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Memory-efficient spatial prediction image compression scheme

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Abstract

In prediction phase, the hierarchical tree structure obtained from the test image is used to predict every central pixel of an image by its four neighboring pixels. The prediction scheme generates the predicted error image, to which the wavelet/sub-band coding algorithm can be applied to obtain efficient compression. In quantization phase, we used a modified SPIHT algorithm to achieve efficiency in memory requirements. The memory constraint plays a vital role in wireless and bandwidth-limited applications. A single reusable list is used instead of three continuously growing linked lists as in case of SPIHT. This method is error resilient. The performance is measured in terms of PSNR and memory requirements. The algorithm shows good compression performance and significant savings in memory.

Keywords: Spatial prediction; Hierarchical tree; Memory-efficient compression

1. Introduction

Image compression is an important component in today's world of networked telecommunication/media processing applications. Among many methods of compression, Discrete Wavelet Transform (DWT) approach has become a popular technique [1–3]. DWT suffers from computational complexity and requirement of more computational power, which hinders its use in real-time/wireless and band-limited applications. DWT requires more power as compared to DCT.

The design of our memory-efficient spatial prediction (MESP) image compression scheme has two parts viz., prediction phase and quantization phase. The traditional predictive scheme uses the preceding pixels according to the raster scan order as the input value to predict the target pixels [4]. The loss-less JPEG compression scheme mentioned in scheme [5] uses the traditional predictive scheme.

The SPIHT algorithm [2], a fast and efficient method, is generally used along with DWT to enhance the compression performance. Similar to EZW [1], the SPIHT algorithm processes the entire image at once. After the image is transformed by DWT, the SPIHT algorithm operates upon its coefficients. The SPIHT accesses the coefficients randomly, since there is no particular order of access among bit planes. The random access nature limits its use in certain memory-constrained environments. Due to the use of pixel/set lists, which significantly increase the working memory requirements, SPIHT could not be included in the JPEG2000 standard. Many modifications have been coming up for SPIHT, like zero-tree algorithms to reduce the memory requirements. JPEG2000 has the ability to encode a large image without storing the entire image in memory. Embedded Block Coding with Truncation (EBCOT) [6] is included in JPEG2000, which reduces the memory requirements through encoding of pixel blocks. It is more complex due to the use of adaptive arithmetic coding, multiple coding passes and rate distortion optimizers.

The No List SPIHT (NLS) [7] is a list free version of SPIHT which uses fixed size arrays in place of lists. The

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working memory is always fixed, irrespective of number of passes to be executed. The other solution is given by Pearlman [8] in which the coefficients are grouped into small spatial blocks in such a way that each hierarchical coefficient tree appears in one of the spatial blocks. The basic SPIHT algorithm is applied to each spatial block independently before making the final bit stream, which makes the coding non-progressive.

In our work, we separate all pixels of an image into many hierarchical levels by utilizing the surrounding pixels to predict every central pixel [9]. Four cross neighboring pixels (across the target pixel horizontally and vertically) are used in the first step and the four diagonal neighboring pixels are used in the second step. A small image is formed by the remaining 1/4 pixels. The above two steps are applied to this new image, which is 1/4th the original image. The error values obtained from the new image are placed in their corresponding locations in the original image. This process is repeated iteratively until all the pixels in the original image are covered. The resulting image will have the hierarchy which is much similar to the one that could have been obtained by DWT. Then we integrate this hierarchy with SPIHT, one of the popular wavelet/subband image compression techniques. We have used modified SPIHT in quantization phase to achieve efficiency in memory requirements. The scheme uses a single reusable list for each bit plane, which processes all the coefficients in the bit plane. The partitioning rule is followed as in case of SPIHT, which is done in a single pass [10].

The designed scheme requires a few integer additions and bit shifts in encoding and decoding processes. The in-place process is followed in the prediction phase, in which the target pixel values will be replaced by the predicted error values. Hence, temporary storage space required is significantly saved in the coding process. The experimental simulations show that the performance of the proposed scheme is competitive with base line JPEG [5] using DCT. Our progressive compression scheme will be useful in applications like real time/wireless transmission in low computational power and compact memory environments.

The structure of the remaining part of paper is as follows. Section 2 covers the background material and Section 3 contains the predictive algorithm along with an algorithm to obtain tree map of an image. Section 4 presents the modified SPIHT to achieve memory efficiency requirements. Simulation results and conclusions are presented in Sections 5 and 6, respectively.

2. Background – spatial prediction

The 2D coding schemes are based on minimizing the redundancy in coding, inter-pixel dependency or psycho visual redundancies [4]. A typical spatial coding scheme is shown below in Fig. 1a. It is based on the principle of coding the result of subtraction of the original value of pixel from the predicted value of the pixel. The encoder and decoder contain the identical predictors. The successive image pixels $[i_k]$ are introduced into the encoder and $[i_{k'}]$, the predicted values are generated. The predicated errors $[e_k = (i_k - i_{k'})]$ are calculated. The symbol encoder (e.g., Huffman coding/arithmetic coding) is used to compress the error values in compact stream. The predicted error image will have low value of entropy indicating the low energy at the decoder. The identical predictor is used in the decoder to reconstruct the compressed image. The traditional prediction scheme uses the raster scan approach for the whole image. To decode the compressed image, a traditional prediction scheme cannot use all the pixels around the target pixel to predict the color value of the target pixel. For example, pixel ‘x’ (Fig. 1b) can be predicted only by the pixels ‘a,’ ‘b’ and ‘c’. Other pixels below ‘x’ cannot be used because they appear later than pixel ‘x’ (occur in future compared to pixel ‘x’). The proposed scheme overcomes this disadvantage of the traditional scheme.

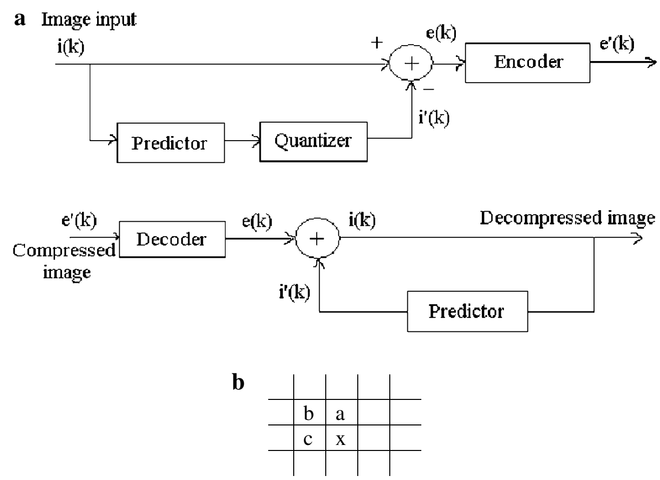

Fig. 1. (a) A typical predictive coding model. (b) Target pixel ‘x’ and its neighbors.

The prediction coding scheme uses the history of sequence of image pixels in a predictive manner to determine its encoding. Predictive encoding is used to minimize or nullify the mutual redundancy between the successive values of a pixel. Based on the estimation rule, a pixel value can be predicted to replace the current value of the pixel. The predicted error value can be encoded in fewer bits compared to the encoding of the current pixel value. In differential encoding (e.g., differential pulse code modulation), the predicted error value (differential error) is encoded.

3. Spatial prediction-based scheme

Image compression standards such as Loss-less JPEG and JBIG use the predictive coding scheme due to its simplicity and efficiency. The predication rule we have used involves the predicting of the central pixel surrounded by its four neighboring pixels [6]. The average value of the four neighboring pixels is subtracted from the central pixel value to get the error value of the central pixel. It is an