Image Ciphering Based Onchaotic ANN and Fibonacci Transform Improved by using the Wavelet Transform

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Abstract

The ciphering based on ANN or Artificial Neuronal Network has the advantage of being more powerful to resist noise and compression but it has a slowerexecution time and presents some similarities between the original image and the ciphered image. Our article consists in adding a wavelet transform with the ciphering based on ANN to reduce the high execution time and adding a Fibonacci transform to get the ciphered image totally scrambled. The criteriaused to comparethe deciphered image with the original image, the ciphered image with the original image and the.studyof the attacks against noise and compression are: correlations, PSNR, UACI, NPCR and execution time. Indeed our work concerns a program on Matlab for ciphering and deciphering the image and know about the algorithm performances by using DWT or Discrete Wavelet Transform to improve the ciphering based on RNA combined with the Fibonacci Transform.

Keywords: *ANN, chaotic, Fibonacci transform, wavelet transform, Image ciphering*

I. INTRODUCTION

The cryptography plays an important role in the information security both at the storage stage and during transmission. For the image, the classicalcipherings like AES orDES, have a high execution time but a bad performance to resist noise and compression. For that, a new approach consistsin using the artificial neuronal network or ANN but this is not good either for the time. To improve it, using the wavelet transform could reduce this ciphering time of execution by using DWT or Discrete Wavelet Transform like Haar Transform, or Daubechies Transform, Bior Transform, Coiflet Transform, Symlet. The scrambling technique could also be added as an extra.It improves the image in such a way as to make it unrecognizable to unauthorised users by using permutation: Fibonacci, Arnold, Lucas, or by using matrix reordering: zigzag, L, U, C… Our experimentation uses the DWT to improve the time of ANN ciphering and the Fibonacci to improve the total scrambling of the image

II. PROPOSED ALGORITHM

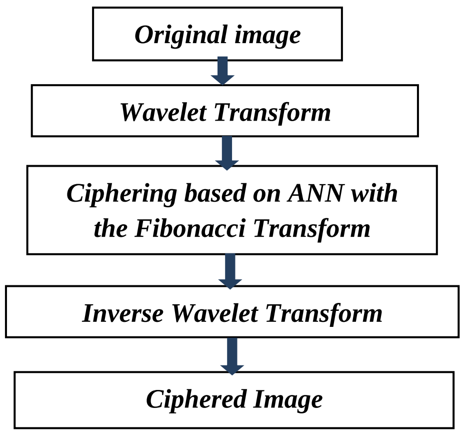


Figure 01: Proposed algorithm

III. GENERALITY OF THE WAVELET TRANSFORM

A. Generality of the Discrete Wavelet Transform (DWT)

The DWT isa multi-resolution description of the image. It divides the image into multiple sub-bands with 3 directions: Horizontal, Vertical and Diagonal.

The transform consists in dividing the signal x[n] into low and high frequencies by using an adequate filter each time [1]:

$H(\omega) = \sum_k h[k] e^{-jk\omega}$ et $G(\omega) = \sum_k g[k] e^{-jk\omega}$ (3)As $H(\omega)$ and $G(\omega)$should be orthogonal :

$$|H(\omega)|^2 + |G(\omega)|^2 = 1 \quad (4)$$

The coefficients obtained are:

$$c[j-1,k] = \sum_n h[n-2k]\, c[j,n]$$
$$d[j-1,k] = \sum_n g[n-2k]\, c[j,n] \quad (5)$$

The return to the original signal referred as IDWT is the reverse process to DWT. This formula summarizes the methods:

$$c[j,n] = \sum_k h[n-2k]\,c[j-1,k] + \sum_k g[n-2k]\,d[j-1,k] \tag{6}$$

The result is an approximate image and the 3 detailed imageswhich show the error between the original image and the approximate image. This process should be repeated many times to give the requested number of sub-bands. After some kind of decomposition, the low frequency is concentrated on the top left hand corner and presented as the compressed image version.

The Wavelet Transform of 2D image is summarized by the following Figures 02 and 03 [2-3]:

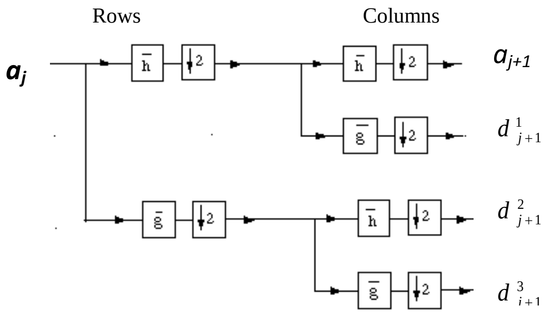


Figure 02: Decomposition of $a_j$into 6groups of monodimensional convolutions under sampling, in the rows and columns of the image

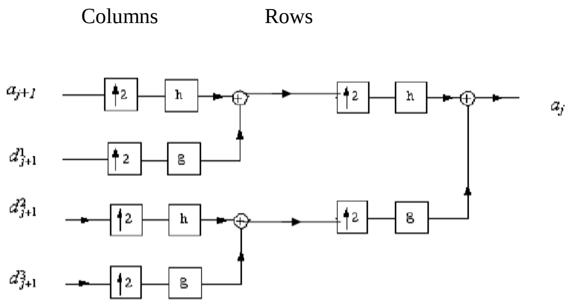
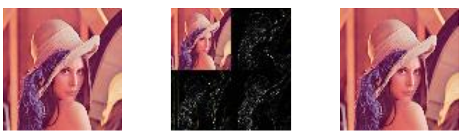


Figure 03: *Reconstruction of a_j by the zeros insertion in the rows and columns of a_{j+1} and d^k_{j+1} with filter*

B. Illustration about the Wavelet Transform



(a) (b) (c)

Figure 04: (a)Original image, (b) image by DWT, (c) reconstructed image by IDWT

The Figure 04 shows us the difference between the original image and the reconstructed image by using the DWT. After these steps, the ANN ciphering is improved by the Fibonacci transform with the approximated image a_{j+1}.

IV. CIPHERINGAN IMAGE BASED ON ANN AND THE FIBONACCI TRANSFORM

The Figure 05 describes us the ciphering process of the ANN combined with the Fibonacci Transform.

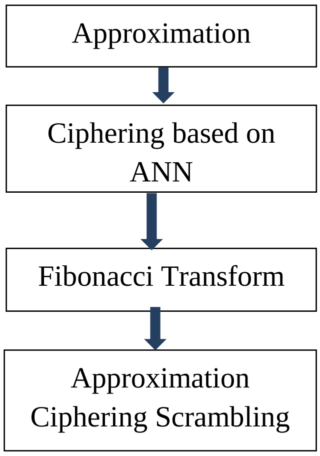


Figure 05: Ciphering process based on the ANN and Fibonacci Transform

A. Ciphering an image based on ANN (CNN)

The Chaotic Neuronal Networks give a high capacity of memory. Each type of memory is coded by an instable periodicchaotic orbit. Our goal is to use this chaotic property for the image ciphering. Each Network Neuronal is chaotic if the weight is determined by a chaotic sequence. As g a numeric signal with length M and g (n) the value of one octet of g positioned on n [4-6].

Step1: Load the image and define its size

Step2: Determine the parameter μ and the initial point x (0) of the network, the equation (1) should have a chaotic behaviour.

Step 3: Progress the chaotic sequence x (l), x (2), x (M) by using simple logistic one-dimensional map defined in the interval E by:

$$x(n+1) = \mu x(n)(1 - x(n)) \tag{11}$$

Step 4: For n to 0 until M-1, we calculate the different parameters of the neuronal networks. To calculate the weight and the parameter theta, the formulas are as follows:

$$w_{ji} = \begin{Bmatrix} 1\ si\ i = j\ et\ b(8n+i) = 0 \\ -1\ si\ i = j\ et\ b(8n+i) = 1 \\ 0\ si\ \ i \neq j \end{Bmatrix} \tag{12}$$

$$\theta_i = \begin{cases} -\frac{1}{2} \; si \;\; b(8n+i) = 0 \\ \frac{1}{2} \; si \;\; b(8n+i) = 1 \end{cases} \qquad (13)$$

And to calculate the error, the following formula is used (14)

$$d_i' = f\left(\sum_{i=0}^{7} w_{ji}.d_i + \theta_i\right)$$

The ciphered signal is given by:

$$g(n) = \sum_{i=0}^{7} d_i 2^i \qquad (15)$$

Step5: The ciphered signal g'' is obtained and the algorithm is finished.

This method of deciphering is the same as the ciphering but the input signal of the CNN of deciphering should be g'(n) and the output signal should be g"(n).

For the image, the pixels are treated by the neuron. The expected result for the ciphered image is supposed to be disorganized. In the caseof thedeciphering by CNN the chaotic system and the initial condition are respected. It means the same binary chaotic sequence, the original image could correctly be obtained by the deciphering algorithm of CNN.

Supposing that the ciphering is known and not the chaotic sequence;if the CNN is applied on the signal with length M, it necessitates 8M bits. The number of the possible results of the ciphering is 8×M. If the data are sized65536 octets. 8M signifies 524288 possibilities and all results possible are 252428 (≈ 10157810).

The chaotic system is better defined by:

- Its dependence on the initial condition
- We could see denselimited non periodic and quasi-periodic paths,in the state space.

In fact, the binary chaotic system is unpredictable. It's quite unthinkable to make the deciphering without knowing x (0) and µ. So, CNN give a high security.

B. Fibonacci Transform

Fibonacci Transform is one technique for scrambling images. It is the very method to make an image non-understandable and scrambled.Many documentations [7-10] have tried to give the right definition of this term "scrambling". In this article, we mainly deal with the scrambling technique based on permutation. Leonard de Pise knownas Fibonacci has shown his interestin this sequence defined by:

$$F_n = \begin{cases} 0 & si \quad n = 1 \\ 1 & si \quad n = 2 \\ F_{n-1} + F_{n-2} \end{cases} \qquad (16)$$

The series' Fibonacci obtained are namely: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34… En 2012, Minati Mishra, Priyadarsini Mishra, M.C. Adhikary, and Sunit Kumar proposed to use this sequence on a transformmatrix (7-8] :

$$T_i = \begin{pmatrix} F_i & F_{i+1} \\ F_{i+2} & F_{i+3} \end{pmatrix} \qquad (17)$$

This transform is defined by :

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = T_i \begin{pmatrix} x \\ y \end{pmatrix} (mod\ N) (18)$$

x' and y' is the new pixel position, x et y the original pixel position, N is the size of the image matrix ; T_i is the Fibonacci transform; and F_i is the i^{th}Fibonacci series term. The Figure 06 gives us the image scrambled with the Fibonacci technique.

Figure 06: Illustration about Fibonacci transform

V. RESULTS AND DISCUSSIONS

A. Criteria of evaluation

The image to be treated is lena.jpg with size 256x256x3.

The following results are obtained byMatlab simulation. The criteria used for this article are: PSNR (Peak Signal to Noise Ratio), SSIM (Structural SIMilarity), NPCR (Number of Pixel change rate), UACI (Unified Average Changing Intensity), rxy (coefficient de correlation), and the execution time.

- ❖ Le PSNR is used to measure the distortion of the numeric image. Le PSNR is defined by the following formula [3] :

$$PSNR = 10.\log_{10}\left(\frac{d^2}{RMSE}\right) \quad (19)$$

d is the maximum value of the pixel. In general, d=255

RMSE or the Root Mean-Square Error for 2 images I_0 and I_r with size m×n is defined by:

$$EQM = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}(I_0(i,j) - I_r(i,j))^2 \quad (20)$$

$I_0(i,j)$ is the value of the coordinates (i,j) of the image I_0 ; $I_r(i,j)$ is the value of the coordinates (i,j) of the image I_r .

- ❖ The Structural Similarity or SSIM is a reliable measure of the similarity between two numeric images[3].

$$SSIM(X,Y) = \frac{(2\mu_X\mu_Y + c_1)(2\sigma_X\sigma_Y + c_2)(2COV(X,Y) + c_3)}{(\mu_X^2 + \mu_Y^2 + c_1)(\sigma_X^2 + \sigma_Y^2 + c_2)(\sigma_X\sigma_Y + c_3)} \quad ,(21)$$

μ_X , μ_Y is the average value of the random variable X, Y; σ_X^2 , σ_Y^2 is the variance of X, Y; $COV(X,Y)$ is the covariance of X andY; c_1 , c_2 , c_3 are 3 values to stabilize the division when the value is too small.

- ❖ The NPCR measures the difference rate between two images. The NPCR formula is given by [11] :

$$NPCR^{R/G/B} = \frac{\sum_{i=1}^{H}\sum_{j=1}^{W} D_{i,j}^{R/G/B}}{W \times H} 100\% \quad (22)$$

With

$$D_{i,j}^{R/G/B} = \begin{cases} 0 & si \quad C_{i,j}^{R,G,B} = \overline{C}_{i,j}^{R,G,B} \\ 1 & si \quad C_{i,j}^{R,G,B} \neq \overline{C}_{i,j}^{R,G,B} \end{cases} \quad (23)$$

$C_{i,j}^{R,G,B}$ and $\overline{C}_{i,j}^{R,G,B}$ represent the components RGB with the two images

$$L^{R/G/B} = 8$$

W and H represent the Width and Height of image.

- ❖ L'UACI is theUnified Average Changing Intensity between two images [11].

$$UACI^{R/G/B} = \frac{1}{W \times H}\sum_{i=1}^{H}\sum_{j=1}^{W}\frac{C_{i,j}^{R/G/B} - \overline{C}_{i,j}^{R/G/B}}{2^{L^{R/G/B}} - 1} \times 100\% \quad (24)$$

- ❖ The coefficient of correlation[12] is defined by :

$$r_{X,Y} = \frac{COV(X,Y)}{\sqrt{V(X).V(Y)}} = \frac{COV(X,Y)}{\sigma_X\sigma_Y} \quad (25)$$

*COV(X,Y)*is the covariance between two random variables X andY; $V(X),V(Y)$ is the variance between de X andY; σ_X,σ_Y is the standard deviation between X and Y.

The covariance is equal to the expectation between the products of the standardised random variables. It is defined by the following formula:

$$COV(X,Y) = E[(X - E[X])(Y - E[Y])] \quad (26)$$

E is the mathematical expectation; X, Y is a random variable.

The variance is defined by the following formula:

$$V(X) = E[(X - E[X])^2] = COV(X,X) \quad (27)$$

E is the mathematical expectation; COV the covariance.

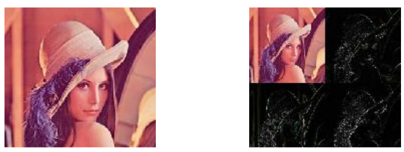
The goal of the covariance is to quantify the liaison between two random variablesX, Y, for theliaison sense and intensity. The coefficient of simple linear correlation, says Bravais-Pearson, is a normalized covariance by the product between the two standard deviations. The correlation is between -1 and 1.Near the extreme value -1 and 1, the similarity between the two variables is important. The expression « intensive correlation » means that two variables are very similar and the correlation is near the value 1.The expression « linear independent » or « no correlation » means that the correlation between two variables is nil and there is no similarity between them. The expression « perfect correlation » means that the value rxy is equal to ± 1 .

B. Results

This result is obtained by the simulation on Matlab

1. Image obtained by wavelet transforms

The wavelet used the Haar transform.



(a) (b)

Figure 07: (a) Original image et (b) Image with Wavelet transform

After the wavelet transform, the original image Figure 07 (a) is composed of the approximation and the three details represented in Figure 07 (b) and described in Figure 08.

a_{j+1} d_{j+1}^{1}

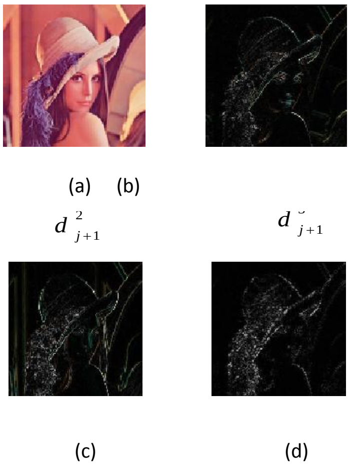
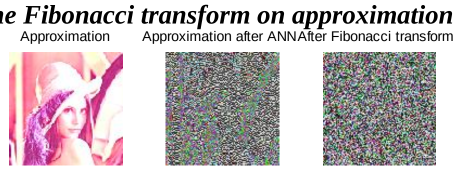


Figure 08: (a) The approximation and (b) (c)(d) the three details after the wavelet transform of the original image

2 Image obtained after the ANN chaotic ciphering and the Fibonacci transform on approximation



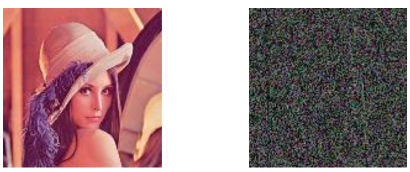
(a) ***(b)*** ***(c)***

Figure 09:Image obtained after the ANN chaotic ciphering and the Fibonacci transform on approximation

After the ciphering based on ANN approximation,a ciphered image like in Figure 09 (a) is obtained, and theciphered image like in Figure 09 (b) too, which could give a few hints of the image approximation. The goal is to improve the result by combining the ciphering techniques with the Fibonacci transform and the approximation ciphered scrambled image is obtained like in Figure 09 (c).

3. Reverse wavelet transform

For having a ciphered image, the reverse wavelet transformis applied on the approximation ciphered reversed scrambled image with the 3 details.

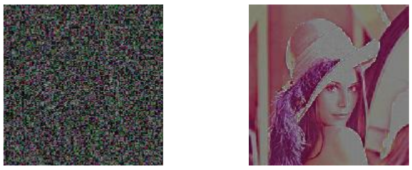


(a) (b)

Figure 10:(a) the original image et (b) the ciphered image with ANN combined with Fibonacci transform and the wavelet

No one will recognize the ciphered image in figure 10which shows nothing of the original imageat all.

4. Image obtained after deciphering



(a) (b)

Figure 11:(a) Image ciphered with the ANN combined with Fibonaccitransform and wavelet transform and (b) deciphered image

After the deciphering the image in Figure 11 (b) a bit dark but still looks like the original image.

4. Table of results and interpretation

Table 01:Correlation between the original image and the deciphered image

rxy between the original image and the ciphered image		
Of the red component	0.0377290297	The value of r_{xy} is near by 0. So, there is no correlation between the original image and the ciphered image
Of the green component	0.0427262743	
Of the blue component	0.0515894090	

Table 02: Coefficient of correlation between the original image and the ciphered image

rxy between the original image and deciphered image		
of the red component	0.728251946	The value of r_{xy} near by 1 , thus high correlation or high similarity between the original image and the deciphered image.
of the green component	0.935113517	
of the blue component	0.924365899	

Table 03:PSNR between the original image and the deciphered image

PSNR between the original image and the deciphered image		
of the red component	11.1715476	High PSNR exclusive of red component which accounts for its darker shade when it is deciphered
of the green component	20.8366127	
of the blue component	24.1707799	

Table 04:PSNR between the original image and the ciphered image

PSNR between the original image and the ciphered image		
of the red component	5.62581830353597	PSNR is very small. There is no similarity between the original image and the deciphered image
of the green component	10.8754223720821	
of the blue component	11.733910520097	

Table 05:SSIM betweenthe original image and the deciphered image

SSIM between the original image and the deciphered image		
of the red component	0.639315080	SSIM has high value nearby 1. This result shows the high similarity between the original image and the deciphered image
of the green component	0.895663703	
of the blue component	0.930689063	

Table 06:SSIM between the original image and the ciphered image

SSIM between the original image and the ciphered image		
of the red component	0.0591477458	SSIM is less than 0,1. The original image and the ciphered image eitherhave a very weak similarity or are totally different.
of the green component	0.0836835227	
of the blue component	0.0839039107	

Table 07:NPCR betweenthe original image and the deciphered image

NPCR between original image and deciphered image		
of the red component	79.5333862%	NPCR is very high. This result explains why the reconstructed image is not the same and why it is darker than the original image
of the green component	29.4265747%	
of the blue component	21.331787%	

Table 08:NPCR between the original image and the ciphered image

NPCR between original image and ciphered image		
of the red component	99.8535156625%	NPCR high, more than 99%, the pixel is nearly 99% modified. It justifies the good quality of the cryptography
of the green component	99.409484863%	
of the blue component	99.3560791015%	

Table 09:UACI betweenthe original image and the deciphered image

UACI between the original image and the deciphered image		
of the red component	22.874001895%	.UACI is so small compared to the red component. That also justifies why it is slightly darker
of the green component	3.8792928059%	
of the blue component	2.3379995308%	

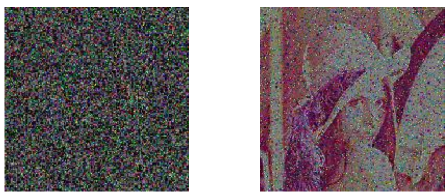
Table 10:UACI between the original image and the ciphered image

UACI between original image and ciphered image		
of the red component	46.503313849%	..UACI has a value near the 18% but for the red value. Yet the pixel rate of changed value is enough to confirm that the image will not be recognizable
of the green component	18.297077253%	
of the blue component	18.828136967%	

5. Performance against noise

The goal is to know if after the attack by adding noise, we could recognize the deciphered image from the original image. The noise considered here is the noise produced by pulses

a- Noise with variance 0.05



(a) (b)

Figure 12:*(a) Ciphered image with noise pulses variance 0.05, (b) Following image deciphered*

Table 11:*(a) PSNR, SSIM and rxy, (b) NPCR and UACI betweenthe original image and the deciphered image with variance of noise 0.05*

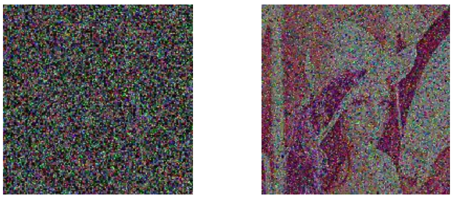
(a)

Component	PSNR	SSIM	Rxy
Red	9.30196	0.14698	0.23308
Green	15.15195	0.29341	0.64336
Blue	15.95988	0.24148	0.47129

(b)

Component	NPCR en %	UACI en %
Red	91.3650512	27.42313160
Green	70.7626342	7.40665211
Blue	66.9662475	6.40100815

b- Noise with variance 0.1



(a) (b)

Figure 13:(a) Ciphered image with noise pulses variance 0.1, (b) Following the deciphered image

Table 12:(a) PSNR, SSIM and rxy, (b) NPCR and UACI betweenthe original image and deciphered image with noise variance 0.1

(a)

Component	PSNR	SSIM	Rxy
Red	8.167437	0.08400832	0.1516538
Green	13.02812	0.1883436	0.4871869
Blue	13.54283	0.1403555	0.3214040

(b)

Component	NPCR en %	UACI en %
Red	94.529724121	30.750397326
Green	80.752563476	9.9044620289
Blue	78.739929199	9.3461698644

The results in Tables 11 and 12 and shown in the Figures 12, 13 is evidence that after the noise with the variances 0.05 and 0.1 we could know the deciphered image but the quality is not so good. We could see that PSNR, SSIM, and UAC is low and is high compared to that of the original image and keeps the same picture after image deciphering. That accounts for the high coefficient of correlation.

VI. COMPARISON OF RESULTS BETWEEN THE CASE WITH ANN COMBINED WITH FIBONACCI TRANSFORM AND THE CASE WITH ANN COMBINED WITH FIBONACCI TRANSFORM AND WAVELET TRANSFORM

The ANN combined with the Fibonacci transform is a complete ciphering technique in the Figure 12. The result could be shown inTable 13.

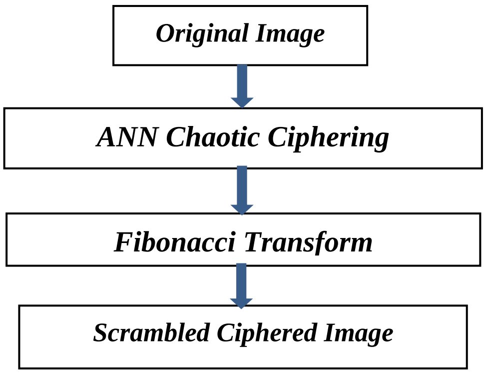


Figure 12:Ciphering image based on ANN and Fibonacci Transform

Table 13:(a)PSNR, SSIM, and rxy,(b) NPCR and UACIbetween the original image and the scrambled ciphered image

(a)

Component	PSNR	SSIM	Rxy
Red	7.65477	0.01197	-0.000998
Green	8.69909	0.008820	0.00044
Blue	10.03479	0.00931	-0.004003

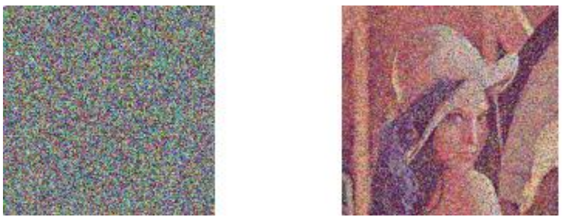
(b)

Component	NPCR en %	UACI en %
Red	99.572753	28.04445752
Green	99.64752197	9.341705920
Blue	99.548339	9.075891831

The two algorithms Figure 10 with DWT and Figure 12 without DWT have a same result with the parameter PSNR and NPCR. The algorithm with DWT has a value SSIM higher than the other algorithm but it still stays at less than 0.2 which is enough to abtain a ciphered unrecognizable image. In this parameter rxy, the algorithm of DWT has a greater value than the other algorithm but it still staysat lower than 0.05 just enough to obtain a ciphered image with a bad correlation in comparison with the original image. For the parameter UACI, suitable values are obtained with the algorithm DWT. This algorithm is more efficient compared with the other algorithm without DWT. The response times of two algorithms are described in Table 14. The main disadvantage of the chaotic algorithm RNA combined with Fibonacci without wavelet transform is the high time of responsiveness. But when combined with the wavelet transform, this time decreases quite much.

Table 14:Ciphering Time of the two algorithms

Ciphering Time	Chaotic ANN with Fibonacci transform without DWT	Chaotic ANN with Fibonacci transform with DWT
Ciphering	763.891435 seconds	95.793438 seconds
Deciphering	833.074809 seconds	100.884309 seconds



(a) (b)

Figure 14: (a) Image ciphered with ANN and Fibonacci Transform without DWT with variance of noise 0.1, (b) Following image deciphering

Table 15:(a) PSNR, SSIM and rxy, (b) NPCR and UACI between the original image and the deciphered image with noise variance 0.4

(a)

Component	PSNR	SSIM	Rxy
Red	11.559762	0.129052	0.438852
Green	12.189017	0.14017	0.470910
Blue	13.167511	0.11544	0.352580

(b)

Component	NPCR en %	UACI en %
Red	39.7552490234	10.9677124023
Green	40.167236328	4.24013025620
Blue	40.0299072265	4.25633449180

For the performance against noise, the results of the figures 14 and 15, the algorithm based on ANN and Fibonacci transform without wavelet is moreefficient against noise with the same algorithmalgorithm. So, the algorithm without DWT could support can standnoise pulses up to variance 0.4.

VII. CONCLUSIONS

The ANN is an advantageous technique of image ciphering on account of its robustness against noise and compression. Yet, it has two disadvantages namely a quite slow execution time for ciphering and still a few possible similarities between the ciphered image and the original image. For those two defects, the DWT could reduce the ciphering time and the Fibonacci transform could do away with the non-similarity between the original and the ciphered images. The criteria used for comparing images in this article are the correlations PSNR, SSIM, NPCR, UACI and ciphering time. When we encrypted Lena with our algorithm, we didn't get an identical image but a similar image between the one that had been deciphered and the original image. The correlation is more than 72% and SSIM more than 63%. But the NPCR is very high for the red component and UACI which accounts for the darker shade of the component red. For the comparison between the original image and the ciphered image, it is actually unrecognizable for strangers. The correlation is less than 3% and even for SSIM less than 8%. As forthe PSNR it is relatively so small unlike for the UACI which is between 20% and 40%. The most interesting feature of the ciphering with Fibonacci Transform combined with DWT is noise pulses with variance 0.1. This article shows also the time efficacy concerning the ciphering and deciphering algorithms between ANN with DWT and without DWT combined with Fibonacci Transform. The time for the algorithm without DWT is0 764seconds instead of 96sec for the ANN with DWT. The deciphering time for the algorithm with DWT is 833sec instead of 100sec with DWT.

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