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LETTERS

A novel method for progressive image transmission using blocked wavelets

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Abstract

The techniques of progressive image transmission (PIT) divide image delivery into several phases. PIT's main objective is to efficiently and effectively provide an approximate reconstruction of the original image in each phase. Therefore, this study proposes the blocked wavelet progressive image transmission (BWPIT) method based on the wavelet transformation and the spatial similarity of pixels, to reduce the bit-rate and increase the image quality in an early phase of PIT. Experimental results show that the transmission bit-rate and the image quality of BWPIT are significantly better than those of bit-plane method (BPM), improved bit-plane method (IBPM), and wavelet-based progressive image transmission (WbPIT) method in each early phase.

Keywords: Progressive image transmission; Discrete wavelet transformation; Haar

1. Introduction

Transmission of high-resolution images or videos over a low speed channel, such as a telephone line, usually meets the problem of the long delivery time. Therefore, users have a high demand for recognizing the picture content or even aborting the transferring process at an early stage [1].

The technique of progressive image transmission (PIT), which partitions an image into several parts to transmit phase by phase, provides an approximate result of the original image in an early transmission phase, and transmits the details progressively by the following phases. In each phase of PIT, the receiver obtains an approximate result of the original image, rather than a part of it. To reduce the transmission load, a well-designed PIT method should have a low transmission bit-rate and a high image quality in an early phase. Several research results have been presented [1–4].

The discrete wavelet transformation (DWT) techniques can transform the signal energy trend to cluster in the low-frequency region. A few transformed significant coefficients in the low-frequency region can efficiently reconstruct an approximate result for the original image. Therefore, the DWT techniques have been widely applied to the domains of the image compression and PIT, such as [3–5].

The pixels in an image usually resemble their neighbors. Segmenting an image into several blocks has a high possibility to result in similar pixels in blocks. Therefore, to integrate the advantages of the wavelet transformation and the spatial similarity of pixels, this study proposes the blocked wavelet progressive image transmission (BWPIT) method by applying the Haar wavelet transformation in each small block. BWPIT more significantly improves the reconstructed image quality in each early phase than do bit-plane method (BPM), improved bit-plane method (IBPM) and wavelet-based progressive image transmission (WbPIT) method.

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For simplicity but without loss of generality, this study focuses on the early phases of PIT and discards related compression techniques in each phase.

2. Related work

BPM is the simplest and best-known method for PIT in a spatial domain [1]. BPM uniformly partitions all pixels into several bit planes for each image. The bit plane is sorted from the most significant bit to the least significant bit. Therefore, BPM can implement PIT by sending a bit plane in each phase in order. The receiver obtains the value "0" or "1" for each pixel to recover the other bits of the corresponding pixel by using the mean value in each phase. The inaccurate prediction of BPM results in poorly reconstructed images in the first several phases.

To improve the image quality in each phase, the IBPM applies a tree-structured codebook to predict the original value of each pixel [2]. In each phase, IBPM sends a bit plane and several codewords of the tree-structured codebook. Although IBPM improves the reconstructed image quality in each phase, the increasing bit-rate of IBPM results in a longer transmission time than that of BPM in each phase.

Chang and Lu applied the simple and efficient Haar discrete wavelet transformation (Haar DWT) for PIT, which is also called the wavelet-based progressive image transmission (WbPIT) method [3]. Haar DWT calculates the DWT coefficients by addition and subtraction operations. Two steps of one-dimensional Haar operations compose the one-scale Haar DWT of two dimensions. In each transmission phase, besides transmitting the coefficients of the current sub-band, WbPIT transmits the half coefficients and the average value of the next sub-band to refine the reconstructed image. In an early phase of PIT, WbPIT can efficiently reconstruct a coarse image. However, the overhead of transmission rapidly increases in next phase.

3. The BWPIT method

The Haar DWT can be applied for PIT well. Moreover, from the viewpoint of the spatial domain of an image, the pixels in a smooth region of the image slightly differ. Therefore, this study proposes the BWPIT method, which utilizes the advantages of Haar DWT and the spatial similarity, to reduce the bit-rate and improve the quality of the reconstructed image in each phase for PIT.

The standard deviation, σ, is a famous measure of the statistical dispersion. The normal distribution has 95.44% of the data points distributed within two standard deviation units of the mean [6]. A low standard deviation unit means that the data are similar. Therefore, this study employs the standard deviation value of each block (subimage) to distinguish the degree of smoothness of each block. BWPIT partitions an image with size $m \times n$ into $(m/w) \times (n/h)$ non-overlap

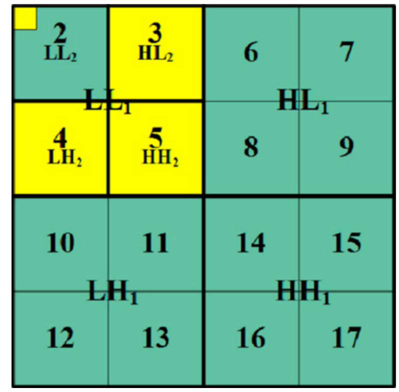

Fig. 1. The transmission order of a block.

blocks with size $w \times h$. Then, BWPIT calculates the standard deviation of each block and assigns its degree. BWPIT distinguishes the degree of smoothness of each block, according to the three pre-defined threshold values, T_1, T_2, and T_3. The degree value of each block is assigned as follows:

$$\text{Degree} = \begin{cases} 1 & \text{if } \sigma \leqslant T_1, \\ 2 & \text{else if } T_1 < \sigma \leqslant T_2, \\ 3 & \text{else if } T_2 < \sigma \leqslant T_3, \\ 4 & \text{otherwise,} \end{cases}$$

where $0 < T_1 < T_2 < T_3$. The reconstructed block with a low degree value only requires a few coefficients to effectively approximate the original block. A high-degree block requires more coefficients to approximately reconstruct the block. Therefore, BWPIT terminates to transmit the coefficients in an early phase for blocks with a low degree value.

Moreover, BWPIT applies the two-scale Haar DWT to each block. In a low-frequency sub-band, the coefficients usually become very large. Therefore, to reduce the transmission cost in each phase, BWPIT quantizes each coefficient into the same number of bits as the original pixel. In the first transmission phase, BWPIT transmits the mean value of each block. Fig. 1 shows the following transmission order of each block. In the second transmission phase, BWPIT transmits the coefficients of LL_2 but skips the first coefficient to deliver, since the first coefficient can be obtained by the simple computation of the mean value with the other LL_2 coefficients. The degree value of each block is also transmitted in the second phase. According to the degree value, each distinct block terminates transmission in different phase. The termination phase ($T\ phase$) is as follows:

$$T\ phase = \begin{cases} 1 & \text{if degree} = 1, \\ 2 & \text{if degree} = 2, \\ 5 & \text{if degree} = 3. \end{cases}$$

If degree $= 4$, the block is terminated to transmit in the phase, which users accept the reconstructed quality of the