High Payload Lossless Digital Image Watermarking Using Integer Wavelet Transform

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ABSTRACT

In this paper a high payload lossless digital image watermarking technique based on Integer Wavelet Transform is proposed. Digital watermarking is the process of embedding the watermark image into a host image which is imperceptible by human visual system. The small deviations in data values are not allowed in certain images for obvious reasons and a potential risk of a person misinterpreting an image. After extracting the embedded data, the original image should be recovered from watermarked image. A preprocessing histogram adjustment is used to prevent overflow/underflow. In proposed technique, the data are embedded into one or more bit planes of wavelet coefficients of high frequency sub bands. This technique embeds much more data imperceptibly than the existing techniques. The experimental results have demonstrated the superiority of the proposed method over existing techniques.

Index Terms; Digital watermarking, Integer wavelet transform, Histogram modification.

INTRODUCTION

In today’s life Internet is being increasingly used as the platform for distribution of digital multimedia. However many publishers may be unwilling to show their work on the internet due to lack of security. Images can be easily duplicated and distributed without the owner’s permission. Digital watermarks came in to picture to avoid this type of issues. A digital watermark is an invisible digital image embedded inside the host image to show ownership. A digital watermark will prevent the obstruction of the original image which is invisible by human visual system [1]. It should be statistically invisible to prevent detection. Digital image watermarking with lossless is of great use in practice.

A lossless high-capacity data embedding for image watermarking based on integer wavelet is proposed. After extracting data embedded, the original image should be reversible from watermarked image. Obviously most of current hiding algorithms are not distortion less. Recently, some distortion less marking techniques have been reported in the literature. The concept of distortion-free data embedding appeared for the first time in an authentication method in a patent owned by Eastman Kodak was published in 1999. This method [2] is carried out in the spatial image domain. These techniques aim at authentication, instead of data embedding. As a result, the amount of hidden data is quite limited. The first distortion less marking technique that is suitable for data embedding was presented in [3]. This amount of hidden data is still not large enough for some medical applications.

INTEGER WAVELET TRANSFORM

The Wavelet Transform produces floating point coefficients even when applied to integer values [4]. The original integer data can be reconstructed perfectly in theory by using these coefficients. However in practice, we usually use the fixed point format for data values because the fixed point systems are easier to implement. The reduced precision arithmetic used in such systems can introduce round off errors in the computations. In practice traditional wavelet transform have some drawbacks such as it is a floating point algorithm, computer finite word length will bring in rounding error and signals can’t be reconstructed exactly, the computation is very complicated, computation cost is very high, it requires more storage space and it is not appropriate to hardware implementation [5]. In order to overcome above drawbacks, this paper uses lifting scheme wavelet - integer wavelet transform. It doesn’t depend on Fourier transform, but it still inherits , multi resolution properties of traditional wavelet transform and transforming coefficient, calculation speed is more fast, and it doesn’t need extra storage cost so it is called second generation wavelet transform. Hence in applications where we need lossless reconstruction, we need transforms which have reversibility properties even when reduced precision is used. It was shown by calderbank et al., [6] that we can build wavelet transforms that map integers to integers by using lifting structure. The reversibility property is obtained by rounding of the predict filter or update filter output before adding or subtracting in each lifting step. Wavelet filters are decomposed into basic modules by integer wavelet transform, that is,
wavelet transform is completed through splitting, predicting and updating, as Fig 1 displays.

![Diagram of Integer Wavelet Transform](image1.png)

Fig 1. Integer wavelets transform decomposition and Reconstruction diagram

After integer wavelet transform, it has four sub-bands. We will embed the information into three high frequency sub bands. Except that it has advantages of traditional wavelet transform, integer wavelet transform which is applied to digital watermarking technology has following advantages:

1. It avoids rounding error of floating point in mathematical transformation;
2. Its transforming speed is fast and it doesn’t need extra storage cost.

**HISTOGRAM ADJUSTMENT**

For a given image, after data embedding in some IWT coefficients, it is possible to cause overflow/underflow, which means that after inverse wavelet transform the gray scale values of some pixels in the water marked image may exceed the upper bound (255 for an eight-bit grayscale image) and/or the lower bound (0 for an eight-bit grayscale image). In order to prevent the overflow/underflow, we adopt histogram modification, which narrows the histogram from both sides as shown in Fig.2. Please refer to [7],[8] for the detailed algorithm. The bookkeeping information will be embedded into the cover media together with the information data.

![Histogram Adjustment](image2.png)

Fig 2(a). Gray scale histogram modification of Original histogram

![Modified Histogram](image3.png)

Fig 2(b). Gray scale histogram modification modified histogram

![Histogram after Embedding](image4.png)

Fig 2(c). Gray scale histogram modification histogram after data embedding

**PROPOSED WATERMARKING SCHEME**

1. **Data Embedding Process**:
   
   a. Histogram modification is applied on original image that prevents possible overflow and underflow.
   
   b. We first apply integer wavelet decomposition to the original image. In our experiments, CDF (2, 2) wavelet filters are used to decompose the original gray scale image into one level. After integer wavelet transform, it has four sub-bands.
   
   c. In order to have the marked image perceptually the same as the original image, we choose to hide data in one (or more than one) “middle” bit-plane(s) in the IDWT domain. To further enhance the visual quality of the marked image, we embed data only in the middle and high frequency sub bands, specifically in the LH1, HL1 and HH1 sub bands.

   d. Construct binary images from 5th bit of LH1, HL1 and HH1 wavelet coefficients. For constructing binary image using LH1, the each integer wavelet coefficients in LH1 is converted into 8 bit binary sequence, if 5th bit of each binary sequence is 1 then assign 2 to binary
image otherwise assign 1. For constructing binary image using HL1 and HH1 is same as above.

e. Compress data in binary image obtained from LH1, HL1 and HH1 by using arithmetic coding because of its high coding efficiency. This compressed data is also embedding along with watermark data; this can be used later for inverting the watermarked image into original one.

f. The watermark signal is chosen to be a binary image or logo consisting of 0’s and 1’s.

g. Insert the header information, compressed data and watermark together, the embed signal consists of these three. If embedded bit is 1 or 0 then convert first integer wavelet coefficient in LH1 sub band into 8 bit binary sequence and replace 1 or 0 to the 5th bit plane of that binary sequence and convert back to integer. In this way all the embedded bits hide in “5th” bit-plane in the LH1, HL1 and HH1 coefficients.

h. The way of accessing each wavelet coefficient for embedding depends on secret key.

i. A secret key function that keeps the hidden data secret even after the algorithm is known to public.

j. Take the Inverse integer wavelet transform to reconstruct the watermark image.

k. Perform histogram modification on watermarked image.

l. The invisibility of the watermarked image

We use the formula (1) to compare the difference between the original image and the watermarked image, Figure 5 demonstrates that the watermark embedded with the proposed algorithm is invisible, where (a) is the original image, and (b) is the watermarked image with PSNR=36.57 db.

$$PSNR = 10 \log_{10} \frac{255^2}{\frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} (H(i,j) - W(i,j))^2}$$

Where

- $H(i,j)$ Is Original cover image 
- $W(i,j)$ Is Watermarked image

2. Extraction Process

Extraction of watermark image and inverting of watermarked image into original one is reverse process of embedding.

a. Perform histogram modification on watermarked image.

b. Perform one level integer wavelet decomposition on watermarked image.

c. Extract the embed signal from 5th bit of LH1, HL1 and HH1 wavelet coefficients.

For extracting embedded signal with using LH1, the each integer wavelet coefficient in LH1 is converted into 8 bit binary sequence and if 5th bit of each binary sequence is 1, then embed bit is 1 otherwise embed bit is 0.

The sample code given below:

```matlab
Index=1
for i=1: size (LH1, 1)
for j=1:size(LH1,2)
binSeq = dec2bin (abs (LH1(i, j)),8);
if binSeq (5) == '1'
embed Signal (index, 1) = 1;
else
embed Signal(index,1) = 0;
end
index = index + 1;
end
end
```

For extracting embedded signal with using HL1 and HH1 same as above.

(a) Based on header information extract binary watermark image from embed signal.

(b) Extract the respective binary images of LH1, HL1 and HH1 from embed signal based on header information.

(c) Decompress to get the original sequence.

(d) Remove the watermark and insert the uncompressed 5th bit data back into LH1, HL1 and HH1.

(e) Take the Inverse integer wavelet transform to reconstruct the original image.
(f) Perform histogram adjustment on original image.

**IMPLEMENTATION**

The program code is written in ‘MATLAB’. Test images of ‘Airplane’, ‘Lena’, ‘Baboon’, ‘Gold hill’, and ‘Barbara’ are used as input images for validation of developed algorithms. The wavelet decomposition of image is done by using CDF (2,2) wavelet filter. The watermark logo is binary image created and embedded as per algorithm discussed. The embedding is done for the visible watermark logo. The resultant coefficients were inverse transformed to obtain the watermarked image. Several test gray scale images of size 512x512 are used in experiments. The original and marked Airplane images are shown in fig.5. The picture signal to noise ratio (PSNR) value of Airplane image after watermark embedding is measured as 36.57 db. It is observed that imperceptibility requirement is met. The same experiment is conducted on other four images. Fig.6 contains other four watermarked images. Table I shows some experimental results.

![Fig.4 Extraction method](image)

![Fig.5 Airplane image](image)

**Table I The PSNR value after watermark embedding**

<table>
<thead>
<tr>
<th>Host Image</th>
<th>PSNR of marked Image (db)</th>
<th>Pay-load (Bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lena</td>
<td>36.81</td>
<td>119716</td>
</tr>
<tr>
<td>Baboon</td>
<td>33.99</td>
<td>17689</td>
</tr>
<tr>
<td>Goldhill</td>
<td>35.37</td>
<td>77284</td>
</tr>
<tr>
<td>Airplane</td>
<td>36.57</td>
<td>196152</td>
</tr>
<tr>
<td>Barbara</td>
<td>35.52</td>
<td>72900</td>
</tr>
</tbody>
</table>

Table I show that Airplane image has a better embedding capacity than the other images in the experiment. It also shows it has a better visual quality as far as peak signal to noise ratio is concerned.

**Table II Comparison of performance of various wavelet families on Airplane image for different payload size**

<table>
<thead>
<tr>
<th>Payload bits</th>
<th>cdf(2,2)</th>
<th>db2</th>
<th>Sym4</th>
<th>bior3.3</th>
<th>bior6.8</th>
<th>rbio3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PSNR (db)</td>
<td>PSNR (db)</td>
<td>PSNR (db)</td>
<td>PSNR (db)</td>
<td>PSNR (db)</td>
<td>PSNR (db)</td>
</tr>
<tr>
<td>10000</td>
<td>37.78</td>
<td>35.84</td>
<td>36.37</td>
<td>36.31</td>
<td>36.31</td>
<td>36.24</td>
</tr>
<tr>
<td>15129</td>
<td>37.73</td>
<td>35.78</td>
<td>36.25</td>
<td>36.28</td>
<td>36.23</td>
<td>36.29</td>
</tr>
<tr>
<td>20164</td>
<td>37.67</td>
<td>35.73</td>
<td>36.26</td>
<td>36.24</td>
<td>36.26</td>
<td>36.16</td>
</tr>
<tr>
<td>25281</td>
<td>37.60</td>
<td>35.69</td>
<td>36.11</td>
<td>36.16</td>
<td>36.00</td>
<td>35.99</td>
</tr>
<tr>
<td>50176</td>
<td>37.11</td>
<td>35.70</td>
<td>35.89</td>
<td>35.76</td>
<td>35.85</td>
<td>35.58</td>
</tr>
<tr>
<td>75076</td>
<td>36.84</td>
<td>35.67</td>
<td>35.90</td>
<td>35.71</td>
<td>36.00</td>
<td>34.67</td>
</tr>
<tr>
<td>100489</td>
<td>36.74</td>
<td>**</td>
<td>35.86</td>
<td>35.51</td>
<td>35.05</td>
<td>33.86</td>
</tr>
</tbody>
</table>
to embed up to 196k bits into image of 512 by 512 imperceptibly and extracts the embedded data and original image from watermarked image without loss of information. The performance of proposed lossless watermarking algorithm verified by various wavelet filters. Among various wavelet filters, CDF (2,2) performs better than others for the same payloads.

REFERENCES

Table III shows the comparison between existing methods in literature and proposed method. The proposed method is able to embed up to 196k bits into image of 512 by 512 imperceptibly.

Table III Comparison between existing methods and proposed method

<table>
<thead>
<tr>
<th>Methods</th>
<th>The amount of data embedded in a 512 × 512 image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goljan’s</td>
<td>3,000-24,000 bits</td>
</tr>
<tr>
<td>Guorong</td>
<td>15,000-94,000 bits</td>
</tr>
<tr>
<td>Proposed</td>
<td>10000-1,96152 bits</td>
</tr>
</tbody>
</table>

Fig.7 Image Quality Tested on Different Waves

CONCLUSION
Simulation experiments on the digital watermarking of images have been performed using two standard images: Lena and Airplane. In proposed method instead of data embedding into single bit plane, the data embedded into multiple bit planes of middle frequency sub band coefficients of host image with sacrificing quality of the watermarked image. The proposed lossless high-capacity digital watermarking algorithm based on integer wavelet transform is able to embed up to 196k bits into image of 512 by 512 imperceptibly and extracts the embedded data and original image from watermarked image without loss of information. The performance of proposed lossless watermarking algorithm verified by various wavelet filters. Among various wavelet filters, CDF (2,2) performs better than others for the same payloads.

Fig.8 Comparison between proposed and existing methods

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