quality parameter using more subjective quality indicator such as DVQ or JND [9].

7. REFERENCES

[1] Tektronix, “A guide to Picture Quality Measurements for modern Television Systems”. *www.tecktronix.com.*

[2] O.Sugimoto, R. Kawada, M. Wada, S. Matsumoto, “A method for estimating PSNR of coded pictures by use of embedded invisible markers,” *Audio Visual and Multimedia Information Processing,* N. 033. (2001).

[3] O. Sugimoto, R. Kawada, M. Wada, and S. Matsumoto, “Objective measurement scheme for perceived picture quality degradation caused by MPEG encoding without any reference pictures,” *Proc. SPIE, Human Vision and Electronic Imaging, San Jose,* CA, vol 4310, pp.932-939, 1998.

[4] M. Holliman, and M. Young, “Watermarking for Automatic Quality Monitoring,” *Proc. SPIE, Security and Watermarking of Multimedia Contents,* San Jose, CA, vol 4675, 2002.

[5] M.C.Q. Farias, S.K. Mitra and M. Carli “Video Quality Objective Metric Using Data Hiding”, *Proc.Of IEEE 2002 Workshop on Multimedia Signal Processing (MMSP).*

[6] Patrizio Campisi, Marco Carli, Gaetano Giunta, and Alessandro Neri, “Blind Quality Assessment System for Multimedia Communications Using Tracing Watermarking” *IEEE Transactions on Signal Processing,* VOL. 51, NO. 4, April 2003.

[7] ITU-T Series J, “Objective picture quality measurement method by use of in-service test signals”, *ITU-T Recommendation J.147.*

[8] O.Ekici, B.Coskun, U.Naci and B.Sankur, “Comparative Assessment of Semi-Fragile Watermarking Techniques”, *SPIE Conf. 4518, Multimedia Systems and Applications IV,* 2002, August 19-24, Denver, USA.

[9] A.B.Watson, J.Hu,J.f.McGowan III, “ DVQ: A digital video quality based on human vision,” *Journal of Electronic Imaging* 2001, pp.20-29.