Classification of Degradation Types Based on Distribution of Blocky Blocks for IP-Based Video Services

Kyung-Yeon Min, Seon-Oh Lee, Dong-Gyu Sim, Hyun-Woo Lee, Won Ryu, and Kyoung-Hee Lee

In this letter, we propose a new quality measurement method to identify the causes of video quality degradation for IP-based video services. This degradation mainly results from network performance issues and video compression. The proposed algorithm identifies the causes based on statistical feature values from blocky block distribution in degraded IP-based videos. We found that the sensitivity and specificity of the proposed algorithm are 93.63% and 91.99%, respectively, in comparison with real error types and subjective test data.

Keywords: Blocking artifacts, no-reference, IP-based video service, video quality, compression error, transmission error.

I. Introduction

With the advent of IP-based multimedia services, consumers enjoy a lot of multimedia content over IP-based networks. However, the video quality is degraded mainly due to compression by the quantization of data compression and channel errors by packet loss and/or packet delays in the transmission of packets. Thus, it is useful to detect and monitor perceptual quality degradation due to compression errors and transmission imperfections in order to improve video quality.

Several algorithms have been proposed to assess degradation of video quality [1]-[4]. Some algorithms assess compression errors by evaluating the periodicity from frequency components in power spectrum domains [1]-[3]. The other algorithms based on network parameters were also proposed to measure degradation caused from transmission errors [4]. In general, delivered images could be degraded by compression errors and/or transmission errors. Therefore, understanding the cause of degradation is essential for video quality improvement. However, no algorithms are available that distinguish types of degradation. In this letter, we propose a new identification method for video degradation type by quantifying blocky block distribution for IP-based video services without original reference frames.

II. Identification of Video Quality Degradation

We are required to monitor subjective video quality for improvement of IP-based video service quality. As mentioned, quality degradation results from the combination of multiple causes. Classification of degradation causes would significantly improve the accuracy of subjective quality evaluations. However, no prior work has been conducted to identify the causes of video degradation. The proposed algorithm is developed to detect whether or not delivered videos for IP-based video services are degraded. The proposed method is also able to determine whether the causes of degradation are from network performance or compression errors. The proposed method identifies the type of degradation based on characteristics of degradation patterns.

The proposed method consists of the extraction part of

Manuscript received July 22, 2010; revised Aug. 25, 2010; accepted Sept. 10, 2010.

This work was partly supported by the IT R&D program of MKE/KEIT [2008-S-006-03, Development of Open-IPTV (IPTV2.0) Technologies for Wired and Wireless Networks] and partly supported by the Ministry of Knowledge Economy (MKE), Korea, under the Information Technology Research Center (ITRC) support program supervised by the National IT Industry Promotion Agency (NIPA-2011-(C1090-1111-0001)).

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doi:10.4218/etrij.11.0210.0277

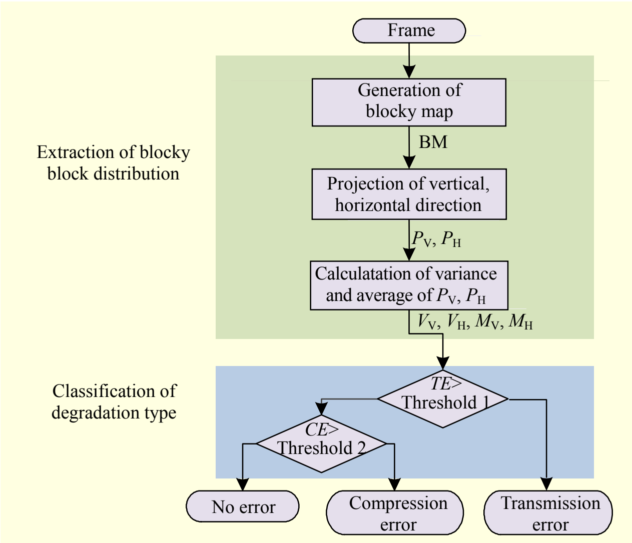

Fig. 1. Flowchart of proposed method.

blocky block distribution and the classification part, as shown in Fig. 1. We measure the distribution of blocky blocks in the extraction part and identify degradation types in the classification part. When the intensity of a block is noticeably different from that of its neighboring pixels, the block should be identified as a blocky block regardless of error causes such as quantization or packet loss.

In order to extract the distribution of blocky blocks, we generate a blocky map (BM) and its vertical and horizontal projections (P_V, P_H). Then, the variance and average of P_V and P_H are calculated.

We generate the BM that indicates which block is blocky. In order to identify a blocky block with minimum computational complexity, we calculate the difference between a target block and its neighboring blocks.

A block, $J\times I$, is divided into two regions, A and B, which are called inside-block and inside-bottom-block, respectively, as shown in Fig. 2. Region C represents adjacent pixel lines to the region B. For the block located on the [m, n] position of a frame, averages for A[m, n], B[m, n], and C[m, n] are defined as

$$M_A[m,n] = \frac{1}{(J-\alpha)\times I}\sum_{j=0}^{J-\alpha}\sum_{i=0}^{I} P_{m,n}[j,i],$$
$$M_B[m,n] = \frac{1}{\alpha\times I}\sum_{j=J-\alpha}^{J}\sum_{i=0}^{I} P_{m,n}[j,i], \quad (1)$$
$$M_C[m,n] = \frac{1}{\alpha\times I}\sum_{j=J}^{J+\alpha}\sum_{i=0}^{I} P_{m,n}[j,i],$$

where j and i are pixel indices, and m and n are block indices. We set α to 2. $P_{m,n}[j, i]$ represents a pixel value of position [j, i]

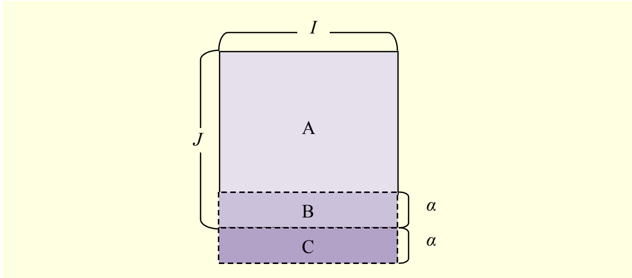

Fig. 2. Target block and adjacent pixel lines for measurement of blocking artifacts

of the (m, n)th block, and $J\times I$ is the block size (J=16, I=16). We can make a decision about whether or not the target block has blocky artifacts based on the following condition. If the condition is true, the target block is regarded as a blocky block. Then, we generate the BM, which is defined as

$$BM[m,n] = \begin{cases} 1, & \begin{aligned}&(|M_B[m,n]-M_A[m,n]| \\ &\quad - w(|M_B[m,n]-M_C[m,n]|)) > 0\end{aligned} \\ 0, & \text{otherwise} \end{cases}, \quad (2)$$

where w is the weight set to 4.

Then, horizontal and vertical projections are computed by accumulating the BM. Note that transmission errors result in aggregated blocky blocks. Therefore, we calculate projections of the BM in order to evaluate how many blocks are aggregated as blocky blocks. Vertical projection (P_V) and horizontal projection (P_H) are defined as

$$P_V[k] = \sum_{m=0}^{M-1}\sum_{n=\frac{N}{K}k}^{\frac{N}{K}(k+1)-1} BM[m,n],$$
$$P_H[l] = \sum_{m=\frac{M}{L}l}^{\frac{M}{L}(l+1)-1}\sum_{n=0}^{N-1} BM[m,n],$$
$$k = 0 \text{ to } K, \quad l = 0 \text{ to } L, \quad (3)$$

where K is the number of vertical partitions set to 4, and L is the number of horizontal partitions set to 4.

The average and variance of blocky block distributions are computed with the following equations.

$$M_V = \frac{1}{K}\sum_{k=0}^{K-1} P_V[k], \quad V_V = \frac{1}{K}\sum_{k=0}^{K-1}(M_V - P_V[k])^2,$$
$$M_H = \frac{1}{L}\sum_{l=0}^{L-1} P_H[l], \quad V_H = \frac{1}{L}\sum_{l=0}^{L-1}(M_H - P_H[l])^2. \quad (4)$$

Visual artifacts are caused by two main factors: transmission and compression errors. It is known that compression errors are periodically shown because video compression is performed on a block-basis [1]. Degradation by transmission errors tends to aggregate because consecutive blocks are aggregated together in a slice [3]. Based on these observations, the proposed algorithm is designed to classify degradation types by quantifying the statistics of blocky block distribution.

Transmission errors cause a high average and variance of the amount of blocky blocks, while only average values are observed for compression errors. Therefore, the variance (*TE*) is used to determine whether transmission errors occurred or not. Then, the average (*CE*) is used to detect compression errors. The proposed decision algorithm can be written as

$$\begin{aligned}&\text{if } (TE(=V_V+V_H)>T_1)\\&\qquad\text{Transmission error}\\&\text{else if } (CE(=M_V+M_H)>T_2)\\&\qquad\text{Compression error}\\&\text{else}\\&\qquad\text{No error.}\end{aligned} \tag{5}$$

Note that people could have significantly different opinions on the perceptual quality of degradation. Once the degradation type is identified, the reliability of perceptual quality evaluation could be improved. In addition, content providers and network providers can take effective action for each error type.

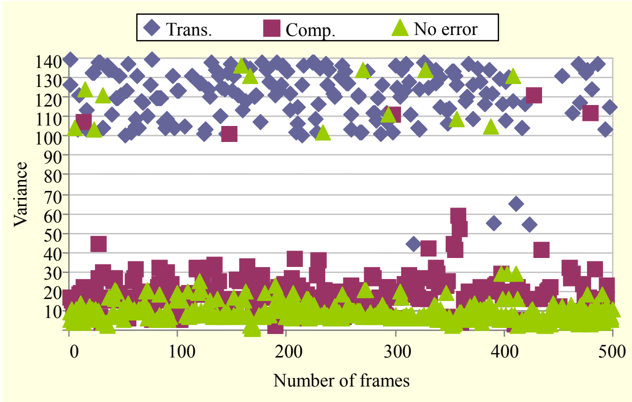

Fig. 3. Variance of blocky block distribution in terms of error type by proposed method.

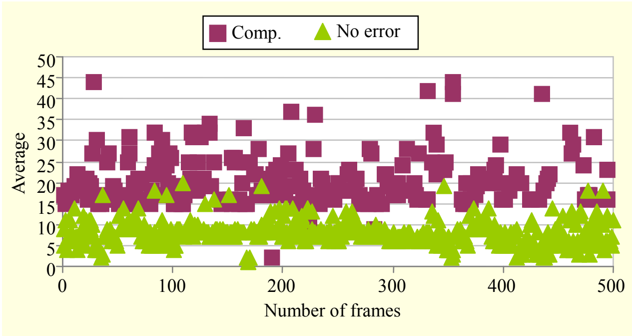

Fig. 4. Average of blocky block distribution in terms of error type by proposed method.

III. Experimental Results

We used two standard test sequences, "Football" and "Foreman", and several IPTV sequences that were served through a Korean commercial IPTV platform. Commercial IPTV sequences are encoded in H.264/AVC on MPEG-2 TS. The standard video sequences are also coded in H.264/AVC. In this experimentation, 500 frames from sixty 720×480 commercial IPTV sequences and two hundred forty 352×288 frames from two standard test sequences were used.

In order to evaluate the accuracy of classification of the proposed algorithm, the classification results by the proposed method for corrupted videos are evaluated with those from a subjective test. For each sequence, 30 degraded frames were used from the beginning of a sequence, and the video clip was coded by large quantization (QP=45) for the compression error. Sixty frames were also produced for transmission errors by removing slices. Thirty error-free frames were used by compressing a video with smaller quantization (QP=15) for the error-free case.

We also compared degradation types computed by the proposed method with those by people for commercial IPTV frames. We regarded the degradation types given by commercial frames to people as ground truth because the original frames or any information of error types are not available. We conducted a subjective quality test. Twenty participants were employed, and they were requested to find one of the three error types after watching each test frame for twenty seconds. Among 500 frames, 100 and 110 frames were degraded by transmission error and compression error, respectively. The rest of the frames were error-free.

As shown in Fig. 3, we can easily distinguish transmission errors from others (compression error and no-error) with the variance of blocky block distribution. However, it is hard to separate compression error types and no-error types with only the variance of blocky block distribution. Thus, we distinguish the compression error type and the no-error type with an average of blocky block distribution as shown in Fig. 4. The distance between two groups is far enough to classify them. T_1 of (5) is empirically set to 100, which is a threshold for transmission error. T_2 of (5) is set to 15, which is a threshold for compression error. Note that the performance of the proposed algorithm can be slightly changed with the thresholds for other datasets.

Conventional algorithms assess the amount of the blocking artifacts or the strength of blocking artifacts. However, the purpose of the proposed algorithm is to classify error types

Table 1. Performance of proposed method for standard test video.

Standard test video	Sensitivity (%)	Specificity (%)
Transmission error	100.00	81.63
Compression error	87.69	94.55
No error	94.44	86.36

Table 2. Performance of proposed algorithm for commercial test video.

Commercial video	Sensitivity (%)	Specificity (%)
Transmission error	84.40	98.90
Compression error	96.39	99.49
No error	98.90	91.06

from corrupted videos.

In Tables 1 and 2, the sensitivity measures the proportion of actual positives which are correctly identified as such, and the specificity measures the proportion of negatives which are correctly identified:

$$\text{Sensitivity} = \frac{TP}{TP+FN} \times 100, \quad \text{Specificity} = \frac{TN}{FP+TN} \times 100, \tag{6}$$

where TP and TN are the number of frames that are correctly identified as positive and negative. FP and FN represent the number of frames that are wrongly identified as positive and negative.

Some conventional algorithms that assess the impairment value using periodical characteristics are not suitable to estimate degradation caused by packet loss. When several packets are lost, it is hard to see a periodic visual pattern in reconstructed frames. Other conventional algorithms that assess transmission errors in the transport layer cannot evaluate subjective visual quality in reconstructed frames. Furthermore, no conventional methods are available to identify the error types.

However, the proposed method assesses the average and variance of the amount of deformed blocks from decoded frames. Therefore, it enables us to classify error types caused by transmission imperfections without network parameters and caused by compression without reference frames, regardless of video codec algorithms.

IV. Conclusion

In this letter, a new quality measurement method to identify causes of video quality degradation for IP-based video services is proposed. In our experiments, we found that the accuracy of the proposed method to distinguish compression or transmission is 92.86%, which is the average of all the figures in Tables 1 and 2. The proposed algorithm can be applied to monitoring and improving commercial IPTV services with a minimum computational load.

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