Digital Watermarking Approach Based on Edge Based Sorted Pixel Value Difference (ESPVD)

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Abstract

Objectives: The major challenge in Imaging applications, particularly Digital Multimedia data transfer over the internet is data authentication with copyright protection to ensure ownership of identification. This paper aims to propose a new digital watermarking approach based on Edgebased sorted pixel value difference (ESPVD) to protect copyrights.  
Method: The hypothesis behind the proposed method is mainly composed of two phases: Watermark inserting phase, detection and extraction phase. In the inserting phase, first of all motif pattern approach is used to generate the mixed Image and then, identify the edge pixel locations using morphological edge (ME) operator to embed the watermark. Now, sorted pixel value difference method is used to insert the watermark. The watermark extraction phase also uses the same procedure which is stated earlier to retrieve the watermark image. To evaluate and match the ground truth images with the proposed watermarked images, peak signal to noise ratio (PSNR) and normalized cross correlation (NCC) are employed as quantitative measures. Findings: The proposed algorithm is tested with two logo images inserted over 30 different popular images and the outcomes indicates that the proposed approach is consistently performing well in terms of PSNR and NCC. Application/Improvements: The present approach provides high level of authentication, robustness, security and copyright protection against several attacks by using motif patterns while changing the order of pattern sequence in the formation of mixed image.

Keywords: Motif Pattern, Security Attacks, Sorted Pixel Value Difference, Watermarked Image

1. Introduction

Nowadays, most of the information is communicated over Internet in digital form and therefore copyright protection is very much essential. To provide the protection to the owner information extra information is embedded to the original image using Digital watermarking technique (DWT). DWT is one of the richest research field in image processing. The real-time applications of watermarking are monitoring broadcast media, authorization, thumb impression, e-commerce, media transformation and e-governance that makes the wide usage of digital watermarking innovations. The data comprises audio, video, digital repositories, libraries or net distributing. Especially, the development of advanced multi-media innovation has shown itself on web and remote operations. Further, considerable part of business and legislative associations like exhibition halls, social
associations, libraries, business ventures, image documenting and recovering offices and so forth makes the broad usage of digital watermarking innovations.

Digital watermarking procedures have as of late been used to secure the uprightness, legitimacy, and responsibility for signal and image. The primary inspiration of digital watermarking is copyright assurance and its applications are not that limited. The watermarking strategies can be mainly categorized into two classes namely spatial space and frequency area techniques. The spatial area systems are procedures that implant the watermark information by specifically changing the pixel estimations of the host image.

The regularly employed watermarking procedures as a part of the spatial space depend on the concept of mixing system. Spatial space approaches are easy to implement and computationally proficient, in light of the fact that they alter the intensity, saturation and color information of image gray levels. Hence their operations are implemented effectively and needs negligible mathematical calculations.

Numerical morphology is a tool used to analyze the shape of an object in imaging applications. Its geometry-arranged nature gives a proficient structure to dissecting object shape qualities, for example, size and boundary, which are not effectively got to by straight methodologies. Operations of morphology use structuring elements to probe the original image. The benefits of morphological methodologies over straight methodologies are they present linear geometric translation and straightforward in usage. The remarkable features viewing the morphological methodology are as per the following:

- Morphological operations give a strategy to the precise modification of the geometric content of an image while keeping up the security of vital geometric attributes.
- There exists an all-around created morphological algebra that can be utilized for representation and advancement.
- It is conceivable to express advanced calculations as far as a little class of primitive morphological operations.
- There exists thorough representation hypotheses by which, the outflow of morphological channels with reference to the primitive morphological operations are derived.

Be that as it may, so far no specialist utilized morphological standards as a part of building up any ideas for Digital Watermarking (DW). Therefore, the current study presented morphological algorithms for DW. However, the present ESPVD strategy locate the pixel areas taking gray values of the edge pixels of the original image into consideration. Next, watermark is incorporated in the selected pixel areas of edge pixels of the source image by utilizing SPVD.

The remaining paper is pre-arranged as follows. ESPVD introduced in section 2 and results are discussed in section 3. Conclusions are presented in section 4.

2. Proposed ESPVD Watermarking Method

With a specific end goal to ensure the privilege of the proprietor of copyright protection to the identification of ownership, the present paper provides a combined solution for copyright protection and authorization. The proposed strategy combines two approaches by way of Motif patterns and Edge based SPVD. This combined approach produces robust watermarks, ideal for copyright protection. On account of using the motif patterns identification in image as it protects from several attacks and using ESPVD a robust and efficient watermarked image is generated. The block diagram of [Figure 1] depicts the ESPVD algorithm.

The embedding approach of present method comprises four basic steps. In the first step, generate the mixed matrix for protecting the several attacks. Identify the location in the mixed image for embed the watermark image in the second step and embedded the water mark image in the third step and remix the image for generating the original watermarked image in the fourth step.

**Step1:** Generation of mixed image
To enhance security and robustness of the embedded watermark next to several operations, the motif patterns...
are identified and change the order of pattern sequence in an image and resultant image called mixed image.

The proposed method uses six categories of Motif patterns on original image for generating the mixed matrix. The motif patterns are characterized over a 2×2 sub window, each exhibiting a particular sequence of pixels beginning from the upper left corner as appeared in Figure 2 for generating mixed matrix. In Figure 2, the six motifs are represented as Z, N, U, C, Gamma and Alpha respectively. Every lattice is examined from upper left and those pixels shaped a motif pattern. Reverse direction of motifs are also considered. In this way, an aggregate of 12 examples are considered. Once any form of pattern is identified over 2×2 sub window, change the order of sequence of existing pattern. The detailed process is depicted in [Figure 3]. The main upper left six motifs of a 2×2 lattice are presented in [Figure 2].

\[ \text{Figure 2. Motif patterns on 2×2 grid.} \]

The [Figure 3] explains the detailed procedure for generating the mixing matrix. If any 2×2 window forms any motif pattern which is shown in Figure 2, then change the direction of pattern in reverse order. For example, the 2×2 window form z pattern which is start from top-left pixel and end at bottom-right then reverse order starting position is bottom-right and ends at top-left.

**Step 2: Identify the Edge Pixel Locations**

Once the mixed image is generated, identify the edge pixel locations to insert the watermark. The proposed method uses the simple region based morphological edge (ME) operator for identify the edge pixel locations where watermark is embedded.

**Edge Extraction Process using Morphology Concept**

 Allow R as a subset of elements to represent the region of the image. Now, R is called a region if it is an associated component. The edge (likewise known as frame) of an area R is the arrangement of elements covering a region that has one or more neighbors outside the R. On the off chance that R could be a whole image of rectangular arrangement of elements, then the edge of R is characterized as the arrangement of elements on the boundary lines of the R. This additional description is essential in light of the fact that the image has no elements outside the edge. Typically, an area usually describes contents or interior points which are surrounded by a boundary which is called regions boundary.

An Edge point is defined to be on boundary, if it is part of the region and at least one pixel in its neighbor-

\[ \text{Figure 3. Mixing matrix generation process (a) Original Matrix (b) generated Mixing matrix.} \]
hood that is not part of the region. The characterization of contours for paired images is accomplished by their network whether the adjust in the region or in the boundary. System operation is employed to remove edge changes present in the binary image. Be that as it may, the homotopy of the primary image couldn't be safe guarded. The Simple ME algorithm is given below.

Algorithm for Edge Detection

Phase 1: Consider structuring elements $E_r$ of various orientations of a neighborhood.

Phase 2: Edges $G_r(D)$ are recognized by morphological gradient edge recognition technique by utilizing $E_r$ on original image.

Phase 3: On recognized edge $G_r(D)$ of phase 2, artificial weighted strategy is utilized, to solve the issue of the size of the shape at boundaries gets reduced by Equation (1):

$$E(D) = \sum_{r=1}^{m} W_r G_r(D)$$

Where, $E(D)$ is the last recognized edge of source image, $m$ is the quantity of organizing elements and $W_r$ is the weight of identified edge data.

Step 3: Embed the Watermark

Once the pixel locations are identified, insert the watermark image into mixed image by using Sorted Pixel Value Difference (SPVD) approach. The SPVD method minimizes the disadvantages of basic Pixel Value Difference (PVD) method. The SPVD method has following advantages over PVD:

- PVD treats an edge as the relationship between adjacent pixels. But in reality, edge is treated as a concept of neighborhood. This disadvantage is overcome in the present paper by using a novel ME algorithm.
- PVD takes the distinction esteem between two successive pixels as a component for recording the mystery message. At the point when unique distinction worth is not same as the secret message, the two back to back pixels are specifically balanced so that their distinction quality can remain for the secret information. Be that as it may, extensive image mutilation can happen when PVD technique modifies two back to back pixels to conceal the mystery information in the distinction esteem. To overcome this proposed SPVD considers two sorted border pixels instead of adjacent pixels as in the case of basic PVD method. That is in the proposed SPVD two sorted pixel values are considered for inserting the watermark without depending on their pixel locations.
- The falling edge issue may presumably more regrettable the circumstance when PVD technique alone is utilized, particularly either when two back to back pixels are situated in a great edge or flat region, or at the time if estimations of two sequential elements frame a differentiation. To surpass this, the present thesis derived SPVD on ME algorithm that is ESPVD.
- Basically PVD scheme is designed for steganography images. The proposed ESPVD is designed for watermarking systems.

The proposed novel ESPVD watermarking procedure is fit for delivering a secret inserted image which is absolutely unclear from the source image by the human eye. In ESPVD, on the source image the morphological boundary pixel areas are recognized. At that point watermark is installed in the selected pixel areas of morphological boundary elements of the source image by utilizing SPVD strategy. This methodology conquers the feeble vigor issue of installing the watermark. In PVD just two back to back pixels are considered for embedding the watermark which prompts critical twists. In the proposed SPVD two sorted pixel qualities are considered for embedding the watermark without relying upon their pixel areas. Amasses just that pixel arranges on the source image chose by step 2, while ensuring the gray values are in monotonically increasing order. On the off chance that any set of pixels possess equal gray levels then they will be rearranged based on their column positions.

The secret image is embedded on the collection of pixels in the sorted request by utilizing SPVD technique. By embedding secret image, if the pixel quality is modified then the sorting order may accordingly be modified. The susceptible nature of watermark in pixel value difference approach particularly when the sorted order is changed due to the insertion of watermark bits is succeeded in the present SPVD technique. In the SPVD approach, the secret image is embedded in the two group of pixels, if its gray levels in the wake of embedding secret image are not exactly the following group of values.

Step 4: Remixing the Image

After embed the water mark image, again identify the motif patterns in the image generated in the step 3 and change the direction of the motif patterns to yield the resultant watermarked image.
Figure 4. Experimental Images (i) Lena, (ii) Barbara, (iii) Monalisa, (iv) Cameraman, (v) Terraux, (vi) House (vii) Airplane, (viii) Jetplane, (ix) Eagle-1, (x) Eagle-2, (xi) MRI-1, (xii) MRI-2, (xiii) MRI-3, (xiv) Mandrill, (xv) CT-1, (xvi) Butterfly, (xvii) Cheetah, (xviii) Landscape, (xix) Chips, (xx) Paint, (xxi) Peppers, (xxii) Baby-1, (xxiii) Baby-2, (xxiv) circles, (xxv) Joker, (xxvi) Milkdrop, (xxvii) Character, (xxviii) Seed, (xxix) Tile, (xxx) Iris.
Extraction Phase
Same procedure is implemented on watermarked image to recover the watermark image i.e. create the mixed matrix of the watermarked image. Identify the location in the mixed image for extracting the watermark image and extract the watermark using the series of embedding locations. Inverse SPVD technique can be employed to acquire the pixel locations and watermark contents.

3. Results
The present ESPVD technique is examined over 30 images of size 256x256. The images used in this experiment are shown in [Figure 4]. The present method is tested with two different watermark images, i.e. logos ‘AITAM’ and ‘GITAM’ of size 64x64 are shown in [Figure 5]. The proposed method is tested with Matlab software on i3 processor and 4GB RAM. The results obtained from the proposed morphological edge algorithm on experimental images are depicted in [Figure 6]. The resultant watermarked images are presented in [Figure 7].

![Figure 5. Watermark images (a) Logo of GITAM and (b) logo of AITAM.](image)

The two popular and effective criteria called Normalized Correlation Coefficient (NCC) and Peak Signal Noise Ratio (PSNR) are used as performance metrics to assess and compare the ESPVD technique.

The quality of the watermark is evaluated by the similarity index NCC between the inserted watermark $W$ and the retrieved watermark $W^*$ as given in Equation 2.

$$\rho = \frac{\sum_{i=0}^{N-1} w(i) \times w^*(i)}{\sum_{i=0}^{N-1} (w(i))^2}$$

Where $\rho$ is Normalized Correlation Coefficient, N is number of pixels, $w(i)$ and $w^*(i)$ are the inserted watermark and the recovered watermark. In the above equation $\rho = 1$ assumes ideal correlation, while an amazingly low values identifies that the watermarks are not precisely identical. In the event that NCC values ranges from 0.65 to 1.0 then one can state that the image preserves high quality after inserting the watermark.

The present method also calculates, Peak Signal Noise Ratio by taking the deviation between the reference image and the watermarked image. The greater the PSNR, the slighter is the deviation, and PSNR is characterized through given Equation 3.

$$PSNR = 10\log\left(\frac{255^2}{MSE}\right)$$

Where, mean squared error (MSE) is evaluated using Equation (4)

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (X_{ij} - X'_{ij})^2$$

Where M and N are respectively the rows and columns of the reference image. $X_{ij}$ indicates the intensity of the reference image at any coordinates, $X'_{ij}$ signifies the intensity of the watermarked image at any coordinates.

PSNR and NCC values of all 30 images are presented in [Table 1 and 2] when two watermark images are used. It is observed from the [Table 1 and 2] the PSNR and NCC values are high. This is an indication that confirms high robustness and quality resulted after inserting of a watermark.

| S.No | Image   | PSNR  | NCC |
|------|---------|-------|-----|
| 1    | Lena    | 46.66 | 0.98|
| 2    | Barbara | 49.13 | 1   |
| 3    | Monalisa| 51.66 | 0.99|
| 4    | Cameraman| 48.08 | 0.99|
| 5    | Terrax  | 46.83 | 0.99|
| 6    | House   | 46.57 | 1   |
| 7    | Airplane| 47.32 | 0.98|
| 8    | Jetplane| 49.49 | 0.99|
| 9    | Eagle-1 | 48.64 | 0.99|
| 10   | Eagle-2 | 48.1  | 0.95|
| 11   | MRI-1   | 47.7  | 0.95|
| 12   | MRI-2   | 48.68 | 0.97|
| 13   | MRI-3   | 49.27 | 0.96|
| 14   | Mandrill| 47.09 | 0.97|
| 15   | CT-1    | 46.55 | 0.98|
| 16   | Butterfly| 46.49 | 0.98|
| 17   | Cheetah | 47.3  | 1.01|
| 18   | Landscape| 48.04 | 0.95|
Figure 6. Some resultant Edge images generated when using Morphological edge operator: a) Monalisa b) Eagle-1 c) Cameraman d) Baby-2 e) MRI-1 f) Landscape g) Jetplane h) House i) Joker k) Cheetah.

Figure 7. Watermarked images: a) Monalisa b) Eagle-1 c) Cameraman d) Baby-2 e) MRI-1 f) Landscape g) Jetplane h) House i) Joker k) Cheetah.

|   |   |   |
|---|---|---|
| 19 | Chips | 48.78 | 0.97 |
| 20 | Paint | 46.02 | 0.99 |
| 21 | Peppers | 45.94 | 1 |
| 22 | Baby-1 | 46.41 | 1 |
| 23 | Baby-2 | 49.22 | 0.99 |
| 24 | Circles | 46.84 | 0.98 |
| 25 | Joker | 47.3 | 0.97 |
| 26 | Milkdrop | 48.04 | 0.96 |
| 27 | Character | 47.32 | 0.97 |
| 28 | Seeds | 49.49 | 0.95 |
| 29 | Tile | 48.64 | 0.95 |
| 30 | Iris | 48.1 | 0.97 |
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**Table 2.** Performance metrics of ESPVD when use logo of AITAM

| S.No | Image   | PSNR  | NCC  |
|------|---------|-------|------|
| 1    | Lena    | 48.01 | 0.97 |
| 2    | Barbara | 50.48 | 0.99 |
| 3    | Monalisa | 53.01 | 0.98 |
| 4    | Cameraman | 49.43 | 0.98 |
| 5    | Terraux | 48.18 | 0.98 |
| 6    | House   | 47.92 | 1    |
| 7    | Airplane | 48.67 | 0.97 |
| 8    | Jetplane | 50.84 | 0.98 |
| 9    | Eagle-1 | 49.99 | 0.98 |
| 10   | Eagle-2 | 49.45 | 0.94 |
| 11   | MRI-1   | 49.05 | 0.94 |
| 12   | MRI-2   | 50.03 | 0.96 |
| 13   | MRI-3   | 50.62 | 0.95 |
| 14   | Mandrill | 48.44 | 0.96 |
| 15   | CT-1    | 47.9  | 0.97 |
| 16   | Butterfly | 47.84 | 0.97 |
| 17   | Cheetah | 48.65 | 1    |
| 18   | Landscape | 49.39 | 0.94 |
| 19   | Chips   | 50.13 | 0.96 |
| 20   | Paint   | 47.37 | 0.98 |
| 21   | Peppers | 47.29 | 0.99 |
| 22   | Baby-1  | 47.76 | 1    |
| 23   | Baby-2  | 50.57 | 0.98 |
| 24   | circles | 48.19 | 0.97 |
| 25   | Joker   | 48.65 | 0.96 |
| 26   | Milkdrop | 49.39 | 0.95 |
| 27   | Character | 48.67 | 0.96 |
| 28   | Seeds   | 50.84 | 0.94 |
| 29   | Tile    | 49.99 | 0.94 |
| 30   | Iris    | 49.45 | 0.96 |

Comparison of the Proposed ESPVD with the Other Methods

[Table 3] Compares the PSNR values after inserting the watermark without assaults by the proposed ESPVD method with various other methods. Table 3 clearly shows that the ESPVD is superior to the other existing methods. [Figure 8] presents a graph that focuses the comparison between proposed method and other methods without assaults.

**Table 3.** Proposed ESPVD method and other methods comparison Results

| S. No | Test Images   | Jiang-Lung Liu Method | Thirugnanam.G Method | Chung Ming Wang Method | Proposed ESPVD |
|-------|---------------|-----------------------|----------------------|------------------------|----------------|
| 1     | Lena          | 34.87                 | 39.98                | 44.1                   | 45.31          |
| 2     | Mandrill      | 32.14                 | 34.45                | 40.3                   | 45.74          |
| 3     | Peppers       | 31.11                 | 36.56                | 43.3                   | 44.59          |
| 4     | House         | 30.49                 | 34.95                | 43.5                   | 45.22          |
| 5     | Barbara       | 33.15                 | 41.62                | 42.5                   | 47.78          |
| 6     | Milkdrop      | 32.67                 | 39.14                | 45.9                   | 46.69          |
| 7     | Airplane      | 33.72                 | 41.15                | 43.5                   | 45.97          |
| 8     | Cameraman     | 31.24                 | 40.32                | 42.1                   | 46.73          |

Figure 8. Proposed ESPVD and other methods comparison graph.

**Attacks on ESPVD**

The tables make a note of the test of the proposed method that under gone several attacks and quality parameters. [Table 4] signifies the results of the proposed ESPVD approach with logo “GITAM”. The PSNR and NCC values of Table 4 explores the efficiency or success rate in terms of robustness and image quality as it is not deteriorated against several attacks except rotation.

The effect of ESPVD watermarked image with Gaussian, Salt and Pepper and poison distributed noise are shown in [Figure 9]. Results specifies that the ESPVD approach is considerably effective with reference to robustness against the noises.
Figure 9. Results of Watermarked images with (a) Gaussian noise (b) Salt and pepper noise and (c) Poisson noise.

The result of applying median filter with mask sizes 3 x 3, 5 x 5 and 7 x 7 on ESPVD watermarked image are shown in [Figure 10]. It can be observed that the filter 3 x 3 is more effective against the noise. [Figure 11] is the watermarked image produced when corrupted by Gaussian blur with 3 x 3, 5 x 5 and 7 x 7 masks. The results exhibits that the ESPVD again survives greatly against Gaussian blur. [Figure 12] yields the results in the wake of turning the watermarked image by 2, 3 and 4 degrees with a particular true objective to keep indistinguishable size from the principal image by which four corners of the rotated images are edited.

Table 4. Experimental Results of ESPVD method with various attacks on the watermarked images with logo ‘GITAM’

| Type of Attack         | Lena  | Mandrill | Peppers | House |
|------------------------|-------|----------|---------|-------|
|                        | PSNR  | NCC      | PSNR    | NCC   | PSNR | NCC | PSNR | NCC |
| Gaussian noise         | 39.57 | 0.83     | 38.48   | 0.82  | 37.4 | 0.81 | 41.53 | 0.97 |
| Salt and pepper noise  | 42.66 | 0.81     | 41.76   | 0.79  | 41.38| 0.79 | 44.53 | 0.95 |
| Poisson noise          | 41.16 | 0.89     | 40.03   | 0.84  | 39.08| 0.84 | 42.49 | 0.92 |
| Median filter (3×3)    | 40.23 | 0.75     | 40.02   | 0.75  | 38.92| 0.76 | 41.8  | 0.93 |
| Median filter (5×5)    | 39.48 | 0.76     | 38.46   | 0.76  | 37.69| 0.75 | 40.7  | 0.94 |
| Median filter (7×7)    | 36.12 | 0.71     | 34.91   | 0.74  | 33.83| 0.73 | 39.53 | 0.82 |
| Gaussian blur filtering (3×3) | 38.86 | 0.81 | 38.13 | 0.8 | 37.8 | 0.77 | 41.43 | 0.89 |
| Gaussian blur filtering (5×5) | 36.96 | 0.7 | 35.77 | 0.69 | 34.59 | 0.68 | 38.49 | 0.8 |
| Gaussian blur filtering (7×7) | 34.7 | 0.64 | 33.36 | 0.64 | 32.28 | 0.64 | 37.6 | 0.78 |
| Rotation 2 degrees     | 31.09 | 0.67     | 30.14   | 0.67  | 29.79| 0.66 | 32.59 | 0.77 |
| Rotation 3 degrees     | 29.68 | 0.61     | 28.76   | 0.57  | 28.14| 0.57 | 31.43 | 0.75 |
| Rotation 3 degrees     | 27.57 | 0.52     | 26.89   | 0.52  | 26.94| 0.53 | 29.43 | 0.62 |
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(a)          (b)                           (c)

Figure 12. Watermarked image rotated by (a) 2 degrees (b) 3 degrees (c) 4 degrees

4. Conclusions

The present paper derived a novel scheme called ESPVD for embedding the watermark. The proposed schemes use three stages for embedding the watermark. In the first stage, mixed image is generated by using motif patterns, in the second stage pixel locations are identified based on novel morphological edge approach for inserting the watermark and in the third stage the watermark image is inserted using SPVD. The ESPVD scheme guarantees high authentication. Further the selection of pixel locations does not require repetitions and one can use this method for security. The proposed ESPVD scheme greatly reduces the visibility of the hiding effect present in the PVD method, which is used for inserting the watermark. The proposed ESPVD approach employs the sorted list of the two consecutive pixels to record the information of the secret data which gains more flexibility with least distortion. The experimental results on variety of images with various attacks prove that the new ESPVD approach provide high image quality and robustness than other methods.

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