PREDICTING BLOCKING EFFECTS IN THE SPATIAL DOMAIN USING A LEARNING APPROACH

Aladine Chetouani, Ghiles Mostafaoui
Laboratory L2TI, Institute of Galilee, University Paris XIII, France

Azeddine Beghdadi
Laboratory L2TI, Institute of Galilee, University Paris XIII, France

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Abstract: A new method for predicting blocking effect in the spatial domain is proposed. This method aims at estimating the appearance of blocking artefacts in the original image prior to compression for a given bit rate and a given compression technique. The basic idea is to use a training process in order to compute a visibility measure. A weighting function of the blocking effects is then derived from this training process performed on a database. The proposed method is objectively and subjectively evaluated on various actual images. The obtained results confirm the efficiency of the proposed method in predicting blocking effect.

1 INTRODUCTION

Block-based image processing approaches are systematically applied to account for the non stationarity of the image signal and the computational constraints. The other motivation behind the development of block-based image treatments is to make them appropriate for real-time application and their possible implementation on parallel architectures. However, block-based methods are prone to artefacts, called blocking effect, that may affect the image quality and limit the efficiency of some image processing techniques. This artefact is the most known annoying image distortion. The efficiency limitation of many compression methods, such as BTC (Block Truncation Coding) technique (Delp, 1979) or VQ (Vector Quantization) coding (Gray, 1984), is essentially due to blocking effect. Many improvements have been proposed in order to reduce this effect. But at our knowledge, the design of formalized procedures allowing to control this effect is still missing. Here, we focus our study on block-based compression methods and especially those using Discrete Cosine Transform (DCT). This method has been widely used in image and video compression standards such as JPEG and MPEG2. For low bit rate, these block-based coding methods produce a noticeable blocking effect, in the reconstructed image. This is mainly due to the fact that the blocks are transformed and quantized independently. This annoying artefact appears at the block frontiers as artificial horizontal and vertical contours. The visibility of this blocking effect depends highly on the spatial intensity distribution in the image. Moreover, the Human Visual System (HVS) increases the perceived contrast between two adjacent regions.

Blocking effect has been widely studied and many had hoc methods for estimating and reducing this artefact have been proposed in the literature. In (Wang et al., 2000), a blind method for estimating the blocking effect in the frequency domain is proposed. It worth to noticing that blind approaches are more appealing than full reference approaches. In (Bovik et al., 2001; Coudoux et al., 1998), the blocking artefacts are modelled as 2D signals in the DCT-coded images. By taking into account some HVS properties, the local contrast in the vicinity of the inter-block boundary is used as an estimate of the blocking effect. In (Jang and al., 2003), an iterative algorithm is applied for reducing the blocking effect artefact in the block transform-coded images by using a minimum mean square error filter in the wavelet domain. Another similar method based on image restoration approach has been

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proposed (Luong et al., 2005). A blocking effect visibility measure based on the local contrast is used to control the iterative process. In (Singh et al., 2007), a new technique based on a frequency analysis is proposed for detecting blocking effects. The artefacts are modelled as 2-D step function between the neighbouring blocks. The presence of the blocking artefacts is detected by using block activity signal based on HVS and block statistics.

Several other interesting methods (Castagno et al., 1998; Lee et al., 1998; Zeng, 1999), dealing with blocking effects have been also developed. However, most of these studies aim to detect or remove the blocking effects on the compressed images.

Here, we propose a different approach which allows to predict the visibility of the blocking effects on images prior to compression. The paper is organized as follows. Section 2 presents the motivations and describes in details the weighting procedure. Section 3 is dedicated to the results and the performance evaluation of our method. The last section contains the conclusion and perspectives.

2 MOTIVATION AND METHOD

The continuing development of high resolution imagery technology leads to higher bit rates because of the increase in both spatial resolution and intensity range. Much research on block-based lossy image compression is still needed. However, lossy compression at low bit rate may produce some annoying artefacts limiting thus their efficiency. Here, we focus the study on blocking effects. One of the main issues related to image compression is how to control these artefacts. One way to achieve this goal is first to predict this structured distortion and then to propose a solution for reducing it. Inspired by the fact that human observer is able to detect and recognize blocking effect, even in the absence of the original image, we propose a new approach based on a learning process. The approach use here is based on a training offline process. The main idea is to compute a weighting function which assigns to each pixel a weight that could be interpreted as a prediction probability of the appearance of the local blocking effect. The main idea developed here is to study the relation between the appearance of the blocking effects and the pixels neighbourhoods in the non-compressed image. Therefore, we perform a learning offline process on a database containing various grey-level and color images. The whole weighting process is summarized in fig. 1.

2.1 Learning Process

The learning process is applied on a database of 211 different real images (from F. C. Donders Centre for Cognitive Neuroimaging database). These images contain various kinds of textures with different roughness and regions with different intensity distribution and uniform regions.

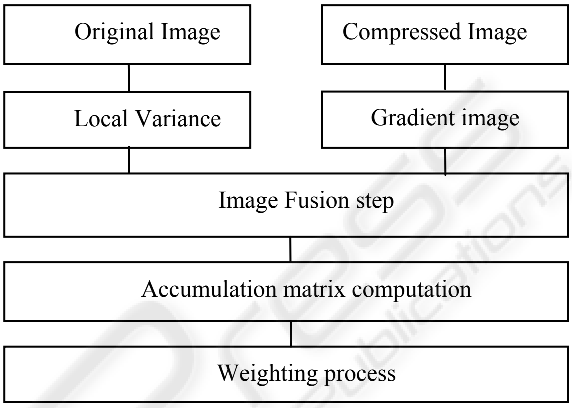

Figure 1: Synoptic.

First, we analyze the spatial distribution of the pixels before extracting some local characteristics from these images. Indeed, the appearance of a blocking effect in an image area depends highly on the local descriptors such as color, homogeneity, gradient etc. These local characteristics could be expressed in the transformed domain such as Wavelet Transform or DCT. To make the method independent of compression method, we use the local variance as a local homogeneity measure. For each image f taken from the learning database, we compute the corresponding local variance image V (see fig. 2.b). Once the local variance image computed, we analyse the compression effect in terms of blocking appearance. To do this, we have to detect the blocking effects on the compressed images. Let us define:

- g_q the compressed images of an original image f of the database where q represents the different quality factors ($q \in [1,100]$ for JPEG compression).
- $\widehat{g}_q$ the gradient absolute values images of g_q.

Depending on the bit rate, the blocking effect tends to create large uniform zones where the gradient is null. The blocking effects on the compressed images g_q could be then detected by analyzing the signal $\widehat{g}_q$. This first simple process gives coarse detection of blocking effect (see fig. 2.c). We will show that by increasing the size of the database, used in the learning process, the blocking effect detection could be improved.

Here, we use a cumulative learning scheme based on a voting process. A table of accumulation representing the statistics of the appearance of blocking effect in the compressed images (at different quality factors) is computed. This vote table is a 2D array denoted *H(v,q)* where *v* is the possible values of the variance and *q* the compression quality factor.

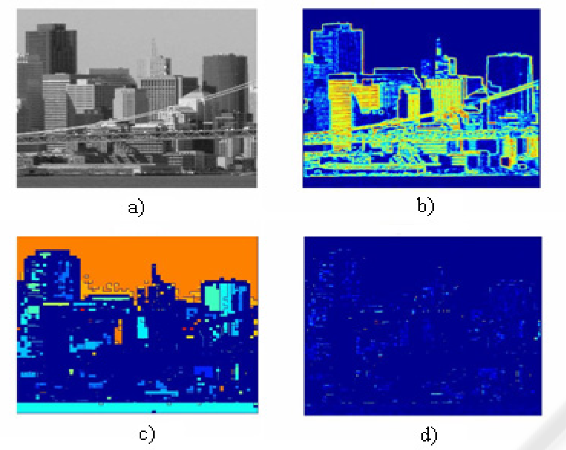

Figure 2: a) Original image, b) Local variances image, c) Labelled regions with null gradients d) Local variances of pixels with null gradients.

Let $\{f^i, i \in [1,N]\}$ be the set of database images, V^i, g_q^i and $\widehat{g_q^i}$ $(q \in [1,100])$ the corresponding images obtained as explained above.

For each pixel $p_j^i\,(x_j^i, y_j^i)$ of an image f^i we define an influence function for each couple *(v,q)*. This function can be written as:

$$Cc_j^i\,(v,q) = \begin{cases} 1 & if \;\; v = V^i(x_j^i, y_j^i) \;\; and \;\; g_q'^i = 0 \\ 0 & else \end{cases} \qquad (1)$$

This expression means that a pixel will have a positive influence on a cell *(v,q)* of *H(v,q)* only if its local variance corresponds to *v* and its gradient absolute value on the compressed image (g_q^i) with *q* as quality factor is null (pixel probably belonging to a blocking effect on g_q^i). After computing the influence functions for all the pixels ($p_j^i\,(x_j^i, y_j^i)$) of all the images f^i of the database, we can define the value of a cell *(v,q)* of the accumulation table as follows :

$$H(v,q) = \sum_i \sum_j c_j^i(v,q) \qquad (2)$$

Fig. 3 displays a part of the accumulation matrix corresponding to variances between 0 and 16 for a better visibility. This table contains the statistical information about the pixel neighbourhood and the corresponding degree of blocking effect appearance. It contains all the relevant local characteristics and compression factors.

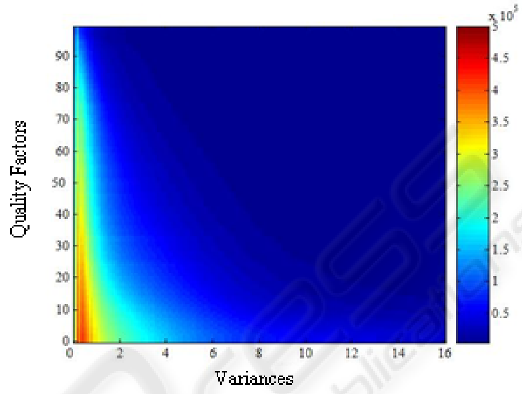

Figure 3: The accumulation matrix.

Fig. 3 clearly shows the coherence of the statistics. In fact, one can notice that less the variance is and less the quality factor is (high compression ratio), higher is the probability of appearance of a blocking effect. The errors due to approximations are completely cancelled by the large mass of correct accumulations.

2.2 The Weighting Process

The obtained voting matrix is used for predicting blocking effect. A weighting function, representing the probability of appearance of a blocking effect on a pixel neighbourhood, is then derived from this table. For each factor quality value, a simple weighting function is to consider the row of the matrix *H* given by:

$$w_q(v) = H(v,q) \quad v \in [0,255] \qquad (3)$$

The matrix *H* is constructed from the image database. Due to the lack of regularity of the weight function, a polynomial interpolation is applied in order to obtain a well behaved function as shown in fig. 4.

Here, we can also notice the coherence of the results related to the fact that for a given local variance value, low the quality factor is (high compression ratio), high the weights are (increase of the appearance probability of blocking effects).

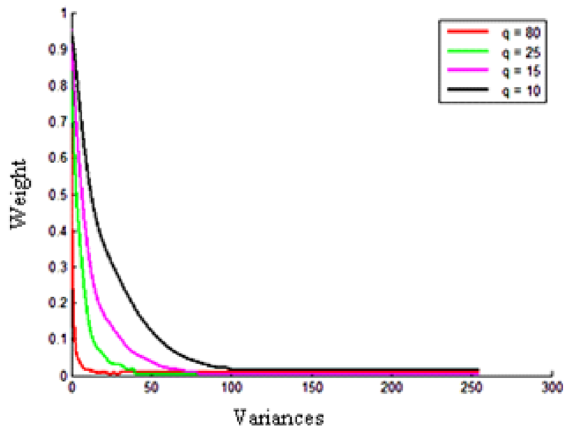

Figure 4: The weighting function for different quality factors.

3 EXPERIMENTAL RESULTS

To evaluate the efficiency of the proposed method in predicting blocking effect, we use both objective and subjective assessment. In the following, we describe the two strategies in details. Since, the subjective evaluation of perceptual distortion measure is the most accepted approach, we evaluate the objective measure in terms of correlation with the MOS obtained through subjective tests.

3.1 Objective Test

To test the efficiency of the proposed measure, various experimental tests are realized over 200 natural images different from those of the learning database and with variable bit rate. The experimental procedure is quite simple and does not require the compressed images. We use only the uncompressed images. Let f be an original test image and V its corresponding local variance image. The probability of a pixel (x,y) to belong to a blocking effect area with a given quality factor q of compression (here JPEG) is :

$$w_q(v) \quad with\ v = V(x,y) \tag{4}$$

Where, w_q represents the weight function obtained from the learning process. This makes the method very fast. In fact, for implementation, the weight function (obtained with the offline learning) could be considered as a simple Look Up Table. The prediction procedure is then based only on to the local variances computation. The proposed method has been successfully evaluated on various images. Here, due to the limited place only one typical case is shown.

Fig. 5, gives an example of the predicted weight images obtained for a natural test image. Fig. 5.a is the original test image. We choose three quality factor q = 49, 17, 4. The predicted weight images are represented in figs. 5.b, 5.c and 5.d respectively. The red and blue regions correspond to the high and low weights respectively.

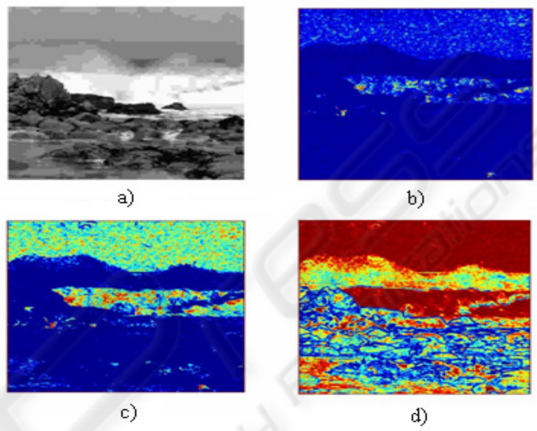

Figure 5: Blocking effect prediction. a) Original image, b)-d): Blocking effect visibility map for q=49, q=17 and q=4, respectively.

It could be noticed that the weights gradually increase as the quality factor decreases. This expresses the fact that homogeneous regions are more affected by blocking effect than texture ones.

3.2 Subjective Test

Subjective evaluation of image quality is still the most accepted solution. Unfortunately, it necessitates the use of several procedures, which have been formalized by the ITU recommendation (CCIR, 1990-1994). These procedures are complex, time consuming, and nondeterministic. In our experiments, we performed subjective tests with ten observers. We present to each observer, various images with different quality factor values q. The observers are asked to visually detect for each compression ratio (quality factor) and for each image of the database, the appearance of blocking effects.

Fig. 6 shows the Mean Opinion Score (MOS) for each image (white line) used in the subjective tests. This MOS corresponds to a quality factor value for which the blocking effect starts to be visible. For each quality factor and for each test image, we compute the corresponding weight. The obtained results show that the mean observer starts to see blocking effects on the compressed images at ratio corresponding to prediction probabilities up to 0.4.

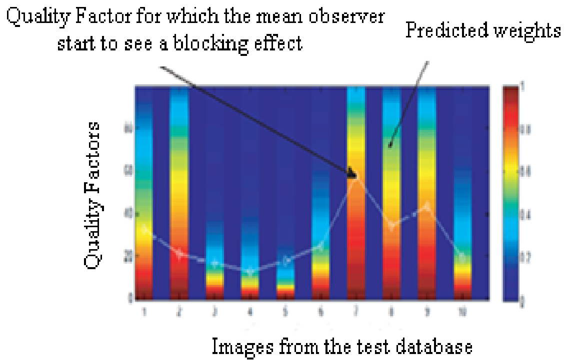

Figure 6: Objective vs subjective quality measure.

4 CONCLUSIONS AND PERSPECTIVES

A simple and efficient method for predicting blocking effects on the original non-compressed image based on a local image analysis and a training scheme is proposed. The obtained results show that the proposed method is efficient in predicting blocking effect and show good correlation with subjective evaluation. This predictive scheme could be used as a blind image quality control system prior to compression in order to achieve the trade-off between bit rate and perceptual image quality. As perspective, we are planning to introduce a masking model in the method to make it more adaptive to image signal activity and HVS limitations. This predictive method could be extended to other block-based image compression techniques.

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