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Adaptive Predictor for Entropy Coding

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엔트로피 코딩을 위한 적응적 예측기

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Abstract In this paper, an efficient predictor for entropy coding is proposed. It adaptively selects one of two prediction errors obtained by MED(median edge detector) or GAP(gradient adaptive prediction). The reduced error is encoded by existing entropy coding method. Experimental results show that the proposed algorithm can compress higher than existing predictive methods.

요 약 본 논문에서 엔트로피 코딩을 위한 효과적인 예측기를 제안한다. 제안하는 예측기는 MED(median edge detector)와 GAP(gradient adaptive prediction)의 예측 에러 중의 하나를 적응적으로 선택한다. 감소한 에러는 기존의 엔트로피 코딩 방법을 이용하여 부호화한다. 실험 결과, 제안하는 알고리즘이 기존 예측 방법보다 향상된 압축이 가능함을 보인다.

Key Words : Predictor, Entropy Coding, Lossless, Image Coding

1. Introduction

Recently, many researches for image compression of digital images are increased. Especially, lossless compression is an important field of application for image compression. High-end digital devices enable the user to access the raw, uncompressed picture, i.e. not altered by any coding algorithm. Many algorithms were proposed. Context-based adaptive prediction schemes [1-5,7,8] have shown significant improvements over fixed prediction schemes. CALIC [1] uses gradient adaptive prediction (GAP). The new lossless compression standard JPEG-LS [2] adopts median edge detector (MED).

A simple data prediction technique such as DPCM can de-correlate image data in smooth areas with very low computational cost. Prediction can be viewed as a context modeling technique of very low model cost that is highly effective under an assumption of smoothness. In JPEG-LS and CALIC, they chose to employ MED predictive coding and GAP predictive coding, respectively.

In this paper, we propose an efficient technique called adaptive prediction algorithm which selects one of results obtained by the MED and GAP prediction, properly. Thus, it can reduce prediction error and obtain the reduced entropy of the residual error. Our proposed prediction method achieves good performance for entropy image coding and outperforms existing methods, such as MED and GAP, while having a low complexity.

2. Overview of Existing Techniques

The context-based compression methods are constituted by two steps. In the first step, the image is spatially

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de-correlated, and then the residual error is determined. In the second step, the residual error is coded by the context-adaptive entropy encoder. In this section, the existing prediction techniques, such as MED and GAP, are reviewed briefly.

2.1 Median edge detector (MED)

To de-correlate, the prediction is performed based on the causal template as shown in Fig. 1, where x is the current sample, and x_1, x_2, x_3, and x_4 are neighboring samples that had been encoded already.

x_3	x_2	x_4
x_1	x	

[Fig 1] Current and neighboring samples

In JPEG-LS [2], a fixed predictor performs a primitive test to detect vertical or horizontal edges, while the other part is limited to an adaptive linear term. The fixed predictor guesses x' of the current sample x as follows

$$x' = \begin{cases} \min(x_1, x_2), & \text{if } x_3 \le \max(x_1, x_2) \\ \max(x_1, x_2), & \text{if } x_3 \le \min(x_1, x_2) \\ x_1 + x_2 - x_3, & \text{otherwise} \end{cases} \tag{1}$$

The predictor chooses x_2 as prediction value in cases where a vertical edge exists at the left of the current position, x_1 in cases of an horizontal edge above the current position, or x_1+x_2-x_3 if no edge is detected. This predictor was renamed MED, because it is seen as the median.

2.2 Gradient adaptive prediction (GAP)

In CALIC [1], gradient-adjusted predictor (GAP) guesses x' by adapting itself to the intensity gradient near the predicted pixel. Hence, it has the better performance than traditional linear prediction. But it has more operations than MED since more boundary pixels are utilized.

GAP differs from existing linear predictors in that it weights the neighboring pixels of x according to the estimated gradients of the image. As shown in Fig. 2, neighboring pixels of x used in prediction are denoted.

		x_{nn}	x_{nne}
	x_{nw}	x_n	x_{ne}
x_{ww}	x_w	x	

[Fig 2] Neighbouring pixels used in prediction

They estimate the gradient of the intensity function at the current pixel x by the following quantities.

$$\begin{aligned} d_h &= |x_w - x_{ww}| + |x_n - x_{nw}| + |x_n - x_{ne}| \\ d_v &= |x_w - x_{nw}| + |x_n - x_{nn}| + |x_{ne} - x_{nne}| \end{aligned} \tag{2}$$

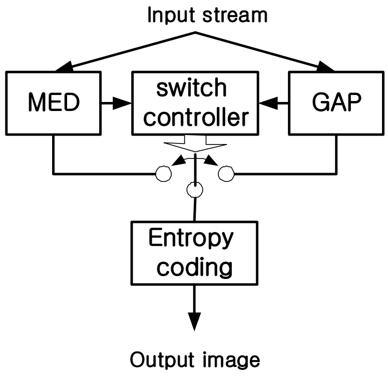
The value of d_k and d_v shows the magnitude and orientation of edges around the x. The gradient predictor guesses x' of the current sample x as follows

$$\begin{aligned} &\text{if}(d_v - d_h > 80)x' = x_w \\ &\text{elseif}(d_v - d_h < -80)x' = x_n \\ &\text{else}\{ \\ &\quad x' = (x_w + x_n)/2 + (x_{ne} - x_{nw})/4 \\ &\quad \text{if}(d_v - d_h > 32)x' = (x' + x_w)/2 \\ &\quad \text{elseif}(d_v - d_h > 8)x' = (3x' + x_w)/4 \\ &\quad \text{elseif}(d_v - d_h < -32)x' = (x' + x_n)/2 \\ &\quad \text{elseif}(d_v - d_h < -8)x' = (3x' + x_n)/4 \end{aligned} \tag{3}$$

Three absolute differences of d_k and d_v represent the magnitude in each direction. The predictor adjusts prediction value according to three absolute differences.

3. Proposed Algorithm

In this section, we proposed an adaptive predictor for entropy coding. Proposed predictor uses hybrid method based on switching approach. Thus, the residual errors of prediction can be reduced more than existing methods. Fig. 3 shows a block diagram of the proposed algorithm. Two predicted error results are obtained by MED and GAP. Then, the switching method adaptively selects one of two results obtained by MED and GAP to compensate for each drawback.



[Fig 3] Block diagram of the proposed adaptive predictor

Switching controller select one between patterns of MED and GAP by choosing minimum count C_k as follows

$$P_{i,j} = \arg\min_{f_k \in \Omega} C_k \tag{4}$$

where $P_{i,j}$ represents final selected pattern f_k denotes a candidate prediction pattern of x, and $\Omega = \{MED_{i,j}, GAP_{i,j}\}$. C_k is counted as follows.

$$\begin{aligned} &\text{if}(SAD_{MED_{i,j}} < SAD_{GAP_{i,j}})\, C_{MED_{i,j}} = C_{MED_{i,j}} + 1; \\ &\text{elseif}(SAD_{MED_{i,j}} == SAD_{GAP_{i,j}})\, \{C_{MED_{i,j}} = C_{MED_{i,j}} + 1; \\ &\qquad\qquad C_{GAP_{i,j}} = C_{GAP_{i,j}} + 1;\} \\ &\text{else}\, C_{GAP_{i,j}} = C_{GAP_{i,j}} + 1; \end{aligned} \tag{5}$$

MED uses three prediction patterns, i=1,2,3 and GAP uses seven prediction patterns, j=1,2,...,6,7. Thus, 21 patterns exist according to those predictors. Additional budget of entropy coding bits is 21 bits per frame. Note that if $C_{MED_{i,j}} > C_{GAP_{i,j}}$, the entropy of results with GAP is smaller than those with MED. Table 1 and 2 show counts C_k of predictors for the test image "*Lena*". The switching result γ is adaptively selected as one between MED pattern, P_{MED} and GAP pattern, P_{GAP} by using (4).

[Table 1] SADs of MED

$C_{MEDi,j}$	1	2	3	4	5	6	7
1	64	1683	474	3077	2908	10016	36658
2	30	1546	386	2468	3021	11853	31960
3	49	1496	508	2828	3679	8326	25625

[Table 2] SADs of GAP

$C_{MEDi,j}$	1	2	3	4	5	6	7
1	64	1683	474	3077	2908	10016	36658
2	30	1546	386	2468	3021	11853	31960
3	49	1496	508	2828	3679	8326	25625

$C_{GAPi,j}$	1	2	3	4	5	6	7
1	62	1663	450	4192	4039	11246	43857
2	30	1555	303	3345	4391	15604	43662
3	47	805	585	3387	3662	10273	32889

For entropy coding and a useful comparison between the proposed and existing methods, an entropy measure is used [2]. Since the proposed predictor using hybrid method can reduce the prediction errors more than predictors of existing algorithms, the proposed predictor can have the higher compression ratio.

4. Simulation Results

For evaluating the proposed scheme, we implemented the hybrid predictor using prediction patterns of MED and GAP. In our simulations, the "*Lena*", "*Baboon*", and "*Airplane*" images of 512x512 pixels were used. Each image has the different patterns as various, complex, and noisy, respectively. Fig. 4 shows the amplitude images of prediction error given by MED, GAP, and proposed predictor for test image "*Lena*". The absolute values of prediction error are shown as gray scale in the amplitude images. It shows that the proposed predictor produces much smaller errors around the edge areas than both MED and GAP.

(a)

(b)

(c)

[Fig 4] Error images of prediction (a) MED, (b) GAP, (c) proposed predictor.

Table 3 presents experimental results of the proposed algorithm's performance. For comparisons, results of the MED and GAP algorithms are included. We use the entropy of the prediction error as the objective measure as follows

$$\text{entropy} = -\sum_{i=0}^{255} p[i] * \ln p[i] \qquad (6)$$

where $p[i]$ is the probability of the gray level i. It is seen that the proposed predictor produces much smaller entropy of the prediction errors than both MED and GAP.

[Table 3] Entropy of MED, GAP, and proposed predictor (bpp)

	Lena	Baboon	Airplane
MED	4.54	6.27	4.37
GAP	4.41	6.23	4.33
Proposed predictor	4.40	6.21	4.30

5. Conclusions

In this paper, a hybrid predictor technique for entropy coding was proposed. The proposed technique efficiently reduces prediction errors by selecting one of two results of the existing predictors. Experimental results show that the proposed scheme outperforms the existing algorithms such as MED and GAP in terms of the entropy reduction.

The proposed algorithm is to be implemented in hardware to realize the lossless or the near-lossless image coding system. The application of the lossless coding can be found in the wireless interface between the flat panel display and the television system.

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Image processing algorithm, image enhancement, lossless compression

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