Adaptive Predictor for Entropy Coding

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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.

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
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.

![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

\[
x' = \begin{cases} 
\min(x_1, x_2) & \text{if } x_1 \leq \max(x_1, x_2) \\
\max(x_1, x_2) & \text{if } x_1 \leq \min(x_1, x_2) \\
x_1 + x_2 - x_3, \text{ otherwise}
\end{cases}
\]  

(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 \( x \) used in prediction are denoted.

![Fig 2] Neighbouring pixels used in prediction

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

\[
d_h = |x_w - x_{ww}| + |x_n - x_{nw}| + |x_e - x_{ne}|
\]

\[
d_v = |x_w - x_{mw}| + |x_n - x_{mv}| + |x_e - x_{me}|
\]

(2)

The value of \( d_h \) 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

\[
\text{if}(d_v - d_h > 80) x' = x_w \\
\text{elseif}(d_v - d_h < -80) x' = x_n \\
\text{else}\{
\begin{align*}
  x' &= (x_w + x_n) / 2 + (x_{mw} - x_{nv}) / 4 \\
  \text{if}(d_v - d_h > 32) x' &= (x' + x_n) / 2 \\
  \text{elseif}(d_v - d_h < -32) x' &= (x' + x_n) / 2 \\
  \text{elseif}(d_v - d_h < -8) x' &= (3x' + x_n) / 4
\end{align*}
\}
\]

(3)

Three absolute differences of \( d_h \) 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
Adaptive Predictor for Entropy Coding

Input stream

[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

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

(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.

$$C_{MED_{i,j}} = \begin{cases} C_{MED_{i,j}} + 1; & SAD_{MED_{i,j}} < SAD_{GAP_{i,j}} \\ C_{MED_{i,j}} + 1; & SAD_{MED_{i,j}} = SAD_{GAP_{i,j}} \\ C_{GAP_{i,j}} + 1; & \text{else} \end{cases}$$

$$C_{GAP_{i,j}} = \begin{cases} C_{GAP_{i,j}} + 1; & \text{else} \end{cases}$$

(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 $P$ is adaptively selected as one between MED pattern, $P_{MED}$ and GAP pattern, $P_{GAP}$ by using (4).

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.

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**Table 1** SADs of MED

<table>
<thead>
<tr>
<th>$C_{MED_{i,j}}$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64</td>
<td>1683</td>
<td>474</td>
<td>3077</td>
<td>2908</td>
<td>10016</td>
<td>36658</td>
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<tr>
<td>2</td>
<td>30</td>
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<td>386</td>
<td>2468</td>
<td>3021</td>
<td>11853</td>
<td>31960</td>
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<tr>
<td>3</td>
<td>49</td>
<td>1496</td>
<td>508</td>
<td>2828</td>
<td>3679</td>
<td>3826</td>
<td>25625</td>
</tr>
</tbody>
</table>

**Table 2** SADs of GAP

<table>
<thead>
<tr>
<th>$C_{GAP_{i,j}}$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62</td>
<td>1663</td>
<td>450</td>
<td>4192</td>
<td>4039</td>
<td>11246</td>
<td>43857</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>1555</td>
<td>303</td>
<td>3345</td>
<td>4391</td>
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<td>43662</td>
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<tr>
<td>3</td>
<td>47</td>
<td>805</td>
<td>585</td>
<td>3387</td>
<td>3662</td>
<td>10273</td>
<td>32889</td>
</tr>
</tbody>
</table>
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

\[
\text{entropy} = - \sum_{i=0}^{255} p[i] \ln p[i]
\]  

(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>
<thead>
<tr>
<th>[Table 3] Entropy of MED, GAP, and proposed predictor (bpp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lena</td>
</tr>
<tr>
<td>MED</td>
</tr>
<tr>
<td>GAP</td>
</tr>
<tr>
<td>Proposed predictor</td>
</tr>
</tbody>
</table>

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.

References


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Image processing algorithm, image enhancement, lossless compression

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