Robustness of Color Image Watermark Using RS Coding Technique against Rotation, Intensity, and Noise attacks

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Abstract - **Watermarking today is one of the most important applications of digital image processing in aiding the authentication and verification of proprietary images. But more often than not, a lot of Watermarking techniques fail when subjected to harsh attacks. In this paper we use the knowledge of RS codes to create a watermarked image that is resilient to afore mentioned attacks. The algorithm is tested for three color images and it works well for all of them providing very good PSNR values.**

Keywords - **Digital Watermarking, RS codes, LSB substitution method, Distortive Attacks.**

I. INTRODUCTION

Digital watermarking is the process of embedding information into a digital signal which may be used to verify its authenticity or the identity of its owners. The signal may be audio, images, or video. If the signal is copied, then the information also is carried in the copy. This feature of Digital Watermarking makes authentication and subsequent verification possible. A Survey of Watermarking Algorithms can be found in [1].

Typically Digital Watermarking is either Visible (where the watermark is distinctly visible) or Invisible (where the watermark is so embedded that it is imperceptible to the human eye).

There are principally two domains for performing digital watermarking; in the spatial domain [2] and in the frequency domain [2]. In this paper, we develop an invisible watermarking algorithm in the spatial domain.

Challenges faced during robust digital watermarking are usually difficult to overcome in spatial domain; this makes for another driving force for writing this paper.

In the spatial domain it becomes necessary to maintain the proportionality of the pixel values with the neighboring pixels throughout the recovered watermark.

In this paper, we propose an algorithm that is based on RS codes [3] and conveniently hides the watermark in the different planes of the color image, providing substantial resilience to rotation and intensity attacks under the impact of salt and pepper noise, individually and combined.

In section 2, we discuss the problem definition and its relevance. Section 3 is a discussion of the various techniques used for watermarking and testing the robustness. The proposed algorithm for watermarking along with the performance parameters is discussed in section 4. Section 5 contains the observations of applying the various tools and their analysis. Section 6 concludes the paper followed by references.

II. PROBLEM DEFINITION

To develop a robust color image watermarking technique using RS codes and LSB Substitution, that resists rotation, intensity and salt and pepper noise attacks in the spatial domain and provides substantial PSNR in the recovered watermark.

Most digital data are prone to tamper. Authentication of published images is essential in today's digital world, and efficient, robust methods to do so are becoming increasingly important. Most of the artists and photographers who frequently publish their images online are faced with situations of theft of intellectual property and hence digital image watermarking comes into play. Also it is important to ensure that the quality of the watermarked image is as close as possible to the original image to maintain the integrity of the art and the artist.

The test images differ considerably in their color content. The host images and the watermark used in this paper are shown in Fig. 1.

III. TECHNIQUES USED FOR WATERMARKING AND TESTING

A. RS Codes [4]

Irving Reed and Gustave Solomon, then working at MIT Lincoln Labs in 1960, invented the RS Codes. RS codes are basically channel codes known to offer distinguished performances against burst errors. They are non-binary cyclic codes with symbols made up of *m*-bit sequences, where *m* is a positive integer greater than 2.

RS (*n, k*) codes on *m*-bit symbols exist for all *n* and *k*, and are governed by the following set of equations:

$$0 < k < n < 2^m + 2 \quad (1)$$

$$(n, k) = (2^m - 1, 2^m - 1 - 2t) \quad (2)$$

$$d_{min} = n - k + 1 \quad (3)$$

$$t = floor\left[\frac{dmin-1}{2}\right] = floor\left[\frac{n-k}{2}\right] \quad (4)$$

where,

- *k* is the number of symbols being encoded
- *n* is the number of symbols in the encoded block
- d_{min} is the code minimum distance
- *t* is the symbol or bit error correcting capability of the code
- *floor(x)* rounds the elements of *x* to the nearest integers towards minus infinity.

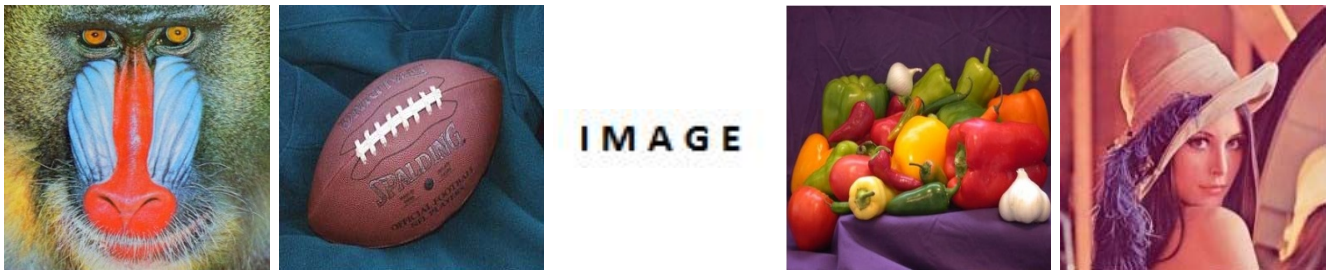


Fig. 1 Host images and watermark.
(a) Baboon (512x512) (b) Football (256x320) (c) Watermark (85x18) (d) Peppers (512x512) (e) Lena (256x256)

In other words, the symbols to be encoded should be of integer value less than 2m -1. Also n-k should be a positive even integer.

Thus equation (4) indicates that correcting *t* symbol errors requires no more than 2*t* parity symbols-one to locate the error and the other to find its correct value.

Any linear code is capable of correcting *n* - *k* symbol erasure patterns if the *n* - *k* erased symbols all happen to lie on the parity symbols. However, Reed-Solomon codes have the remarkable property that they are able to correct any set of *n* - *k* symbol erasures within the block.

B. LSB Substitution Method [5]

LSB substitution is one of the oldest and most convenient methods for hiding data. It is observed that the LSBs do not contain visually significant information. In LSB substitution the few least significant bits of a pixel of the host image are replaced by values extracted from the watermark. This enables in secure data hiding without compromising the visual quality of the host image. Fig. 2 shows the concept of LSB substitution.

In this paper we extract three MSB bits from the RS coded watermark and substitute two bits each in the second and third least significant bits of each color planes. This makes it impossible for the human eye to distinguish the watermarked image from the original. Also, this enables us to extract the watermark in case one or more color planes are removed in an attack.

C. Distortive Attacks

The most common attacks are geometrical, intensity and noise attacks. In this paper, we test the robustness of the proposed algorithm in detection and recovery of watermarks under Rotation, intensity and salt and pepper noise attacks.

1) Rotation Attack [6]

Rotation attack is known to disturb the synchronization of the embedded watermark with the cover image, which is the general requirement of most algorithms for recovery, thereby causing further errors. It is one of the most menacing attacks.

2) Intensity Attack

Since the RS encoded watermark bits are substituted in the bit planes of the host image. There is a high probability that increasing or decreasing the intensity of a watermarked image might remove a majority of the embedded watermark. The PSNR of the retrieved watermark is still substantially high.

3) Salt and Pepper Noise

Salt and pepper noise is a random noise that affects individual pixels in an image. It is highly dangerous as it completely destroys the pixels. The pixels affected by this noise are either reduced to the minimum value or enhanced to the maximum value in the image, rendering black and white pixels on the image. This gives the noise it's so called name as the affected image appears to be showered with salt and pepper.

While most algorithms give in above 10% noise, the proposed algorithm endures much more noise.

IV. PROPOSED ALGORITHM AND PERFORMANCE PARAMETERS

In this subsection we discuss the proposed algorithm and the performance evaluation parameters for the paper.

A. Proposed Algorithm

TABLE I: PROPOSED ALGORITHM

Step No.		Function
1		Read the host image, h and the watermark image, w.
2		Determine the sizes of both images.
3		Split w into sub-blocks of r2 x k, where k is the number of symbols to be encoded and r2 is the number of rows in w.
4		Code each block using RS codes.
5		Convert the coded blocks to decimal and reshape.
6		Reassemble the blocks.
7		Extract three MSBs of the coded watermark.
8	8a	Substitute MSB1 in 3rd and 2nd bit of one color plane, s (R/G/B).
	8b	Substitute MSB2 and MSB3 in 3rd and 2nd bit of another color plane, t (R/G/B).
	8c	Substitute MSB3 and MSB2 in 3rd and 2nd bit of last color plane, u (R/G/B) to obtain watermarked image, wi.
9		Subject wi to various attacks to get nw.
10		Crop nw from the top left to a size of w.
11		Extract bit3/bit2 from s, t and u color planes and combine them to obtain wmark.
12		Split wmark into sub-blocks of r2 x n, where n is the number of symbols in the encoded data.
13		Decode each block using RS codes.
14		Convert the decoded blocks to decimal and reshape.
15		Reassemble the blocks.
16		Calculate MSE, RMSE, MAE, PSNR and C described in section IV-*B*, equations 5 through 8.

First the host and watermark image data are read. The next step is to determine their sizes. Then we split the watermark into blocks of size r2 x k. This facilitates RS encoding as the number of symbols to be encoded is k. Then we apply RS coding to each block. The resultant Galois Field array obtained is converted to decimal and reshaped. The blocks are then reassembled to form a complete coded watermark. The next step is to extract three MSBs from the encoded watermark. These are substituted in the host image as explained in step 8. The ninth step involves deliberate attacks viz. intensity, noise and combinational. Then the substituted bits are extracted from the corresponding color planes. These bit planes are combined to get a noisy watermark. This image is split into blocks of size r2 x n. This facilitates RS decoding as the number of symbols in the encoded data is n. RS decoding is performed in the next step. The resultant Galois Field array obtained is converted to decimal and reshaped. The blocks are then reassembled to form a complete decoded retrieved watermark. The final step involves calculating the performance parameters.

B. Performance Parameters

In this subsection we describe the performance criteria used to evaluate the watermarking scheme discussed in subsection *IV-A*.

The performance is evaluated on the basis of the five parameters, namely: *Mean Square Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Peak Signal to Noise Ratio (PSNR)* and *number of pixels changed in the retrieved and original watermark (Count, C).* They are governed by the following equations:

$$MSE = \frac{1}{M*N}\sum_{M,N}[OI(I,J) - RI(I,J)]^2 \quad (5)$$

$$RMSE = \sqrt[2]{MSE} \quad (6)$$

$$PSNR = 10 * log_{10}\left(\frac{Q^2}{MSE}\right)\ [dB] \quad (7)$$

$$MAE = \frac{1}{M*N}\left(\sum_{M,N} abs\ (OI(I,J) - RI(I,J))\right) \quad (8)$$

where,

- OI = original watermark image.
- RI = retrieved watermark image.
- M = number of rows in the watermark.
- N = number of columns in the watermark.
- Q = maximum possible value of the luminance.

Count is calculated in the algorithm by comparing the values of pixels at the corresponding values in original watermark image and retrieved watermark image.

V. RESULTS AND OBSERVATIONS

Table II, III, IV and V illustrate the observations for Intensity, Salt and Pepper Noise, Rotation and Combinational (Intensity + Salt and Pepper, Intensity + Rotation, and Salt and Pepper + Rotation) attacks on the watermarked image and the performance characteristics of the subsequently retrieved watermark for Baboon, Football, Peppers and Lena respectively. They provide sufficient evidence to suggest the robustness of the algorithm.

To further strengthen the observation, supporting images for BABOON for Intensity, Salt and Pepper Noise, Rotation and Combinational attacks are illustrated in Fig. 2 through Fig. 7. The images show distorted watermarked images and retrieved watermarks.

TABLE II: OBSERVATIONS FOR BABOON

Attack \ Parameter		MSE	RMSE	PSNR	MAE	C
Intensity	+40	0.0707	0.265	59.639	0.012	0
	+48	0.1342	0.366	56.852	0.022	0
Salt and Pepper	1%	0.2538	0.503	54.085	0.047	13
	5%	1.4562	1.206	46.499	0.274	60
	10%	2.9027	1.703	43.502	0.533	118
	20%	4.9554	2.226	41.18	0.945	187
	50%	8.5691	2.927	38.801	1.778	348
Rotation	-5°	2.4038	1.550	44.321	0.399	30
	-70°	1.3582	1.165	46.801	0.310	134
	90°	0	0	Inf	0	0
	360°	0	0	Inf	0	0
Intensity+ Salt and pepper	10%,-40	2.5027	1.582	44.146	0.499	106
	10%,+40	2.9054	1.704	43.498	0.573	130
	20%,-40	4.6647	2.159	41.442	0.901	187
	20%,+40	4.3375	2.082	41.758	0.871	205
Intensity+ Rotation	-5°, +40	2.3277	1.525	44.461	0.394	33
	-70°,+40	0.8234	0.907	48.974	0.237	227
	-5°, +48	2.5446	1.595	44.074	0.418	30
	-70°,+48	1.0886	1.043	47.762	0.261	200
Salt and Pepper + Rotation	10%, -5°	4.6565	2.157	41.450	0.788	133
	10%,-70°	2.7946	1.671	43.667	0.595	187
	20%, -5°	5.9462	2.438	40.388	1.175	217
	20%,-70°	4.5810	2.140	41.521	0.960	222

TABLE III: OBSERVATIONS FOR FOOTBALL

Attack \ Parameter		MSE	RMSE	PSNR	MAE	C
Intensity	+40	0	0	Inf	0	0
	+48	0	0	Inf	0	0
Salt and Pepper	1%	0.4734	0.688	51.378	0.074	17
	5%	1.5179	1.232	46.318	0.289	52
	10%	2.4766	1.573	44.192	0.479	118
	20%	5.7647	2.401	40.523	1.002	200
	50%	8.8549	2.975	38.659	1.804	366
Rotation	-5°	5.0348	2.244	44.620	0.457	147
	-70°	7.1237	2.669	43.867	0.493	172
	90°	0	0	Inf	0	0
	360°	0	0	Inf	0	0
Intensity+ Salt and pepper	10%,-40	2.5538	1.598	44.058	0.526	109
	10%,+40	2.4766	1.573	44.192	0.479	118
	20%,-40	3.8326	1.957	42.295	0.837	183
	20%,+40	5.7647	2.401	40.523	1.002	200
Intensity+ Rotation	-5°, +40	5.0348	2.244	44.620	0.457	147
	-70°,+40	7.1237	2.669	43.867	0.493	172
	-5°, +48	5.0348	2.244	44.620	0.457	147
	-70°,+48	7.1237	2.669	43.867	0.493	172
Salt and Pepper + Rotation	10%, -5°	5.6613	2.379	44.366	0.460	160
	10%,-70°	7.6077	2.758	43.725	0.499	197
	20%, -5°	5.9332	2.436	44.264	0.466	171
	20%,-70°	8.1670	2.857	43.572	0.506	219

TABLE IV: OBSERVATIONS FOR PEPPERS

Attack \ Parameter		MSE	RMSE	PSNR	MAE	C
Intensity	+40	0	0	Inf	0	0
	+48	0	0	Inf	0	0
Salt and Pepper	1%	0.0804	0.283	59.076	0.019	4
	5%	1.0799	1.039	47.797	0.158	41
	10%	1.5402	1.241	46.255	0.287	71
	20%	3.8511	1.962	42.275	0.8	200
	50%	8.6304	2.937	38.770	1.840	357
Rotation	-5°	9.0609	3.010	38.559	1.898	313
	-70°	9.5011	3.08	38.353	1.964	310
	90°	0	0	Inf	0	0
	360°	0	0	Inf	0	0
Intensity+ Salt and pepper	10%,-40	1.7603	1.326	45.674	0.327	84
	10%,+40	1.5402	1.241	46.255	0.287	71
	20%,-40	3.8473	1.961	42.279	0.786	180
	20%,+40	3.8511	1.962	42.275	0.8	200
Intensity+ Rotation	-5°, +40	9.0609	3.010	38.559	1.898	313
	-70°,+40	9.5011	3.082	38.353	1.964	310
	-5°, +48	9.0609	3.010	38.559	1.898	313
	-70°,+48	9.5011	3.082	38.353	1.964	310
Salt and Pepper + Rotation	10%, -5°	9.2102	3.034	38.393	2.028	351
	10%,-70°	9.4131	3.068	38.086	2.061	361
	20%, -5°	9.5712	3.093	38.321	2.079	378
	20%,-70°	9.9576	3.155	38.149	2.154	367

TABLE V: OBSERVATIONS FOR LENA

Attack \ Parameter		MSE	RMSE	PSNR	MAE	C
Intensity	+40	0.7281	0.853	49.507	0.070	27
	+48	1.3952	1.181	46.683	0.151	63
Salt and Pepper	1%	0.3724	0.610	52.415	0.073	10
	5%	1.2129	1.100	47.295	0.233	49
	10%	3.5090	1.873	42.678	0.618	111
	20%	4.6241	2.150	41.480	0.925	189
	50%	9.3585	3.059	38.419	1.841	341
Rotation	-5°	11.685	3.418	37.454	2.387	231
	-70°	12.169	3.488	37.278	2.425	277
	90°	0	0	Inf	0	0
	360°	0	0	Inf	0	0
Intensity+ Salt and pepper	10%,-40	2.8645	1.692	43.560	0.544	111
	10%,+40	3.4585	1.859	42.741	0.594	114
	20%,-40	4.6091	2.146	41.494	0.900	180
	20%,+40	4.8560	2.203	41.267	0.988	203
Intensity+ Rotation	-5°, +40	11.121	3.334	37.669	2.249	287
	-70°,+40	12.434	3.526	37.184	2.508	319
	-5°, +48	11.515	3.393	37.517	2.271	263
	-70°,+48	13.140	3.624	36.944	2.560	356
Salt and Pepper + Rotation	10%, -5°	11.377	3.373	37.570	2.327	311
	10%,-70°	11.369	3.371	37.573	2.320	344
	20%, -5°	11.617	3.408	37.479	2.392	357
	20%,-70°	11.625	3.409	37.476	2.398	370

VI. CONCLUSION

We proposed a simple and novel algorithm to digitally watermark images that are resilient to four different types of harsh noises. The proposed algorithm works well on numerous images, four of which, that are extensively used in the field of digital image processing the world over, have been presented as specimen images for the paper. The simplicity of the algorithm is suitable for quick and reliable watermarking. Future work can be extending this algorithm to watermark audio and video signals.

REFERENCES

[1] Christian Rey, Jean-Luc Dugelay, "A Survey of Watermarking Algorithms for Image Authentication" in EURASIP Journal on Applied Signal Processing 2002:6, 613–621

[2] Vidyasagar M. Potdar, Song Han, Elizabeth Chang"A Survey of Digital Image Watermarking Techniques" in 3rd IEEE International Conference on Industrial Informatics (INDIN) 2005.

[3] Jaejin Lee and Chee Sun Won, "A Watermarking Sequence Using Parities Of Error Control Coding For Image Authentication And Correction" in IEEE Transactions on Consumer Electronics, May2000

[4] Bernard Sklar, " Digital Communications – Fundamentals and Applications". Second Edition, Pearson Education India, 2002.

[5] Abdullah Bamatraf, Rosziati Ibrahim and Mohd. Najib B. Mohd Salleh "Digital Watermarking Algorithm Using LSB" in International Conference on Computer Applications and Industrial Electronics (ICCAIE 2010), December 5-7, 2010, Kuala Lumpur, Malaysia

[6] Zhang Li, Sam Kwong and Gang Wei "Geometric Moment In Image Watermarking" in Proceedings of the 2003 International Symposium on Circuits and Systems (ISCAS '03).

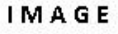
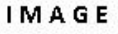
Noisy Image Due to Intensity Attack (Intensity Variation)		
	(+40)	(+48)
Retrieved Watermark		

Fig. 2 Noisy Image and Retrieved Watermark after being subjected to Intensity attack on Baboon.

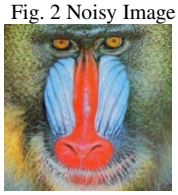
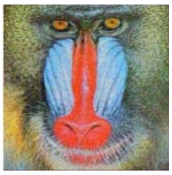
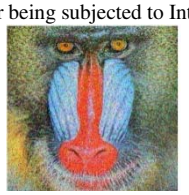
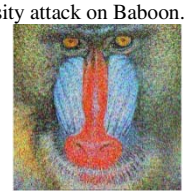
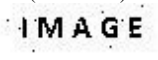
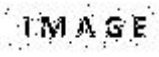
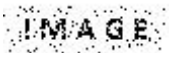
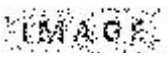
Noisy Image Due to Salt & Pepper Noise (Noise Value)					
	(1% Noise)	(5% Noise)	(10% Noise)	(20% Noise)	(50% Noise)
Retrieved Watermark					

Fig. 3 Noisy Image and Retrieved Watermark after being subjected to Salt and Pepper Noise attack on Baboon.

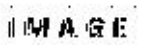
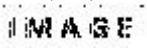
Noisy Image Due to Rotation Attack (Rotation Angle)				
	(-5°)	(-70°)	(90°)	(360°)
Retrieved Watermark				

Fig. 4 Noisy Image and Retrieved Watermark after being subjected to Rotation attack on Baboon.

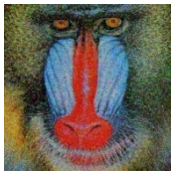
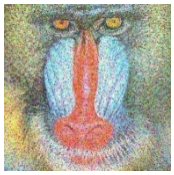
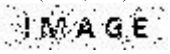
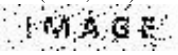
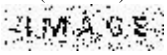
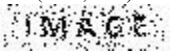
Noisy Image Due to Intensity Attack and Salt & Pepper Noise (Noise Value, Intensity Variation)				
	(10%, -40)	(10%, +40)	(20% -40)	(20%, +40)
Retrieved Watermark				

Fig. 5 Noisy Image and Retrieved Watermark after being subjected to Intensity and Salt & Pepper Noise attack on Baboon.

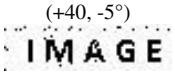
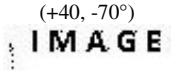
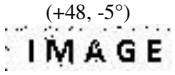
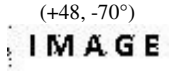
Noisy Image Due to Intensity and Rotation Attack (Intensity Variation, Rotation Angle)				
	(+40, -5°)	(+40, -70°)	(+48, -5°)	(+48, -70°)
Retrieved Watermark				

Fig. 6 Noisy Image and Retrieved Watermark after being subjected to Intensity and Rotation attack on Baboon.

Noisy Image Due to Salt & Pepper Noise and Rotation Attack (Noise Value, Rotation Angle)				
	(10%, -5°)	(10%, -70°)	(20% -5°)	(20%, -70°)
Retrieved Watermark				

Fig. 7 Noisy Image and Retrieved Watermark after being subjected to Intensity and Salt & Pepper Noise attack on Baboon.