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Digital Watermarking using a Multiple Signals Embedding Technique and Cropping Detection Algorithm in HSV and YIQ Color Spaces

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Abstract. In this paper, a multiple signals embedding technique is applied in *HSV* and *YIQ* color spaces. Also, a new algorithm is proposed to detect and eliminate the cropping areas within the attacked image to achieve the higher performance in extraction process. The experimental sets are designed to support the proposed concepts. The obtained results show significant improvement in terms of *NC*. In addition, the improvements in terms of robustness by the proposed method work effectively against various common image-processing-based attacks especially against cropping attacks. The results are strongly shown and supported our proposed algorithm that achieves higher accuracy of signal extraction compared to the previously proposed algorithm.

Keywords: multiple signals embedding, HSV color spaces, YIQ color spaces, cropping detector algorithm

1. Introduction

Digital watermarking is a kind of standard technology to maintain access control for the documents. Good introduction on digital watermarking including its essential requirements can be found in [1] and [2].

Watermarking methods can be classified into frequency and/or spatial domain based watermarking. In the frequency domain, the watermark embedding can be accomplished by modifying the image coefficients from its transformed domain. For instance, [3],[4],[5],[6] and [7] are also proposed the watermarking schemes in frequency domain recently. However, there are many researches demonstrated that the frequency domain based approach is not robust enough against geometrical attacks. In contrast, in the spatial domain based approach, it is obvious that the processes of watermark embedding and extraction are simple to perform by modifying the image pixels directly.

For example, M. Kutter et al. [8] presented a method to embed a watermark signal into an image by modifying the pixel using either additive or subtractive depending on the watermark bit, and proportional to the luminance of the embedding pixel. According to their method, the blue colour channel was selected to carry the watermark bit since it is the one that human eye is least sensitive to.

Later, many researchers [9],[10] proposed the methods to improve the quality of the watermarked image by modifying the pixel depending on and proportional to the luminance of the embedding pixel. Especially in [10], T. Amornraksa et al. proposed some techniques to enhance watermark retrieval performance by balancing the watermark bits around the embedding pixels, tuning the strength of embedding watermark in according with the nearby luminance, and reducing the bias in the prediction of the original image pixel from the surrounding watermarked image pixels. However, all the methods mentioned above encountered a deficiency when implemented with an image having a large number of high frequency components.

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Our approach applies the same image watermark technique as proposed in [10] because this technique can be used to embed large number of watermark bits into a coloured image. The next section gives a brief concept of digital watermarking based on image pixels modifications in the blue colour channel. Section 3 describes the proposed technique. In section 4, the experimental results are shown and discussed. The conclusion is finally drawn in section 5.

2. The Previous Watermarking Method

2.1. The Embedding Process

Firstly, The watermark pixels are converted from {0,1} to {1,-1} by changing the value of the zero bits to be the one bits. Then, the watermark balance and security are improved by using the XOR operation to permute the watermark bits with a pseudo-random bit-stream generated from a key-based stream cipher. The scaling factor *s* is used to adjust and control the watermark strength of the output previous process outputs. Then, the embedding process is started by modifying the image pixel in the blue channel $B_{(i,j)}$, in a line scan fashion. The result $B'_{(i,j)}$ are either additive or subtractive, depending on $w_{(i,j)}$, and proportional to the modification of the luminance of the embedding pixel $L_{(i,j)}$. In addition, the modification of luminance $L'_{(i,j)}$ is calculated from a Gaussian pixel weighting mask. The representation of the watermark embedding process can be expressed by

$$B'_{(i,j)} = B_{(i,j)} + w_{(i,j)} s L'_{(i,j)} \qquad (1)$$

2.2. The Extraction Process

To extract the watermark signal, the following steps are used to estimate the embedded watermark bit at *(i,j)*. Firstly, each original image pixel in the chosen channel is predicted from its neighbouring watermarked image pixels in the same embedding channel. Each original image pixel in the chosen channel is predicted from its neighbouring watermarked image pixels in the same channel. The predicted original image pixel $B''_{(i,j)}$ is determined by

$$B''_{(i,j)} = \frac{1}{8}\left(\sum_{m=-1}^{1}\sum_{n=-1}^{1} B'_{(i+m,j+n)} - B'_{(m\_\max,N\_\max)}\right) \qquad (2)$$

where $B'_{(m\_max,\, n\_max)}$ is a neighbouring pixel around *(i,j)* that most differs from $B'_{(i,j)}$. Then, the embedded watermark bit $w'_{(i,j)}$ at a given coordinate *(i,j)* can then be determined by the following equation

$$w'_{(i,j)} = B'_{(i,j)} - B''_{(i,j)} \qquad (3)$$

where $w'_{(i,j)}$ is the estimation of the embedded watermark *w* around *(i,j)*. Since $w_{(i,j)}$ can be either 1 and -1, the value of $w'_{(i,j)} = 0$ is set as a threshold, and its sign is used to estimate the value of $w_{(i,j)}$. That is, if $w'_{(i,j)}$ is positive (or negative), $w_{(i,j)}$ is 1 (or -1, respectively). Notice that the magnitude of $w'_{(i,j)}$ reflects a confident level of estimating $w_{(i,j)}$.

3. Proposed Method

3.1. The Embedding Process

3.1.1. *YIQ* Color Space

RGB color model is the most common color system. However, there are many color models that were applied and used in various purposes nowadays. YIQ is the color space used by NTSC color TV system and sometimes employed in color processing transformation. For instance, the histogram equalization is applied to the Y channel of the YIQ representation of the image, which only normalizes the brightness levels of the image. Also, the digital watermarking techniques are applied to embed and extract in YIQ both spatial and frequency domain approach.

The conversion between two models is illustrated below;

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.595716 & -0.274453 & -0.321263 \\ 0.211456 & -0.522591 & 0.311135 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (4)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0.9563 & 0.6210 \\ 1 & -0.2721 & -0.6474 \\ 1 & -1.1070 & 1.7046 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix}$$

3.1.2. *HSV* Color Space

HSV *is* the most common cylindrical-coordinate representations of points in an *RGB* color model. *HSV* stands for hue, saturation, and value, and is also often called *HSB* (*B* for brightness). This color model is also frequently used widely in digital image processing research and proposed many new algorithms.

3.1.3. Multiple Signals Embedding Technique

We proposed to use the multiple signals embedding technique to improve the performance of extracted watermark signal accuracy. In this paper, we applied this technique in *YIQ* and *HSV* to embed and extract a watermark signal. Each color channel of each color model was processed and evaluated individually. Thus, the comparison of embedding in *I*, *Q*, *H* and *S* is illustrated in next section. The processes of embedding and extracting by using the multiple signals embedding technique are given below;

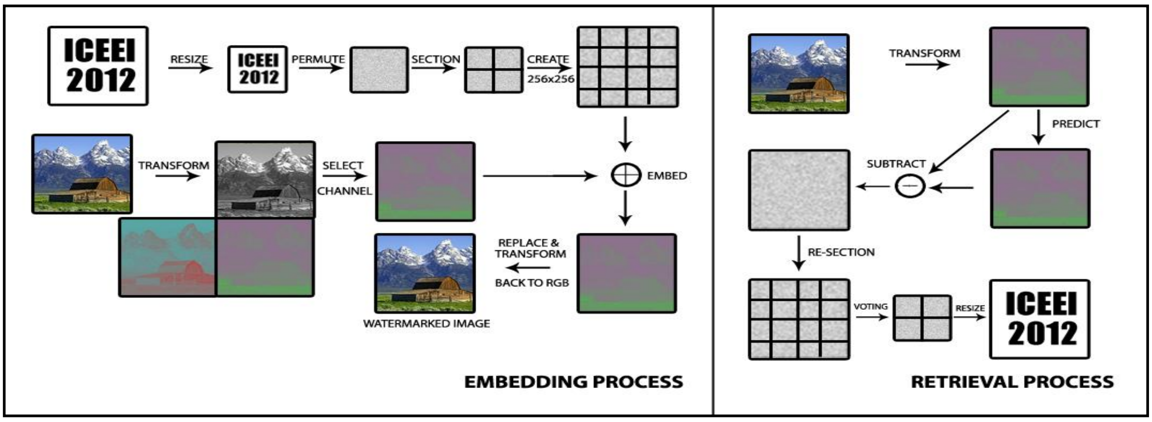

Fig. 1: Multiple Signals Embedding Technique

3.2. The Extraction Process

We proposed to use average value of eight neighbor pixels in the extraction process as follow;

$$B''_{(i,j)} = \frac{1}{8}\left(\sum_{m=-1}^{1}\sum_{n=-1}^{1} B'_{(i+m,j+n)}\right) \quad (5)$$

Then, the embedded watermark bit *w'(i,j)* at a given coordinate *(i,j)* can then be determined by the following equation

$$w'_{(i,j)} = B'_{(i,j)} - B''_{(i,j)} \quad (6)$$

3.2.1. Cropping Detection Algorithm

We proposed a new algorithm to detect cropping part and re-calculate by ignoring the cropped area. After extracting process, we evaluated the *NC* value of all five extracted watermark signals. Then, we sorted all values and eliminate two lowest out of calculation. After that the cropping detection algorithm was applied to re-evaluate the final *NC* value. The process of the algorithm is given as follows;

```
Function Cropping Detection and NC Evaluation
START :
NC[0] = NC_Calculation(W_PART1);
NC[1] = NC_Calculation(W_PART2);
NC[2] = NC_Calculation(W_PART3);
NC[3] = NC_Calculation(W_PART4);
NC[4] = NC_Calculation(W_PART5);
Sorted_NC = Sort(NC);
Call Cropping_Detector(Sorted_NC);
Function Cropping_Detector
for i=1:256
  for j=1:256
    for m=-1:1
```

```
            for n=-1:1
                if (W==0)
                    cnt++;
                else
                    cnt--;
                k=k+1;
            end
        end
    if(cnt==9 || cnt ==6  )
        cropping_window++;
    end
    end
end
total = count(cropping_window);
set_weight();
calculate(NC)
return NC;
END
```

4. Experimental Results

4.1. Experimental Settings

In the experiments, four standard color images, namely 'Lena', 'Tower', 'House' and 'Pens' with the size of 256×256 pixels were used as the original images. the 256×256 pixels black & white image containing a logo 'ICT' is also used as a watermark signal, i.e. by considering the black color pixel as -1, and white as 1. In all experiments, we evaluated the quality of watermarked image by measuring its *PSNR* (Peak Signal-to-Noise Ratio) and evaluated the quality of extracted watermark by measuring its *NC* (Normal Correlation). For both measuring methods, the higher value indicates a better quality of the results obtained.

(a) *Lena* (b) *Pens* (c) *Flowers* (d) *ICEEI 2012*

Fig. 2: The Original testing images and the watermark logo

4.2. Performance comparison

In this experiment, the performance of proposed method has been evaluated for being compared with the previous method in [10]. Note that we tested the performance of the extracted watermark image by fixing a *PSNR* value at 35, 40 and 45dB once a time. Then, the *NC* value was evaluated and compared. As shown in the Fig. 3, our proposed channel performed better in all fixed *PSNR* values. For instance, at *PSNR* = 35dB, the NC value of the watermark extraction from *I*, *Q*, *H* and *S* channels were improved ≈ 0.075,0.075, 0.031, 0.54, respectively.

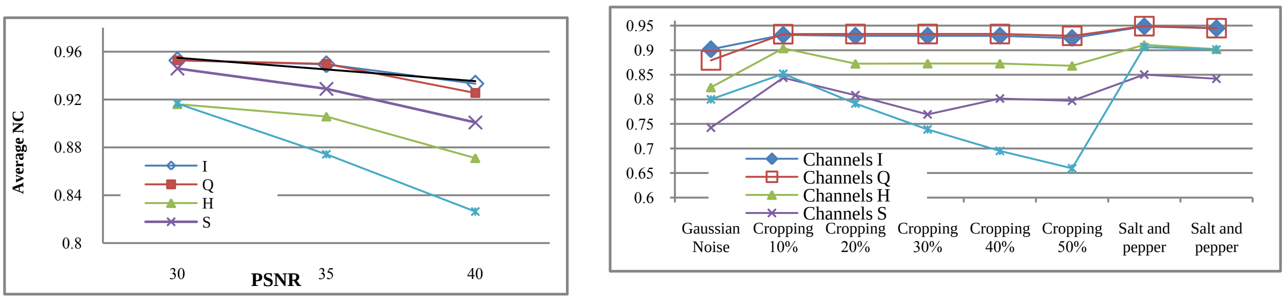

Fig. 3: The Performance Comparison between Color Channels

4.3. Robustness against Attacks

Finally, robustness of the proposed watermarking method has been evaluated by applying six different types of attack. The *NC* values from the attacked images were then computed and compared. A list of the attacks in the experiment consisted of additive Gaussian distributed noise with zero mean at various variances, the cropping attacks at various percentage and various cropping styles and the salt and pepper noise at various densities

Attack Types	**Average *NC* Values**				
	I	***Q***	***H***	***S***	***B***
Gaussian Noise Variance = 0.001	0.901617	0.879109	0.824097	0.742311	0.799956
Cropping 10%	0.930852	0.932599	0.90371	0.843802	0.851853
Cropping 20%	0.929103	0.932867	0.872526	0.808324	0.791499
Cropping 30%	0.929103	0.932867	0.872632	0.769381	0.738731
Cropping 40%	0.929103	0.932867	0.872632	0.80137	0.695009
Cropping 50%	0.924359	0.929121	0.868324	0.796867	0.659745
Salt and pepper Noise density = 0.01	0.948355	0.948878	0.91096	0.850422	0.906263
Salt and pepper Noise density = 0.03	0.944405	0.944734	0.902179	0.841957	0.900989

5. Conclusion

In this paper, we have proposed a new channel to embed and extract watermark by applying a multiple sections embedding technique. From the experimental results, *I* and *Q* channels from *YIQ* color space perform better than the other channels. In addition, even though *H* and *S* channel are not better that *I* and *Q* channel, their NC values are still greater than original Blue about 0.03 and 0.05 at *PSNR* 35 *dB*, respectively. Also, in the attack cases, we can observe that our proposed channels have a significant improvement in terms of *NC* value and readability with human eyes. We finally suggest that channel *I* and *Q* can be used for embedding and extracting the watermark signal instead of *B* channel.

6. References

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