POST-PROCESSING OF BLOCK-CODED IMAGES AT LOW BITRATES

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ABSTRACT

A post-processing method suitable for low bit rate spatial domain block coded images is described. In this paper, an adaptive filtering process is employed to reduce the visually annoying artefacts introduced from compression. The type of filtering is decided based on an estimation of the local characteristics of the coded image. For the areas of low image detail a smoothing operator is used; whereas in the high image detail areas (edges - texture) an adaptive Gaussian-type filter is employed. The main advantage of this filter is that the shape and the position of the Gaussian kernel are adjusted according to the characteristics of the local image region. Simulation results demonstrate that this method enhances the quality of coded edges and reduces annoying blocking effects, resulting in overall better picture quality.

1 INTRODUCTION

1.1 Definition of the problem

Post-processing of coded images aims to remove the visually annoying impairments of quantization noise that otherwise degrades the picture quality. This is an important issue in image coding, since it can improve the subjective performance of the coder without an increase in bit rate. Typical post-processing techniques reported in literature for enhancing the picture quality of block coded images are based on spatial filtering [1]-[5].

In spatial domain block coding techniques, such as vector quantisation (VQ) and block truncation coding (BTC), the quantisation noise is highly correlated with the characteristics of the original signals, so that different areas of the coded image suffer from distinctly different impairments [1]. In particular, uniform areas suffer from the blocking effect, where the boundaries of adjacent blocks become visible resulting into false contours. Moreover, all diagonal edges appear jagged, which is known as staircase effect. Finally, most of the textured areas are “washed-out”.

1.2 Design considerations of a post-processing method

Following the description of the main picture quality impairments due to low bit rate spatial VQ, the design requirements of an efficient post-processing method can be outlined as follows. The compressed image should be initially segmented into different regions which correspond to areas that suffer from different types of degradation. Typically, one must be able to design a classifier which distinguishes the regions of slowly varying intensity from the detailed ones. Corruption of the image features due to quantisation noise (especially at low bit rates) makes region classification in coded images a difficult task.

Provided that the above step has been implemented successfully, an adaptive filtering technique should be devised to take into consideration the characteristics of quantisation noise in the different areas of the coded images. More specifically:

- Staircase noise along the edges must be removed, so that edges appear sharp and continuous. This requires smoothing along but not across the edge direction to avoid blurring.
- False contours visible in the areas of slowly varying intensity should be smoothed out. This requires smoothing of the intensity changes that occur between adjacent blocks.
- The disturbing blocking effect should be removed from textured areas, while any high detail that survived the coding process should be preserved.

2. POST-PROCESSING METHOD

The post-processing method presented, utilises a useful tool for the description of local image characteristics, referred to as windowed second
moment matrix (WSMM) [7], whose elements are locally-smoothed functions of the image derivatives. The formal definition of WSMM is given in the Appendix A.1.

2.1 Region classification

A simple algorithm, based on the values of the WSMM coefficients, is used to distinguish low from high detail areas in the coded image. Quantities \( A \) and \( B \), defined in eqn. (A.1), contain information about the local edge strength. It is expected that a large value of either of them will be due to the presence of a jagged edge or image texture. This is especially true when the area of smoothing defined by parameter \( M \) is chosen to be of a similar extent as the coding block. Thus, region classification is performed by comparing the values of \( A \) and \( B \) against a predefined threshold. If at least one of them exceeds the threshold value then the corresponding pixel is declared as belonging to a highly detailed area of the image; otherwise, it is supposed to come from a uniform low detail area. A robust performance is achieved because the smoothing operation in the calculation of \( A \) and \( B \) reduces the effect of noise. The filtering strategy is then decided according to the outcome of the classification.

2.2 Filtering

Filtering of high detail areas. The purpose of the post-processing in high detail areas is, as described in the previous section, twofold: to eliminate the visible noise from the edges and preserve any detail that remains in the texture blocks. An adaptive filtering operation which satisfies both requirements is employed. The process computes for a pixel a Gaussian-type kernel which is shaped and displaced according to locally smoothed image gradient functions [4]. The filter kernel \( K(x,y) \) is defined as follows:

\[
K(x,y) = \frac{1}{S} \frac{\hat{A}(x+\delta_x,y+\delta_y) + \hat{B}(x+\delta_x,y+\delta_y) + \hat{C}(x+\delta_x,y+\delta_y)}{2\sigma^2} \tag{1}
\]

where \( S = \sum_{(u,v) | (N=N)} e^{-(u+\delta_x)^2 + (v+\delta_y)^2} / 2\sigma^2 \) is a normalisation factor, \( N \) is the side length of the square truncation mask that contains the kernel, \( \sigma \) is the standard deviation of the variable Gaussian kernel, \( \hat{A}, \hat{B}, \) and \( \hat{C} \) correspond to the coefficients of the WSMM (eqn. (A.1)) normalised by quantity \( F = A + B \) to reduce image dependency problems, and \( \delta_x \) and \( \delta_y \) determine the magnitude of the kernel displacement along each of the principal axes and are defined in Appendix A.2. The three terms in the exponent adapt the shape of the kernel, so that its longest axis is parallel to the edge direction locally dominant in the image. The function of the displacement components, which are also obtained from gradient calculations, is to displace the main weights of the kernel away from edges. The effect is that, when the centre is in the area of an intensity edge the greatest contribution to the convolution comes from the region the centre is in, not from the other side of the boundary, and hence the sharpness of the edge is preserved.

The filter satisfies the requirements for processing detailed areas of a VQ-coded image. First, near an intensity edge the filter kernel is oriented along the edge which is important in order to avoid blurring. Secondly, the fact that the main weights of the kernel are displaced in or out of the edge - depending on the relative position of the centre pixel - ensures that the continuity and the sharpness of the edge will be recovered. Finally, the presence of strong intensity discontinuities in different directions has the effect of a reduction in weights away from the centre of the filter kernel which means that image details will be preserved in textured areas.

Filtering of low detail areas. For the low detail areas of the image the adaptive filter described above is not appropriate. The reason is that intensity changes across the boundaries of neighbouring blocks will be perceived mistakenly as corresponding to intensity discontinuities with a non-appreciable result. For these areas simple small-scale Gaussian filtering smoothes the boundaries between coding blocks, as required, without introducing any noticeable defects in the output image.

3. SIMULATION RESULTS

In this section simulation results are presented to evaluate the performance of the post-processing method. The main aim of these experiments is to demonstrate that it can enhance the picture quality of still images that have been compressed using low bit rate spatial-domain vector quantisation. For this purpose, a memoryless spatial VQ scheme is used. It operates on \( 4 \times 4 \) pixel blocks and employs a universal codebook designed using the Generalised Lloyd's Algorithm [6]. The training set consists from five ISO/ITU-T test images, namely, Barbara, Boats, Girl, Gold and Zelda, at resolution \( 720 \times 576 \times 8 \). Results of pictures coded at 0.5 bpp are presented.
The selection of the parameters related with the filtering process was guided by the size of the coding block (i.e., 4 × 4). Smoothing of the image derivative functions (see Appendix A) was performed over an area of size \( M=7 \) on each side. This means that image data from at least four (and at most nine) neighbouring coding blocks are involved in the calculation of WSMM at an image point. The kernel size of the Gaussian filter applied to smooth areas was 5 on each side, so as to overlap more than one coding block and to allow smoothing of their boundaries.

In Figure 2, a part near the hat in the image is magnified. This example illustrates that the staircase noise has been reduced in the edges without blurring.

Figure 2. Magnified (× 2) part of LENA (hat) (a) original (b) coded (c) post-processed

4. CONCLUSIONS

In the post-processing method described, information from the image gradients is used to identify and separate areas of high and low image detail in the decoded image. Based on this region classification, an appropriate filtering process is decided. The main advantage of the proposed method is that a fully adaptive Gaussian-type filter is
employed for the high image detail regions, which include edges and texture. By adapting the shape and the position of the Gaussian kernel according to the characteristics of the local region, all jagged edges appear continuous and sharp while at the same time any detail that survived the coding process is preserved. Simulation results illustrated that the proposed post-processing method can significantly improve the picture quality of the compressed images. Small gains in signal-to-noise ratio are also obtained; nevertheless, it is the subjective performance that we had expected to improve.

REFERENCES


APPENDICES

A.1 Definition of WSMM

The Windowed Second Moment Matrix (WSMM) [7] is defined by the following equation:

\[
W = \begin{pmatrix}
A & C \\
C & B
\end{pmatrix}
\] (A.1)

where:

\[
A = \sum_{(x,y) \in (M \times M)} w_b(x,y) l_x^2(x,y)
\]

\[
B = \sum_{(x,y) \in (M \times M)} w_b(x,y) l_x l_y
\]

\[
C = \sum_{(x,y) \in (M \times M)} w_b(x,y) l_y^2(x,y)
\]

\(w_b(x,y)\) is a symmetric and normalised window function (e.g., a gaussian) which is used for local smoothing of the image features, and \(\nabla l = (l_x, l_y)^T\) is the image gradient. This is necessary due to the sensitivity of the first order spatial derivatives of image intensity to noise.

A2. Calculation of Kernel displacements

The components of the kernel displacement are computed as [8]:

\[
\delta_{l(x,y)} = \frac{N}{2} \frac{\nabla l(x,y)}{\sqrt{\mu^2 + \nabla l_x^2 + \nabla l_y^2}}
\] (A.2)

where \(\mu\) is an attenuation constant and:

\[
\nabla l_x = \frac{1}{F} \sum_{(x,y) \in (M \times M)} w_b(x,y) (l_x^2(x,y) + l_x(x,y) l_y(x,y))
\]

\[
\nabla l_y = \frac{1}{F} \sum_{(x,y) \in (M \times M)} w_b(x,y) (l_x(x,y) l_y(x,y) + l_y^2(x,y))
\] (A.4)

with \(F=A+B\). A qualitative explanation regarding this choice of displacement components is given by Nitzberg et al. [8].

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