

Image Compression based on Octagon Based Intra Prediction

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Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 28 April 2021

Abstract: Recently image coding has been an important research area in many fields. Various compression algorithms have been developed in different ways for image compression. One of the ways in image coding is prediction based image coding. This paper proposes a novel technique for finding the prediction of a current pixel. Instead of traditional four mode prediction, this paper proposes an eight mode prediction scheme. The proposed method is tested with nine traditional images and compared with four recent methods. Experimental results substantially proved that the proposed method is better than recent methods..

Keywords: Intra Prediction, distortion, predictive coding, prediction residual

1. Introduction

Spatial image prediction was a key component of efficient image lossless compression [1 - 2]. Existing lossless image compression techniques attempt to predict image data using their spatial neighborhood. This will reduce image compression efficiency. A natural image often includes a large number of components of the structure such as edges, contours, and textures. It is possible to repeat these components at various locations and scales. Therefore, a more efficient image prediction scheme needs to be developed in order to exploit this type of image correlation. The concept of enlightening effectiveness of coding and image prediction by traced back to sequential data compression [3 - 4] and vector quantization of image compression [5]. A text substring is represented by a displacement / length reference to a previously seen substring in the text in sequential data compression. The storage device extended sequential data compression to lossless compression of the image [6]. However, the algorithm does not compete with the state of the art in terms of coding efficiency, such as Context - Adaptive Lossless Image Coding (CALIC) [1]. During Vector Quantization (VQ), the input image is processed as image pixel vectors for lossless image compression. The encoder takes up a vector and finds the best match from its stored codebook. It then transmits the best match address, the residual between the original vector and its best match to the decoder. To access an identical codebook, the decoder uses the address and gets the reconstructed vector. VQ image compression method follow up version is Visual Pattern Image Coding (VPIC) [7] and Visual Pattern Vector Quantization (VPVQ) [8]. The encoding performance of VQ - based methods is largely dependent on codebook design. Compared to state - of - the - art image coding schemes, these methods still suffer from lower coding efficiency. In the intra - prediction scheme proposed by Nokia[9], there are ten possible prediction methods: DC prediction, directional extrapolation, and block matching. DC and directional prediction methods are very similar to H.264 intra prediction methods [10]. As mentioned earlier, this barrier will limit image compression efficiency as components of the image structure can be repeated at different locations. Text and image compression is basically compressed by using Predictive coding. To achieve more efficient compression, it encodes the difference between the current data estimate derived from past data and actual current data [11]. The degree of efficiency depends greatly on the estimation's accuracy as the difference becomes smaller, as well as the information to be encoded. Several lossless algorithms of image compression have been developed using this predictive coding method [12 - 14]. JPEG - LS is an example of an approach to predictive coding that works well with continuous - tone images [15, 16]. Unlike the previous JPEG compression, which uses the DCT method to compress loss [17], JPEG - LS is not complex and works well with gray images. However, their performance is not as impressive when applied to indexed color or color map images. The leftover of the paper is planned as follows. Section II describes the System architecture of the proposed encoder and decoder. Section III discusses the proposed octagon based prediction algorithm. Section IV demonstrates some experiments followed by conclusion in Section V.

2. System Architecture

The prediction process consists of a statistical estimation of future random variables from past and present observable random variables. The prediction of an image pixel value calculated from the before transmitted pixel values. The predicted pixels are subtracted from the original pixels and a residual signal is obtained. In general, the prediction is considered successful if the energy of the residual signal is lower than the energy of the original

signal. As a consequence, the residual pixels might be more efficiently encoded by entropy coding algorithms, being transmitted with fewer bits. Since the early days of image compression, predictive coding has showed to be an effective technique, being widely used for both lossless and lossy image coding. The proposed encoder and decoder architecture are shown in Fig. 1 and 2. The Encoder consists of traditional steps like Transformation, Quantization and Entropy coding. As the system is prediction based image coding, it includes inverse transformation and inverse quantization in the encoder itself. In addition to these steps, the proposed predictive image coding consists of intra prediction for finding predicted pixel in the neighboring blocks. The predicted pixel is calculated using the proposed octagon based intra prediction scheme. The Prediction Error is calculated after finding the predicted pixel. Instead of encoding the current pixel, only the prediction error is encoded which reduces the coding.

In the decoder, the traditional inverse transformation and inverse quantization steps are included. The prediction error is added with the predicted pixel to calculate current pixel in the intra prediction.

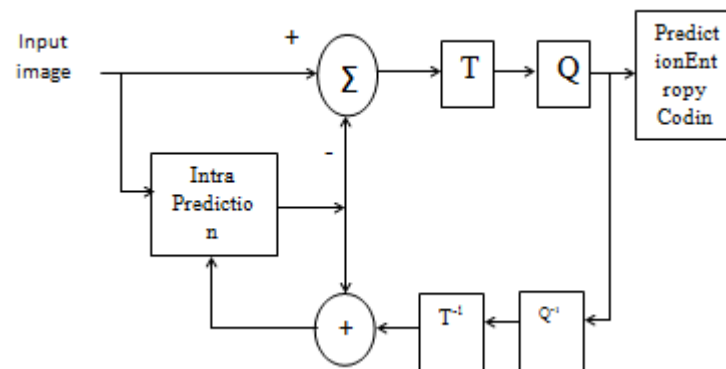


Fig. 1 Proposed Encoder Architecture

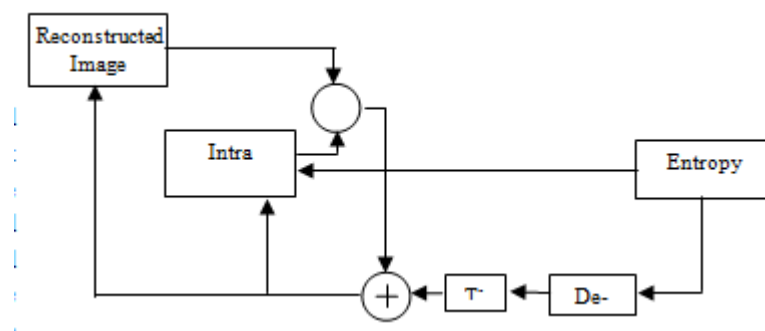


Fig. 2 Proposed Decoder Architecture

3. Intra Prediction

Intra prediction is mainly used in video coding. A prediction signal is obtained from previously coded samples for the coding unit and it is subtracted from the original coding unit to create a residual signal that has much less data than the obtains the same prediction signal using previously decoded samples, decodes the residual signal and adds them together to reconstruct the coding unit. In intra prediction each coding unit is predicted using the surrounding pixels (which have been already coded and decoded) in the same image. Intra coding is used in the first image of a sequence. Intra coding is also very useful in coding uniform regions where surrounding pixels of the block has similar value as the pixels inside the block. Intra prediction is only used in recent video coding standards such as H.263 [77] and H.264/AVC [78].

4. Proposed Octagon based Prediction Algorithm

Intra prediction plays a vital role in recent video coding standards. One among them is block-based intra prediction technique which is used for efficient spatial redundancy exploitation. In this paper, a research is made in image compression by incorporating intra prediction coding to improve the efficiency. Intra Prediction is

defined as the prediction in which the image content of a particular region can be represented with other previously decoded region in the image. Hence, in the intra prediction, decoding is done during encoding also. Here, the regions are termed as blocks. Initially, the image is divided into blocks. Intra predicted blocks are generated based on the pixels of the previously encoded and reconstructed blocks. There are some prediction modes for identifying predicted block. These prediction modes are defined for square block sizes from 4 x 4 up to 32 x 32. The encoder tests all the available intra prediction modes and signals the best mode to the decoder. The decoder must generate an identical prediction block, based on the reconstructed pixels from the previously encoded neighboring blocks. The reconstructed reference samples used in the prediction process belong to the neighboring blocks. For an $N \times N$ block, intra prediction searches the predicted block in the neighboring blocks according to the search ranges described next. It is shown in Fig. 3. The proposed algorithm uses 20 neighboring blocks for intra prediction. The similarity of the blocks is measured using Block Distortion Measure (BDM). The block with the minimum BDM is selected as the predicted block.

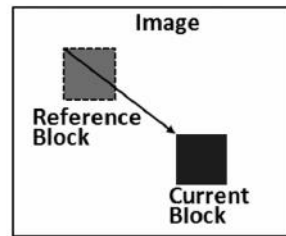


Fig. 3 Illustration of Intra prediction

The proposed Algorithm consists of two search ranges: Square and Octagon search. The square pattern consists of 8 pixels whereas the octagon pattern consists of 21 pixels including the square pattern. The Octagon Based Intra Prediction Mode

Mode Selection Algorithm is as follows:

Algorithm 1: Octagon Based Intra Prediction Mode Selection

Input: Current Block

Output: Predicted Block, Prediction Error

Steps:

1. For each current block, calculate BDM for the 8 neighboring blocks in the square range. If minimum BDM is zero in any of the neighboring blocks, Predicted block is found. Stop the search. Go to step 5.
 2. Calculate BDM for the 12 blocks in the octagon range.
 3. Calculate minimum BDM obtained from the above two steps.
 4. The block with minimum BDM obtained in the previous step is selected as Predicted block.
 5. Calculate prediction errors using the current block and the predicted block.
 6. Stop the process.
-

Matching of one block with the other is based on the output of the BDM. The candidate block with minimum BDM is the one that matches closest to the current block. Among the various cost functions, the one that is less computationally expensive is the Mean Absolute difference (MAD) and is given by the formula:

$$MAD = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} |C_{ij} - R_{ij}| \quad (1)$$

Where M and N is the size of the block, C_{ij} and R_{ij} are the pixels being compared in current block and reference block, respectively. The search range of the proposed algorithm is shown in Fig. 4. The inner square search range is shaded with dark gray while the outer octagon search range is shaded with light gray.

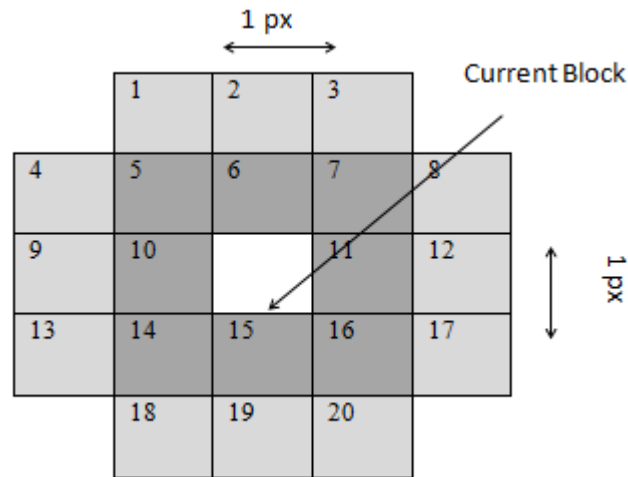


Fig. 4 Search Range of Proposed Algorithm

An example showing how the predicted block is selected is shown in Fig. 5. In Fig. 5 (a), the input image is subdivided into 25 blocks (B_1 to B_{25}) in which B_{13} is assumed as the current block. Hence, prediction block for B_{13} has to be found. Figure 5(b) shows BDM calculation of square and octagon ranges. Initially, the BDM of blocks in the square range (8 neighboring blocks) is calculated. If minimum of BDM is zero, then prediction block is found. Otherwise, the BDM of blocks in the octagon range (12 neighboring blocks) is calculated. Minimum of BDM is calculated from the square and octagon range. The block which has the minimum BDM is selected as the predicted block

5. The Octagon Based Intra Prediction Mode Selection

Let $S = \{x / x \in \mathbb{N} \text{ and } x \leq 5\}$ and

$T = \{y / y \in \mathbb{N} \text{ and } y \leq 20\}$

Define a map $f : S \times S \rightarrow T$ by $f(i,j) = a_{ij}$

Let O be the collection of all (i,j) such that where image from 1 to 12 .

That is $O = \{f(i,j) / f(i,j) = a_{ij}, 1 \leq a_{ij} \leq 12\}$

Then $n\{O\} = 12$, that is there are 12 pixels namely

$\{(1,2),(1,3),(1,4),(2,1),(2,5),(3,1),(3,5),(4,1),(4,5),(5,2), (5,3),(5,4)\}$ satisfy the condition that these pixels form an octagon. Let S be the collection of all (i,j) such that whose image from 13 to 20

That is $S = \{(i,j) / f(i,j) = a_{ij}, 13 \leq a_{ij} \leq 20\}$

Here there are 8 pixels namely $\{(2,2),(2,3),(2,4),(3,2),(3,4),(4,2),(4,3),(4,4)\}$ satisfy this condition. These pixels form a square.

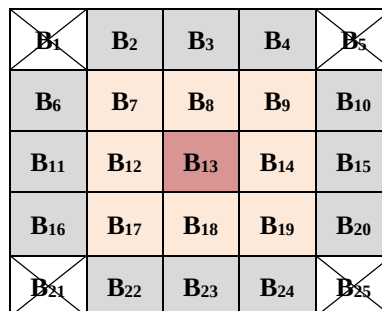


Figure 5 (a)

B₁	B ₂	B ₃	B ₄	B₅
B ₆	B ₇	B ₈	B ₉	B ₁₀
B ₁₁	B ₁₂	B ₁₃	B ₁₄	B ₁₅
B ₁₆	B ₁₇	B ₁₈	B ₁₉	B ₂₀
B₂₁	B ₂₂	B ₂₃	B ₂₄	B ₂₅

(b)

B₁	B ₂	B ₃	B ₄	B ₅
B ₆	B ₇	B ₈	B ₉	B ₁₀
B ₁₁	B ₁₂	B ₁₃	B ₁₄	B ₁₅
B ₁₆	B ₁₇	B ₁₈	B ₁₉	B ₂₀
B₂₁	B ₂₂	B ₂₃	B ₂₄	B₂₅

(c)

Figure5 (a) search points with numbering (b)(c) searching pattern if a point 19 and 9 has minimum BDM in (a) respectively.

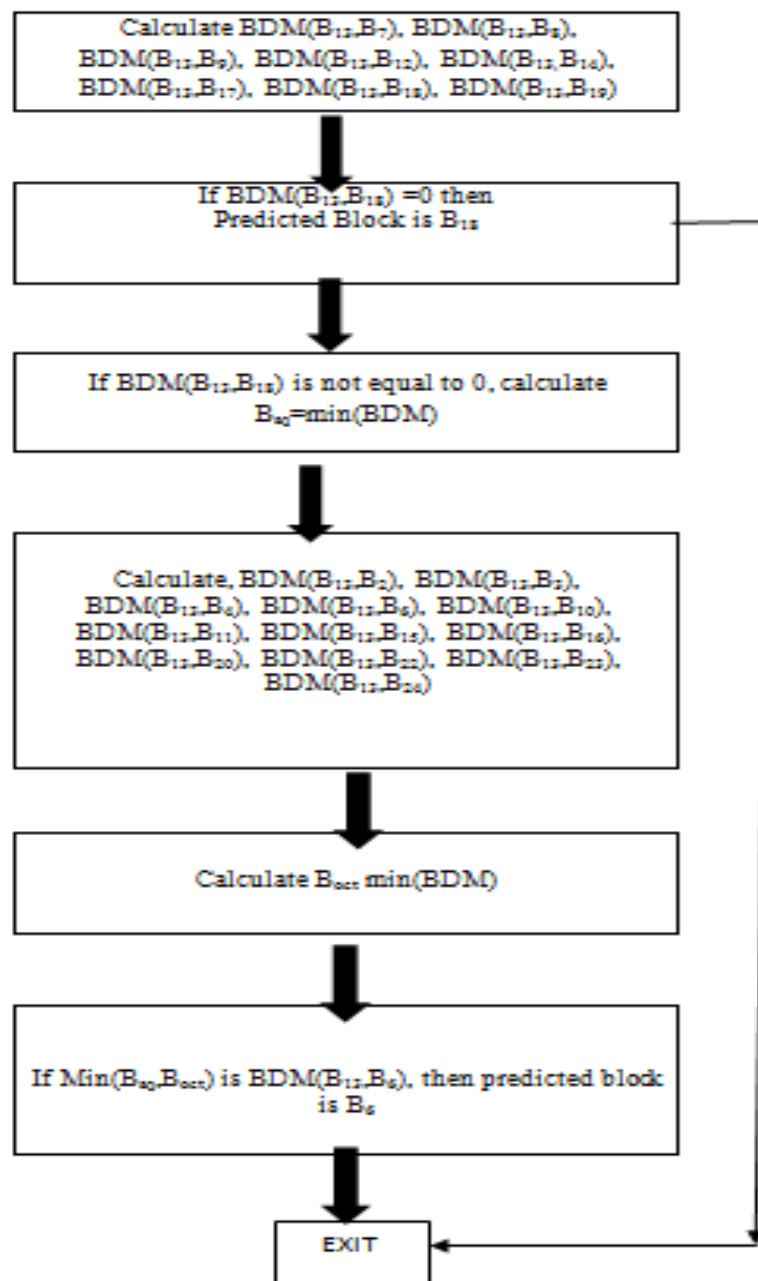


Fig. 6 Demonstration of calculating Prediction Block - Work flow of calculating prediction block

Figure 6 shows BDM calculation of square and octagon ranges in which we consider B_{18} to have min BDM in square range and B_6 to have min BDM in octagon range. Initially, the BDM of blocks in the square range (8 neighboring blocks) is calculated. If minimum of BDM is zero, then prediction block is found. Otherwise, the BDM of blocks in the octagon range (12 neighboring blocks) is calculated. Minimum of BDM is calculated from the square and octagon range. The block which has the minimum BDM is selected as the predicted block.

6. Experimental Results

The proposed method uses integer transformation, H.264 (video coding standard) quantization and (Content Adaptive Variable Length Coding) CAVLC encoding. Experiments are conducted on 7 different images. The image types and its sizes are listed in Table 1. The proposed method is compared with JPEG and recent methods in terms of PSNR, SNR, Compression ratio and bits per pixel.

Table 1 Test Image and its size

Image	size
Cman.tif	256x256
Baboon.tif	256x256
Barbara.png	512x512
Boat.gif	512x512
Lena.png	512x512
Peppers.png	512x512
Lifting.png	256x256
GoldHill.bmp	256 x 256

Compression ratio is used to quantify the reduction in data-representation size produced by a data compression algorithm and is defined as the ratio between the uncompressed size and the compressed size:

$$\text{Compression Ratio} = \text{Uncompressed Size} / \text{Compressed Size} \quad (2)$$

$$MSE = \frac{1}{MN} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \|I(i, j) - K(i, j)\| \quad (3)$$

The PSNR is defined as

$$PSNR = 20 \log_{10} \left(\frac{MAX_I}{\sqrt{MSE}} \right) \quad (4)$$

Signal-to-noise is defined as the ratio of a signal power to the noise power corrupting the signal. Signal-to-noise ratio is the ratio between a signal and the background noise:

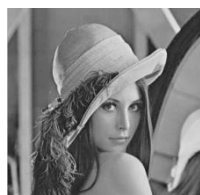
$$SNR = \frac{\sum_{i=0}^{m-1} \sum_{j=0}^{n-1} K(i, j)^2}{\sum_{i=0}^{m-1} \sum_{j=0}^{n-1} I(i, j) - K(i, j)^2} \quad (5)$$

Figure 6 shows the final reconstructed output of Lena Image. Table 2 shows the results obtained by the proposed method.



(a)

(b)



(c)

Fig. 6(a) Input Image (b) After Block subdivision (c) Output obtained by the proposed method of Lena Image

Table 2 Results method

Method/ Image	Compression Ratio	PSNR (dB)	Bits per Pixel
Cman	5.0221	75.1147	0.1991
Baboon	3.2408	65.9077	0.32408
Lifting	15.2294	68.8612	0.0657
Barbara	5.1885	68.2644	0.1927
Boat	5.4346	69.2197	0.1840
Lena	7.9194	70.3744	0.1263
Peppers	6.9896	66.0549	0.1431
Average	7.003486	69.11386	0.176426

obtained by the proposed

The proposed method is compared with JPEG 2000, Variable Block Size coding (VBS) [18], Adaptive Predictive (APC) [19] and Then (ETC) [20]. It is Table 3.

Table 3 of the proposed JPEG and its methods

Method/ Image	JPEG 2000	VBS (2010)	APC (2013)	ETC (2014)	Proposed
Barbara	4.600	3.1815	3.75	1.223	0.1927
Lena	4.684	4.280	3.45	0.766	0.1263
GoldHill	4.603	4.207	4.20	1.137	0.1751
Avg.	4.629	3.8895	3.75	1.042	0.165

Combination
Encryption
Compression
shown in

Comparison
method with
recent

7. Conclusion

It employs new octagon based searching for still image compression which helps reducing the distortion there by improving the reconstructed image quality. In OBIP searching range of neighboring pixel is increased, in order to efficiently identify the predicted block. The proposed method achieves PSNR ranges from 49.1767db to 60.3744db and bits per pixel ranges from 0.1263 to 0.3086. The performance of the proposed method is compared with JPEG 2000. From the experiments, it is proved that the quality of the image is sustained while reducing the data rate and computational time.

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