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A fast progressive image transmission scheme using block truncation coding by pattern fitting

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ABSTRACT

In this paper, we have proposed a novel progressive image transmission scheme. In the present method, the concept of the BTC-PF is used for faster decoding. Here, images are decomposed into a number of blocks based on smoothness criterion. The smooth blocks are encoded by block means and the others are by BTC-PF method. To encode a block by BTC-PF method, the codebook is organized like a full search progressive transmission tree which helps greatly in efficient progressive transmission. The present method provides good image quality at low bit-rate and faster decoding compared to other spatial domain progressive transmission methods. We extend this method for color images also. In color image coding, each color plane is encoded separately and then the encoded information of the planes are transmitted in interleaving manner to obtain color images right from the early stages.

1. Introduction

In the context of information sharing and communication through Internet, bandwidth is a major issue. Particularly during search, transmission of large images takes huge time. Furthermore, after transmission if it is found that the image is not the desired one then it results into huge wastage of time and bandwidth. Progressive image transmission (PIT) provides a solution to this. Initially, PIT method transmits the most significant information to the receiver so that the receiver can generate a rough sketch of the original image. From the initial sketch, the receiver can decide whether it is the desired image or not and accordingly may continue or abort the transmission. In progressive scheme, it is necessary that the quality of the initial sketch should be good enough so that the receiver can take the decision easily. If the transmission continues, in the subsequent steps less significant information are transmitted to the receiver to improve the quality of the reconstructed image.

The objective of this work is to propose a PIT scheme having the following features: (i) it can give good quality images at the early stages with low bit-rate and (ii) the method (decoder) should be fast and suitable for both grayscale and color images.

In this paper, we first present a progressive scheme for grayscale images and then it is extended for color images. The present method is suitable for the real-time application (i.e., decoder must be fast). Whenever, we talk of fast decoding, the obvious choice is the spatial domain based coding method as the inverse transformation, required in frequency domain techniques, can be avoided. The inverse transform usually is the major time consuming module in the decoding part of any transform domain compression scheme. In this paper, a spatial domain PIT method is proposed. The proposed method is based on block truncation coding using pattern fitting (BTC-PF) [1,2], which has very low computational cost at decoding time. In the proposed PIT, the image is first divided into fixed-size non-overlapping blocks that may be subsequently partitioned based on smoothness. The leaf-blocks are then coded using BTC-PF method progressively. Unlike transform domain approach, where after each stage of progressive transmission decoder has to carry out inverse transformation to display the updated image, a major achievement in the proposed method is that the decoder requires only a few additions and/or multiplications by 2 (binary shift) and table look-up operations after each stage [1,2].

Another novelty of the proposed method lies in the construction of patternbook as well as selection of patterns progressively corresponding to an image block such that sufficiently high quality image can be reconstructed at a low bpp in the initial stages. To achieve this goal, geometrically designed patterns are arranged in a tree fashion in such a way that coarser to finer details come up

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in the reconstructed image. The performance of the proposed grayscale and color image coding methods is compared with other spatial domain methods and is found superior to them.

The rest of the paper is organized as follows. Section 2 provides a brief survey of literature on PIT. The BTC-PF method is briefly described in Section 3. The proposed progressive transmission scheme, for grayscale images, using BTC-PF (PBTC-PF) is presented in Section 4. Section 5 describes extension of proposed method for color images. Experimental results are reported in Section 6 and finally, conclusions are drawn in Section 7.

2. Related works

Tzou [3] has presented a thorough review and comparisons of some PIT methods. The PIT methods can be classified into *transform domain methods*, pyramid-structure methods, and *spatial domain methods*.

Transform domain PIT methods may be divided into different sub-classes depending on the transformation applied: some of them [4,5] are based on DCT, while some others [6–9] are based on wavelet transformation. The techniques in [10–13] transmit wavelet coefficients in different passes according to their significance. The main drawback of these methods is the complexity of the inverse transformation at each stage of PIT.

In the pyramidal approach [14–16], successive levels of the pyramid structure correspond to successive approximation of an image. Accordingly, information of the pyramid structure is transmitted to the receiver from top to bottom.

Among the spatial domain methods, bit plane method (BPM) [3] is the simplest and straightforward. In this method, the transmitter transmits one bit for each pixel in each step, and the transmission starts from most significant bit (MSB). The major drawback of BPM is the poor quality of reconstructed images at the initial stages. An improved BPM (IBPM) [17] has been proposed to enhance the image quality at early stages, but this method requires more data to be transmitted to the receiver. Guessing by neighbor method (GBN) [18] is proposed to reduce the bit-rate by exploiting the spatial correlations between neighbor pixels. Here, pixels are ordered by row-major distribution and then even and odd streams are defined. In GBN, first even stream is transmitted (2 bits at a time) and using that odd stream is estimated. If error occurs at some positions of odd stream, actual bits of the original image are transmitted. For the transmission of a grayscale image four rounds are required and each round consists of two stages: (i) reconstruction with estimation followed by (ii) error-free reconstruction. In quadtree based method (QuadSeg) [19], each image block is decomposed like a quadtree. To partition a block, thresholding is applied on the block mean and for each subset corresponding mean is used to determine whether the block will be further partitioned or not. To reconstruct the image, each block is represented by its mean. In this method, a number of thresholds $\{Th_1, Th_2, \ldots, Th_r\}$, where $Th_i > Th_{i+1}$, are used to refine the partition of the blocks. Here, the quadtree partition QT_i of a block is restructured to QT_{i+1} relative to the threshold Th_{i+1}. In the first stage of 'QuadSeg', the information related to block decomposition (with respect to Th_1) and the corresponding mean values are transmitted. In the subsequent stages, if $QT_i = QT_{i+1}$ an indicator of no change is transmitted; otherwise the bit stream to represent the change in quadtree along with the mean values are transmitted.

In [20], a block truncation coding based progressive scheme (PBTC) is proposed where image blocks are first encoded by BTC [21] and then all the pixel positions represented by 0 and 1 are separately encoded again by BTC. It is repeated until all pixels have either same value or having only one pixel. This coding scheme can be expressed by a tree and the information of the BTC trees are transmitted level by level.

An ordered dither block truncation coding (ODBTC) method is proposed by Guo [22] and the method has the capability to send the coded information progressively (PODBTC). In ODBTC, images are partitioned into 8×8 blocks and an 8×8 dither array is used to encode the blocks. Here, pixels are binarized with respect to the dither value and block intensity profile (maximum graylevel, x_{max}, and minimum graylevel, x_{min}). A block is reconstructed using binary pattern and graylevels x_{max} and x_{min}. For progressive transmission (PODBTC), co-located bit pattern (CBP) is defined. A CBP is the collection of bit value of the pixels located at the same position of each block. For an image 64 CBPs are considered, which are sorted with respect to number of 1s in decreasing order. The smooth/non-smooth CBPs are indicated by an overhead bit stream. In progressive transmission, at the very first step the overhead bit stream, x_{max} and x_{min} of all blocks and the middle most CBP are transmitted to the receiver. To reconstruct the image, copy of the middle most CBP is used for all non-available CBPs. Then in a loop, one non-smooth CBP is selected and transmitted. One CBP covers a number of non-available CBPs.

Vector quantization (VQ) based method can also be used to reduce the bit-rate of PIT. A tree-structured vector quantization (TSVQ) based PIT scheme is proposed in [3]. Multistage vector quantization (MSVQ) based schemes are proposed in [23,24]. In [25], an index sampling method based PIT method is proposed. Another VQ based method using full-search progressive transmission tree (FSPTT) is presented in [26]. In such a tree, the leaf nodes are generated by clustering method and all leaf nodes are at the same level. These leaf nodes are considered as final codewords. The internal nodes, considered as temporary codewords, are derived from the child nodes using bottom-up approach. A block is encoded through an exhaustive search of the terminal nodes of the FSPTT. The index of the selected codewords are then transmitted progressively, and internal codewords are used to reconstruct the block gradually.

Almost all the methods mentioned above are applicable for PIT of both grayscale and color images. In color progressive scheme, two approaches may be adopted. In the first approach, grayscale PIT technique is employed to each color planes (R, G, B) separately and then information is transmitted for each plane with equal importance. For example, BPM and PBTC methods can be extended and let us call these methods as CBPM and CPBTC, respectively. The expected bit-rates of these methods are very high. To reduce the bit-rate of CPBTC method, a method using common bit-map for each of three color blocks (CBMCPBTC) is presented in [27]. In other approach, first an image is transformed from RGB to another domain, say, *XYZ*. Then certain PIT method is employed on them and more data is transmitted from visually sensitive plane compared to other planes. These transmissions of data must be in interleaved fashion according to their importance. The color GBN method (CGBN) utilizes this concept for color image transmission.

3. BTC-PF method

BTC-PF [1,2] method is a combined version of block truncation coding [21] and vector quantization [28] methods. In block truncation coding, an image is divided into non-overlapping blocks of size $n \times n$ ($n = 2^k$). Compression is achieved by representing each block by Q different graylevels ($Q \ll n^2$) corresponding to a Q-level pattern of size $n \times n$. In conventional BTC [21] Q is 2. In BTC-PF method, instead of determining the Q-level pattern based on the block statistics, it is selected from a set of, say, M predefined Q-level patterns. The pattern should match the candidate image block in terms of some quality measure. Thus, the index of selected pattern and Q graylevels are sufficient for reconstruction.

The method of selection of the best pattern for an image block B is as follows. For an image block B, let pixels are $x_i (i = 1, 2, \ldots, n^2)$ and