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Weighted median algorithm applied to steganography in RGB images

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Abstract. In this paper, we present a novel method for hidden information in the wavelet domain. The proposed method uses the wavelet domain iterative center weighted median algorithm to estimate the noise areas of an RGB image. We propose to use the noise pixels as places to hidden information to provide good invisibility and fine detail preservation of processed images. The proposed method consistently identifies if the wavelets coefficients of an image contains noise pixels or not, this algorithm works with variances and standard deviations of the same wavelet coefficients of image. The experimental results from a known technique are compared with the proposed method to demonstrate its performance in terms of objective and subjective sense.

Keywords: Steganography, Wavelet domain, Iterative center weighted median algorithm.

1. Introduction

The steganography is the science of data hiding, and make it invisible for anyone else without authorization to be able to view or extract information [1], [2], the which employs one innocent way like a image, with the information inserted, the we can call stegoimage or host image and this information only accessible the final destination, with the correct permission. The final recipient might not have permission, are not aware of the existence of hidden information. A host image in his original composition is not altered, the embedded data are placed so that no one suspects. Two mains aim of the steganography techniques are: insertion capability and visual quality of the obtained stegoimage. The approach of a good steganographic algorithm allows a full recovery of the information inserted, and a small degradation of the stegoimage. The steganography algorithms are divided into two methods for manipulation information to insert, in the last years the spatial domain methods have been more common, where the principal task is to insert information in the least significant bit, representing each color component that integrates. Over time more sophisticated methods have emerged, which implies Frequency domain such as the Discrete Fourier Transform (DFT), the Discrete Cosine Transform (DCT) and the Discrete Wavelet

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Transform (DWT). Few algorithms use color images due to the complexity of calculus, however, they have more advantages as the ability to insert random data. The proposed steganographic method use the wavelet domain iterative center weighted median (WDICWM) algorithm [3]. We are proposing to use the noise pixels or areas detected by WDICWM the places to hide information that provides good invisibility and fine detail preservation of processed images. The proposed method identifies if the wavelets coefficients of an image contains noise or not, this algorithm works with variances and standard deviations of the same wavelet coefficients of image. The experimental results from a technique are compared with the proposed method to demonstrate its performance in terms of the obtained results.

2. Proposed Method

Our proposed algorithm is composed by two stages in the wavelet domain [3]. The first stage is based on the redundancy of approaches [4],[5] that smoothes low frequencies (LF) of image through of a double convolution operation (first of decomposition, and after reconstruction) of the coefficients and samples of stegoimage [2]. In the host image is important the frequency separation to locate the areas where the value of the pixels can be interpreted as noise. The second stage is the WDICWM that provides an analysis of the wavelet coefficients into multiple images (original and hide), and conducts a better estimate of the variance of such ratios of the noise areas of the image, which are places for hiding information not alter visibly the fine details of the image host[4],[5]. The proposed method is depicted in Figure 1.

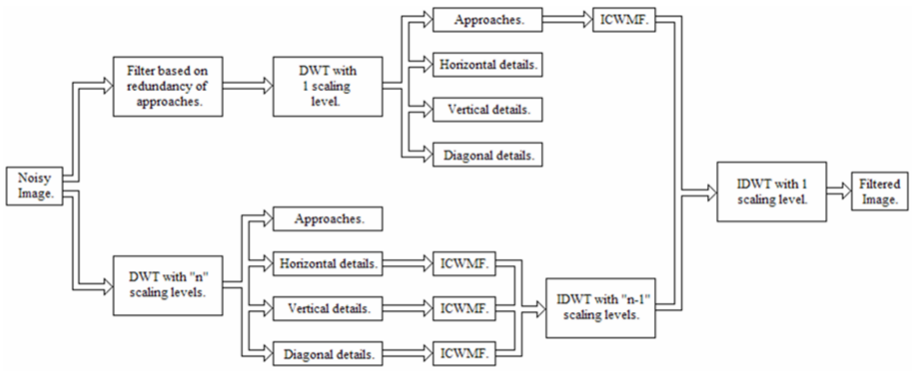


Fig. 1. Block diagram of the WDICWM algorithm.

The WDICWM is described below. The right place to hide information in an image pixel is given by the following equation:

$$G(k,i,j) = F(k,i,j) + N(k,i,j) \tag{1}$$

where *G(k, i, j)* represents the host image with pixels that can be interpreted as noise, *F(k, i, j)* denotes the host image without noise, *N(k, i, j)* represents the value for each pixel that is interpreted as noise, k indicates the depth of the image, in this case of RGB images k=3, and i, j represent the location of a pixel in the image by row and column, respectively.

So, for each frequency decomposition is applied a 3x3 kernel in the host image. Assuming that an image is corrupted by noise, a variance σ_A^2 can be obtained for each kernel. This variance can be estimated by the Median of Absolutes Deviations *(MAD)* for each one of the wavelet coefficients of the diagonal details using σ_{A-d}^2 in each one of the RGB components of the host image [3],[4],[5]:

$$MAD_n = med\{x_{i,j} - M_n\} \tag{2}$$

where $x_{i,j}$ are the values of 3x3 kernel of host image, and $M_n = med\{x_{i,j}\}$ is the median of pixels in the current kernel. To define a threshold value that is correct so as to select areas where are the pixels whose value is reached to consider such as noise, and hide information of the hidden image, then define a threshold value given by [3],[4]:

$$\lambda_{th} = \frac{\sum_s \lambda_s 2^{-s}}{\sum_s 2^{-s}} \tag{3}$$

In the case of this research it was chosen a new approach for this algorithm, instead of implementing the threshold given by the equation (3), we employ the standard deviation obtained for each subset of the kernel of the wavelet coefficients of host image λ_s given by the expression [3],[4]:

$$\sigma_A = \sqrt{\sum_{l=1}^{m} (x_l - x)^2 / m} \tag{4}$$

where x_l is the value of each coefficient taken from the row or column of the corresponding kernel, m is the total number of coefficients of the row or column and is the median value of which is obtained by the relationship:

$$\bar{x} = \sum_{l=1}^{m} x_l / m \tag{5}$$

From the new matrix of standard deviations λ_s, a recalculation is done for the new matrix λ_{th} for the wavelet coefficients belonging to the details of the image in each of its color components. This matrix λ_{th} together with the matrix λ_s, before obtained the values of standard deviation, are used to make a recalculation of the variances of the wavelet coefficients [2],[3],[4]:

$$\tilde{\sigma}_{gs}^2(i,j) = \begin{cases} \tilde{\sigma}_{gs}^2(i,j) & \lambda_s \geq \lambda_{th} \\ med\left(\tilde{\sigma}_{gs}^2(i,j)\right) & otherwise \end{cases} \tag{6}$$

where $\tilde{\sigma}_{gs}^2 = \tilde{\sigma}_s^2 + \tilde{\sigma}_n^2$, and $\tilde{\sigma}_n^2$ is the variance of the pixels considered as noise from the eq. (2).

Finally, within a scale we can distinguish the regions where the image information is dominant, those are regions where some pixels are considered as noise, these values are larger than the maximum energy level of the coefficients for each kernel from the image, then we can propose the following selection criteria: If the standard deviation of the current coefficient (central coefficient of the kernel) is larger or similar to the threshold defined by the region, then the found region is dominated mainly by pixels which it is not possible to insert the information of the hidden image, and not "noise". Otherwise, if the values of the pixels are smaller than the standard deviation, then in such area can be inserted the hide information.

3. Experimental Results

Many measures of quality or distortion in images are used in the processing of visual information, which are based on the difference in magnitude of the values of each pixel of the original image and modified image [6], thus giving a notion that has been modified the original image compared with the modified. Today the most common distortion measures are SNR and PSNR shown below, and are usually given in decibels (dB).

$$SNR = \frac{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\sum_{k=0}^{2} I(i,j,k)^2}{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\sum_{k=0}^{2} \left(I(i,j,k)-K(i,j,k)\right)^2} \quad (8)$$

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \quad (9)$$

where, MAX_I^2 is the maximum pixel value from an original image, $I\ (i,j,k)$ is the original image and $K(i,j,k)$ is the modified image.
The Mean Square Error (MSE) is given by:

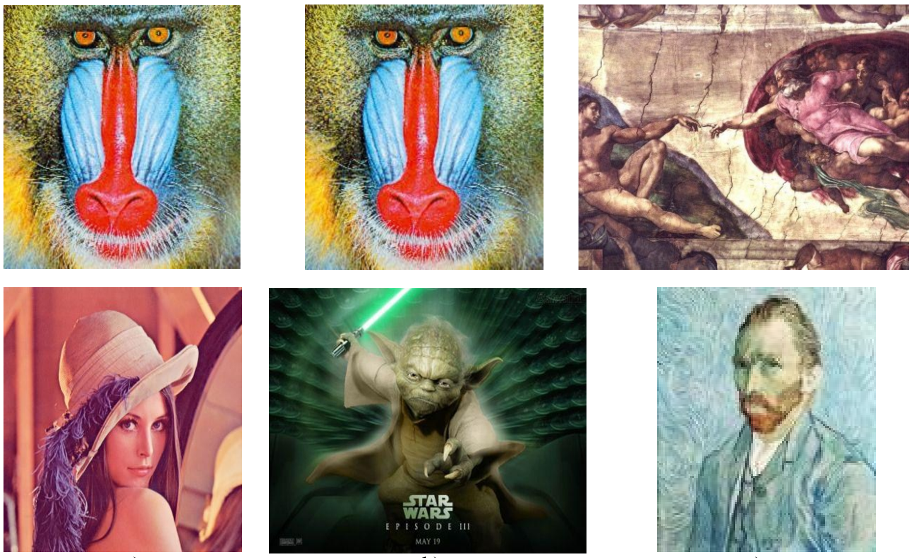
$$MSE = \frac{1}{3mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\sum_{k=0}^{2} \left\| I(i,j,k)-K(i,j,k)\right\|^2 \quad (10)$$

The popularity of these measures is due to their facility of calculation. In the last years, recent researches have focused on the metric distortion suitable for human visual system [6,7]. The masking of the peak signal to noise is one of them is given.
We also use the Original Image Correlation (OIC), the Original Image Energy (OIE), and the Modified Energy Image (MEI) as measures of quality in the following tests.
Table 1 shows the performance results by use the "Baboon" and "Sunflowers" images as host images and "Lena", "Joda" and "Van Gogh" images as hide images, where OIC is the Original Image Correlation, OIE is the Original Image Energy, and MEI is the Modified Energy Image. Where the correlation is indicates the strength and direction of a linear relationship between two random variables, for example: values of the pixels of the image to hide and the host image.
The results from test A, B, and C were obtained with our proposed method, and tests D, E, and F by using a comparative method. Figure 2 presents the visual results for different tests using our proposed method. We can observe from the results that the

proposed method provides good performance in terms of objective and subjective sense in comparison with the method proposed in reference [8].

Table 1. Performance results for different tests.

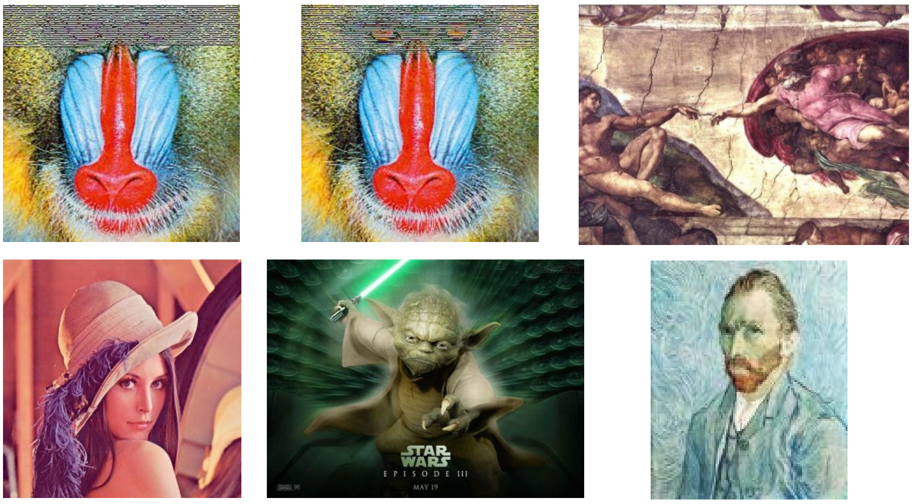
	Test	PSNR db	OCI %	OIE	MEI	MAE
A	Host image	44.949	99.7	4.40E09	4.40E09	2.61
	Hide image	52.907	99.9	6.72E09	6.72E09	1.51
B	Host image	45.037	99.9	4.44E09	4.44E09	2.58
	Hide image	47.070	99.9	15.84E09	15.85E09	1.11
C	Host image	46.150	99.8	19.32E09	19.34E09	2.05
	Hide image	47.070	99.8	12.45E08	12.44E08	70.19
D	Host image	43.714	72.4	4.44E09	4.82E09	18.47
	Hide image	52.907	99.9	6.70E09	6.71E09	10.72
E	Host image	43.423	76.1	4.44E09	4.73E09	18.51
	Hide image	47.892	99.9	15.85E08	15.87E08	10.72
F	Host image	45.959	99.0	31.94E09	31.99E09	2.49
	Hide image	47.194	99.8	12.46E09	12.45E09	85.10



a) b) c)

Fig. 2. Visual results for different tests by using our proposed method, the host and hide images are displayed from top to bottom a) column of test A, b) column of test B, and c) column of test C.

Figure 3 shows the visual results by using the method proposed in ref. [8] according with Table 1 and Figure 2. From the results presented in Table 1 and Figures 2 and 3, one can see that the proposed method provides better capabilities in terms of objective and subjective sense in comparison with the comparative method.



a) b) c)

Fig. 3. Visual results for different tests by using a comparative method, the host and hide images are displayed from top to bottom a) column of test D, b) column of test E, and c) column of test F.

4. Conclusions

In this paper, we proposed a new steganographic method for embedding a RGB image into another RGB image while providing high hiding capacity and retaining high image quality. It was found that the wavelet domain iterative center weighted median algorithm presents good results when it is applied to steganography in images. It can be seen in Table 1 where the values obtained for each test made to the images that the remains almost constant the OCI, OIE and MEI. Unlike other method [9, 10] the value of the variances for each kernel is different, so it does not follow a fixed pattern to hide the information, since being a chaotic algorithm can not be easily interpreted in the same way, wishing to manipulate the information inserted. We compared the image quality and hiding capacity of the hidden image and host image of the proposed method with those of the scheme in [9],[10].According to the experimental results, the image quality of the proposed method was better than that of the scheme in [9], [10]. The PSNR, OIC, MEI values of the stego-images were all higher than those in the scheme in [9], [10]. The hiding capacity of the proposed method is greater than that of other compared schemes [9], [10]. The proposed method is a secure steganographic method providing high hiding capacity and high image quality, because when working with random processes will always be different every time you use or transmit the host image and hidden image. Unlike other schemes based on the modification of the color palette or quantization vectors [9], [10].

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