



Adaptive Selective Predictive For Image Data Compression

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Abstract

In this paper, an adaptive selective predictive coding method is proposed for intraframe coding techniques. The adopted techniques overcome the complexity residual ideal case (i.e., residual does not become random noise) where the residual still suffers from the existence of redundancy. The suggested techniques attempt to sift over any redundancy embedded in the residual where the quality improves than that of traditional predictive coding, selective predictive coding and of fixed predictor coding.

Index Terms- Predictive coding, Selective coding, Predictive coding of fixed predictor.

طريقة الانتقائية التنبؤية المطورة لضغط بيانات الصورة

غادة كاظم طعمة

وحدة الاستشعار عن بعد، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

يقدم هذا البحث طريقة ضغط مطورة تعتمد على التنبؤ بالاختيار للتغلب على الضوضاء الناتجة من القيم المتبقية. نجحت الطريقة المقترحة في هذا البحث بإزالة الضوضاء في القيم المتبقية لغرض تحسين نوعية الصورة الناتجة مقارنة بالطرق التقليدية.

1. Introduction

Predictive coding methods are a promising technique for image compression, still under development, and not yet a recognized standard like JPEG (i.e. do not yet have an extension of the type *.pc like as JPEG of extension *.jpeg) even it is used by the main image and video coding standards. In recent decades, a number of researchers have exploited the technique to compress images. In addition to its simplicity, its symmetry of encoder and decoder and flexibility of use are the most significant advantages of this technique [1].

Predictive coding first appeared in the middle of the last century, introduced by [2]-[4], further information on the history of predictive coding

techniques and early contributions can be found in [5]-[9]. Typically such methods partitioned image into smaller nonoverlapping blocks that are either of fixed size or variable sizes where spatial redundancy present within the image is mathematically modelled which depends on the image's pixel neighbours.

In this paper, an adaptive selective predictive coding is introduced, that efficiently sift over any redundancy in the decorrelation image with improving the resulting image quality. The rest of this paper is organized as follows; the theory behind the predictive coding is discussed in section 2. Discussion of the selective coding techniques and the adaptive selective coding

techniques with the experimental results is given in sections 3, 4 and 5 respectively.

2. Theory

The Predictive Coding Technique is referred as Autoregressive (AR) coding or differential coding, and it also known as Direct Data Compression, following [10], and non-transform techniques [11]. It is based on utilizing the image directly within the spatial domain, by modelling the correlation or statistical dependency embedded between neighbouring pixels, where each pixel's value can be predicted or estimated from nearby or neighbouring pixels. The difference between the actual pixel value and the predicted pixel value is referred to as the residual or prediction error that is encoded, because of the reduced image information compared to the original image. For details of this technique see [12]-[16].

The general form of the encoder is composed of image modelling or predicting after subtracting the mean value of each block of the original image and differencing, as shown in equations below:

$$W(x, y) = I(x, y) - m(x, y) \quad (1)$$

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

$$\tilde{I}(x, y) = \sum_i a_i W(nbrhd(x, y, i)) \quad (3)$$

$$e(x, y) = \tilde{I}(x, y) - W(x, y) \quad (4)$$

Here I represents the original image, W denotes a local zero mean image or stationary image, m denotes a block local mean of an $n \times n$ image block size, \tilde{I} represents the predicted image, which is the weighted sum of neighbouring pixels, $nbrhd(x, y, i)$ is a function defining a neighbourhood of (x, y) from W local zero mean image, and a refers to the autoregressive coefficient or prediction parameters that commonly estimated using the Least Square Approximation Method based on minimizing the sum square error or residual between the actual and the predicted values, and e represents the residual or differencing between the original and the predicted image.

The choice of the prediction model is the most vital step, and really the most complex. It is a trade-off between efficiency in terms of compression ratio, quality, and the complexity involved in estimating the coefficients, here a 2-

D 5th causal model is adopted that used by [17] as described by equation (5), figure (1) shows the model in more details.

$$\tilde{I}(x, y) = (a_1W(x - 1, y) + a_2W(x, y - 1) + a_3W(x - 1, y - 1) + a_4W(x - 2, y) + a_5W(x, y - 2)) \dots \dots \dots (5)$$

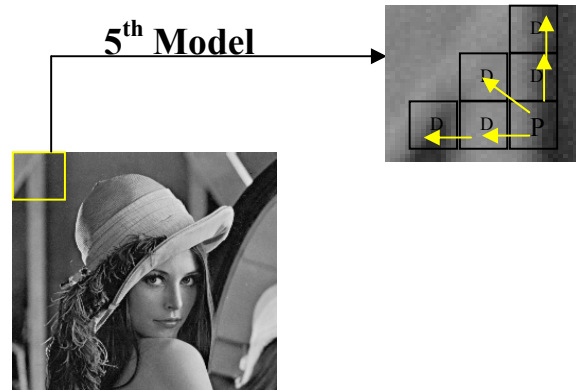


Figure 1-A Fifth Order Model That Uses Five Neighbouring Pixels Corresponding To The Left, Top, Left Top, Second Left, Second Top, Where P Corresponds To The Predicted Pixel While D Corresponds To The Known Dependent Pixel[1].

The residual and AR coefficients are lossily encoded, extra information needs to be encoded to rebuild or reconstruct the image. This is composed of the mean values of each block and the seed neighbouring pixels (i.e., some neighbouring values or initial conditions) that are used to predict the image, where both the mean and seed are coded losslessly, using Huffman coding. The seed values the 5th AR models makes use of the first two rows and columns of each block.

The decoder exploits the information received from the encoder to reconstruct the image, by first utilizing the seed values with the AR coefficients to build a predicted image using the identical encoder predictor, and then adding the residual and the mean to the prediction, such as:

$$\hat{I}(x, y) = \tilde{I}(x, y) + e(x, y) + m(x, y) \quad (6)$$

Here $\hat{I}(x, y)$ is the decoded compressed image.

3. Selective coding

The Space-varying Mean Autoregressive (SMAR) method developed by [18], based on exploiting two predictors, where the first predictor is designed to remove the mean variation between the original image and the predicted image from the original, by using the

fourth order causal local mean predictor (predictor 9 in table (1)), then exploiting the residual between the original and predicted images through the second predictor, which is a traditional AR predictor, to remove any further redundancy in the residual image [1]. More details can also found in [19]-[21] where its successful application to medical images is compared with other lossless medical techniques. Because of the feature dependency of predictive coding, results vary depending on the image details. The idea extended by [22] by utilizing various predictors, each being responsible for removing certain variation between image details. The selection between them depends on the amount of the error between neighbours, thereby to selectively chose the residual image (i.e., the predictor that produces the smallest error for each block). This entails the need for an index that records which predictor was adopted for each block, as well as the seed values for each block. Then the selective residual image utilizes the predictive coding techniques, which now work more efficiently (i.e., with more decorrelation and accuracy) compared to the fixed predictor [1].

Put simply, the idea relies on selecting some prediction models depending on the image features, here we use twelve's selected predictors, shown in table (1) and figure (2) where generally the candidate predictors are very simple to calculate compared to the AR model, then computing the residuals between these predictors and the original image. Once we have these residual images, we construct the selective residual image with lowest error block values (block by block), where the block with the lowest minimum error is selected. After that we perform the traditional predictive coding on this selective residual image; the selective techniques clearly added to the computation requirements, with extra time taken, due to additional complexity in terms of comparison and selection among the predictors for each image block of the smallest error values [1]. Figure (3) illustrates this idea of selective coding in more detail.

3.1 Experiment and results

Experiments to evaluate the traditional predictive coding, selective predictive coding and predictive coding of fixed predictors using various number of quantization levels utilized was selected to be between 4 and 256, using 2 to 8 bits on both the residual image and the autoregressive coefficients for different block

sizes, 4×4, on 'Lena' standard monochrome images of 256 gray levels (8bits/pixel) of size 256×256. The normalized root mean square error as in equation (7) between the original image I and the decoded image \hat{I} was adopted as a fidelity measure, where the range of the values is between 0 and 1. A value near zero indicates high image quality, i.e. the decoded image closely resembles the original, and vice versa.

$$NRMSSE(I, \hat{I}) = \sqrt{\frac{\sum_{x=0}^{N-1} \sum_{y=0}^{N-1} [\hat{I}(x, y) - I(x, y)]^2}{\sum_{x=0}^{N-1} \sum_{y=0}^{N-1} I(x, y)^2}} \quad (7)$$

Certainly, the quality of the decoded image is improves as the number of quantization levels of both the autoregressive coefficients and residual image increase. The main disadvantage of increasing the quantization levels, however, lies in increasing the size of the compressed information. It is a trade-off between the desired quality and the consumption of bytes; the higher the quality required, the larger the number of quantization levels that must be used, these relations illustrated in figure (4) [1].

The results in figure (4) showed that the quality measured in terms of NRMSE improved about twice on average in the selective coding techniques compared to the traditional AR and the predictive coding techniques of fixed predictor followed the same behaviour as the selective techniques, where it converged to nearly the same quality. This was due to the removal of the different levels of variation from the image details[1].

At the same time, all the above mentioned techniques uses the same size of compressed information in bytes, where the traditional AR techniques suffer from the large size of the residual where the limitation of modeling efficiency due to insufficient model flexibility, since the image features or characteristics cannot usually be fully described by a model where the details vary from part to part, while in the selective coding techniques the residual size decrease (i.e., sift over any redundancy embedded in the residual), but the need for the index and the other seed values constitutes the main bytes consumption problem, this is also the case for the predictive of fixed predictor where the other seed information are required as well [1].

Table 1- The Predictors Utilized On The Selective Coding Technique[1].

index	Predictor	Description
1	S_a	Left
2	S_b	Bottom
3	S_c	Left-Bottom
4	S_d	Right-Bottom
5	$(S_a+S_b)/2$	Local2 (Left + Bottom)/2
6	$S_a+(S_a-S_b) /2$	Local2 (Left +Left-Bottom)/2
7	$S_b+(S_d-S_b)/2$	Local2 (Bottom+ Right-Bottom)/2
8	$S_b+(S_a-S_b)/2$	Local2 (Bottom + Left-Bottom)/2
9	$(S_a+S_b+S_c+S_d) /4$	Local4 (Left +Bottom +Left-Bottom + Right-Bottom)/4
10	$(S_a+S_b+S_c+S_e+S_f)$	5thAR (Left + Bottom + Left-Bottom+ Left2+Bottom2)
11	$(S_a+S_c+S_b+S_e+S_d+S_k)$	Non Symmetric Half Plane (NSHP) (3×3)
12	$(S_a+S_q+S_c+S_b+S_d+S_t+S_u+S_e+S_k+S_z+S_y)$	Non Symmetric Half Plane (NSHP) (4×4)

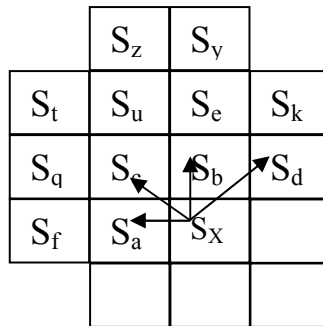


Figure 2-Local Neighboring Pixels Where The Predictors Are Designed According To Table (1) Where S_x Refers To The Current Predicted Pixel, Using S_a, \dots, S_y Predictor Pixels [1].

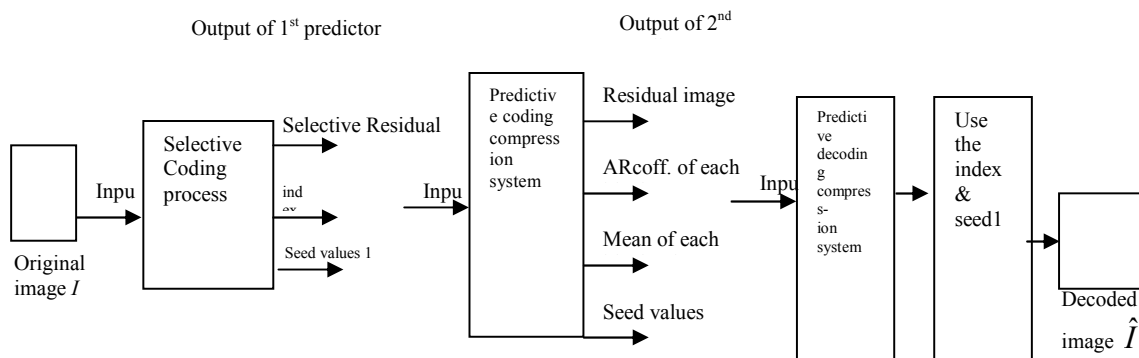


Figure 3- Selective Predictive Coding Technique Structure [1].

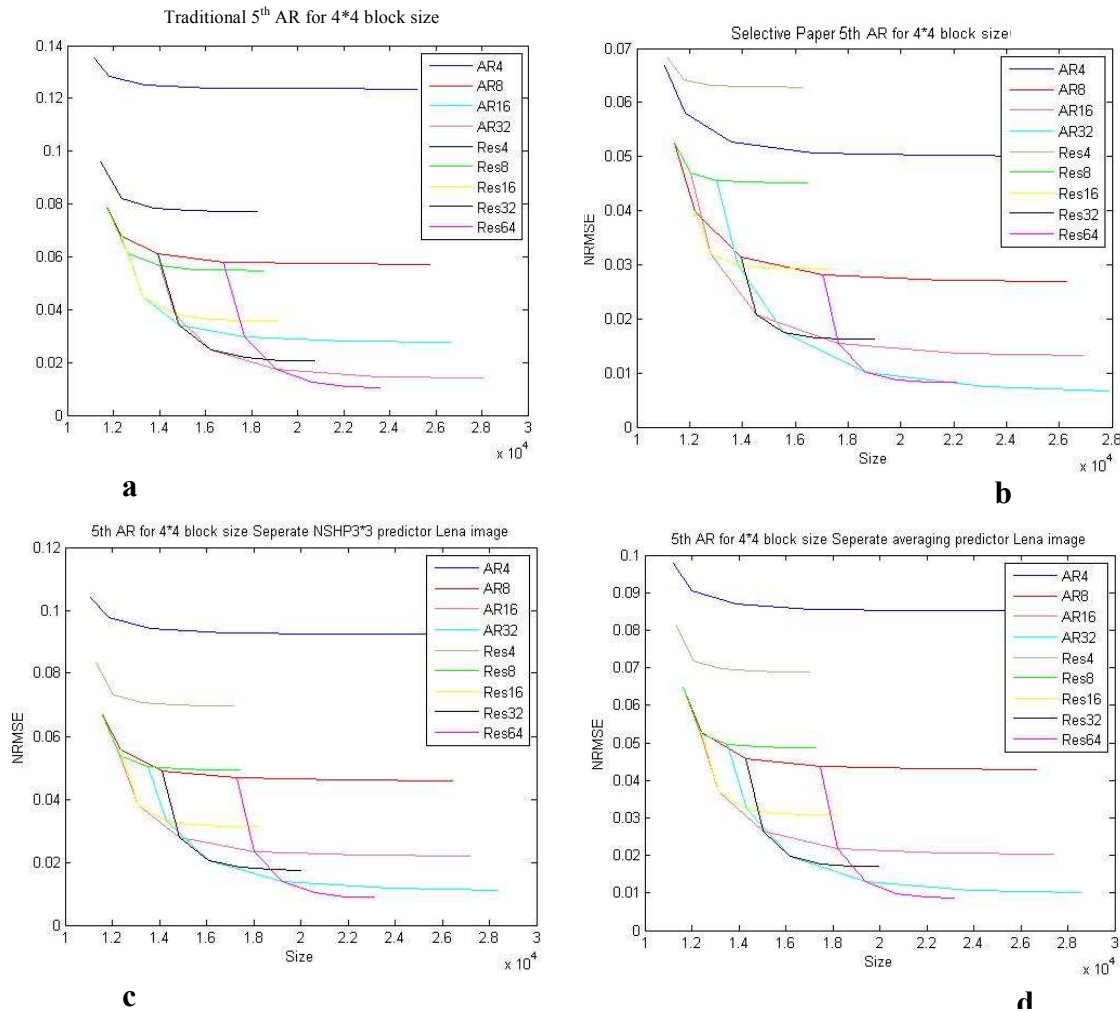


Figure 4-Compressed Size Versus The Normalized Mean Square Error Using Different Predictive Coding Techniques (A) Traditional Predictive Coding Technique (B) Selective Predictive Coding Technique (C) Predictive Coding Of NSHP 3*3 Fixed Predictor (D) Predictive Coding Of Averaging Fixed Predictor, On Lena Image Of Block Size Of 4*4, Using Various Quantization Levels For Residual And AR Coefficients (I.E., By Fixing One At A Specific Quantization Level And Changing The Other Over A Range Of Quantization Level, For Example AR4 Means We Fixed The Autoregressive Parameters To A Certain Quantization Level, The Fourth, While The Residual Image Changed Over A Range Of Quantization Levels From 4 To 256. Also Res4 Means, We Fixing The Residual Image Into A Certain Quantization Level, The Fourth As Well, While The Autoregressive Coefficients Were Varied From Levels 4 To 256) [1].

4. Adaptive Selective Coding

As figure (4 c & d) illustrates, that by applying predictor 9 (Space Varying Mean AR adopted by [18]) or predictor 11 (NSHP (3*3)) from table (1), over the other predictors listed in the same table, the performance of the fixed predictor is close to the selective predictor (see figure 4-b). This meant a simple implementation was an option, without the need for the comparison process, or finding the index, though at the same time this result indicated a drawback, in that the predictive coding was clearly still influenced by image features or detail [1].

To overcome this complexity, another selective coding technique of various predictors adopted which assumed the implementation of the traditional autoregressive of each residual image that resultant from the original image and the predictors listed in table (1) separately, then at the end the residual selective image was selected based on the lowest minimum error (block by block) from the resultant residual images. This technique is referred to as the adaptive selective coding method [1], figure (5) shows this method more clearly.

4.1 Experiment and results

In order to evaluate the performance of the adaptive selective coding method using the eight predictors which are among the table (1) predictors (i.e., the same predictors from 1 to 7 and the 9th predictor as well) by utilizing various quantization levels, the same previous experiment adopted (see section 3.1).

The results shown in figure (6) illustrates that this technique is better than the traditional AR and predictive coding of fixed predictor also looks similar to the selective coding adopted by [22], using a smaller number of predictor. An interesting point that there is a small interaction between the autoregressive coefficients and the residual as that found in the traditional or predictive of fixed predictor or selective coding (see figures 4 a-d) respectively. That was due to removing the variation between the selected residual images chosen or selected from the

already sifted residual images of predictive coding techniques. The only limitation of performing this technique compared to the selective one, in addition to the inherent fact that selective coding requires extra information, is the extra time required for performing or implementing the predictive coding: n^{th} times proportional to the number of predictors adopted [1]. So, there are two issues that needs to be improved or enhanced the currently suggested coding system, first speeding up the selection of the residual image using a fast techniques including classification, second utilizing an efficient coding technique to compress the index and the seed values efficiently, to overcome the exhausted bytes, either by using a hybrid coding technique, or by exploring a technique that selects only the significant seed values of each block.

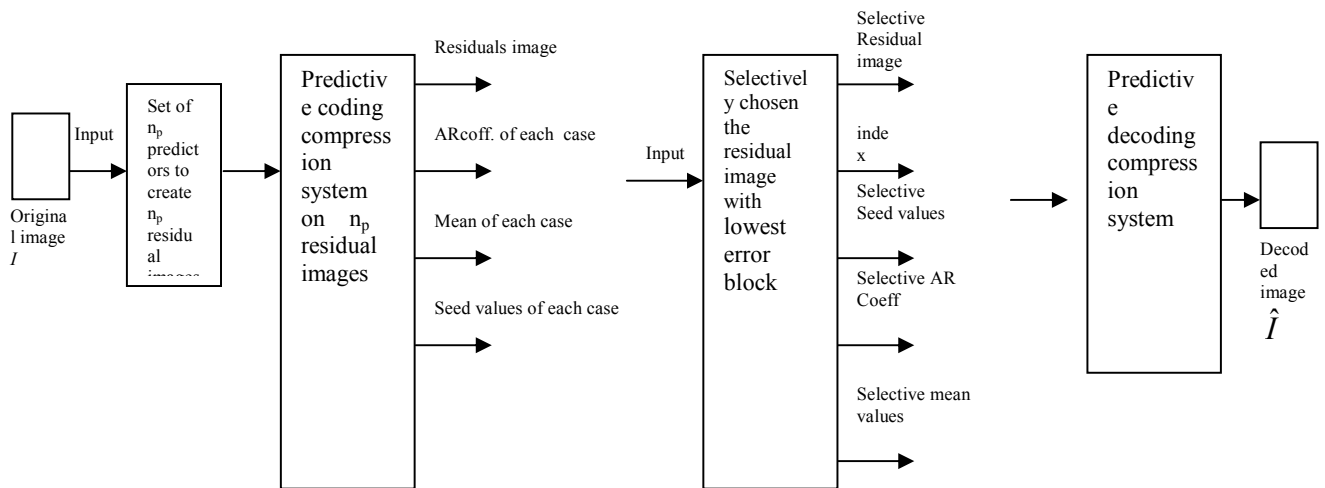


Figure 5-Adaptive Selective Predictive Coding Technique Structure [1].

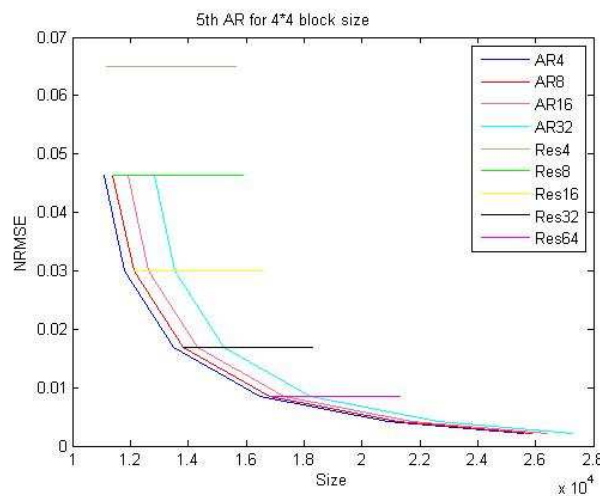


Figure 6-Compressed Size Versus The Normalized Mean Square Error On Lena Image Using The Adaptive Selective Coding Technique Of Block Size Of 4×4 [1].

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