Recursive Prediction for Lossless Image Compression

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Abstract

   This paper introduced an algorithm for lossless image compression to compress natural and medical images. It is based on utilizing various casual fixed predictors of one or two dimension to get rid of the correlation or spatial redundancy embedded between image pixel values then a recursive polynomial model of a linear base is used.

The experimental results of the proposed compression method are promising in terms of preserving the details and the quality of the reconstructed images as well improving the compression ratio as compared with the extracted results of a traditional linear predicting coding system.

Keywords: Polynomial Coding , Lossless Image Compression, Fixed Predictor, Image Compression.

التنبوء الرجوعي لضغط الصورة بدون فقدان البيانات

رنا طالب التميمي

قسم العلوم المالية والمصرفية، كلية الأدارة والأقتصاد، الجامعة المستنصرية، بغداد، العراق

الخلاصة

قدم هذا البحث خوارزمية لضغط الصور بدون فقدان البيانات لضغط الصور الطبيعية والطبية. وهو يعتمد على استخدام العديد من المتنبئات الثابتة العرضية ذات البعد أو البعدين للتخلص من الارتباط أو التكرار المكاني المضمن بين قيم بكسل الصورة ثم تم استخدام النموذج الخطي متعدد الحدود.

النتائج التجريبية لطريقة الضغط المقترحة واعدة من حيث الحفاظ على التفاصيل وجودة الصور المعاد بناؤها وكذلك تحسين نسبة الضغط مقارنة بالنتائج المستخرجة من نظام الترميز التنبئي الخطي التقليدي.

Introduction

   Image compression techniques aims to eliminate the redundancy in an image in order to store or transmit over the network in an efficient way. These techniques can be categorized into lossless and lossy. In Lossy compression there is a high loss of image information while in lossless the reconstructed image will be exactly the same as the original but it achieves low compression ratio; this consequence of the fact of exploiting the statistical redundancy only (i.e. exploits the coding redundancy and/or inter pixel redundancy) [1-2].

Over the last years, so many researchers in the field of image compression were competing to design efficient algorithms to improve the compression ratio as well the quality of the

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reconstructed images by merging several coding techniques. Review on image compressions techniques can be found in [3-5].

The first order Taylor series linear polynomial coding based on modelling the distance between image pixels and the centre was used effectively to compress images by several researchers to remove the redundancy between image pixel neighbours; further information can be found in [6-10].

The primary objective of this paper is to design an efficient algorithm to compress lossless images by combining the fixed predictor with a recursive polynomial model of a linear base.

Materials and Methods

All the estimated predictors in this study as illustrated in table (1) were casual; i.e. pixel (i,j) will be predicted from the previous visited pixels as shown in Figure 1 [11,12]; on the other hand; a recursive polynomial coding or top-down levels scheme is adopted to remove the redundancy embedded within the coefficients to improve the compression ratio and preserve image quality, it worked reversely from subsequent levels to construct up layers [2,13]. Figure 2 illustrates the layout of the suggested compression algorithm.

Table 1-The Models of the tested Predictors

| Index	Predictor	Description
1	x(i-1,j-1)	First order, one dimension Predictor
2	x(i-1,j)	First order, one dimension Predictor
3	(x(i,j-1)+x(i-1,j))/2	second order, two dimension Predictor
4	x(i,j-1)+(x(i-1,j)-x(i-1,j-1))/2	Third order, two dimension Predictor
5	x(i-1,j)+(x(i,j-1)-x(i-1,j-1))/2	Third order, two dimension Predictor
6	x(i,j-1)+x(i-1,j)-x(i-1,j-1)	Third order, two dimension Predictor
7	(x(i,j-1)+x(i-1,j)+x(i-1,j-1)+x(i-1,j+1))/4	Fourth order, two dimension Predictor
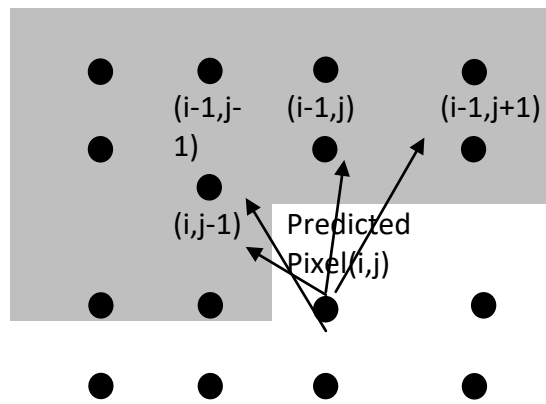
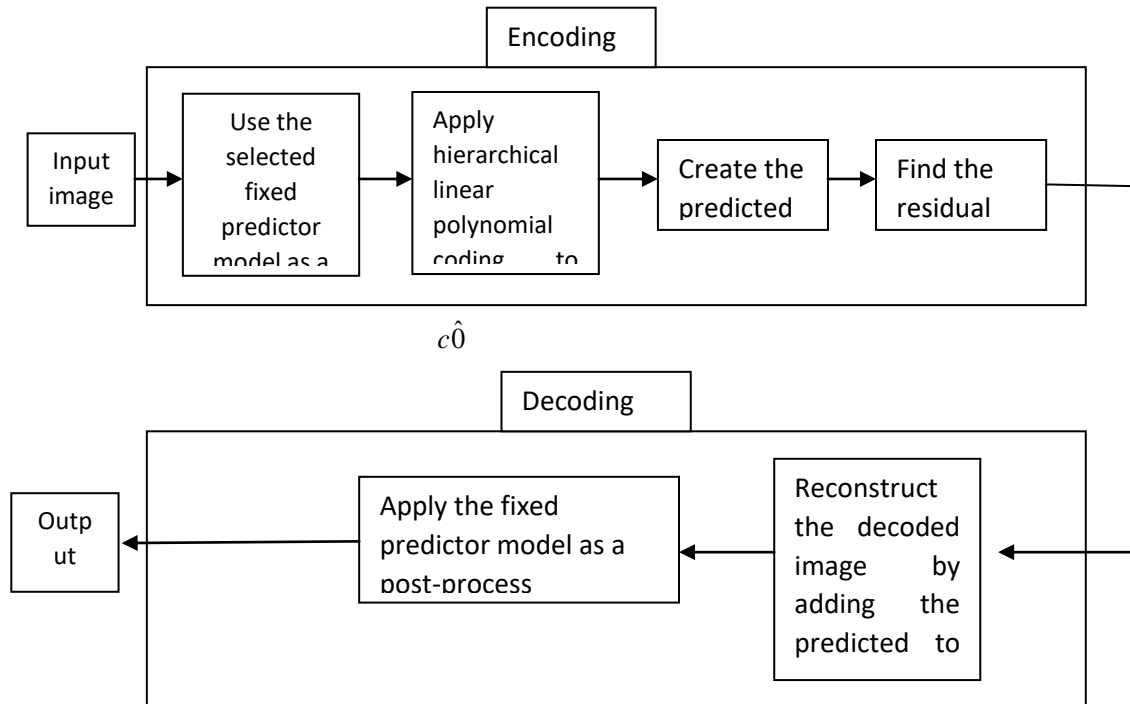**Figure 1 -** The Predicted Pixel and the Casual Region [11]

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                          ┌──────────┐
                          │ Encoding │
              ┌───────────┴──────────┴──────────────────────────────────┐
              │  ┌──────────┐   ┌────────────┐                           │
  ┌────────┐  │  │ Use the  │   │ Apply      │   ┌──────────┐  ┌────────┐ │
  │ Input  │─────│ selected │──→│ hierarchical│──→│Create the│─→│Find the│ │
  │ image  │  │  │ fixed    │   │ linear     │   │predicted │  │residual│ │
  └────────┘  │  │ predictor│   │ polynomial │   └──────────┘  └────────┘ │
              │  │ model as a│  │ coding  to │                           │
              └──────────────────────────────────────────────────────────┘
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$c\hat{0}$

```
                          ┌──────────┐
                          │ Decoding │
              ┌───────────┴──────────┴──────────────────────────────────┐
              │                 ┌──────────────┐   ┌──────────────┐      │
  ┌────────┐  │  ┌────────────┐ │ Apply the    │   │ Reconstruct  │      │
  │ Outp   │←────│ Apply the  │←│ fixed        │←──│ the decoded  │←─────│
  │ ut     │  │  │ fixed      │ │ predictor    │   │ image   by   │      │
  └────────┘  │  │ predictor  │ │ model as a   │   │ adding   the │      │
              │  │ model as a │ │ post-process │   │ predicted to │      │
              │  │ post-process│ └──────────────┘  └──────────────┘      │
              └──────────────────────────────────────────────────────────┘
```

Figure 2- The suggested Compression System

The proposed algorithm was implemented on each predictor model in table (1) separately as follows:

Step 1- Apply the predictor model on the input image; name the output image Ip.

Step 2- A recursive polynomial linear model is applied on image Ip such that two layers will be generated.

In layer 1; three coefficients are calculated namely c_0, c_1 and c_2 using equations 1,2 and 3 [5,6].

$$c_0 = \frac{\sum_i \sum_j Ip(i,j)}{n \times n} \qquad \text{.......(1)}$$

$$c_1 = \frac{\sum_i \sum_j Ip(i,j)*(j-xx)}{\sum_i \sum_j (j-xx)^2} \qquad \text{.......(2)}$$

$$c_2 = \frac{\sum_i \sum_j Ip(i,j)*(i-yy)}{\sum_i \sum_j (i-yy)^2} \qquad \text{.........(3)}$$

       Where

       n is the image block size

$xx = yy = \dfrac{n-1}{2}$

      i=j=0,….n-1

In layer2 another three coefficients will be generated c00, c01 and c02 depending on the c0 coefficient in layer 1 using equations 4,5 and 6 [13].

$$c00 = \frac{1}{n \times n} \sum_i \sum_j c0(i,j) \qquad \text{.........(4)}$$

$$c01 = \frac{\sum_i \sum_j c0(i, j) \times (j - xx)}{\sum_i \sum_j (j - xx)^2} \qquad \dots.(5)$$

$$c02 = \frac{\sum_i \sum_j c0(i, j) \times (i - yy)}{\sum_i \sum_j (i - yy)^2} \qquad \dots.(6)$$

For Layer 2:

a- Determine the deterministic part (function formula) $c\tilde{0}$ [13].

$$c\tilde{0} = c00 + c01(j - xx) + c02(i - yy) \qquad \dots.(7)$$

b-Find residual [13].

$$c0\,Re\,sd = c0 - c\tilde{0} \qquad \dots\dots.(8)$$

c- Build the modeled approximated $c\hat{0}$ [13].

$$c\hat{0} = c\tilde{0} - c0\,Re\,sd \qquad \dots\dots(9)$$

Step 3- Determine the deterministic part $L\tilde{L}$ [14].

$$L\tilde{L} = c\hat{0} + c1(j - xx) + c2(i - yy) \qquad \dots.(10)$$

Step 4-Find the error (residual) [14].

$$LL\,Re\,sd = Ip - L\tilde{L} \qquad \dots\dots..(11)$$

Reconstruct the compressed image using the following steps:

a - find the approximation model using [14].:

$$LLall = L\tilde{L} + LL\,Re\,sd \qquad \dots\dots(12)$$

b-Build the decoded image [10,12]:

$$L\hat{L}(i, j) = LLall(i, j) + Ip(i - 1, j) \qquad \dots\dots(13)$$

Where i=2…N/2   j=1….N/2

Results

In this work, all the tested natural and medical images (as indicated in Figure 3) were of size 65536 bytes. The tests were done using block size of 8*8. To measure the efficiency of the lossless compression method; the compression ratio was determined (which is the ratio of the original image size to the compressed size). Table 2 illustrates the results of a traditional coding system and a recursive polynomial linear base without applying the predictors; while Table 3 summarizes the compressed image size and the compression ratio obtained by applying the predictors models listed in table 1 and the recursive linear model.

Any way, it obvious that the suggested recursive linear model (with or without using the predictor) is better than the traditional coding system where the compression ratio was improved.

Figure 4 records the resulting images of the suggested recursive prediction using the predictors in Table 1.
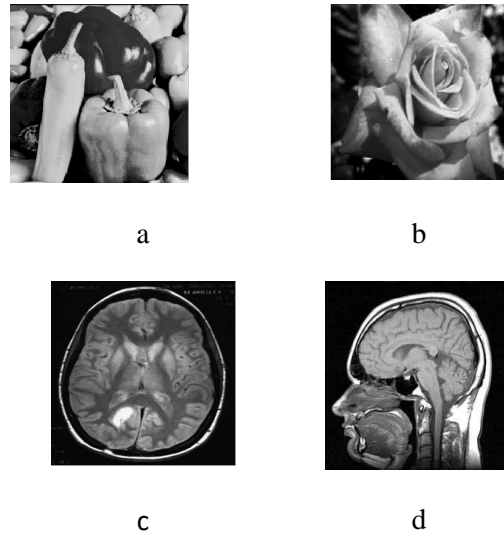
Figure 3- Input Images : (a) Pepper (b) Rose (c) Brain1 and (d) Brain2

Table 2 - Compression Performance of a Traditional Linear System and Recursive Prediction

Test image	Performance of a Traditional Linear System		Performance of the Recursive Linear Polynomial without using any predictor	
	Size	**Compression Ratio**	**Size**	**Compression Ratio**
Pepper	28674	2.2856	7391	8.8670
Rose	26622	2.4617	6116	10.7155
Brain1	6967	2.2207	4150	9.4066
Brain2	28290	2.3166	8443	7.7622

Table 3 - Performance of the Recursive Prediction using the predictor

Image	Predictor1		Predictor2		Predictor3		Predictor4		Predictor5		Predictor6		Predictor7	
	Size	**Compression Ratio**	**Size**	**Compression Ratio**	**Size**	**Compression Ratio**	**Size**	**Compression Ratio**	**Size**	**Compression Ratio**	**Size**	**Compression Ratio**	**Size**	**Compression Ratio**
Pepper	6524	10.0454	6442	10.1732	5624	11.6529	6232	10.5160	6466	10.1355	7088	9.2460	5528	11.8553
Rose	5202	12.5982	5188	12.6322	4610	14.2161	5064	12.9415	5060	12.9518	5432	12.0648	4422	14.8204
Brain1	6136	10.6806	6044	10.8432	5598	11.7070	5902	11.1040	5870	11.1646	6188	10.5908	5350	12.2497
Brain2	7726	8.4825	7668	8.5467	6666	9.8314	7242	9.0494	7474	8.7685	8260	7.9341	6196	10.5771
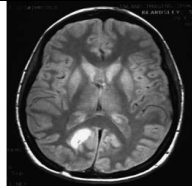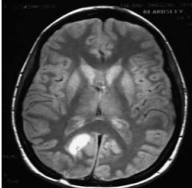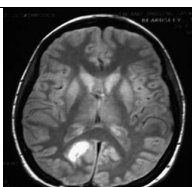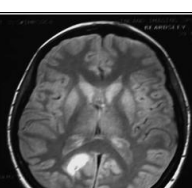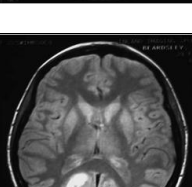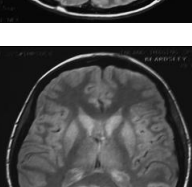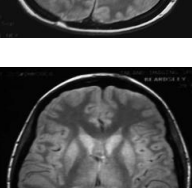
	Peper	Rose	Brain1	Brain2
Predictor 1				
Predictor 2				
Predictor 3				
Predictor 4				
Predictor 5				
Predictor 6				
Predictor 7				

Figure 4 -Resulting Images of the Recursive Prediction using the predictors (1-7)

Conclusions

The results obtained from the proposed method showed a promising performance due to the spatial domain utilization to eliminate the redundant image pixels. The best compression results for the tested images was recorded using predictor of order 4; i.e a predictor with four pixels was better than one. Another factor affects the compression ratio in this study is the characteristics of the test image, where high compression rate was recorded for the detailed image (such as rose).

In future, this work can be extended to fit the video compression system

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