Color Image Watermarking Robust to JPEG Compression

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Introduction

With the growth of networked multimedia systems, the need of secure communication and data transfers go increasingly. For applications dealing with images, the watermarking can be an answer to such problems. A watermark is an invisible information inserted on an image before transmission over a network.[1,2] At the reception this information can be extracted from the watermarked image for several needs.

In this paper we tackle the problem of transmitting an invisible message inside the image data. The length of the transmitted message can be relatively important, in practice, longer than just for identification. We have designed here a new method for color image watermarking working in the spatial domain. Because of the compressed network transmission, the watermark should be robust to JPEG compression. We use here RGB inforation in order to increase the robustness of the watermark.

Grey Level Spatial Watermarking of Image Least Significant Bits

The most common spatial method for image watermarking works on the least significant bits (LSB), modifying them according to the bits of the message.[4,5] These methods are based on the assumptions that the LSB data are insignificant in regard to the noise, and that the human vision system is sensitive to roughly 64 grey levels. Unfortunately, the modification of just the LSB at each pixel is not robust enough for applications involving image compression. For example JPEG compression removes high frequency signal data and a watermarked message on the LSB is lost, in this operation.

To enhance the robustness of such approach, we consider, as the JPEG compression algorithm do, 8×8 blocks of pixels. In each block we modify the LSB of the mean of the grey levels of the block such that the LSB of its value corresponds to a bit of the message. We investigate in this section the robustness of watermarking the least significant bits, for the first, second and third bit of the mean of the block.

We first present the watermark method used for the comparison applied to grey level images. For each 8×8 block we compute the average grey level of the block quantified on 8 bits. Then, if we want to mark a 0 or a 1, we increase or decrease by the corresponding LSB, the grey level of the 64 pixels of the block in order to obtain a 0 or a 1 for the LSB of the mean of the block.

For example: for the mark of the third bit of the mean of a block:

to obtain —0-:

$$p(i) = \begin{cases} p(i)+1 & if \quad --000 \\ p(i) & if \quad --001 \\ p(i) & if \quad --010 \\ p(i)-1 & if \quad --011 \\ p(i)-2 & if \quad --100 \\ p(i)-3 & if \quad --101 \\ p(i)+3 & if \quad --110 \\ p(i)+2 & if \quad --111 \end{cases} \tag{1}$$

to obtain —1-:

$$p(i) = \begin{cases} p(i)-2 & if \quad --000 \\ p(i)-3 & if \quad --001 \\ p(i)+3 & if \quad --010 \\ p(i)+2 & if \quad --011 \\ p(i)+1 & if \quad --100 \\ p(i) & if \quad --101 \\ p(i) & if \quad --110 \\ p(i)-1 & if \quad --111 \end{cases} \tag{2}$$

One can remark that watermarking using the third bit is more robust than simply watermarking using the second or first bit, because the possible modification of the block mean value due to the compression affects principally the two LSB. In revenge the quality of the watermarked image decreases, the watermark becomes visible at the boundaries of blocks.

Color Spatial Watermarking of Image LSB

In order to increase the robustness of watermarking methods using first or second LSB, we propose to use color information. We mark the three RGB channels separately with the same message, and we use a voting technique to recover information altered by compression. To improve the robustness, the decoding of the mark can use error correcting codes.[3]

This method allows stronger compression rates for a given LSB. For example, for a mark of the first LSB, with a message composed of 888 bits and a JPEG compression with a quality factor of 100%, only 5% of the bits of the message are altered by channel. But 30% of the characters of the message are false, and consequently very few characters have more than one false bit. In this case, a statistical study has shown that the number of false bits per character follows a Poisson's law. Considering color watermarking, the message is recovered.

If we decrease the quality factor of the compression, the statistical number of false bits per character tends to be a gaussian law. From compression quality factor of 75%, 50% of the bits become false and all of the characters are false. In this case, color information does not give better results than grey level and the message is lost.

Color Spatial Watermarking of Image LSB 1.5

The third LSB is robust against compression but of poor visual quality of the watermarked image, the first LSB is sensitive to compression (good visual quality of the watermarked image). In order to improve the quality using the first LSB watermark, we have defined a method of watermarking using the 1.5 LSB. We modify only a subset of the 64 pixels of each block to obtain the decimal part of the mean exactly equal to 0.5. For example, a value of the mean of 56.6 means for a 0, and a mean of 57.5 means for a 1. The JPEG compression can move the mean value in an interval of [-0.5 , 0.5]. We show results of this improvement in the next section.

Results

In this section, we apply our method firstly to a grey level image and secondly to a color image. We show, Figure 1.b a watermarked image using the first LSB. The differences with the original image and the noise brought by compression are illustrated in Figures 1.c and d. In Table 1, we show several results at different rates of compression using first, second, third and 1.5 LSB. These results show the limits of the different LSB. We can remark that to read the original message without error from a compressed image we need at least to use the third LSB. The 1.5 LSB watermarked allows a JPEG compression at 78% of quality, the use of color information increases the efficiency of this method till 60% of quality. In Figure 2.a, we can show the watermarked image using 1.5 LSB with a JPEG compression at 78% of quality. Figure 2.b illustrates the difference between Figure 2.a and original image.

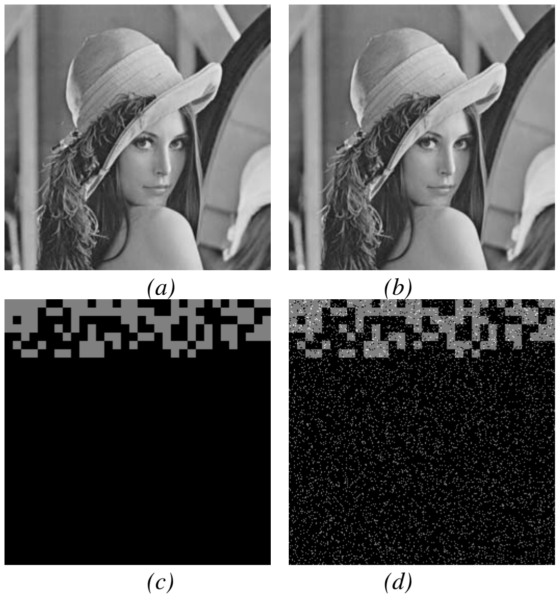

Figure 1. a) Original image, b)Watermarked image using the first LSB, c) Difference between the watermarked image using the first LSB and the original image, (d) Difference between the watermarked image using the first LSB compressed by JPEG at 100% of quality and the original image.

(a) (b)

Figure 2. a) Watermarked image using 1.5 LSB with a JPEG compression at 78% of quality, b) Difference between image (a) and original image.

Table 1. Different Results

	bit 1	bit 2	bit 3	bit 1.5
original PSNR *dB*	OK 57.85	OK 52.08	OK 49.74	OK 55.76
100% PSNR *dB*	× 55.19	× 51.19	OK 49.21	OK 53.97
90% PSNR *dB*	× 41.16	× 40.91	OK 40.68	OK 41.12
75% PSNR *dB*	× 36.73	× 36.64	OK 36.56	× 36.69
50% PSNR *dB*			OK 33.97	
40% PSNR *dB*			× 33.77	

Figure 3. Original color image and the three channel Red, Green and Blue.

Figure 4. a) Watermarked Red channel of the image using the second LSB, b) Watermarked Red channel with a compression at 100% of quality, c) at 80% of quality, d) at 60% of quality, e) Watermarked Green channel with a compression at 80% of quality, f) Watermarked Blue channel with a compression at 80% of quality.

In the second example we illustrate our method on the three channels of the color image of Lena, Figures 3.b, c, and d. We choose to use the second LSB block watermarking to increase the robustness of our method. We have inserted a text of 111 characters i.e. 888 bits. The Figures 4.a, b, c and d show the Red channel watermarked to the second LSB of the mean of the block without compression and with compression at respectively 100%, 80% and 60% of quality. We apply the same method on the channels Green and Blue with a quality factor of compression of 80%, Figures 4.e and f. The PSNR (Peak Noise Signal to Noise Ratio) has been determined and used as a quality estimation of the method. We can compare the different PSNR, Figure 11. The PSNR value of the Red channel is lower than the other channels because the color image is a red image. And because of this, some 255 pixels value (or 0 value) of this channel change in 0 pixels value (or 255 value). The image, Figure 5.a, represents the difference between the original Red channel and the watermarked red channel without compression Figure 4.a. We can remark it is still possible to extract the watermarked text.

From the compression of 90% of quality, we can see, Figure 5.c, that it becomes difficult to retrieve the watermarked information. If we use the Blue channel, we can notice, in the difference between original Blue channel and the watermarked Blue channel without compression, Figure 5.d, that the modified blocks are not the same.

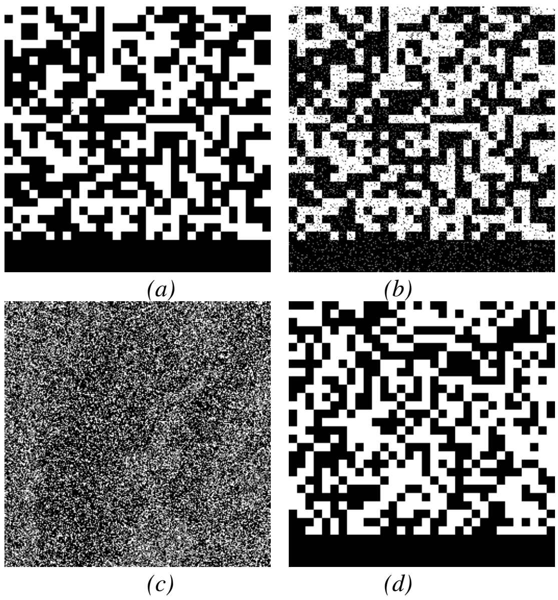

Figure 5. Difference between original Red channel and a) the watermarked image Figure 4.a, b) the watermarked Red channel Figure 4.b with a compression at 100%, c) the watermarked Red Channel Figure 4.c with a compression at 90%. d) Difference between original Blue channel and the watermarked Blue channel without compression.

The Figure 6 illustrates the result of our color watermarking method. The Figure 6.a and b showed the watermarked color image with a compression at 90% of quality and at 60% of quality. The Figures 6.e and f illustrate the difference between original color image and the three watermarked channels without compression and with a compression at 100% of quality.

The Figure 7 illustrates the evolution of the number of false bits in function of the quality factor of compression. For example, with the text of 888 bits, for a compression with a quality factor of 90%, we have 48 false bits in the Green channel, 40 false bits in the Red channel, 39 false bits in the Blue channel and only 5 false bits in the watermarked color image. We can remark, Figure 8, that for the compression with a quality factor of 90%, each false bit in the watermarked color image corresponds to a false character. Indeed, the Figure 9 shows that very frew characters have more of one false bit. If we decrease the quality factor of the compression, the statistical number of false bits per character tends to be a gaussian law, illustrated Figure 10, for a compression at 60% of quality.

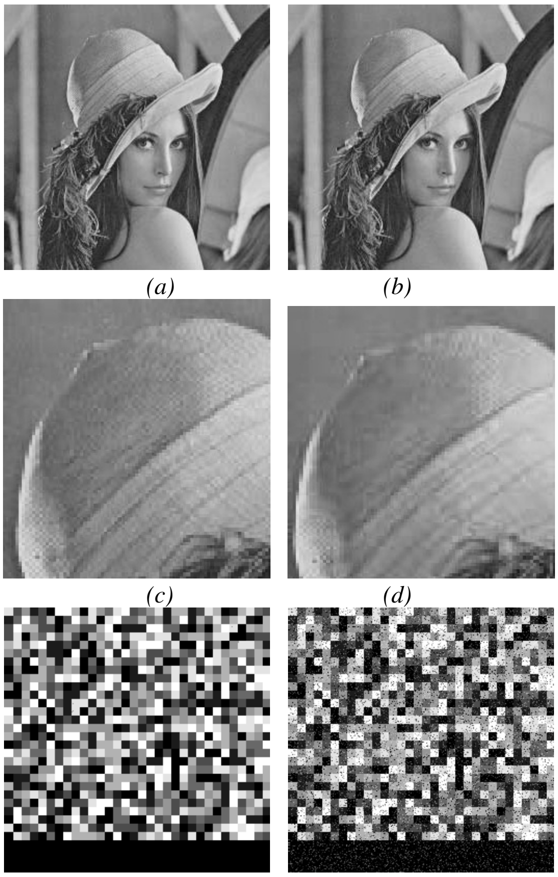

Figure 6. Watermarked color image with a compression, a) at 90% of quality, b) at 60% of quality. c) d) Details of the images a) and b). Difference between original color image and the three watermarked channels, e) without compression, f) with a compression at 100% quality.

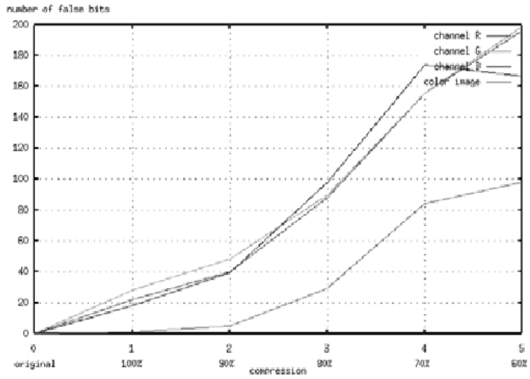

Figure 7. Number of false bits depends on the quality factor of compression.

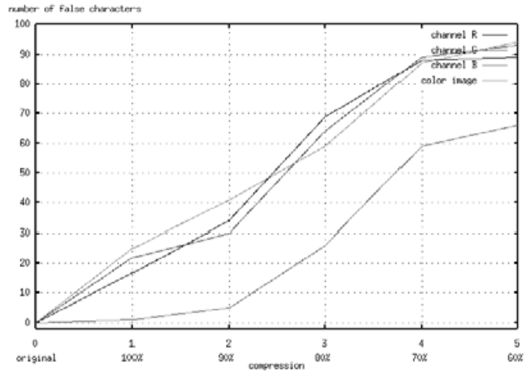

Figure 8. Number of false characters depends on the quality factor of compression.

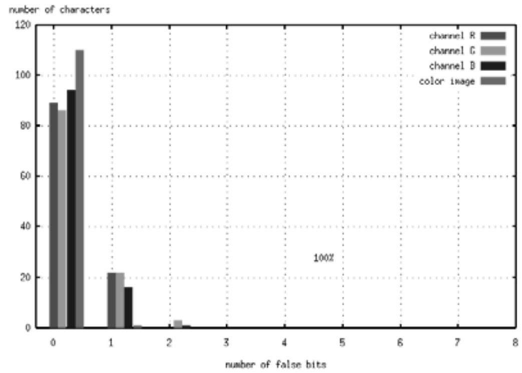

Figure 9. Number of characters depends on number of false bits with compression at 100% of quality.

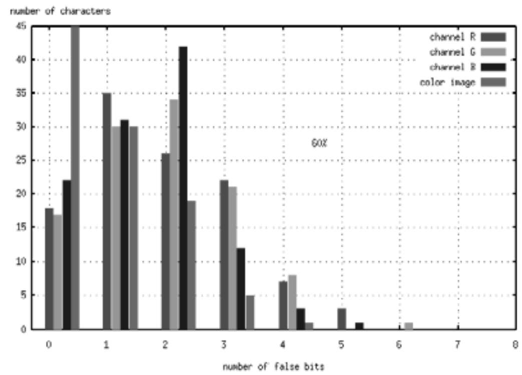

Figure 10. Number of characters depends on number of false bits with compression at 60% of quality.

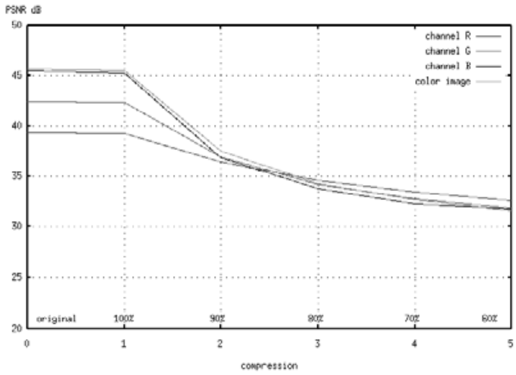

Figure 11. PSNR of the three channels and the color image.

Conclusion

In this paper we have presented a new method for color image watermarking working in the spatial domain. Because of the compressed network transmission the watermark should be robust to JPEG compression. We have shown the possibility to use RGB information in order to increase the robustness of a spatial watermark method. We have compared the different possibilities to insert the message on the first, second and third LSB. We have included color images and have compared the different results.

The choice of the LSB to modifiy depends on the quality you need for the image and the text. The color image increases the quality of the watermarked text, on the other hand the color image does not improve the PSNR value.

References

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Biography

W. Puech is a French national, born in December 1967. He received the diploma of Electrical Engineering from the University of Montpellier, France, in 1991 and the Ph.D. Degree in Signal-Image-Speech from the Polytechnic National Institute of Grenoble, France in 1997. He initialised its research activities in image processing and computer vision. He served as a Visiting Research Associate at the University of Thessaloniki, Greece. From 1997 to 2000, he had been an Assistant Professor at the University of Toulon, France, with research interests including methods of active contours applied to medical image sequences. Since 2000, he has been Associate Professor at the CEM2 Laboratory, University of Montpellier, France. His current interests are in the areas of security of digital image transfer (watermarking and cryptography) and edges detection applied to medical images and road security.