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A Method of Image Compression using Lossless Prediction Compression

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In predictive coding the prediction is done by previous value, present value and error of them, for example DPCM, MED. [1]

As for the method of compression, predictive compression is much simpler than transformation-based compression, and in addition usually results in lower bit rate.

During recent years, several algorithms for predictive lossless image compression have been presented.

Several predictors, based on the least squares optimization, have been proposed, which in comparison with fixed predictors can be more efficient, but they are much more complicated and computationally demanding.

Optimization is based on finite group of casual pixels, so called, context.

Since the optimization for each pixel can be computationally demanding, adaptation of coefficients is usually done when another type of region occurs, for example an edge.

For effective adaptation a larger context, comparing with fixed predictors, is required.

The prediction may be linear or nonlinear.

Linear prediction is based on one or more fixed predictors, which can be combined with appropriate weights or it is possible to choose the optimal sub predictor on the basis of the properties of a certain part of the picture, i.e. on the basis of context of the region.

Nonlinear prediction is based on neural networks, vector quantization, etc.

This paper is organized as follows.

1. The edge detection and estimation of local gradient.

2. A novel prediction algorithm based on advantages of median predictor and gradient predictor.

3. A comparative analysis of the proposed predictor and other predictors.

1. The Median Predictor and Gradient Predictor

As the most important predictors for lossless image compression the median predictor used in standard JPEG-LS and the gradient predictor, used in CALIC algorithm, are emphasized.

Median Edge Detection (MED) belongs to the group of switching predictors that select one of the three optimal sub predictors depending on whether it found the vertical edge, horizontal edge, or smooth region [3].

In fact, MED predictor selects the median value between three possibilities *W*, *N* and *W*+*N*–*NW* (common labels are chosen after sides of the world, Fig. 2), and the optimal combination of simplicity and efficiency.

The prediction is based on:

$$\begin{cases} \min(W,N), & if\ NW \ge \max(W,N), \\ \max(W,N), & if\ NW \le \min(W,N), \\ N+W-NW, & else, \end{cases}$$

Gradient Adjusted Predictor (GAP) is based on gradient estimation around the current pixel [4].

Gradient estimation is estimated by the context of current pixel, which in combination with predefined thresholds gives final prediction.

GAP distinguishes three types of edges, strong, simple and a soft edge, and is characterized by high flexibility to different regions.

Gradient estimation is done using:

$$g_v = |NW - W| + |NN - N|,$$
$$g_h = |WW - W| + |NW - N|.$$

Local gradient estimation is followed by a simple predictor. The prediction is done using the algorithm:

$$if\ g_v - g_h > T, P = W$$
$$elseif\ g_v - g_h < -T, P = N$$
$$else\ P = 3\frac{N+W}{8} + \frac{WW+NW+NN}{12}$$

3. The Prediction Algorithm based on Advantages of Median Predictor and Gradient Predictor

As MED predictor, chooses between the context of vertical edges, horizontal edges and smooth regions.

Selection is done by simple estimation of horizontal and vertical gradient and one threshold.

The number of contextual pixel is also a compromise between the MED and GAP predictors, and in contrast to the GAP predictor, which has three predefined threshold, the proposed predictor is based on one threshold.

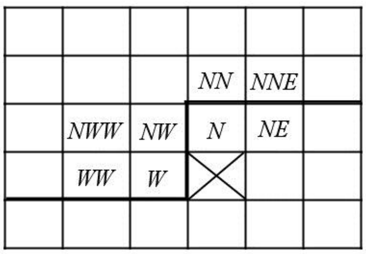

Fig. Causal and contextual neighbours

Gradient estimation is based on the equation; predictor is based on edge detection.

Median Edge Detection (MED) belongs to the group of switching predictors, which select one of the three optimal sub predictors depending on whether it found the vertical edge, horizontal edge, or smooth region [3].

Here we have proposed a solution that takes advantage of the MED and GAP predictors, i.e. simplicity of the median predictor and advantages of gradient estimation in GAP predictor.

The horizontal and vertical gradient estimation is done using:

$$g_v = |W - WW| + |N - NW| + |N - NE|,$$

$$g_h = |W - NW| + |N - NN| + |NE - NNE|$$

The prediction is made by the algorithm:

$$\begin{aligned}
&\text{If } g_v - g_h > 80,\ P = W\\
&\quad \text{Else if } g_v - g_h < -80,\ P = N\\
&\qquad \text{else } \{P = (W+N)/2 + (NE - NW)/4\\
&\text{If } g_v - g_h > 32,\ P = (P+W)/2\\
&\quad \text{Else if } g_v - g_h > 8,\ P = (3P+W)/4\\
&\quad\ \text{Else if } g_v - g_h < -32,\ P = (P+N)/2\\
&\quad\ \text{Else if } g_v - g_h < -8,\ P = (3P+N)/4\}
\end{aligned}$$

3. Comparative Analysis

Medical images are usually represented as a 12-bit or 16-bit image, and the gradient adaptive predictor used fixes thresholds defined with 8-bit images.

A lossless image compression has to preserve the exact value of each pixel, regardless of whether there is noise or not.

Measure performance predictor can be expressed over the degree of compression, i.e. relations between required memory space before and after compression, or equivalently by bit rate, which is the average number of bits needed to code a single pixel.

As a measure of predictor efficiency entropy of prediction error image is used.

Entropy means value after prediction of 150 CT images with different predictors. In practice, medical images can be a series of 2D data, i.e. slices. Those often use as sequential slices with low spatial step, and then they make 3D image, Fig. 3. Therefore, series images of computer tomography (CT) and magnetic resonance imaging (MRI) are used for testing. As an output parameter, the total entropy of prediction error 3D image has calculated. The set test images contain 150 previously uncompressed medical images.

By analysis of the results in table can be concluded that the best performance has predictor P6 based on the penalty and the combination of several simple sub predictors. However, this predictor is much more complicated than the other examined predictors. The scaling method of gradient estimation GAP predictor, given by (12), does not guarantee efficient prediction, although considerably complicating prediction algorithm. Also, it is noticeable that simple predictors, such as those in the MED, P6 and GED2, give a better prediction than those complicated predictors, such as those in the GAP or GED.

Comparative analysis entropy of prediction error of 3D medical images, which applies different predictors.

Table. Comparative analysis of prediction

Predicter	Image 1	Image 2	CT	MRI
MED	**7 615**	**5 796**	**4 747**	**4 253**
GAP	**7 563**	**5 727**	**4 851**	**4 175**
GED264	**7 522**	**5 699**	**4 738**	**4 170**
DARC	**7 725**	**5 937**	**5 044**	**4 596**
DPCM	**7 755**	**6 322**	**6 238**	**5 745**

Conclusion

This paper describes predictive lossless image compression process. Also, the most important predictors of the most important algorithms for lossless compression are described, which are accepted in standards or that are representative to their characteristics. Novel solution for the simple linear prediction is based on the detection of edges, called the GED and its comparison with the described predictors is made. GED algorithm is a mixture of distinguish features of most representative linear predictors, namely MED and GAP. Proposed predictor has shown satisfactory results on a chosen set of uncompressed medical images.

References

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