Sorted Pixel Value Difference on Fuzzy Watermarking Scheme

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SORTED PIXEL VALUE DIFFERENCE ON FUZZY WATERMARKING SCHEME

Strictly as per the compliance and regulations of:

Sorted Pixel Value Difference on Fuzzy Watermarking Scheme

S.Maruthuperumal [α], Dr.V.Vijayakumar [σ] & B.Vijayakumar [ρ]

Abstract - A robust watermark scheme for copyright protection is proposed in the present paper. The present method selects the pixel locations to insert the watermark by a new technique called fuzzy based wavelet approach. The watermark is embedded in the sorted pixel locations of fuzzy based wavelet approach by using pixel value difference method. The proposed approach overcomes the weak robustness problem of embedding the watermark in the spatial domain and also in pixel value difference method. Further the watermark extraction does not require the original image as in the case of many digital watermarking methods. The fuzzy logic approach in the wavelet domain eliminates the requirement of repeated embedding process. The experimental results indicate the high image quality and robustness against various attacks when compared to several approaches.

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I. INTRODUCTION

In recent years, watermarking has become an attractive topic and many watermarking schemes have been proposed [3], [6]. Many literatures have reported about watermarking based on spatial domain with different conventional extraction techniques [4]. Watermarking in the frequency domain is more robust than watermarking in the spatial domain [1], because the watermark information can be spread out over the entire image [2]. Transform domain watermarking techniques are more robust, due to the fact that when image is inverse wavelet transformed, watermark is distributed irregularly over the image, making the attacker difficult to read or modify.

In 2002, Joo et al. proposed a robust watermark scheme by embedding a watermark into wavelet low frequency sub-band [5]. According to the embedding location, the watermark is extracted by comparing the two wavelet coefficients by three level wavelet transforms LL3 and LL3'. Finally, the extracted watermark is compared with the original watermark by similarity measure formula. Although the above scheme provides the characteristics of robustness and imperceptibility, but the embedding process is quite time-consuming. Besides, the original image is required in the watermark extraction process, which is impractical in real application. In one of the recent method [7], the original image is transformed into wavelet coefficients by one-level wavelet transform first. Then, three high-frequency sub-bands are modified and obtain its reference image by performing inverse wavelet transform. The watermark is embedded into the reference values between the original image and its reference image. In the watermark extraction process, the watermark extraction does not require the original image. This method suffers from poor identification of pixel locations where watermark is to be inserted. To overcome the above disadvantage, the proposed method initially locates the pixel locations by applying fuzzy logic on two level wavelet coefficients and further they are sorted to insert the watermark by PVD method [8]. This makes the present method more powerful then earlier methods in breaking the watermark and also it gives high robustness.

The rest of this paper is organized as follows: The section 2 presents a brief introduction of the PVD; Section 3 describes the proposed method for embedding and extraction of watermark. The section four describes the experimental results. The conclusion is discussed in the final section.

II. PIXEL VALUE DIFFERENCE (PVD) METHOD

The basic PVD scheme [8] is meant for steganographic images. This scheme offers high imperceptibility to the stego image by selecting two consecutive pixels as the object of embedding. The payload is determined by the difference value between the pixels as given below. The basic PVD method, determines whether the two consecutive pixels belong to an edge or smooth area by checking out the difference value between two consecutive pixels. If the difference value is large, i.e. the two pixels are located in an edge area; more secret data can be hidden here. On the contrary, if the difference value is small, i.e. the two pixels are located in a smooth area, less secret data can be embedded. Therefore, this scheme produces stego images that are more similar to the original images than those produced by LSB substitution schemes, which

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directly embed secret data into the cover image without considering the differences between adjacent pixels.

Given a cover image I of size M×N, I_i is a sub block of I that has two consecutive pixels broken down by partitioning I in raster scan order such that I={ I_i /i=1,2,…….(M×N)/2}. By definition each I_i has two elements $E_{(r,L)}$ and $E_{(r,R)}$. The pixel values of $E_{(r,L)}$ and $E_{(r,R)}$ are $V_{(r,x)}$ and $V_{(r,y)}$ respectively. The difference value d_i of $V_{(r,x)}$ and $V_{(r,y)}$ can be derived by Equation (1).

$$d_i = |V(r,x) - V(r,y)| \qquad (1)$$

The range Table 1 which consists of n contiguous sub ranges T_j; T= {T_j | j=1, 2,..n}, provides major information about the hiding capacity of Ii. Each sub range T_j has its lower and upper bound values, say l_j and uj, so that it will have $T_j \in [l_j, u_j]$. The width w_j of each T_j is selected to be a power of 2, and can be computed by $w_j = u_j - l_j + 1$. Each sub block I_i relates to its sub range T_j from the range Table 6.1 such that T_j = min(d_i, w_j) and $d_i \in [l_j, u_j]$. This way, the hiding capacity of two consecutive pixels can be obtained by Equation (2).

$$bi = \log(w_j) \qquad (2)$$

Here, b_i is the number of bits that can be hidden in I_i. Table 1 clearly indicates the number of bits of watermark to be selected.

Table 1 Range table showing hiding capacity

Range	l_j	u_j	w_j	b_i =log(w_j)
T1=[0,7]	0	7	8	3
T2=[8,15]	8	15	8	3
T3=[16,31]	16	31	16	4
T4=[32,63]	32	63	32	5
T5=[64,127]	64	127	64	6
T6=[128,255]	128	255	128	7

The PVD method selects b_i bits from the binary secret data stream and transform b_i into its decimal equivalent value bi'. Then it computes the remainder values $E_{rem(r,x)}$, $E_{rem(r,y)}$ and $I_{rem(r)}$ of $E_{(r,x)}$,$E_{(r,y)}$ and sub block I_i respectively by using the following Equations (3).

$$E_{rem(r,x)}) = E_{(r,y)} \bmod 2^{bi}$$
$$E_{rem(r,y)} = E_{(r,y)} \bmod 2^{bi} \qquad (3)$$
$$I_{rem(r)} = (E_{(r,x)} + E_{(r,y)}) \bmod 2^{bi}$$

After this the PVD embeds b_i bits of secret data into I_i by altering $E_{(r,x)}$ and $E_{(r,y)}$. The optimal approach for

altering the $E_{(r,x)}$ and $E_{(r,y)}$ to achieve the minimum distortion is as follows:

Case1: $I_{rem(r)} > b_{i'}$, m ≤ $(2^{bi})/2$, $E_{(r,x)} \geq E_{(r,y)}$

$(E'_{(r,x)}, E'_{(r,y)}) = (E_{(r,x)} - \lceil m/2 \rceil, E(r,y) - \lfloor m/2 \rfloor 2)$

Case 2: $I_{rem(r)} > b_i'$, m <= $(2^{bi})/2$, $E_{(r,x)} < E_{(r,y)}$

$(E'_{(r,x)}, E'_{(r,y)}) = (E_{(r,x)} - \lfloor m/2 \rfloor, E_{(r,y)} - \lceil m/2 \rceil 2)$

Case 3: $I_{rem(r)} > b_i'$, m > $(2^{bi})/2$, $E_{(r,x)} >= E_{(r,y)}$

$(E'_{(r,x)}, E_{(r,y)}) = (E_{(r,x)} + \lfloor m_1/2 \rfloor, E_{(r,y)} + \lceil m_1/2 \rceil 2)$

Case 4: $I_{rem(r)} > b_i'$, m > $(2^{bi})/2$, $E_{(r,x)} < E_{(r,y)}$

$(E'_{(r,x)}, E'(r,y)) = (E(r,x) + \lceil m_1/2 \rceil, E_{(r,y)} + \lfloor m_1/2 \rfloor 2)$

Case 5: $I_{rem(r)} > b_i'$, m > $(2^{bi})/2$, $E_{(r,x)} \geq E_{(r,y)}$

$(E'_{(r,x)}, E'_{(r,y)}) = (E_{(r,x)} + \lfloor m/2 \rfloor 2, E_{(r,y)} + \lceil m/2 \rceil 2)$

Case 6: $I_{rem(r)} \leq b_i'$, m > $(2^{bi})/2$, $E_{(r,x)} < E_{(r,y)}$

$(E_{(r,x)}, E'_{(r,y)}) = (E_{(r,x)} + \lceil m/2 \rceil 2, E_{(r,y)} + \lfloor m/2 \rfloor 2)$

Case 7: $I_{rem(r)} \leq b_i'$, m > $(2^{bi})/2$, $E_{(r,x)} \geq E_{(r,y)}$

$(E'_{(r,x)}, E'_{(r,y)}) = (E_{(r,x)} - (\lceil m_1/2 \rceil, E_{(r,y)} - \lfloor m_1/2 \rfloor 2)$

Case 8: $I_{rem(r)} \leq b_i'$, m > $(2^{bi})/2$, $E_{(r,x)} \geq E_{(r,y)}$

$(E'_{(r,x)}, E'_{(r,y)}) = (E_{(r,x)} - \lfloor m_1/2 \rfloor, E_{(r,y)} - \lceil m_1/2 \rceil 2)$

In the above approach, m= $|I_{rem(r)} - b_i'|$, m_1 = 2^{bi} - $|I_{rem(r)} - b_i'|$ and $E'_{(r,x)}$, $E'_{(r,y)}$ are new pixels values after embedding bi bits of the secret data into sub block I_i.

In the recovery process, the secret data is extracted quickly without using the original image. It is essential to use original range Table 1 designed in the embedding phase in order to figure out the embedding capacity for each sub block I_i. Given a sub block I_i with two consecutive pixels from the watermarked image with their pixel values being $E_{(r,x)}$ and $E_{(r,y)}$ respectively, the difference value di of $E_{(r,x)}$ and $E_{(r,y)}$ can be derived by Equation (1). Each I_i can be related to its optimal sub range T_j from the original Table 1 according to the difference value d_i. Hence, the width of the sub range by $w_j = u_j - l_j + 1$ is computed and the number of bits bi of secret data can be extracted from I_i by Equation (1). The value of b_i' is computed by using the Equation (4).

$$b_i' = (E'_{(r,x)} + E'_{(r,y)}) \bmod 2^{bi} \qquad (4)$$

Then transform b_i' value into a binary string with the length b_i. If di value is zero or either or both of $E'_{(r,x)}$, $E'_{(r,y)}$ overflows the boundary 0 or 255, consider the three situations below where the falling off boundary problem happens and revise the binary string with the length b_i .

Case 1: if $E_{(r,x)} \approx 0$, $E_{(r,y)} \approx 0$ and $E'_{(r,x)} < 0$ or $E'_{(r,y)} < 0$, then re adjust $E'_{(r,x)}$ and $E'_{(r,y)}$ to be $E''_{(r,x)}$ and $E''_{(r,y)}$ by $(E''_{(r,x)}, E''_{(r,y)}) = (E'_{(r,x)} + (2^{bi}) / 2)$, $E'_{(r,y)} + (2^{bi}) / 2)$

Case 2: if $E_{(r,x)} \approx 255$, $E_{(r,y)} \approx 255$ and $E'_{(r,x)}$ >255 or $E'_{(r,y)}$ >255, then re adjust $E'_{(r,x)}$ and $E'_{(r,y)}$ to be $E''_{(r,x)}$ and $E''_{(r,y)}$ by $(E''_{(r,x)}, E''_{(r,y)}) = (E'_{(r,x)} - (2^{bi}) / 2)$, $E'_{(r,y)} - (2^{bi}) / 2)$

Case 3: if $E_{(r,x)}$ and $E_{(r,y)}$ form a great contrast (i.e $d_i > 128$),then re adjusted $E'_{(r,x)}$ and $E'_{(r,y)}$ by

Case (i): if $E'_{(r,x)} <0$ and $E'_{(r,y)} \geq 0$ then

$(E''_{(r,x)}, E''_{(r,y)}) = (0, E'_{(r,y)} + E'_{(r,x)})$

Case (ii): if $E'_{(r,x)} \geq 0$ and $E'_{(r,y)} <0$ then

$(E''_{(r,x)}, E''_{(r,y)}) = (E'_{(r,x)} + E'_{(r,y)}, 0)$

Case (iii): if $E'_{(r,x)} >255$ and $E'_{(r,y)} \geq 0$ then

$(E''_{(r,x)}, E''_{(r,y)}) = (255, E'_{(r,y)} + (E'_{(r,x)} -255)$

Case (iv): if $E'_{(r,x)} \geq 0$ and $E'_{(r,y)} >255$ then

$(E''_{(r,x)}, E''_{(r,y)}) = (E'_{(r,x)} + (E'_{(r,y)} -255), 255)$

After that, the recovery process is accomplished.

III. Proposed Fwspvd Watermarking Method

The proposed watermark embedding scheme contains three basic steps. The block diagram of FWSPVD is given in the Figure 1.
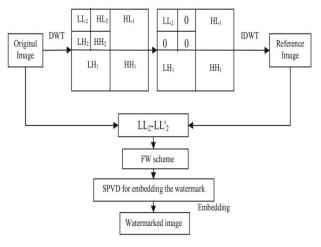

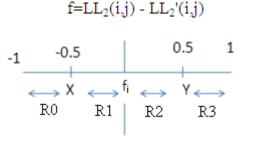*Fig.1.* Block diagram of the proposed FWSPVD method
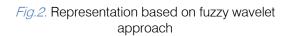
a) Watermark embedding process

The proposed FW method modifies the original image into transform domain and selects the pixel locations to insert a watermark in the difference values between the original image and its reference image based on a novel fuzzy logic in step one.

Step 1: In the first step, a novel FW approach is determined based on the pixel locations where watermark is embedded. DWT decomposes an image into subbands having a bandwidth approximately equal on a logarithmic scale. To achieve imperceptibility, the lowest band of the image is left unmodified. The gray level image is transformed into a DWT of both vertical and horizontal directions, resulting in one low frequency subband (LL) and three higher frequency subbands (LH, HL and HH). The same is repeated on LL subband to generate the next level of decomposition. This process can be repeated to n level decomposition by considering the length of watermark, robustness, fidelity and so on. The determined LL_n can be seen as a reduced version of the original image. Based on this a reference LL_n' is prepared by inverse wavelet transforming the original LL_n by initializing the three high frequency subbands (LH_{n+1}, HL_{n+1} and HH_{n+1}) excluding LL_{n+1} as zeros. The proposed FW approach is not selecting all those pixels that have the difference in LL_n' and LL_n. The difference between LL_n and LL_n' mainly ranges from -1 to +1, because the error content in the wavelet transform is minimum, that is the reason one always obtains the original image by inverse transformation. In the proposed approach the fuzzy difference between LL_n and LL_n' is obtained for selecting the pixel locations where watermark is embedded. The pixel locations to embed watermark are identified by taking the difference between ($LL_2 - LL_2'$) based on FW approach. The proposed FW approach divides the range -1 to +1 in to four regions as R0, R1, R2 and R3 as shown in the Figure 2. The pixel locations are selected based on the FW algorithm.

The pixel locations are selected for the embedding of watermark if they fall in the fuzzy region R1 and R2. Finally, the watermark information is embedded into the subband LL_2.

Fig.2. Representation based on fuzzy wavelet approach

Fuzzy Wavelet algorithm:
```
begin
for i =1 to n
for j = 1 to m
    f(i,j)=LLₙ(i,j) – LLₙ'(i,j)
if ((f(i,j) < 0.5) and (f(i,j)> -0.5))
    then P(i,j) is considered for inserting the watermark
else
```

$P_i(i,j)$ is not considered for inserting the watermark end

Step 2 : The second step, groups only those pixel coordinates selected by step one based on their pixel values in ascending order. If two or more pixels are having same values then they will be sorted by row wise positions.
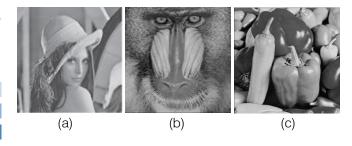
Step 3 : The pixel value differencing method only inserts watermarking bits in the adjacent pixels location based on pixel differences. By this it is easy to break or detect the watermark. To overcome this, the proposed method initially selects the pixel location where watermark is to be inserted based on FW approach. The watermark is inserted on the group of pixels in the sorted order by using SPVD method in the second level of wavelet transformed image as indicated in step two. By inserting watermark, the pixel value may be changed; and the sorted order may also be changed. The quality of the watermark is affected if the sorted order is changed after inserting the watermark bits by pixel value differencing method. To overcome this, in the proposed SPVD method watermark is inserted in the group of two pixels, if its values after inserting watermark are less than the next group of values.

b) Watermark extraction process

Transform the watermarked image into wavelet coefficients by second level wavelet transformations. To extract the watermark signal, the sequences of embedding locations are utilized. Perform the inverse FWSPVD scheme to obtain the pixel locations and watermark contents.

IV. RESULTS AND DISCUSSION

Eight 256 × 256 sized cover images are used in the following experiments. As shown in Figure 3, those are Lena, Baboon, Pepper, House, Barbara, Milkdrop, F16 and Boat. The watermark considered for the experiments is logo SRRF GIET of size 32×32 as shown in Figure 4. Table 2 shows the PNSR and NCC values for all the cover images. From the Table 2 it is clearly evident that all the images shows high PSNR and NCC values which indicates robustness and high quality of image after watermark insertion.
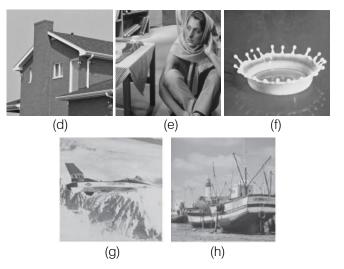

(a)   (b)   (c)

(d)   (e)   (f)

(g)   (h)

Fig.3 Cover images (a) Lena (b) Baboon (c) Pepper (d) House (e) Barbara(f) Milkdrop (g) F16 (h) Boat

Fig. 4 Watermark Image (a) Logo SRRF GIET

Table 2 Quality measures of proposed FWSPVD

Image	PSNR	NCC
Lena	44.81	0.96
Baboon	46.79	0.97
Pepper	45.45	0.99
House	47.28	0.98
Barbara	44.70	0.96
Milkdrop	47.64	0.97
F16	49.81	0.97
Boat	47.37	0.97

The proposed method is tested with various attacks and the quality parameters are listed in tables. Table 3 shows the PSNR and NCC values with various attacks using the proposed FWSPVD method on the watermark images with SRRF GIET respectively. The PSNR and NCC values of Table 3 clearly indicate the robustness and quality of the image is not degraded for all attacks.

The resultant image after adding Gaussian (10%), Salt and Pepper (10%), and Poisson noise (10%) to the watermarked image by the proposed FWSPVD is as shown in Figure 5, which demonstrates that FWSPVD scheme is significantly robust against these noises. Median filtering with different window sizes is applied to the watermarked images of the FWSPVD method and the resultant images are shown in Figure 6, which reflects the maximum detector response.

Table 3 Result of the experiments on FWSPVD method with various attacks on the watermarked images with 'Logo SRRF GIET'

Type of Attack	Lena		Baboon		Pepper		House	
	PSNR	NCC	PSNR	NCC	PSNR	NCC	PSNR	NCC
Gaussian noise (10%)	38.99	0.84	37.36	0.79	37.78	0.74	41.38	0.93
Salt and pepper noise (10%)	42.22	0.80	41.63	0.76	41.13	0.74	44.39	0.84
Poisson noise (10%)	41.39	0.86	39.90	0.83	38.93	0.76	42.35	0.82
Median filter (3×3)	40.46	0.70	38.99	0.70	38.48	0.73	41.77	0.88
Median filter (5×5)	39.34	0.81	38.87	0.71	37.52	0.7	40.65	0.89
Median filter (7×7)	35.20	0.70	34.92	0.73	33.49	0.65	39.20	0.75
Gaussian blur filtering (3×3)	38.67	0.74	38.46	0.74	37.65	0.74	41.58	0.84
Gaussian blur filtering (5×5)	36.81	0.66	35.39	0.68	34.43	0.68	38.59	0.73
Gaussian blur filtering (7×7)	34.03	0.62	33.49	0.62	32.12	0.53	37.20	0.76
Rotation 2 degrees	30.27	0.65	30.28	0.66	29.62	0.66	32.42	0.75
Rotation 3 degrees	29.48	0.56	28.47	0.58	27.91	0.54	31.24	0.70
Rotation 3 degrees	27.40	0.51	26.92	0.53	26.74	0.45	29.26	0.52

Figure 7 is the Gaussian blurred watermarked image by the FWSPVD method which demonstrates that FWSPVD scheme is significantly robust against this noise. Figure 8 shows, the results after rotating the watermarked image by 2, 3 and 4 degrees in order to keep the same size as the original image by which four corners of the rotated image are cropped. The extraction algorithm extracted more than 50% of the watermark.
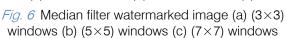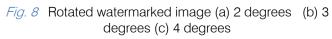

(a)   *(b)*   *(c)*

Fig. 5 Watermarked image corrupted by different noises (a) Gaussian noise (10%) (b) Salt and pepper noise (10%) (c) Poisson noise (10%)

(a)   (b)   (c)

Fig. 6 Median filter watermarked image (a) (3×3) windows (b) (5×5) windows (c) (7×7) windows

(a)   (b)   (c)

Fig. 7 Watermarked image corrupted by Gaussian blur (a) (3×3) windows (b) (5×5) windows (c) (7×7) windows

(a)   (b)   (c)

Fig. 8 Rotated watermarked image (a) 2 degrees (b) 3 degrees (c) 4 degrees

a) *Comparison of the proposed FWSPVD with the existing methods*

Table 4 compares the PSNR values after inserting the watermark without attacks by the proposed FWSPVD method with various other methods [7, 8, 9]. Table 4 clearly indicates the FWSPVD outperforms the other existing methods. A graph is also plotted in Figure 9 which indicates the comparison of the proposed FWSPVD method with various other methods without attacks.

Table 4 Comparison of the proposed FWSPVD method with various other methods

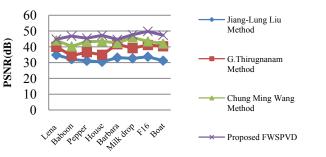| Test images	Jiang-Lung Liu Method	G.Thirugnanam Method	Chung Ming Wang Method	Proposed FWSPVD
	PSNR(dB)			
Lena	34.87	39.98	44.1	44.81
Baboon	32.14	34.45	40.3	46.79
Pepper	31.11	36.56	43.3	45.45
House	30.49	34.95	43.5	47.28
Barbara	33.15	41.62	42.5	44.70
Milk drop	32.67	39.14	45.9	47.64
F16	33.72	41.15	43.5	49.81
Boat	31.24	40.32	42.1	47.37

Fig. 9 Performance comparison of the proposed FWSPVD method with existing schemes

V. CONCLUSION

By transforming the original image in wavelet domain and embedding a watermark in the difference values based on fuzzy approach between the original image and its reference image, the proposed scheme overcomes the weak robustness problem of embedding watermark in the spatial domain. Our approach does not require the original image for watermark extraction. The experimental results on various images with various attacks show that the proposed technique provides good image quality and robustness when compared to other methods. This factor is clearly evident from the table 2, table 3 and table 4.

VI. ACKNOWLEDGMENT

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