FEATURES OF USING WATERMARKS PROTECTION FOR THE REAL DIGITAL PHOTOREALISTIC IMAGES

Nataly V. Voloshina, Ph.D

Saint-Petersburg State University of Aerospace Instrumentation,
Saint-Petersburg, Russia
Phone: +7(812) 4947052
Nataliv@yandex.ru

Abstract

In this paper the problem of the design of the copyright protection systems for the digital video images is addressed. The conducted research is based on the method of the digital watermarks injection into the source image. The methods to improve the efficiency of the steganographic scheme for the photorealistic images are introduced, accounting for the proper consideration of the distortion perception by the human vision system.

Key words: steganography, digital watermarks, digital image processing, artifacts visual perception.

I. INTRODUCTION

The problem of the copyright protection of digital data is especially critical in the modern world, mainly due to the simplicity of the copy and transmission processes that involve this kind of data.

More specifically, digital images and video flows are the important examples of the vulnerable objects. There are two main approaches to their copyright protection: involving cryptography or steganography methods, respectively. The former approach assumes the data encryption to be evident and to rely on the strength of the cryptographic scheme. As a side-effect of this process we notice that the encrypted image changes the format of its representation. The latter approach involves the concealment of the additional information an image contains. This way the necessary copyright information becomes embedded into the image. Additionally, it is important to ensure the resistance of this injected information to various distortions. A renowned technique that belongs to the steganographic approach is digital watermarking.

A digital watermark (DWM) may be embedded into the source image either directly into brightness/chromatic components or by some modification of the coefficients of an image transformation applied to the source (container) image. The practice shows that the second approach is more reliable in the presence of the container image distortions.

The general stegosystem structure is illustrated in Fig.1.

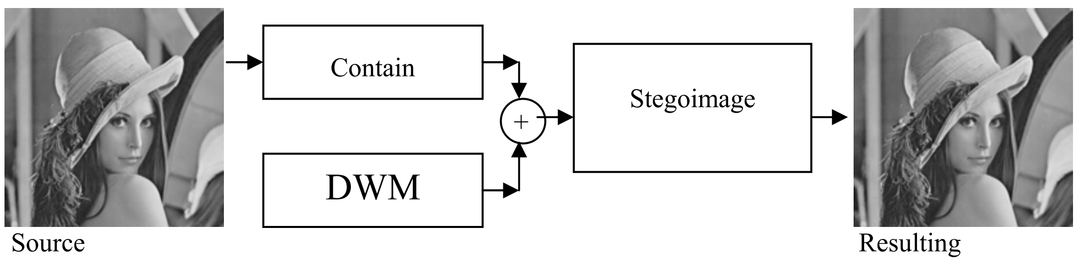

Fig. 1. General stegosystem structure

Firstly, a container is created from the source image, in which a DWM is embedded. Secondly, the resulting stegoimage is used as a part of the source image. The target of the above transformation is to embed the copyright data into the resulting image and to avoid its visual change in comparison to the source image. The extraction of a DWM is performed in the reverse order.

In the real systems much more sophisticated schemes of DWM injection are used in order to complicate the stegoanalysis. Such schemes involve the use of secret keys at the stages of the container creation as well as the DWM injection. Fig.2 demonstrates the scheme, which is considered in the current research.

The process of the DWM injection can be viewed as a distortion of the source image. Accounting for the fact that the steganographic schemes must conceal the copyright information insertion in the source image, a natural requirement for the watermarking scheme is to make DWMs hidden for the human vision. The quality of the distortions concealment is determined by the nature (features) of the distortion itself, the type of the source image and the features of the human vision system (HVS).

The current research addresses the perception of the DWMs in the digital images by the HVS. The existing approaches are analyzed and some additional measures to improve the quality of the digital image stegosystems are demonstrated.

II. DWM INJECTION SCHEME ANALYSIS

Below a practical DWM injection scheme is considered (see Fig.2), which complicates the stegoanalysis procedure of the image.

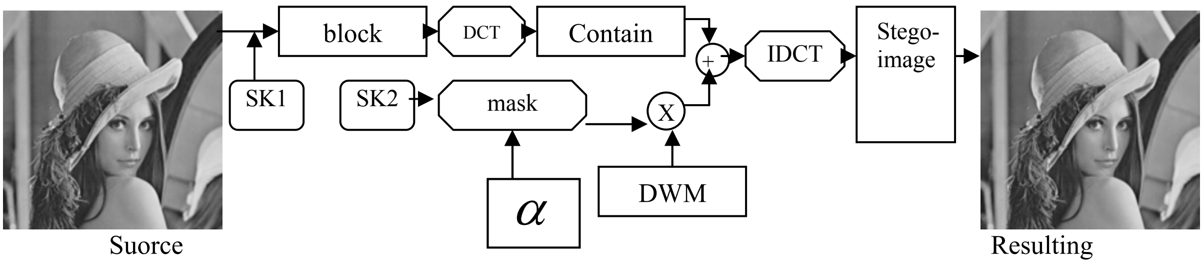

Fig.2. Practical DWM injection scheme

The main features of the scheme are:

1. A block of the discrete cosine transform (DCT) of the source image (frame) is used as the container for a DWM. The DCT and the inverse DCT formulae are demonstrated below:

DCT

$$DCT_{ij} = \frac{2}{R} \cdot c(i) \cdot c(j) \cdot \sum_{k=0}^{R-1} \sum_{p=0}^{R-1} L_{kp} \times$$
$$\times \cos\left[\frac{\pi}{R} \cdot i \cdot \left(k + \frac{1}{2}\right)\right] \cdot \cos\left[\frac{\pi}{R} \cdot j \cdot \left(p + \frac{1}{2}\right)\right]$$

where R – size of the container frame; L – pixels luminance of the container frame.

IDCT

$$L_{kp} = \frac{2}{R} \cdot \sum_{i=0}^{R-1} \sum_{j=0}^{R-1} \cdot \cdot c(i) \cdot c(j) \cdot DCT_{ij} \times$$
$$\times \cos\left[\frac{\pi}{R} \cdot i \cdot \left(k + \frac{1}{2}\right)\right] \cdot \cos\left[\frac{\pi}{R} \cdot j \cdot \left(p + \frac{1}{2}\right)\right]$$

2. The secret key (SK1) determines the pseudorandom choice of the position of the container frame (FC) within the source image. The addition of the SK1 complicates the search of the stegoimage within the copy of source image.

3. The secret key (SK2) determines the pseudorandom masking signal that is used to secure the contents of an injected DWM. The masking procedure is given by the following expression:

$$MWM_{lk} = WM_{lk} + \alpha * M_{lk}$$

where l, k – current element position; MWM – masked watermark; WM –initial watermark; α – pressure factor.

The DWM injection procedure is described by the next formula:

$$WMDCT_{ij}^{FC} = DCT_{ij}^{FC} + MWM_{pq}$$

where i, j – current container element position; $WMDCT$ - watermarked DCT block; DCT – DCT block; MWM – masked watermark; FC – container frame.

The DWM extraction process is illustrated in Fig.3 and involves the knowledge of the resulting and source images as well as both secret keys SK1 and SK2.

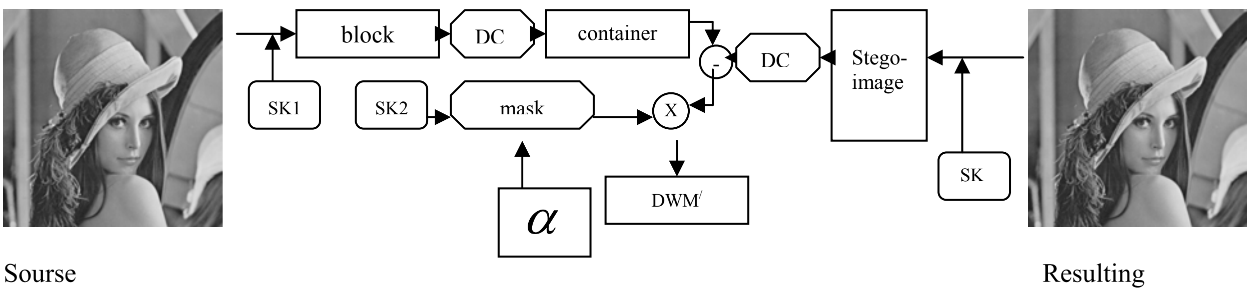

Fig.3. Scheme of the DWM extraction process.

We notice that in the considered scheme the DWMs are embedded into the luminance component of the source image for the purposes of generality. Importantly, it improves the reliability of the watermarking procedure by reducing the probability of the accidental removal of a DWM by the standard image processing techniques (e.g. lossy image compression and filtering).

However, the pseudorandom nature of the choice of the container frame position within the source image and the mask generation may lead to the artifacts visualization. Consequently, it becomes possible for the HVS to determine the position of the embedded stegoimage within the resulting image. Clearly, this situation contradicts the principles of steganography and should be avoided.

The paper presents the results of the research performed to determine the influence of the stegosystem parameters on the DWM injection quality and the artifacts visualization process.

III. RESEARCH RESULTS

A program complex was designed and implemented to enable the analysis of the DWM injection scheme described above. The main features of the discussed complex are:

1. The choice of the source image and the setting of the position of the container frame within it. The positioning of a DWM within the container matrix (by altering the shift value Δ) and the changing of the DWM pressure factor α.

2. The performance of a step-by-step visual control of the main stegosystem elements (the source and the resulting images, the initial and final DWMs and masks, container frame and stegoimage).

3. The numerical evaluation of the distortion level $PSNR$ introduced by the DWM injection for the entire image, the container frame and the DWM itself by the following formula:

$$PSNR = 10\lg \frac{D^2 \cdot n^2}{\sum_{i=1,\, j=1}^{n,n} (L_{ij} - L'_{ij})^2}$$

where D – dynamic range (255 for grayscale image); n – square image size; L_{ij} – pixels luminance of sours.

The estimation of the DWM recognition possibility by the below expression:

$$P = \frac{N}{n} \times 100\%$$

where n – number of initial DWM image elements; N – number of resulting DWM image elements that equal to initial one.

The main research restrictions are as follows:

1. The standard grayscale (non-synthesized) images were taken as the source images.

2. A block of the source image of size R was taken as the container frame, where R is divisible by 8 (8×8, 16×16, 32×32).

3. A synthesized black-and-white image of size $r \le R$ was taken as a DWM. Additionally, the DWM images were semantically meaningful.

4. A similar pseudorandom black-and-white image was used as the mask (as determined by the SK2). Also DWM image is a semantic one.

5. Pressure factor α is a positive integer $\alpha > 0$

Some results of the conducted research are summarized in the below tables.

The standard test image (Lena.bmp) was analyzed for the DWM size of $r = 8$ and the container frame size of $R = 16$. The results are given for the two scenarios. In the first one the DWM was injected into the DCT block without any offset from the zero DCT coefficient $\Delta = 0$, while another scenario considered the offset by 8 elements $\Delta = 8$. Therefore the above scenarios studied the injection of a DWM into the low frequency and the high frequency regions, respectively. Pressure factor $\alpha \in \{1,3,5,7\}$.

Additionally the quality of the stegosystem was analyzed for different distortions. These distortions included the most popular digital image transformation procedures, namely, lossy image compression smoothing and edge sharp filtering. Both pre-distortions and post-distortions were addressed.

All the below results are demonstrated for the different values of the DWM pressure coefficients α. It could be noticed that for $\alpha > 0$ the artifact visualization is high, which makes further stegosystem analysis for such values impractical.

IV. SUMMARY AND CONCLUSIONS

Summarizing the results of the conducted research the following propositions may be formulated:

1. For the stegosystem without additional distortions.

Although the overall quality of the resulting image is decreased after the DWM injection, it remains unnoticed and lies under the perception threshold of the HVS. As the value of the pressure factor α increases an additional quality decrease is noticed. The use of the masking signal further decreases the image quality on average. Shifting of a DWM in its container may slightly decrease the quality parameters of the image; however, this decrease is not visually noticed. This fact is explained by the reduced sensitivity of the HVS to the high frequency distortions. The probability of a masked DWM recognition is considerably lower than that without masking. Therefore, the masking allows for avoiding the DWM extraction from the resulting image given the illegal copy of source image is available.

The visual expertise of the resulting images considered the images with the equal numerical quality parameters but different positions of DWMs. Those images that include the DWM injected into the semantically meaningful regions are more frequently recognized by the HVS as containing artifacts.

2. For the stegosystem with additional distortions.

The presence of the pre-distortions does not influence the overall quality of the stegosystem operation. Consequently, the quality of the source image is irrelevant to the stegosystem operation.

Table 1

JPEG compression distortion

α			Without additional distortion		JPEG	
			(0;0)	(7;7)	(0;0)	(7;7)
1	MW	$PSNR^{SI}$, dB	80,555	80,357	52,551	54,106
		$PSNR^{StI}$, dB	50,452	50,254	47,804	47,772
		P^{WM},%	100	100	81,25	34,375
	MWM	$PSNR^{RI}$, dB	79,787	80,702	54,024	49,921
		$PSNR^{SI}$, dB	49,684	50,599	40,662	46,898
		P^{MWM}, %	35,9375	34,375	35,9375	34,375
		P^{WM}, %	100	100	100	100
3	MW	$PSNR^{SI}$, dB	75,745	75,122	40,7	40,696
		$PSNR^{StI}$, dB	45,642	45,019	41,686	41,331
		P^{WM},%	98,4375	34,375	87,5	34,375
	MWM	$PSNR^{RI}$, dB	73,779	74,173	52,51	52,536
		$PSNR^{SI}$, dB	43,676	44,07	43,128	43,597
		P^{MWM}, %	35,9375	34,375	35,9375	34,375
		P^{WM}, %	100	98,4375	100	98,4375
5	MW	$PSNR^{SI}$, dB	71,697	71,123	52,506	38,56
		$PSNR^{StI}$, dB	41,594	41,02	41,285	40,279
		P^{WM},%	98,4375	34,375	98,4375	50
	MWM	$PSNR^{RI}$, dB	69,851	70,109	52,536	52,466
		$PSNR^{SI}$, dB	39,748	40,006	43,597	39,802
		P^{MWM}, %	35,9375	34,375	50	50
		P^{WM}, %	100	98,4375	51,5625	51,5625
7	MW	$PSNR^{SI}$, dB	68,819	68,438	40,468	40,467
		$PSNR^{StI}$, dB	38,716	38,335	37,186	36,814
		P^{WM},%	100	34,375	100	34,375
	MWM	$PSNR^{RI}$, dB	67,181	67,263	52,379	52,426
		$PSNR^{SI}$, dB	37,078	37,16	37,014	37,183
		P^{MWM}, %	35,9375	34,375	35,9375	34,375
		P^{WM}, %	100	98,4375	100	98,4375

Table 2

Smoothing and edge sharp filtering distortion

α			Edge sharp filtering		Smoothing	
			(0;0)	(7;7)	(0;0)	(7;7)
1	MW	$PSNR^{SI}$, dB	45,904	45,924	54,048	54,106
		$PSNR^{StI}$, dB	42,729	41,579	41,997	47,772
		P^{WM},%	71,875	59,375	98,4375	82,8125
	MWM	$PSNR^{RI}$, dB	45,907	45,905	54,022	54,106
		$PSNR^{SI}$, dB	43,09	41,549	40,662	47,067
		P^{MWM}, %	34,375	32,8125	35,9375	34,375
		P^{WM}, %	92,1875	90,625	100	82,8125
5	MW	$PSNR^{SI}$, dB	45,885	36,674	16,432	37,276
		$PSNR^{StI}$, dB	38,095	33,168	15,851	44,746
		P^{WM},%	98,4375	96,875	100	82,8125
	MWM	$PSNR^{RI}$, dB	45,89	45,821	54,101	54,119
		$PSNR^{SI}$, dB	36,58	32,209	49,807	50,54
		P^{MWM}, %	35,9375	32,8125	35,9375	34,375
		P^{WM}, %	100	90,625	84,375	82,8125

The presence of the post-distortions results in the following effect. The increase in the pressure coefficient values does not provide the increase in the DWM recognition probability. However, this increase leads to the decrease in the overall quality of the resulting image. By contrast, the use of masking may increase the DWM recognition probability.

Summarizing the above, we conclude that for the considered scheme masking is preferable together with the relatively small (less than 5) values of the pressure coefficient for the high quality of the stegosystem operation under the standard post-distortions. Under this circumstances it is not necessary to control additionally the position of a DWM, such as this position avoids coincidence with the semantically meaningful parts of the source image.

SUBSCRIPT

DWM – digital watermark
HVS – human vision system
DCT – discrete cosine transform
IDCT – inverse discrete cosine transform
WM – watermark
MWM – masked watermark
SI – source image
StI – stegoimage
PSNR –peak signal noise ratio
P – DWM recognition possibility

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