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An Advanced Watermarking Algorithm with Reversibility

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Abstract In this paper, an efficient reversible watermarking algorithm is proposed. By using the proposed algorithm, it is possible to increase the amount of copyright-related information to be embedded in cover image. Depending on the spatial locality and surface characteristics, it is possible to precisely predict the pixel value using neighboring pixels. If the predicted pixel value almost the same as the pixel value of the cover image, the differential value between the predicted pixel value and the pixel value of cover image is very small. So, the frequency is increased greatly at the peak point of histogram of difference sequence. Thus, it is possible to increase greatly the amount of secret data to be embedded in cover image. The experimental results show that the proposed watermarking algorithm is superior to the previous algorithms.

Key Words : Watermarking, Reversible watermarking, Cover image, Watermarked image, APD, Spatial locality

요 약 본 논문에서는 효율적인 가역 워터마킹 알고리즘을 제안하였다. 제안된 기법을 사용하여, 커버 이미지에 은닉할 수 있는 저작권관련 정보의 양을 증가시킬 수 있다. 공간적 지역성과 표면 특성에 따라, 주변 픽셀들을 사용하여 픽셀 값을 정밀하게 예측할 수 있다. 예측된 픽셀 값과 커버 이미지의 원본 픽셀 값이 거의 같게 되면, 커버 이미지의 원본 픽셀 값과 예측 픽셀 값의 차이가 매우 적게 된다. 그러므로 차분 시퀀스에 대한 히스토그램의 피크 포인트에서의 빈도수가 크게 증가하게 된다. 따라서 커버 이미지에 은닉할 수 있는 기밀 데이터의 양이 크게 증가하게 된다. 실험 결과를 통하여 제안된 워터마킹 알고리즘이 기존의 알고리즘보다 우수함을 확인 할 수 있다.

주제어 : 워터마킹, 가역 워터마킹, 커버 이미지, 워터마킹 이미지, APD, 공간적 지역성

1. Introduction

Reversible watermarking is an important scheme to hide secret data related to copyright into cover image. The result image is called watermarked image. The secret data and original cover image can be extracted from the watermarked image. The recovered cover image and the extracted secret data from watermarked image are equal to the original cover image and original secret data respectively. The quality of watermarked image must be excellent to satisfy the imperceptibility of watermarked image.[1,2] In most watermarking algorithms which were proposed to enhance the image quality of the watermarked image, the restored cover image obtained after extracting confidential data from the watermarked image does not coincide with the original cover image due to distortion.[3] Reversible watermarking algorithm is important for medical

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applications, military applications, and digital library applications etc.[4]

Recently, various reversible watermarking algorithms have been proposed.[2-15]. NSAS algorithm was proposed by Ni etc. to embed secrete data into cover image using histogram shifting.[2] The maximum number of bits to be embedded in cover image are limited to the number of pixels at peak point in the histogram of cover image. To overcome the limit of NSAS, APD(Adjacent Pixel Difference) algorithm was proposed by Li etc.[3] In APD scheme, the similarity between adjacent pixels was used to increase greatly the frequency at peak point in histogram of difference sequence of cover image. The maximum number of bits to be embedded of APD is much greater than that of NSAS.

To improve the performance of APD, this paper proposed an efficient reversible watermarking algorithm. In the proposed algorithm, spatial locality and surface characteristics are used to predict pixel value. If the predicted pixel value almost the same as the pixel value of the cover image, the differential value between the predicted pixel value and the pixel value of cover image is very small. So, the frequency is increased greatly at the peak point of histogram of difference sequence using prediction image and cover image. The proposed algorithm increases the frequency greatly at the peak point in histogram of difference sequence of cover image. So, the embedded data are much greater than that of APD. In this paper, an efficient watermarking algorithm that is improvement of existing algorithms[13-15] was proposed to enhance the performance of APD.

2. Related works

Ni, Shi, Ansari, and Su proposed NSAS algorithm to embed secrete data into cover image using histogram shifting. The frequencies at the largest peak point and the second largest peak point in the histogram of cover image are very small. The maximum embedding bits are equal to the sum of the frequencies at the largest peak point and the second largest peak point in the histogram of cover image. So, the maximum number of bits to be embedded in cover image is very small. Actually, the frequencies at the largest peak point and the second largest peak point in the histogram of 512x512 gray scale Lenna image are 2,859 and 2,842 respectively. Thus, the maximum embedding bits are limited to 5,701 for 512x512 gray scale Lenna image.

Li, Yeh, and Chang proposed APD(Adjacent Pixel Difference) algorithm to overcome the limit of NSAS. In APD algorithm, the similarity between adjacent pixels was used to increase greatly the frequency at peak point in histogram of difference sequence of cover image. There are similarity between adjacent pixels in natural image. So, the difference is very small between adjacent pixels. Thus, the frequencies at the greatest peak point and the second greatest peak point in histogram of difference sequence of cover image are very large. Actually, the frequencies at the greatest peak point and the second greatest peak point are 25,010 and 23,414 respectively for 512x512 gray scale Lenna image. The maximum embedding bits are 48,424 bits for 512x512 gray scale Lenna image. So, the maximum number of bits to be embedded of APD is much greater than that of NSAS.

3. Proposed algorithm

In general, spatial locality exists in natural image. So, pixel value can be predicted precisely using neighbor pixels at a region with high spatial locality. Figure 1 shows a position its coordinate is (x_i,y_j) and its neighboring pixels. Spatial locality at a position can be checked as equation (1), (2). If $dev(x_i,y_j)$ is less than threshold value(β), the locality at the position is considered as high. $P(x_{i-2},y_{j-1})$is equal to A.

A	B	C	D	E
		val	G	F

Fig. 1. Pixel value prediction

$$V_1(x_i,y_j)=int\{\{P(x_{i-1},y_{j-1})+P(x_i,y_{j-1})+P(x_{i+1},y_{j-1})+P(x_{i+1},y_j)+\{P(x_{i-2},y_{j-1})+P(x_{i+2},y_{j-1})+P(x_{i+2},y_j))\}*\alpha\}/(4+3*\alpha)+0.5\} \quad (1)$$

$$dev(x_i,y_j)=abs(V_1-P(x_{i-1},y_{j-1}))+abs(V_1-P(x_i,y_{j-1}))+abs(V_1-P(x_{i+1},y_{i-1}))+abs(V_1-P(x_{i+1},y_j))+\{abs(V_1-P(x_{i-2},y_{j-1}))+abs(V_1-(x_{i+2},y_{j-1}))+abs(V_1-P(x_{i+2},y_j))\}*\alpha \quad (2)$$

Prediction image can be generated from left to right, from top to bottom in inverse s-order. Pixel values of top 1 row and left-right 2 columns in the prediction image are equal to the pixel values of cover image. The other region of prediction image is called predictable area. If the locality of a position in predictable area is low, pixel value prediction is not executed at the position and the pixel value of cover image is copied to the pixel value of prediction image. If the locality of a position in predictable area is high, pixel value prediction is executed at the position as follows. First, the surface characteristics is estimated at the position. The slope of x-axis direction at left side is (C-B), and the slope of x-axis direction at right side is (D-C) and (G-C). If the slope of x-axis directions at left side and right side are all positive or all negative, the surface characteristics at the position is considered as simple inclined surface. If none is greater than δ times of the other slope, the slope is considered as simple inclined surface with the slope of small change. If anyone is greater than δ times of the other slope, the slope is considered as simple inclined surface with the slope of abrupt change. If the slope of x-axis directions at left side and right side are all zero, the surface characteristics at the position is considered as flat surface.

If the surface characteristics at the position is simple inclined surface with little change slope or flat surface, the predicted pixel value is calculated as equation (3). If the surface characteristics at the position is not simple inclined surface and flat surface, or simple inclined surface with abrupt change slope, the predicted value is equal to V_1 of equation (1).

Cover image sequence C and prediction image sequence P can be generated by scanning the cover image and prediction image respectively from left to right, from top to bottom in inverse s-order. The difference sequence D can be generated as equation (4). Histogram of difference sequence D can be generated to find the largest peak point(PP_1), the second largest peak point(PP_2), the closet zero point1(CZP_1), and the closest zero point2(CZP_2). PP_1, PP_2, CZP_1, and CZP_2 are the information to shift difference sequence D. The shifted difference sequence DS can be generated as equation (5), (6). Secret data are embedded into DS as equation (7), the result sequence is DE. Watermarked image sequence W is generated by using C and DE as equation (8), where n=(image width)*(image height). Watermarked image is generated in inverse s-order by using watermarked image sequence W.

$$\text{Predicted pixel value}=int\{(B+C+D+G)/4.0+0.5\} \quad (3)$$

$$D_i=\begin{cases} C_i & \text{if } i=0 \\ C_i-P_i & \text{else if 예측 픽셀값 사용} \\ C_{i-1}-C_i & \text{otherwise(예측 픽셀값 미사용)} \end{cases} \quad (4)$$

$$DS_i=\begin{cases} D_i & \text{if } i=0 \text{ or } D_i \notin [PP_j+sd_j, CZP_j] \\ D_i+sd_j & \text{if } D_i \in [PP_j+sd_j, CZP_j] \end{cases} \quad (5)$$

$$sd_j=\begin{cases} 1 & \text{if } PP_j < CZP_j \\ -1 & \text{if } CZP_j < PP_j \end{cases} \quad \text{where } j \in \{1,2\} \quad (6)$$

$$DE_i=\begin{cases} DS_i & \text{if } i=0 \text{ or } F'_i \neq PP_j \text{ or } data=0 \\ DS_i+sd_j & \text{if } F'_i=PP_j \text{ and } data=1 \end{cases} \quad (7)$$

$$W_i=\begin{cases} DE_i & \text{if } i=0 \\ C_{i-1}-DE_i & \text{if } 1 \le i \le n-1 \end{cases} \quad (8)$$

The process of secret data extraction and original cover image restoration is as follows: Scan the pixels of watermarked image from left to right, from top to bottom in inverse s-order. The result sequence is W. While increasing the value of i, each position can be determined whether predictive area or not. In the case of predictive area, it is possible to check the pixel value at the position of watermarked image is predicted pixel value or not. So, the extraction mode can be determined at each position. There are 3 extraction mode. Secret data extraction and original cover image restoration at each mode are executed as follows:

Mode 1: In the case of top row of the image($i \leq$ imagewidth), the prediction value was not used at previous position and current position. Restore DE_i and C_i as equation (9), (10).

Mode 2: In the case of predicted value was used at current position. Restore DE_i by using equation (9). Restore Cover image sequence C_i by using equation (11), (12). RP_i is a calculated prediction value at i^{th}locationduringrestorationprocess.AV_i is an associated value for restoration of C_i.

Mode 3: In the case of predicted pixel value was used at previous position, but the predicted value was not used at current position. Restore DE_i as equation (9), and restore C_i by using equation (13).

Secret data are extracted from DE as equation (14) and original cover image is restored in inverse s-order by using cover image sequence C.

$$DE_i = \begin{cases} C_i & \text{if } i = 0 \\ C_{i-1} - W_i & \text{otherwise} \end{cases} \quad (9)$$

$$C_i = \begin{cases} W_i & \text{if } i = 0 \\ W_i + sd_j & \text{else if } 1 \leq i \leq n-1 \text{ and } C_{i-1} - W_i \in [PP_j + sd_j, CZP_j] \\ W_i & \text{otherwise} \end{cases} \quad (10)$$

$$C_i = RP_i + AV_i \quad (11)$$

$$AV_i = \begin{cases} C_{i-1} - W_i - sd_j & \text{if } C_{i-1} - W_i \in [PP_j + sd_j, CZP_j] \\ C_{i-1} - W_i & \text{otherwise} \end{cases} \quad (12)$$

$$C_i = RP_i - AV_i \quad (13)$$

$$\text{Extraction bit} = \begin{cases} 0 & \text{if } DE_i = PP_j \\ 1 & \text{else if } DE_i = PP_j + sd_j \end{cases} \quad (14)$$

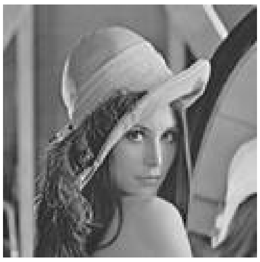
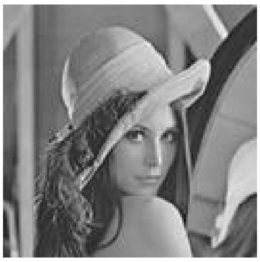
If the threshold value (β) is 0, the proposed algorithm works the same as the APD algorithm. By applying the proposed algorithm, it is possible to embed much more secret data into the cover image and the secret data and original cover image are restored from the watermarked image without distortion.

3. Experimental results

512x512 gray scale images such as Lenna, sail-boat, Barbara were used as cover image to evaluate the performance of the proposed algorithm. The ASCII code of the abstract of this paper was used as secret data. The value of α is 0.09, and δ is 4. The notation proposed(β) was used to denote that the experiments were carried out by applying the proposed algorithm with the threshold value( ). The experimental results are shown in table 1. If threshold value(β) is 0, the prediction image is equal to cover image. So, the proposed algorithm works the same as the APD algorithm when threshold value(β) is zero. The cover image and watermarked images are shown in figure 2.

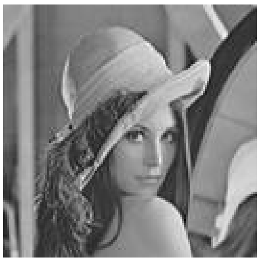
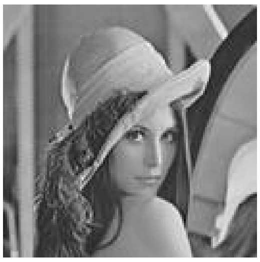
Table 1. Experimental results of the proposed algorithm

Image	Algori-thm	Embedded bits	PSNR (dB)	Prediction hit ratio (%)	Avg. prediction error	Num. of prediction	Increase rate of embedded bits (%)
Lenna	APD	48,424	48.60	x	x	x	x
	Pro(0)	48,424	48.60	x	x	x	x
	Pro(12)	58,167	34.08	16.90	2.03	151,13	20.1
	Pro(24)	62,492	30.98	15.09	2.46	203,53	29.1
sail-boat	APD	30,880	48.42	x	x	x	x
	Pro(0)	30,880	48.42	x	x	x	x
	Pro(12)	35,825	33.01	14.47	2.89	82,42	16.0
	Pro(24)	37,939	27.66	10.59	4.08	160,59	22.9
Elaine	APD	30,487	48.42	x	x	x	x
	Pro(0)	30,487	48.42	x	x	x	x
	Pro(12)	31,690	32.43	11.93	3.70	66,41	3.9
	Pro(24)	34,593	26.63	8.32	4.77	177,17	13.5

(a-1) Lenna, cover image

(a-2) Proposed(0)=APD

(a-3) Proposed(12)

(a-4) Proposed(24)


(b-1) sail-boat cover image

(b-2) Proposed(0)=APD


(b-3) Proposed(12)

(b-4) Proposed(24)


(c-1) Elaine cover image

(c-2) Proposed(0)=APD


(c-3) Proposed(12)

(c-4) Proposed(24)

Fig 2. Cover images & watermarked images

Increasing the threshold of the (β) from 0 to 24, PSNR value of watermarked image is decreased. However, visually the watermarked image is almost same as the cover image as shown in figure 2, and the embedding data are increased greatly. By applying the proposed algorithm, it is possible to embed secret data at different levels into the cover image. Also, the secret data and original cover image can be restored from the watermarked image without distortion. So, the proposed algorithm is very useful for the medical applications, military applications, and digital library applications etc.

3. Conclusions

This paper proposed a reversible watermarking algorithm to hide secret data into the cover image. When the proposed algorithm is applied to watermarking, it is possible to embed huge secret data into cover image at various levels. The visual quality of watermarked image is almost same as the cover image, and the number of embedded bits was increased up to 29.1% compared to the APD algorithm. The embedded secret data and original cover image can be restored from the watermarked image without loss. So, the proposed algorithm is very useful for reversible watermarking for the medical applications, military applications, and digital library applications etc.

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