Reduced-reference picture quality estimation by using local harmonic amplitude information

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Abstract: In this paper, we present a reduced-reference picture quality assessment method for compressed digital images and video. Reduced reference refers to the availability of a preferably small subset of information extracted from an unprocessed, original picture. We propose local harmonic amplitude information computed from an edge-detected picture as the reduced-reference. By comparing the local harmonic amplitude information from both the original and the decoded (degraded) picture, we come up with a method employing *gain* and *loss* information which can be used to identify typical degradations such as blockiness or blur in the decoded picture. The proposed model can estimate picture quality even when the original, full reference picture is not present.

1 Introduction

Reduced-reference quality assessment framework has been proposed as one of the methodologies to assess digitally compressed image/video picture quality [1]. In this method, variable-bandwidth features are extracted from spatial-temporal regions of an original and a degraded version of the picture and quality is estimated based on this reduced-amount of information [2]. What makes reduced-reference approach interesting is the flexibility to determine what kind and how much information is required in performing the evaluation.

Although many factors influence image quality, blocking artefact has been regarded as one of the distinctive degradations that contributes to the picture quality in a discrete cosine transform (DCT) based severe-compressed digital image. Various blockiness quantification methods have been proposed either in spatial domain or frequency domain. In the frequency domain, for example, good results have been shown by harmonic amplitude analysis method [3]. However, its performance relies on the full availability of the original (reference) image. It is therefore interesting to see whether we can use the method in the absence of full reference picture such as in a reduced-reference framework.

Previous attempts to quantify picture quality through blockiness measurement in frequency domain [3] mostly concentrate on the severe degradation of the picture. The method would fail to function properly when applied to high quality picture because they would over-estimate the amount of blockiness in the picture. Another interesting property that has not been addressed much is the interplay between blockiness and blur although there are numerous research has been reported to deal with each of this property independently. We believe that the interdependency between blockiness and blurriness also plays an important role in high quality environment.

To address the above-mentioned problems, in this paper we propose a combined blockiness/blurriness detection method based on harmonic amplitude analysis in frequency domain that requires a subset of the image information (reduced-reference) only. Our method makes use of the interrelationship between blockiness and blurriness and hence works better when applied to high quality picture. The proposed model can estimate picture quality even when the original, full reference picture is not present.

2 Review of harmonic amplitude analysis

Basic concept of harmonic analysis is explained in [3]. In short, the appearance of blockiness tiling pattern on the picture produces pseudo-periodic signal that generates harmonics in frequency-domain. The significance of the harmonics is proportional to the amount of blockiness in the picture. To test the significance of these harmonics, a relative comparison of these harmonics with respect to the rest of the frequency components is calculated. Significant test is performed by comparing this ratio against some predetermined threshold. A drawback of this approach is the possibility of misleading interpretation of the significance test of these harmonics since there is no way for the harmonic amplitude analysis to differentiate contextual horizontal/vertical edges from blocking artefact. This problem is then alleviated by incorporating *edge cancellation* followed by spatial masking process prior to harmonic analysis stage [3]. Edge cancellation is performed by calculating a product gradient image between geometrical mean of the reference gradient image and the decoded gradient image. Spatial masking is then employed to take into account the dependency of the visibility of blocking artefact on the distance of the artefact from the contextual details. The process of edge cancellation followed by masking requires the availability of the original, uncompressed, reference picture. The quality metric is then expressed as the blockiness index which is calculated as the total harmonic amplitude strength (energy) over blocks which are considered blocky. The whole process of double-input, full reference method is illustrated in Figure 1(a).

3 Proposed method

3.1 Overall process

We propose a reduced-reference objective picture quality method based on harmonic amplitude analysis. Our goal is to produce a 'reduced-reference information' consisted of only the extracted features ('harmonic strength') from each picture. First, we calculate gradient image by applying a 3×3 Sobel operator [4] to the picture. Subsequent processes are then carried out to this gradient image in blocks of 32×32 pixels. Block size is chosen such that it is sufficiently big enough to account for any vertical and/or horizontal activity within each blocks. In the harmonic analysis stage, we apply Fast Fourier Transformation (FFT) to block-segmented gradient picture on each of the original image and the decoded image separately. Local harmonics strengths are then extracted from each of these FFT blocks. Our proposed method is depicted in Figure 1(b), where R and D represent the reference (original) and degraded (processed) picture, respectively. The reduced-reference of each corresponding pictures are given by R' and D'.

3.2 Contextual edges removal

Prior to harmonic analysis stage, we also use contextual edges removal in much the same purpose as explained in the previous section. Note, however, that in our method there is no direct calculation to remove contextual edges because edge cancellation process is not present. The reason is because full-reference picture is unavailable for this purpose. Therefore, contextual edges removal is achieved independently on each picture through *spatial masking*.

Spatial masking works by changing the visibility of pixels according to their position and amplitude on the picture. The degree of masking depends on the magnitude/amplitude of the pixel; i.e., higher amplitude implies higher degree of spatial masking effects. We observed that the magnitude of the gradient for contextual details are mostly of high amplitude which will make the contextual details easily noticeable. By doing this way, we can estimate pixels classified as contextual details at certain regions on the picture and remove them accordingly.

3.3 Development of the reduced-reference information

Harmonics strength can be interpreted as spatial activity in terms of vertical/horizontal edges in the picture. We suggest using these harmonics as potential candidate for the reduced-reference; i.e., the variable-bandwidth features extracted from spatial-temporal regions of original and decoded picture. When the local harmonics are extracted, they are also identified by the location of its corresponding block within the picture. With respect to the whole picture, grouping these local harmonic strength values according to their position will result in a matrix representation of the harmonic strength.



(a) Double-input blockiness detector prototype

(b) Modification: separate harmonic analysis in a reduced-reference fashion

Figure 1: The model - (a) is the double-input, full reference prototype, while (b) is the reduced-reference prototype built from a modification of (a) by separating the analysis stage.

To aid our goal in picture quality evaluation, we construct a visual map of harmonic frequency activity on the picture and label it as LHAM (local harmonic activity map). This map serves as a quality indicator to visualize how much distortion is introduced to the decoded picture and give some helpful hints on where the degradation appear on the picture. The reduced-reference information in our proposed method is none other than this LHAM matrix. Blockiness and blurriness identification in this reduced-reference fashion is performed by comparing these spatial activities. Any degradation on the reconstructed image can be inferred from the difference between the map generated from the original image and the map from the decoded image. Where the difference is positive, spatial 'gain (added) activity' is indicated, and it is likely that this gain is related to the appearance of additional edges due to blocking artefacts. On the other hand, in the areas where the difference is negative, spatial 'loss activity' is indicated, and it is likely that the losses correspond to blurring or disappearance of contextual detail. To get the overall quality of the picture, an average of local harmonic amplitude is also computed by firstly separating the calculation for each *gain* and *loss*. Quality metric is then derived from these two averages.

4 Experiments and Results

We give two examples of the proposed method; each corresponds to the application of the proposed method to identify (a) blockiness (increase in spatial activity) through gain information and (b) bluriness (decrease in spatial activity due to disappearance of contextual details) through loss information. This is illustrated in Figure 2. In Figure 2(a), blockiness is deliberately introduced in certain areas of the degraded picture; i.e., upper part of the picture that constitute some part of the man's arm and lower part of the picture that constitute the 'radiator' section of the picture as contextual details containing horizontal/vertical edges. In Figure 2(b), the same area are also used, but now we introduce blur to



(a) Picture deliberately contaminated by blockiness



(b) Picture deliberately contaminated by blurriness





Figure 3: Local harmonic amplitude map.

	Our proposed method	Full reference	PSNR
	(Reduced-reference)	method [3]	
Pearson correlation	0.902	0.897	0.4795
Spearman correlation	0.9053	0.9198	0.4741

Table 1: Mean Opinion Score (MOS) prediction performance

these areas. Our proposed method should be able to recognize the upper part of the picture either as blocky or blur, while the radiator part of the picture should not be judged blocky/blur because it contains contextual details that hide the visibility of the artefact.

The result is depicted in Figure 3 where we show the visualization of local harmonic amplitude map across the picture. In the first case, shown in Figure 3(a), blocking artefact in the upper part of the degraded picture can be identified as *gain*, while blocking artefact in the 'radiator' area is not visible due to the masking effect introduced by the contextual detail of the radiator. Similarly, in Figure 3(b) where blur is introduced, blur in the upper part of the picture can be identified properly as *loss*. On the other hand, blur in the radiator area which is slightly masked by the contextual detail is not clearly visible; i.e., the proposed method can predict such masking effect properly. In both cases, the remaining part of the picture contain no change in the harmonic activity.

We also apply our method to evaluate the quality of still pictures taken from JPEG coded images with five different quality factor. The performance of our proposed method are summarized in Table 1. As a comparison, performance of full-reference method as well as traditional PSNR method are also tabulated. The quality of the prediction of our method is characterized by a Pearson correlation of 0.902 and Spearman (rank order) correlation of 0.9053, which are comparable to the performance of its full-reference counterpart. The comparable performance of our reduced-reference method (or even a slightly better one) with respect to the full-reference method is due to the advantage of our method to use the gain and loss information. The FR model 'over-estimate' the quality of the picture in higher bit rate since it assumes that blockiness is not present in the picture, but in reality the quality may be determined by other factor than the blockiness. According to our simulation, when the picture is coded at higher rate (better quality), blockiness may not be the 'most' important degradation, but we may also have such 'smearness' in which much of contextual details were lost due to compression. Hence, we may have more loss factor in higher bit rate environment rather than gain. Therefore, in higher bit rate, we could give more attention to loss rather than to gain.

5 Conclusions

This paper has presented a framework to develop a reduced-reference evaluation model by using local harmonic activity as reduced-reference information. By using our proposed method, we are able to extract *gain* and *loss* information associated with the picture. These information can then be used to indicate typical degradations such as blockiness tiling or blur in the image. The results have shown that the approach presented here is promising since the proposed model is able to estimate picture quality even when the original, full reference picture is not present.

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