WATERMARK DRIVEN DECENTRALIZED BEST MATCHING

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Abstract

Confronting with high packet loss conditions in the transmission of compressed images, inadequacy of intact received data severely affects the performance of error concealment (EC) techniques. Thus, it is of great interest to determine sufficient features from the original image to be transmitted as side information to the receiver, so that in the case of missing data, the EC employs the corresponding features as a priori knowledge for the recovery procedure. In order to take the advantages of side information, the Watermark driven Decentralized Best Matching (WDBM) is proposed in this paper; in each block of the image, the position of its best matching block within the original image is embedded, so that each block not only represents itself, but also describes the best similar copy of another block. Our simulation results show that as a supplementary procedure, WDRM improves the performance of existing methods, especially in high loss ratios.

Index Terms— Still Image Transmission, Sequential Error Concealment, Watermarking, SBRM

1. INTRODUCTION

A number of popular visual compression standards e.g. JPEG and MPEG, aim to eliminate the perceptual redundancies of still images by locally decreasing the representing data. To this purpose, the image(s) are divided into non-overlapping blocks so that each block is compressed separately. Such an approach is inherently compatible with the transmission protocols employed by packet switched networks.

Nevertheless, those approaches seriously suffer from the disadvantage of packet loss conditions, that is, any channel impairment may result in losing a wide region of the transmitted image. In order to reveal the missing data, error correction methods cannot help in high rates of packet loss. Also, the automatic request solutions impose a great waste of channel capacity. However, since the natural correlations within the image are kept by the compression, so as the perceptual reasonableness of the image is preserved, the error concealment approaches can be exploited to derive and structure those correlations in order to reconstruct the missed regions using the intact ones.

The similarities within an image can be categorized in two general types; the centralized similarities which indicate the local correlations of micro regions, and decentralized similarities which point to the exact or approximate correlations scattered over the image. Although employing centralized correlations by an EC technique may result in reasonable estimations, if a lost region originally contains a feature of slight/no correlation with its neighborhood, the estimation process fails to recover it. On the other hand, detection of the decentralized similarities within a corrupted image is uncertain due to the insufficiency of intact received data.

The most of existing EC methods rely on the centralized similarities in either spatial or spectral domain by assuming simplified deterministic models to describe blockwise dependencies [4]-[7]. Avoiding the weak assumptions imposed by linear estimation, some methods like best neighborhood matching determine the best candidates from the image itself which can be utilized to replicate to fill the lost regions [3]. Their dependency on the existence of reliable data causes a crucial fragility in high loss conditions that calls their performance into question. The sequential best range matching (SBRM) [1] obviates this drawback using an iterative structure, but one problem is remained unsolved; suffering from the insufficiency of a priori knowledge, those approaches also fail to estimate the isolated features that are independent to their neighborhood.

Meanwhile, some methods utilize data hiding to transmit convenient pieces of side information so that the EC technique can rely on the hints provided by embedded information along with the correctly received regions of the image [8]-[11]. This potentiality can be employed to take decentralized similarities into account. To this purpose, the features to be embedded must be derived in regard to the characteristics of the performing EC. Besides, since the embedding causes extra distortion, the restrictions on the perceptually feasible embedding rate must be addressed.

In this paper, the Watermark driven Decentralized Best Matching (WDBM) is proposed as a supplementary module to operate along with centralized EC methods, which improves the performance in high packet loss conditions. Each block of the image is referred to another one as an analogue by means of the watermarked information.

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Correctly received blocks are utilized to fill the corrupted regions as possible. The remaining corrupted regions are reconstructed by SBRM in this work. The effect of packet loss is assumed to appear as the loss of 8×8 blocks. Also, the positions of lost blocks are considered to be readily detected by means of packet error control coding techniques. Though the main idea of the proposed approach can be adapted to various compression standards, the JPEG standard is considered in this work.

The rest of this paper is organized as follows. Section 2 describes the proposed method, including the feature extraction and embedding strategy, and the decentralized and centralized phases of reconstruction process. The experimental results are reported in section 4, and conclusion remarks are made in section 5.

2. THE PROPOSED METHOD

Considering the limitations on the watermarking rate, and also avoiding the unnecessary complexity imposed by object oriented feature recognition, the proposed method treats the decentralized similarities in a blockwise manner; it initially processes the original image to extract similar blocks, then structures the regarding information as referral features to be watermark in the image. The reconstruction process includes two general steps at the receiver side; first, the decentralized similarities described by referral features are utilized to fill the missed regions as far as possible. Then, the SBRM method is employed to reconstruct the remaining regions so that centralized similarities are also concerned.

2.1. Referral Features

In order to exploit decentralized similarities within the image, the sufficiency of referral features and the constraints on the embedding rate must be considered compromisingly. The following subsections explain the proposed approach to achieve this aim.

2.1.1. Representation of Decentralized Similarities

The proposed method divides the image into non-overlapping basic blocks of the size 8×8 to accord with the JPEG data structure. To each basic block, a referred block of the same size is determined within a referral area (Fig.1), so that they comply with the most similarity in MSE sense. The position of the referred block is watermarked in the basic block. Thus, each basic block of the image not only represents itself, but also refers to another block of the image as an analogue.

Since the feasible rate of watermarking depends on the quality of compression due to the limitations on perceptual distortion caused by data embedding [2], [12], the size of referral area is chosen according to the watermarking rate; higher quality of compression provides more room for referral features to be embedded, so a broader referral area can be taken into account.

Consider the feasible embedding rate to be \( N \) bits per basic block. These \( N \) bits are used to address the position of the most similar block, thus the proposed method takes the referral area to be a square of the size \( 2^{(N/2)} \times 7 \) pixels, encompassing the basic block. In this way, row and column of the up left pixel of the most similar block are represented by an \( N \)-bit binary referral feature \( f = (f_1, f_2, ..., f_N) \).

2.1.2. Embedding the Referral Features

The embedding strategy is to be robust to the lossy phase of JPEG compression in which the image is partitioned into 8×8 blocks and the discrete cosine transform (DCT) coefficients of each block is quantized according to the standard quantization table \( q \), scaled by the quality factor \( a \) as [12] \( q^a = \begin{cases} q \times 50/a, & a \leq 50 \\ q \times (2 - 50/a), & 50 < a < 100 \end{cases}; \) (1)

where \( q^a \) is the scaled quantization table. The standard quantization tables are available in the JPEG specification.

In order to watermark the referral features, the proposed method performs the following procedure on each basic block of the image. Let \( e \) denote the vector in which the DCT coefficients of an 8×8 basic block are put in a specific order. The corresponding referral feature \( \hat{f}^a \) is embedded in \( N \) predetermined coefficients \([2]\). Let the set \( I^N \) contain the \( N \) indexes which indicate the watermark carrier coefficients. The embedding function is a Quantization Index Modulation (QIM) scheme [13] as

\[
c'_j = q^a_c \times \left( f_j + 2 \times \text{round} \left( \frac{c_i - f_j}{2 \times q^a_c} \right) \right), \quad 1 \leq j \leq N, \quad i \in I^N, \quad (2)
\]

where \( c_i, q^a_c, c'_i, f_j \) stand for the \( i^{th} \) DCT coefficient, its corresponding quantization step of the quality \( a \), the watermarked coefficient, and the \( j^{th} \) bit of the embedded referral feature, respectively. In this way, the embedding is robust to JPEG compression due to the inherent compatibility of quantization and embedding procedures.
The selection of carrier coefficients is made based on two intuitions which are experimentally investigated in [2]; first, embedding in the coefficient prone to rather larger quantization steps causes more perceptual distortion, and second, embedding in the coefficients which are more likely to become zero due to the quantization affects the benefits of run-length coding step of JPEG compression.

2.2. Reconstruction Procedure

Reconstruction procedure includes two steps; first, the decentralized similarities are extracted using the referral features and the decentralized reconstruction fills the lost regions; for every correctly received basic block, the proposed method checks for a loss happened in the region where the intact block refers to, and if loss is detected, the block takes the role of analogous block to fill the lost region as much as possible. To this end, the following procedure is performed on each correctly received block.

Let \( c' \) denotes the received block. The embedded referral feature \( f \) is initially extracted by

\[ f_j = \text{mod}\left(\frac{c_i'}{q''_i}, 2\right), \quad 1 \leq j \leq N, \quad i \in 1^N, \quad \text{(3)} \]

which is the reverse operation of (2). Exploiting the extracted referral feature, position of the referred block is revealed. So, the intact block is considered as an analogue for the referred block. The proposed method checks for corrupt in the referred block, that is, checks if the referred block contains any number of lost pixels. If corrupt is detected, the corresponding pixels of the analogous block are copied in the lost pixels of the referred block. The decentralized reconstruction proceeds until all intact blocks are utilized. In this way, some parts of the lost regions are filled by the best possible candidates (Fig.3). The unrevealed pixels remain to the centralized reconstruction step that can be any of existing centralized EC methods.

The second step of reconstruction procedure exploits the centralized similarities by means of a centralized EC approach. In order to reconstruct the remaining lost regions, the Sequential Best Range Matching method is employed in this work [1].

3. EXPERIMENTAL RESULTS

The standard images of Lena and Barbara are used in the simulation of this work. The effect of JPEG compression is considered by applying the scaled quantization according to the equation (1). To concentrate on the performance evaluation of the proposed reconstruction procedure, the quality of JPEG compression is set to ordinary 80%. Thus, we have accepted an extra distortion of 1-2dB in PSNR, and an increment of 10-15% in the size of watermarked image in order to set the embedding rate of 18 bits per basic block (0.28 bits/pixel). So, the referral area is chosen to cover the entire image; that is 512×512 pixels. The carrier coefficients are chosen according to [2] as

\[ \{(2,1),(1,2),(2,2),(3,1),(1,3),(3,2),(2,3),(4,1),(1,4),\ldots\\} \]

where each pair indicates a coefficient in the 2D DCT transform of a basic block. Also, the size of range blocks and searching areas used in the centralized reconstruction are identical to [1] so that, \( M=10 \) and \( A=3 \times 8 \).

The PSNR evaluation of the recovered Lena is compared to the existing EC methods for a broad range of packet loss ratios (Fig.4). The results of decentralized and centralized reconstruction steps applied to Barbara are separately shown in Fig.5; the decentralized reconstruction
A watermark driven error concealment technique is proposed in this paper as a supplementary module which can operate along with another optional EC methods to improve their performance in high loss conditions. The function of WDBM is to represent decentralized similarities in a blockwise manner and exploit them using a watermarking technique robust to the JPEG compression. The proposed method is tested along with the sequential best range matching (SBRM) method and the power of this combination in recovery of isolated features is shown to outperform the existing EC methods, especially in high packet loss ratios.

The main advantage of joint application of WDBM and SBRM is its simplicity of implementation; no complicated processing is exploited neither in the determination of similar blocks, nor in the recovery procedure. The most of proposed operations include simple indexing which cause no computational complexity. Besides, the complexity of employed watermarking process is identical to the complexity of JPEG compression, due to the inherent compatibility of the embedding function to the quantization procedure utilized by JPEG.

5. REFERENCES


