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Pixel value prediction algorithm using three directional edge characteristics and similarity between neighboring pixels

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Abstract

In this paper, a pixel value prediction algorithm using edge components in three directions is proposed. There are various directional edges and similarity between adjacent pixels in natural images. After detecting the edge components in the x-axis direction, the y-axis direction, and the diagonal axis direction, the pixel value is predicted by applying the detected edge components and similarity between neighboring pixels. In particular, the predicted pixel value is calculated according to the intensity of the edge component in the diagonal axis direction. Experimental results show that the proposed algorithm can effectively predict pixel values. The proposed algorithm can be used for applications such as reversible data hiding, reversible watermarking to increase the number of embedded data.

Keywords: *pixel value, prediction, neighboring pixels, Image*

1. Introduction

Digital image consists of many pixels. Generally, there is similarity between adjacent pixels and various edge components in natural image. Therefore, it is possible to predict the pixel value at an arbitrary point by utilizing the similarity between pixels and the edge component detected in the surrounding pixels. In this paper, an algorithm for predicting pixel value at an arbitrary position using similarity between pixels and three directional edge components existing in surrounding pixels was proposed.

Many pixel value prediction algorithms have been developed to predict pixel values using adjacent pixel values. [1]-[8] The proposed algorithm is an improvement of the existing GAP algorithm.[1][2] An algorithm of detecting the edge component in the direction of the diagonal axis has been added to the GAP algorithm, so that three directional edge components can be detected. The proposed algorithm predicts pixel values using similarity between pixels and three directional edge components. The proposed algorithm predicts pixel value using the surrounding 10 pixel values. The proposed algorithm can predict effectively the pixel value in the boundary region where the pixel value change is large as well as the region in which the pixel value variation is small. By using the proposed algorithm, pixel value prediction can be performed effectively and pixel value prediction accuracy becomes high. The proposed algorithm can be applied to the data hiding and watermarking applications to increase the amount of data that can be concealed into image.

The composition of this paper is as follows. The proposed algorithm is described in Section 2. The experimental results are described in Section 3. Finally, conclusion is described in Section 4.

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2. Proposed Algorithm

In natural images, there is similarity and various directional edge characteristics between adjacent pixels. Therefore, pixel values can be predicted using similarity and various edge characteristics. In GAP(gradient-adjusted prediction) algorithm, edge characteristics in the x-axis direction and y-axis directions are detected, and then pixel value is predicted using the edge characteristics. In GAP algorithm, the degree of x-axis and y-axis edge components are determined, and the pixel value is predicted by reflecting the determined degree. In the proposed algorithm, we improve the limitation of the GAP algorithm. GAP algorithm uses two dimensional edge characteristics to predict pixel value. In the proposed algorithm, three dimensional edge characteristics were used to predict pixel value.

In the proposed algorithm, pixel value is estimated using 10 neighboring pixels as shown in Fig. 1. The procedure of the proposed algorithm is shown in Fig. 2. Equation (1) - (2), (4) - (5), and (7) - (15) correspond to the GAP algorithm. In the proposed algorithm, edge features of diagonal components are detected by adding equation (3), (6), and (16) - (19). The pixel values are estimated using the diagonal edge components detected in the proposed algorithm and the x-axis and y-axis edge components detected in the GAP algorithm.

The sum of the difference components between adjacent pixels in the horizontal direction(d_h) can be obtained as shown in equation (1). The sum of the difference components between adjacent pixels in the vertical direction (d_v)can be obtained as shown in equation (2). The sum of the difference components between adjacent pixels in the diagonal direction (d_x)can be obtained as shown in equation (3).

As shown in equation (4) - (5), (8), (10), (12), and (14), the intensity of the edge in the x-axis direction or the edge in the y-axis direction is determined as sharp horizontal edge, horizontal edge, weak horizontal edge, sharp vertical edge, vertical edge, and weak vertical edge according to the magnitude of the value of d_v-d_h.

The predicted pixel values are obtained as shown in equation (7), (9), (11), (13), 15) to reflect the edge characteristics according to the intensity of the determined edge. In the proposed algorithm, edge strengths of diagonal components are classified into sharp diagonal edge, diagonal edge, and weak diagonal edge using equation (6), (16), and (18). In the proposed algorithm, the predicted pixel value is calculated using equation (6), (17), and (19) for the sharp diagonal edge, diagonal edge, and weak diagonal edge respectively.

Xc	Xd	A	B
Xg	C	D	E
F	G	P	

Figure 1. Pixel value prediction

The predicted pixel value P at the position to be predicted using proposed algorithm is obtained as follows:

$$d_h=(|G-F|+|D-C|+|D-E| \quad (1)$$

$$d_v=|G-C|+|D-A|+|E-B| \quad (2)$$

$$d_x=|G-Xg|+|C-Xc|+|D-Xd| \quad (3)$$

IF (d_v-d_h>80) {sharp horizontal edge} P=G (4)

ELSE IF (d_v-d_h <-80) {sharp vertical edge} P=D (5)

ELSE IF((d_x-d_h < - 40) || (d_x-d_v < – 40) {sharp diagonal edge} P=C (6)

ELSE {

P=(G+D)/2+(E-C)/4 (7)

IF (d_v-d_h >32) {horizontal edge} (8)

P=(P+G)/2 (9)

ELSE IF (d_v-d_h >8) {weak horizontal edge} (10)

P=(3P+G)/4 (11)

ELSE IF (d_v-d_h <-32) {vertical edge.} (12)

P=(P+D)/2 (13)

ELSE IF (d_v-d_h <-8) {weak vertical edge} (14)

P=(3P+D)/4 (15)

ELSE IF ((d_x-d_h < - 20) || (d_x-d_v < - 25)) {diagonal edge.} (16)

P=(P+C)/2 (17)

ELSE IF ((d_x-d_h < - 5) || (d_x-d_v < - 5))) {weak diagonal edge.} (18)

P=(3P+C)/4 (19)

}

P=int (P+0.5) (20)

Figure 2. Pixel value prediction

The proposed algorithm determines the directionality of the edge with the gradient value, and determines the predicted pixel value according to the x-axis, y-axis, and diagonal directionality. If there is a sharp edge in the diagonal direction, the value of adjacent pixel C is set as the predicted pixel value as shown in equation (6), reflecting the sharp edge characteristics in the diagonal direction. If there is diagonal edge and weak diagonal edge, the predicted pixel value is determined as shown in equation (17) and (19), reflecting the edge characteristics in the diagonal direction. When there is no directional edge component, the predicted pixel value is determined as shown in equation (7). As shown in equation (20), after rounding the predicted pixel value, let this be the final predicted pixel x.

3. Experimental results

512x512 pixel gray scale Lenna, Woman, Hara images were used in the experiment to measure the performance of the proposed algorithm. The images used in experiment are shown in Fig. 3. In experiment, pixel values were predicted in the region excluding the top 2 lines, the left 2 lines in the image. The obtained predicted pixel value is rounded to an integer value as shown in equation (20), and this value is used as a final predicted pixel value.

Pixel value prediction accuracy was calculated as the ratio of precise pixel value prediction frequencies to the total pixel value prediction frequencies. Precise pixel value prediction means that the predicted pixel value is equal to the original pixel value of the image. The total predicted pixel values per image are 260,100. When GAP algorithm and the proposed algorithm were applied to Lenna, Woman, and Hara imges, the pixel

value prediction accuracy was 13.08%, 21.74%, 20.75%, 13.21%, 22.81%, 20.86% respectively. The proposed algorithm can be used in reversible data hiding and reversible watermarking applications.

(a) Lenna (b) Woman (c) Hara

Figure 3. Images used in experiment

4. Conclusion

In this paper, pixel value prediction algorithm using x-axis direction, y-axis direction, and diagonal direction edge characteristics was proposed. The pixel value prediction accuracy is 13.21%, 22.81%, and 20.86% respectively when the proposed algorithm is applied to Lenna, Woman, and Hara images. The proposed algorithm can be used for reversible data hiding and reversible watermarking applications.

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