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Image $\xrightarrow{\textit{Zoning}}$ Encryption

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ABSTRACT

This study focuses on image shuffling where the image is segmentd into four and then to each segment, various shuffling algorithms are applied and iterated until the vertical, horizontal and diagonal correlation values are minimum. Then to the shuffled segment, Cipher Block Chaining (CBC) algorithm is applied. Then the same procedure is applied for all the four segments and then combined again to form the original shuffled image. To authenticate the proposed method, correlation values, Number of Pixels Changing Rate (NPCR) and the Unified Averaged Changing Intensity (UACI) histogram analysis are computed to validate the sterness of the proposed algorithm and compared with the available literature.

Key words: Information security, image encryption, segmenting, shuffling, correlation values, UACI, NPCR

INTRODUCTION

The modern era digital communication bloomed with the evolution of internet. As it is nothing but the interconnection of computer networks globally, it employs state-of-the-art modern day optical and wireless technologies. This has paved the way for extensive researches in the field of information security to mainly detect and correct datum sabotage. The first and foremost functions of information security are information protection, control access and administer users. Some threats for the aforementioned include attacks erudition, rapid exposure to weaknesses, disseminated attacks and intricacies of patching. Information security makes certain the veracity, discretion, ease of use and off the record facts. Information security could be classified as Steganography (Amirtharajan and Rayappan, 2012a, b, 2013; Amirtharajan *et al.*, 2013a-d; Ramalingam *et al.*, 2014; Janakiraman *et al.*, 2012; Rajagopalan *et al.*, 2012; Thanikaiselvan *et al.*, 2012, 2013), Watermarking (Amirtharajan and Rayappan, 2013), Spread Spectrum (Praveenkumar *et al.*, 2012a-c, 2014a-j) and Encryption (Amin *et al.*, 2010; Alvarez *et al.*, 1999, 2000; Chen *et al.*, 2004).

The main goal here is to cater to the quandaries in the administrative, technical and physical fields in secure applications. Sivaranjani and Bright Prabahar (2013) has proposed an Image encryption algorithm that implements a random permutation, rotation operation and cipher block chaining. The scrambling operation is performed in horizontal, vertical and diagonal directions based on the RGB planes. Naik and Pal (2013) has proposed a two stage image Encryption employing Arnold's cat map shuffling in the first phase and diffusion on selected bit planes in the latter. Fu *et al.* (2013) have brought in the concept of a novel chaotic symmetric image encryption with permutation diffusion architecture. Pixel shuffling here is done based on chaotic henon map. Panduranga *et al.* (2013) proposed a partial image encryption based on block based image shuffling where pixel positions within the block are permuted with the help of chaotic maps.

Image encryption by image diffusion through pixel shuffling and bitplane separation operations performed prior to XOR operation was proposed by Maksuanpan *et al.* (2013) and Li-Hong *et al.* (2013), presented a hyper-chaos and the logistic chaotic encryption algorithm, where the chaotic sequences are used to modify the generated key. Sun *et al.* (2012) proposes a encryption methodology in which the original gray scale image is been separated into several bit planes, is shuffled using a random shuffling method and merged to obtain a single encrypted image.

Krishnamoorthy and Murali (2012) proposed an image encryption which employs the matrix inversion and Arnald cat shuffling. Matondo and Qi (2012) proposed a qi hyper chaotic system where two level image encryption scheme which involves Discrete Cosine Transform Coefficients. The selective coefficients are encrypted in frequency domain and for the second level shuffling is done in the spatial domain.

Feng-Ying *et al.* (2012) proposed chaotic logistic map which is used for pixel shuffling and medical image encryption using the combination of Logistic and chebyshev maps was proposed by Dai and Wang (2012). Encryption based on piece wise linear chaotic map used in nested fashion was presented by Abdlrudha and Nasir (2011) that involves the shuffling of the grey and colour levels. Masmoudi *et al.* (2012) introduced an encryption that combines the usage of chaotic maps with larger key space and Engle Continuous Fractions map.

Shahram and Mohammad Eshghi have brought in with the combination of chaotic maps and Tompkins-Paige algorithm based on permutation-substitution to provide image encryption. Tompkins- Paige algorithm and logistic maps are used to generate a bit sequence and pseudorandom numbers under 2D permutation. Loukhaoukha *et al.* (2012) have proposed Rubiks cube encryption in which the encrypted rows and columns are Xored using secret keys. Adrian-Viorel Diaconu1 and Khaled Loukhaoukha analysed a cryptosystem making use of chaotic cipher with Rubik's cube are used to shuffle and scramble to provide confusion and diffusion in image encryption.

Borujeni and Eshghi (2007) proposed a VHDL implementation of encrypted system using PRNG and tompkins paige algorithm and quantum logistic map by Akhshani *et al.* (2012). Rakesh *et al.* (2012) proposed a block based scrambling and logistic mapping to provide encrypted crypto system. Loukhaoukha *et al.* (2012) introduced rubick's cube principle with chaotic cipher to provide image encryption. Zhang *et al.* (2012) introduced image encryption utilizing the properties of DNA operation. Bahrami and Naderi (2012) utilised encryption based on light weight crypto algorithm. Patidar *et al.* (2010) presented a chaotic standard map to provide permutation-substitution with initial conditions, iterations, number of rounds and the parameters to the map that acts as a key of the algorithm.

After reviewing the available literature this study focuses on image encryption that was based on segmenting, shuffling and CBC encryption algorithm.

METHODOLOGY

The proposed scrambling ensures segmentation, shuffling and Cipher Block Chaining (CBC) needs a specific key or algorithm to stipulate the scrambling of the secret as shown in Fig. 1.

Proposed encryption algorithm: The proposed model was shown in Fig. 1 by considering the Lena image of 256×256:

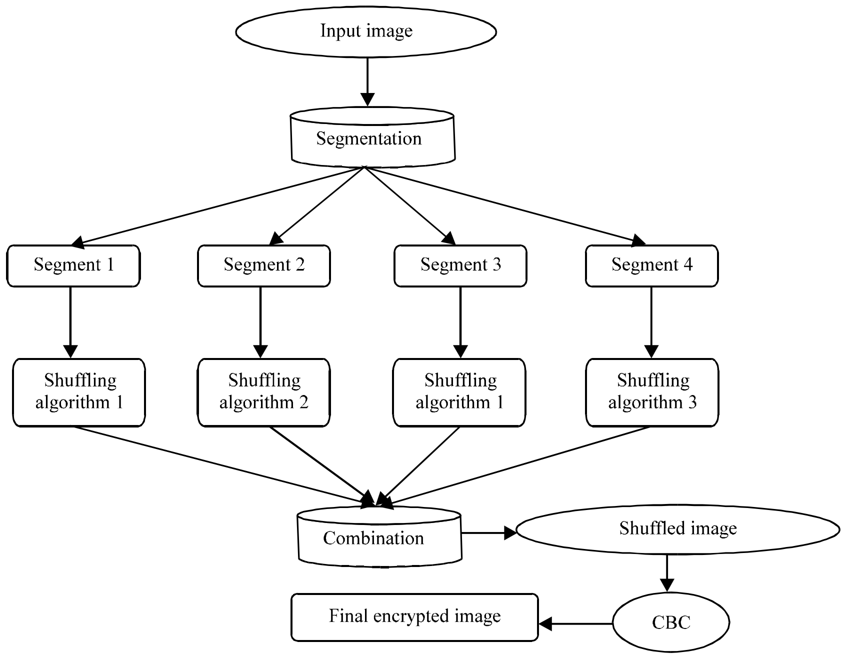

Fig. 1: Proposed model

- **Step 1:** Consider a Lena image I of size 256×256 in 8 bit format whose intensity value varies from 0-255. Initially Partition the input image I (i, j) of size 256×256 into four equal segments of size 128×128 using:

$$Im1 = I\ (1: (c/2),\ 1: (r/2))$$

$$Im2 = I\ (1: (c/2),\ ((r/2)+1): r)$$

$$Im3 = I\ (((c/2)+1): c,\ 1: (r/2))$$

$$Im4 = I\ (((c/2)+1): c,\ ((r/2)+1): r)$$

where, r and c represents the row and column of the original image.

- **Step 2:** Then the partioned segments are shuffled using shuffling algorithms

  For shuffling segments 1 and 3 do the following operations for 26 and 91 times, respectively:

$$n1 = [\ (x+5y^3) \bmod r]+1$$

$$n2 = [\ (y+2\ ((x^3+10y) \bmod c)\ ) \bmod c]+1$$

$$new\_seg\ (x,y) = orig\_seg\ (n1,\ n2)$$

Where:
x, y = Rows and columns of new shuffled segment
n1, n2 = Rows and columns of original segment
r, c = No. of rows and columns

For shuffling segment 2 do the following operations for 6 times:

$$n1 = [\,(1+y+x^2) \bmod r]+1$$

$$n2 = [\,3x \bmod c]+1$$

$$new\_seg\,(x, y) = orig\_seg\,(n1, n2)$$

For shuffling segment 4 do the following operations for 88 times:

$$n1 = [\,(2x+y) \bmod r]+1$$

$$n2 = [\,(x+y) \bmod c\,]+1$$

$$new\_seg\,(x,y) = orig\_seg\,(n1, n2)$$

- **Step 3:** After shuffling all the four new segmented images, group them to form a single encrypted image IMENC of size 256×256 and convert it into an unsigned 8 bit integer
- **Step 4:** Then CBC is applied to the segmented shuffled image to get the final encrypted output

Decryption can be obtained by reversing the above mentioned steps.

RESULTS AND DISCUSSION

The proposed methodolgy was carried out using MATLAB 7.1 considering LENA image of size 256×256 in 8 bit format whose intensity value varies from 0-255 as in Fig. 2a. Initially the image is segmented into four parts as in Fig. 2b. Then to each segment of size 128×128, different shuffling algorithms like Arnold, Henon and Polynomial are applied. The shuffled segmented images are given in Fig. 2c-f, respectively.

The segments are shuffled until the least correlation value for the particular segment is obtained. The correlation may be horizontal (HC), vertical (VC), diagonal (DC) or minimum sum of horizontal+vertical+diagonal.

In this method images are shuffled using shuffling algorithms but no encryption is applied. The number of iterations and the correlation values for various images are tabulated in Table 1.

Original Baboon image was given in Fig. 3a and the segmented image was given in Fig. 3b. Original camera man image was given in Fig. 3c and the segmented image was given in Fig. 3d. Original Lena image was given in Fig. 3e and the segmented image was given in Fig. 3f. Original Peppers image was given in Fig. 3g and the segmented image was given in Fig. 3h.

Table 2 provides the metrices of the encrypted Lena image. Figure 4a provides the Lena image after performing segmenting and shuffling. From the table, correlation values are nearing zero and

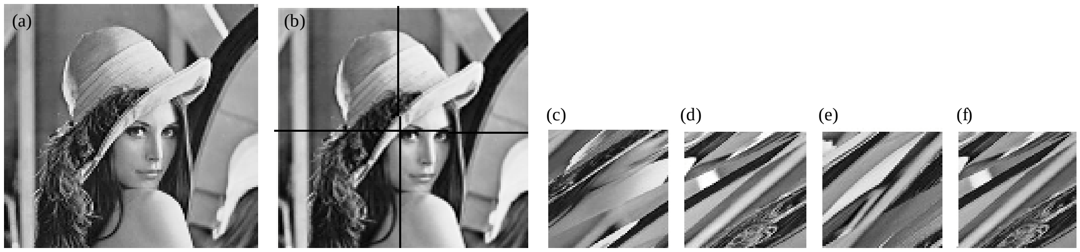

Fig. 2(a-f): LENA image (a) Orignal image, (b) Segmented image, (c) Segment 1 (d) Segment 2, (e) Segment 3 and (f) Segment 4 after shuffling

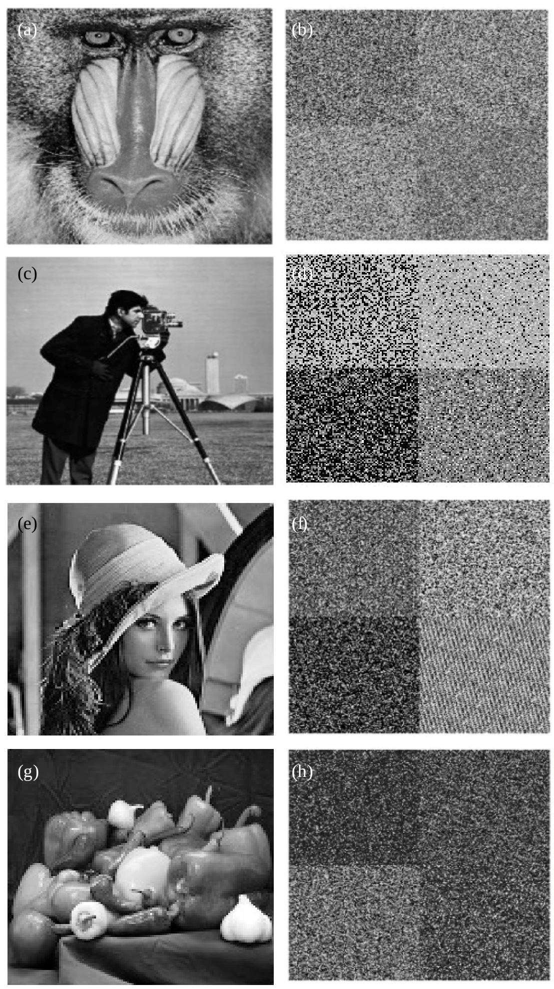

Fig. 3(a-h): (a, c, e, g) Orignal and (b, d, f, h) Segmented and shuffled Baboon, Cameramon, Lena and Pepper images

is compared with the available literature (Borujeni and Eshghi, 2009; Diaconu and Loukhaoukha, 2013; Loukhaoukha *et al*., 2012; Zhang *et al*., 2012; Bahrami and Naderi, 2012).

Table 1: Shuffling algorithms with correlation values for each segment of the images

Image	Horizontal	Vertical	Diagonal	No. of times shuffled	Shuffling algorithm
Lena segment1	3.3702e-004	3.1062e-004	-1.9116e-004	26	Quadratic shuffling
Lena segment2	-0.0025	-4.8043e-004	-0.0027	6	Hennon
Lena segment3	-5.0353e-004	2.9632e-004	-9.0579e-004	91	Quadratic
Lena segment4	-0.0350	2.4357e-004	-0.0230	88	Arnold
Baboon segment1	5.1733e-004	-0.0011	-0.0012	66	Quadratic shuffling
Baboon segment2	-0.0043	-7.3968e-004	-7.0700e-004	102	Hennon
Baboon segment3	0.0038	-1.4023e-006	6.0016e-005	27	Hennon
Baboon segment4	-0.0015	-8.4101e-004	-6.0133e-004	30	Hennon
Peppers segment1	-0.0032	-8.9373e-005	0.0017	118	Quadratic
Peppers segment2	3.5326e-004	3.8241e-004	0.0027	19	Quadratic
Peppers segment3	0.0015	-8.1707e-004	-0.0010	57	Hennon
Peppers segment4	-0.0019	7.1901e-004	0.0020	42	Quadratic
Camera segment1	1.6972e-004	-6.8820e-004	-0.0024	16	Hennon
Camera segment2	0.0010	2.0126e-004	0.0030	5	Quadratic
Camera segment3	-0.0028	-0.0015	-6.1090e-005	53	Quadratic
Camera segment4	0.0017	-0.0012	2.2282e-004	76	Quadratic

Table 2: Metrices of the proposed scheme with the available literature

Metrics	Borujeni and Eshghi (2009)	Diaconu and Loukhaoukha (2013)	Li-Hong *et al.* (2013)	Zhang *et al.* (2012)	Bahrami and Naderi (2012)	Proposed method
HC	0.005	0.0006	0.0068	0.1360	-0.0074	0.0054
VC	0.011	0.0002	0.0091	0.0166	0.0072	-0.0014
DC	0.023	0.0043	0.0063	0.0021	0.0105	0.0024
NPCR	99.700	99.60	99.5850	NA	70.2000	99.6307
UACI	29.300	30.50	28.6200	NA	26.2000	30.5468

NPCR and UACI values are 99.6 and 30 of the encrypted image are found to better than (Borujeni and Eshghi, 2009; Diaconu and Loukhaoukha, 2013; Loukhaoukha *et al.*, 2012; Zhang *et al.*, 2012; Bahrami and Naderi, 2012). Figure 4b provides the histogram of Fig. 4a, since no encryption was performed it resembles the original image histogram. Figure 4c provides the final encrypted Lena image after CBC and Fig. 4d provides the histogram of Fig. 4c. From the histogram after encryption, it is revealed that the encryption is uniform.

Correlation analysis: Correlation analysis has to be very minimum for a better cryptic image. The correlation co-efficient is computed as:

$$\Phi = \frac{\text{cov}(a,b)}{\sqrt{F(a)}\sqrt{F(b)}}$$

where, a and b represents the adjacent pixels of the shuffled image. The value of Φ can be calculated as:

$$T(a) = \frac{1}{S}\sum_{h=1}^{s} a_h$$

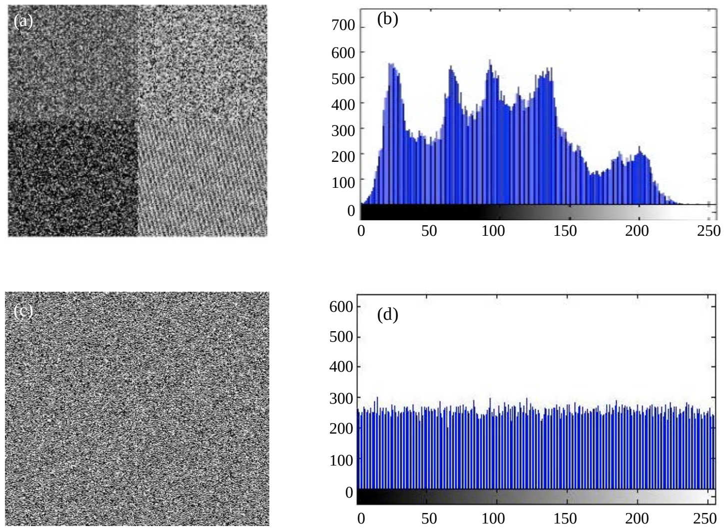

Fig. 4(a-d): Segmented and shuffled Lena image, (b) Histogram of 4(a), (c) Encrypted after CBC and (d) Histogram of 4c

$$F(a) = \frac{1}{S}\sum_{h=1}^{s}(a_h - T(b))^2$$

$$\text{cov}(a,b) = \frac{1}{S}\sum_{h=1}^{s}(a_h - T(a))(b_h - T(b))$$

where, S denotes the pixel pairs, From Table 1, its infered that the correlation values are nearing zero indicates that there exists no correlation between the original and the shuffled image.

NPCR and UACI: NPCR and UACI are the metrices to assess the strength of the proposed encryption algorithms. They are intended to evaluate the number of pixel change rate and the number of average intensity between the original and the encrypted ciphered image. Higher the values of NPCR and UACI indicate high resistance to differential and stsatistical attacks. Original and the encrypted image are represented as O_p and E, respectively.

NPCR can be calculated as:

$$\text{NPCR} = \frac{\sum_{a,b} B(a,b)}{A \times B} \times 100\%$$

UACI can be calculated as:

$$\text{UACI} = \frac{1}{A \times B}\left[\sum_{i,j} \frac{O_p(m,n) - E(m,n)}{2^n - 1}\right] \times 100\%$$

where, n represents the number that represents the image. The a, b represents the rows and columns of the image, B (a, b) represents the array having the same size as O_p and E.

CONCLUSION

In this study, image shuffling adopting three shuffling algorithms followed by segmenting and CBC mode of operation to provide the final encrypted output. The computed horizontal, vertical and diagonal correlation values reveals that there exists no correlation between the original and the shuffled image. NPCR and UACI values of 99.6 and 30.54 reveals that the proposed encryption algorithm resists differential and statistical attacks.

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