Steganography in RGB Images using an Energy Adjustment

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Abstract. When processing RGB images for the implementation of steganographic algorithms, it is imperative to study the quality of the host image and retrieved image, since it is typically used digital filters, reaching visibly deformed images. The measures used are qualitative and quantitative related to the multichannel of Human Vision System (HVS). When this algorithm is employed we see that the numerical calculations performed by the computer cause errors and alterations in the images chosen, so we apply a scaling factor depending on the number of bits of the image to adjust these errors.

Keywords: HVS, steganography, scaling factor.

1. Introduction

The information concealment concerns to the process of integrating an element of data or information into music, video and/or images [1,2]. This ability to hide can be divided into two categories, according to the relationship of the image to hide to the host image, known as steganography and watermark. In steganography, the hidden information does not have relationship with the host image. The information contained in the host image is just a distraction to the receiver, so this is not of much interest in its full recovery, but the host image must have the minimum quality, considered because any relief, color or misplaced characteristic can cause some suspicion and is susceptible to extract the hidden information without authorization from the transmitter. The most important information is the hidden, which must have a full recovery.

This information does not substantially alter the image host, however, is susceptible to Human Vision System (HVS). The host image with the hidden information is known as stegoimage. Typically there are two types of stegoimages: in the Space Domain and Frequency Domain. The most common method for Space Domain is the Last Significant Bit (LSB), which is the modification of the least significant bit in each pixel of the image [3]. For the Frequency Domain as: the Discrete Fourier Transform (DFT), the Discrete Cosine Transform (DCT) and Discrete Wavelet

Transform (DWT), which are used to transform the values of a pixel in the spatial domain within the coefficients of the frequency [4]. A number of factors causing certain sensitivity to the effects of noise to the human eye are the luminance, the frequency band, texture and/or proximity to an edge. The human eye is less sensitive to noise in high frequency sub band [5]. The human eye's sensitivity to noise in the textures that conforms an image is less if is closer to the edges. Based on these observations, are developing an adaptable model for quantization of the wave coefficients of image compression [5]. With some modifications, Barni et al. (2001) developed a concealment function for calculating the weight of the factors to integrate into the pseudo random binary sequence in the high frequency components of the host image. For this work, we use the steganographic method implemented in [6]. In this work to ensure that, with the first technique, it is not affected the host image and hidden information is not visible to the HVS, it is purposed a scaling factor that depends directly on the number of bits of the host image. Applying this scale factor for energy conservation by the host image, there by avoiding any substantial alteration to be visible to the HVS.

2. Proposed Method

The algorithm proposed here for the implementation of steganography is based on the DWT [7]. In the optimization and evaluation of compression algorithms in digital images, the SNR and PSNR are the most frequently used to evaluate the quality of these images [8]. However, the use of qualitative measures of the image are based on the properties of HVS, then the models usually are embedded into HVS sensitivity to light, sensitivity to spatial frequency and masking impact [9].Thus, in applying the steganographic algorithm based on wavelets, is got compression ratio. If we apply the wavelet Haar, the image resolution is divided into two submatrices known as: approximations and details [10, 11]. If we use the wavelet Daubechies4 image resolution is divided into 4 submatrices called: approximations (a), horizontal (h), vertical (v) and diagonal (d), see Figure 1, which provide a certain amount of energy [10, 11] to the image, being the matrix (a) the most important because it contains more information [10, 11]. In this subdivision of images the steganographic algorithm is implemented, to apply it only used the sub matrix "h" and other submatrices discarded.

Discrete Wavelet Transform DWT is closely linked to the analysis of multi-resolution, that is, the observation of the signal at different frequencies [12], which allows to have a broader knowledge of the signal and facilitates the rapid calculation when the family of wavelets is orthogonal [13-15]. The discrete signal $x[n]$ must pass through a series of mirror filters banks in quadrature [11, 12, 14], these filters are: Low Pass Filter (LPF) and High Pass Filter (HPF). The signal from each filter is decimated by a factor of 2. This process of filtering and decimation in a continuous way is known as sub-band coding, see Figure 2.

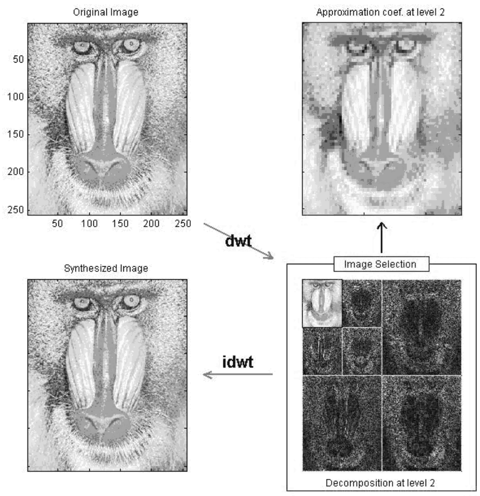

Fig. 1. Wavelet decomposition.

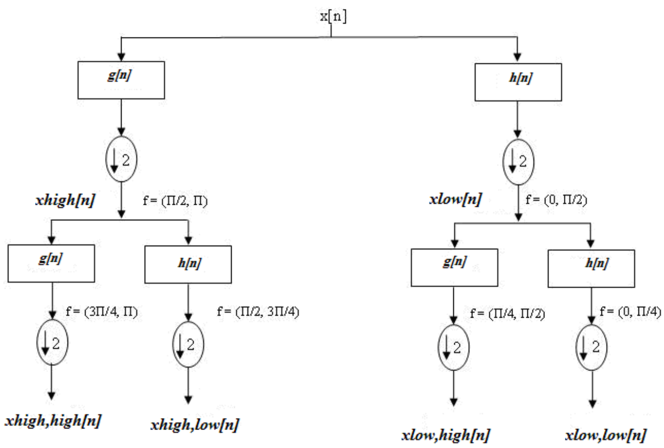

Fig. 2. Filters bank for encoding sub-bands.

This operation is interpreted as follows:

$$x_{high}[k] = \sum_{n} x[n] \bullet g[2k-n] \quad (1)$$

$$x_{low}[k] = \sum_{n} x[n] \bullet h[2k-h] \quad (2)$$

where $x_{low}[k]$ and $x_{high}[k]$, are outputs of the LPF and HPF, respectively; *g[2k-n]* and *h[2k-h]* represent the response to the momentum of HPF and LPF, respectively, sub-sampled by a factor of 2 as expressed in Figure 2 [12]. The DWT decomposes a discrete signal into two sub-signals of half the original length. A sub-signal is known as the approaches and the other sub-signal is known as the details [11]. The first sub-signal $a^1 = (a_1, a_2, \cdots, a_{m/2})$, for the signal *x* is obtained making the average of the signal as follows: The first value a_1 is calculated by taking the first set of values vector $x[m]: (x_1 + x_2)/2$ and multiplying it by $\sqrt{2}$, that is, $a_1 = (x_1 + x_2)/\sqrt{2}$, similarly $a_2 = (x_3 + x_4)/\sqrt{2}$, etc. The precise formula is:

$$a_{m/2} = \frac{x_{2m-1} + x_{2m}}{\sqrt{2}} \tag{3}$$

where *m* is the total number of vectorial elements. The other sub-signal is also known as the first fluctuation of the signal *x* is denoted as: $d^1 = (d_1, d_2, \cdots, d_{m/2})$ and is calculated by taking the difference between the first pair of values of $x, (x_1 - x_2)/2$ and then is multiplied and divided by $\sqrt{2}$, and so on. The exact formula is:

$$d_{m/2} = \left(\frac{x_{2m-1} - x_{2m}}{\sqrt{2}} \right) \tag{4}$$

where *m* is the size of the vector. After applying the DWT are gotten two vectors, which are *approximations* and *details* obtained, with a length of half the original vector. Finally, continuing the recovery of the vector:

$$f[n] = \left\{ \frac{a_1 + d_1}{\sqrt{2}}, \frac{a_1 - d_1}{\sqrt{2}}, \cdots, \frac{a_{n/2} + d_{n/2}}{\sqrt{2}}, \frac{a_{n/2} - d_{n/2}}{\sqrt{2}} \right\} \tag{5}$$

We note that the terms a_1 y d_1 in (4) and (5) can be interpreted as follows $\varepsilon_{(a^1|d^1)} = a_1 + \cdots + a_{n/2} + d_1 + \cdots + d_{n/2}$:

$$\begin{aligned} a_1 + d_1 &= \left[\frac{f_1 + f_2}{\sqrt{2}} \right]^2 + \left[\frac{f_1 - f_2}{\sqrt{2}} \right]^2 \\ &= \frac{f_1^2 + 2 f_1 f_2 + f_2^2}{2} + \frac{f_1^2 - 2 f_1 f_2 + f_2^2}{2} = f_1^2 + f_2^2 \end{aligned} \tag{6}$$

and similarly for each set of vectorial *approaches* and *details* [11]. So, when it is mentioned the conservation of energy in wavelets, are mentioned also the factor $1/\sqrt{2}$ [11]. By applying the steganographic algorithm to the *h* sub-matrix, it is necessary to use the scaling factor, but as the work is with a 8-bit RGB image, this scaling factor is closely related to energy conservation applied the theory of wavelets, for grayscale images as shown in most applications. However, for RGB images is proposed as follows: $1/\sqrt{2^n}$, where *n* is directly dependent on the number of bits that integrate the image.

3. Experimental Results

Many of the distortion measures or quality measures used in the images during the visual information processing belong to the group of measures of difference in distortion [7], which are based on the difference between the original and modified images. At present the most common distortion are the signal to noise relation *SNR* and the peak signal to noise relation *PSNR* are shown below.

$$SNR = \frac{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\sum_{k=0}^{2} I(i,j,k)^2}{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\sum_{k=0}^{2} \left(I(i,j,k) - K(i,j,k)\right)^2} \tag{7}$$

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \tag{8}$$

where, MAX_I^2 is the maximum value of a pixel of the image, *I (i,j,k)* is the host image and *K(i,j,k)* is the modified image (host image with the information inserted), and $MSE = \frac{1}{3mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\sum_{k=0}^{2}\left\| I(i,j,k) - K(i,j,k)\right\|^2$ is the Mean Square Error. The popularity of these measures is due to their easy calculation; however, they do not give a comprehensive overview for the operation HVS. In recent years, research has focused on the metric distortion suitable for human visual system [7]. The Masking peak signal to noise ratio *MPSNR* is given by:

$$MPSNR = 10\log_{10}\frac{255^2}{E^2}, \text{ vdB} \tag{9}$$

where *E* is the distortion calculation. This measure is not exactly in dB's, but are called visual decibels vdB's. It also uses the standardization of quality factor *Q* set by the ITU-R Rec. 500 [7],

$$Q = \frac{5}{1 + N \times E} \tag{10}$$

where *N* is usually chosen as the reference for the distortion that corresponds to the level of quality given in Table 1.

Table 1. Recommendation Of ITU-R Rec. 500, Ranges Of Quality.

Range	Degeneration	Quality
5	Imperceptible	Excellent
4	Perceptible, but not annoying	Good
3	A little annoying	Acceptable
2	Annoying	Poor
1	Very annoying	Very bad

and for the assessment of the preservation of the details using the mean absolute error (*MAE*) given by [16]:

$$MAE = \frac{1}{MN3}\sum_{P=1}^{3}\sum_{i=1}^{M}\sum_{j=1}^{N}\left|\left(f(p,i,j) - \hat{f}(p,i,j)\right)\right| \tag{11}$$

where, *M*, *N* is the image size and p the depth of the same in this case $p = 3$, $f(p,i,j)$, is the original image and $\hat{f}(p,i,j)$ the retrieved image.

Some tests were conducted with 8-bit RGB images to show our mentioned scaling factor in this investigation. As mentioned previously, the filter can distort the images, as will be shown in subsequent tests applied filters to distort the host image with the DWT. However, applying the proposed scaling scheme can be seen a clear improvement in visual images. Table 2 shows the performance results in the case of different *n* values in the scaling factor by use the "Mandrill" image as host image and "Peppers" image as hide image, where COI is the Correlation with the Original Image, OIE is the Original Image Energy, and MIE is the Modified Energy Image. From these results, one can see when the *n* value increases the performance results increase too. Figure 3 presents the visual results according to Table 2. We observe from this figure that the best results are obtained when *n*=9. Where n represents the number of bits resolution of the image to hide.

Table 2. Performance results for different values of *n*.

N		PSNR db	COI %	OIE	MIE	MAE
n=0	Host image	35.28	80.00	44.00 E 09	5.20 E 09	12.70
	Hide image	25.42	32.37	6.192 E 09	16.74 E 09	4.21
n=2	Host image	34.78	75.18	4.44 E 09	4.76 E 09	17.35
	Hide image	33.62	39.10	6.192 E 09	8.37 E 09	5.76
n=5	Host image	33.05	88.11	4.44 E 09	4.49 E 09	13.50
	Hide image	48.33	99.90	6.192 E 09	6.40 E 09	4.48
n=9	Host image	33.96	97.09	4.44 E 09	4.45E 09	6.79
	Hide image	48.33	99.90	6.192 E 09	6.38 E 09	2.25

Table 3 shows the performance results in the case of use *n*=10 in the scaling factor. Figure 4 presents the visual results according with Table 3. We also present the error images. The proposed scaling factor $1/\sqrt{2^n}$ for each test presents a different result as can be seen in the previous tests, the scaling factor does not affect the steganographic algorithm and preserving the energy of images. As can be seen also in the image to the right of the figure 4 the difference in values between the host image and the recovered image is approximately zero. Then the hidden information is almost imperceptible.

a) b) c)

Fig, 3. Visual results for different values of *n* in the scaling factor, a) column with *n*=2, b) column with *n*=5, and c) *n*=9.

Table 3. Performance results in the case of *n*=10 in the scaling factor.

Host image “Mandrill”	Hide image “Peppers”
Quality Factor (Q): 5	Quality Factor (Q):5
MPSNR:48.131 vdB	MPSNR: 48.131vdB
PSNR: 35.002 db	PSNR: 48.33 db
Correlation with the Original Image: 98.7 %	Correlation with the Original Image: 99.9%
Original Image Energy l:4.43 E 09	Original Image Energy: 6.192 E 09
Modified Energy Image:4.45 E 09	Modified Energy Image:6.38 E 09
MAE: 4.87	MAE: 1.61

4. Conclusions

It was checked that RGB images are altered, in their energy contribution in each sub-matrix of wavelet decomposition when the steganographic algorithm is applied. It is known that the value of $1/\sqrt{2}$ is the key Factor in the adjustment of the wavelets energy this adjustment value has been applied only in gray scale images tests. However, the energy conservation factor mentioned above is not valid for true color images, such as formed by 3 sub matrices (RGB) which separately provides some level of energy, must have a value close to the total energy calculated up to the image, because if is not right or there are energy gap in the components, the images may have a poor display as: distortion. By applying the proposed scaling factor $1/\sqrt{2^n}$, where *n* represents the number of bits that integrates each image, there is an adjustment factor for the energy input in each submatrix. It is also noted as when changing the value of n, is adjusting sharpness, image clarity and provides a visible improvement of the visual image.

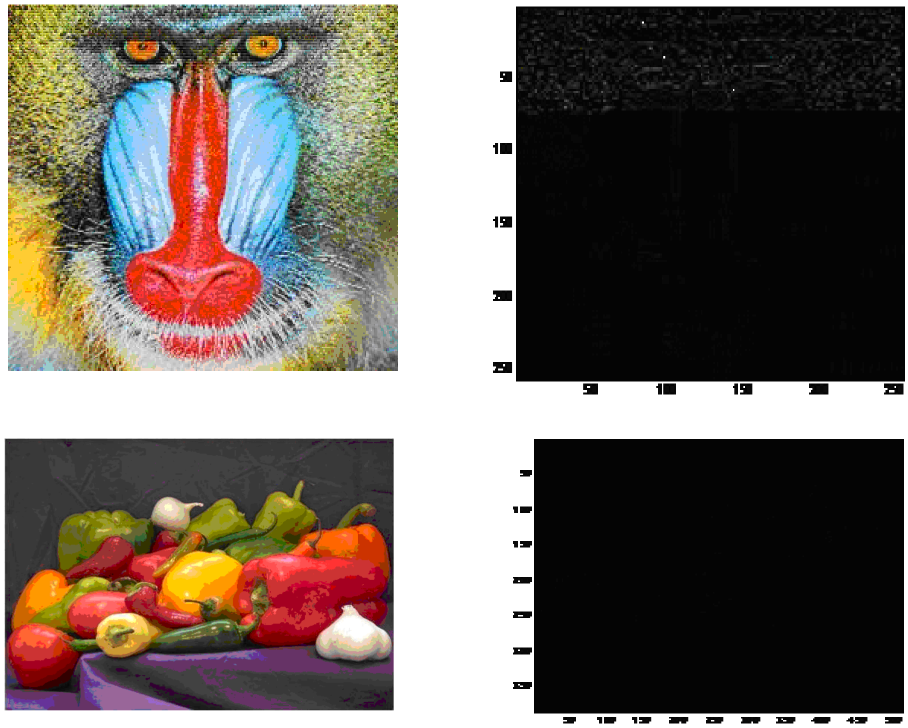

Fig. 4. Visual results in the case of n=10.

5. Acknowledgements

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