Image encryption algorithm based on the density and 6D logistic map

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ABSTRACT

One of the most difficult issues in the history of communication technology is the transmission of secure images. On the internet, photos are used and shared by millions of individuals for both private and business reasons. Utilizing encryption methods to change the original image into an unintelligible or scrambled version is one way to achieve safe image transfer over the network. Cryptographic approaches based on chaotic logistic theory provide several new and promising options for developing secure Image encryption methods. The main aim of this paper is to build a secure system for encrypting gray and color images. The proposed system consists of two stages, the first stage is the encryption process, in which the keys are generated depending on the chaotic logistic with the image density to encrypt the gray and color images, and the second stage is the decryption, which is the opposite of the encryption process to obtain the original image. The proposed method has been tested on two standard gray and color images publicly available. The test results indicate to the highest value of peak signal-to-noise ratio (PSNR), unified average changing intensity (UACI), number of pixel change rate (NPCR) are 7.7268, 50.2011 and 100, respectively. While the encryption and decryption speed up to 0.6319 and 0.5305 second respectively.

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1. INTRODUCTION

Information such as photographs, data, documents, speech, and videos may now be sent in seconds thanks to technological advancements. Because this information is transferred via a single frequency band, it may pose a security risk to the end user’s data [1], [2]. Images are important in a variety of industries, including information exchange, authorization, Google maps, satellite, medical, and military applications. The most critical challenge becomes protecting these photographs from unauthorized users. One technique to protect data from being hacked is to encrypt it [1], [3]. Cryptography is a method of storing and transferring data in a validated format so that only a single intended client can read and process it [4], [5]. Confidentiality, authenticity, integrity, and non-repudiation are all provided [3], [5]. Text encryption is not the same as image encryption [6]. Traditional encryption algorithms such as advanced encryption standard (AES), and others are not suitable for multimedia files due to their enormous data capacity, significant pixel correlation, and high redundancy [7], [8]. In 1963, Edward Lorenz became the first person to apply chaos theory to a computer system [4]. Because of the unauthorized person's noise-like signal, ergodicity, mixing, and sensitivity to the initial conditions, chaos-based cryptography has gotten a lot of attention in the recent decade. These properties may be linked to those of excellent ciphers, such as confusion and diffusion [6], [9].

Many picture encryption techniques based on chaotic systems have been presented in the field of information security research [3], [10]. Many picture encryption methods have been developed based on chaotic maps, such as the Logistic map [11]. Cryptanalytic attacks are significantly less effective on higher-dimensional chaotic functions [4], [12]. The main problem that may face the process of sending data such as images, texts, and other types of data is that it is exposed to many strong attacks, so we need to protect and preserve data by encrypting it. This paper presents an efficient and robust method for encrypting gray and color images based on chaotic logistic 6D with image density to generate key and encrypted images using exclusive OR (XOR) operation.

The remaining sections of the paper are organized as follows: section 2 focuses on related work. Section 3 explains the proposed system. Section 4 displays the results and discussion. Section 5 displays the National Institute of Standards and Technology (NIST) randomness test. Section 6 gives the conclusion.

2. RELATED WORK

The researchers focus on the chaotic systems of image encoding and decoding processes. Shahna and Mohamed [13] proposed a method to encrypt a grayscale image using the Z-order curve and logistic map. The key stream formed by this approach is influenced by the chaotic map. The original image is scrambled using the Z-order curve. The jumbled image is then encrypted using the random matrix provided by the logistic map. Entropy has the highest value of 7.9972, while unified average changing intensity (UACI) and number of pixel change rate (NPCR) have the highest values of 33.5124% and 99.6713%, respectively. It takes 0.52619 seconds to encrypt an image. Li *et al.* [14] A novel chaotic map is presented, which is based on a real-time variable logistic map with a randomly chosen decimal. This chaotic mapping is used to encrypt images. Several simulations indicate that the novel encryption technique may produce a securely encrypted image with low time complexity. The greatest value of entropy is 7.9979, while the highest values of UACI and NPCR are 33.47 percent and 99.62%, respectively. While encryption speed is 0.0386 (second). Elmanfaloty and Abou-Bakr [15] suggest a 1D chaotic function with five control parameters as a solution for addressing the issue of a restricted number of control parameters. The function's chaotic qualities and capacity to create a cryptographically safe random stream of integers are revealed via analysis. To demonstrate its resilience, a novel picture encryption technique is developed that uses the function as its random number generator. Several tests of the proposed system show that it is secure and has strong confusion-diffusion capabilities. The greatest entropy value was 7.902073, while the highest UACI and NPCR values were 33.5088% and 99.5994%, respectively. The encryption speed was 1.4598 (second).

Patel *et al.* [3] for confusion and dispersion of picture pixels, a 3D chaotic logistic map with deoxyribonucleic acid (DNA) encoding is suggested. In addition, the 3D chaotic logistic map is initialized with three symmetric keys, making the encryption technique robust. The random pixels are diffused using DNA encoding, followed by an XOR logical operation between the DNA encoded input image and the key image. The suggested system provides NPCR 99.6994% and UACI 31.5592%, while the entropy value is 7.9996. Oravec *et al.* [16] proposed a plaintext-related picture encryption technique that changes the parameter values of the logistic map in response to pixel intensities in the plain image. Row by row, the parameter values are changed, allowing the same encryption and decryption technique to be used. The parameter modification technique takes into consideration prior knowledge of the logistic map, its fixed points, and any periodic cycles. Because the resultant interval of parameter values contains large positive Lyapunov exponents, the logistic map's chaotic character should be clear. The test results indicate the highest values of UACI and NPCR being 33.4857% and 99.6143%, respectively. Kumar and Gupta [17] proposed an innovative and safe medical picture encryption system using a 1-dimensional logistic map and pseudo-random integers. The logistic map's initial values and parameters are used to generate key metrics for shuffling and replacing pixels in the picture (as secret keys). The encryption process's number of rounds can be raised or lowered. To counter known plain-image assaults, two pseudo-random rows and two pseudo-random columns were constructed on each side of the original picture during the encryption method. For the chosen images, the average entropy and NPCR of encrypted pictures were 7.99 and 99.6%, respectively.

3. PROPOSED METHOD

The main objective of this procedure is to secure images using a new encryption technique based on using density and a 6D chaotic logistics map. The new 6D logistics map is generated based on the image density value, which overcomes the logistic insecurity weakness, and the image is encrypted using the resulting map in addition to a master encryption key. Figure 1 shown the stages of the proposed system as described below:

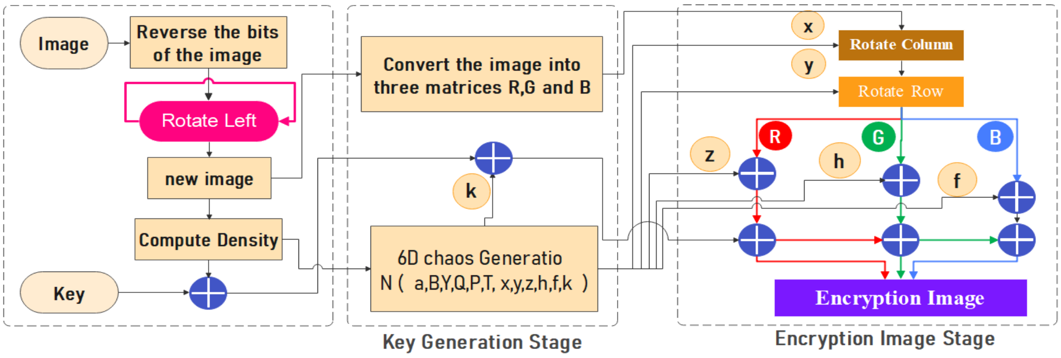


Figure 1. A block diagram illustrating the steps of the proposed method

3.1. Encryption image stage

The important stage in the proposed system is encryption stage. It is divided into five steps. These steps are described in the following:

Step 1: Image density calculation

The (1) was used to compute the density of the original image [18]:

$$D = \frac{\sum_{x=0}^{N} \sum_{y=0}^{M} image(x,y)}{N*M} \tag{1}$$

where *D*, *N* and *M* represent the density, width and height of the image, while image (*x*, *y*) represents the image pixel value for points *x* and *y*.

Step 2: 6D logistic chaotic map

The logistic map is the simplest process of chaos generation given by (2).

$$x_{i+1} = r\, x_i(1 - x_i) \tag{2}$$

The requirement to make this equation chaotic is $0 < x_i < 1$ and $r = 4$ [19]. Liu *et al.* [20] suggest a 2D logistics map using quadratic coupling to enhance security. Hossain *et al.* [4] suggest a 3D logistics map using quadratic-cubic coupling for added safety. The extended 6D version is suggested by (2) to (7).

$$x_{i+1} = \mathrm{a}x_i(1 - x_i) + \mathrm{B}k_i^2 x_i + \mathrm{Y}f_i^3 + \mathrm{Q}h_i^4 x_i + \mathrm{P}z_i^5 + \mathrm{T}y_i^6 x_i \tag{2}$$

$$y_{i+1} = \mathrm{a}y_i(1 - y_i) + \mathrm{B}x_i^2 y_i + \mathrm{Y}k_i^3 + \mathrm{Q}f_i^4 y_i + \mathrm{P}h_i^5 + \mathrm{T}z_i^6 y_i \tag{3}$$

$$z_{i+1} = \mathrm{a}z_i(1 - z_i) + \mathrm{B}y_i^2 z_i + \mathrm{Y}x_i^3 + \mathrm{Q}k_i^4 z_i + \mathrm{P}f_i^5 + \mathrm{T}h_i^6 z_i \tag{4}$$

$$h_{i+1} = \mathrm{a}h_i(1 - h_i) + \mathrm{B}z_i^2 h_i + \mathrm{Y}y_i^3 + \mathrm{Q}x_i^4 h_i + \mathrm{P}k_i^5 + \mathrm{T}f_i^6 h_i \tag{5}$$

$$f_{i+1} = \mathrm{a}f_i(1 - f_i) + \mathrm{B}h_i^2 f_i + \mathrm{Y}z_i^3 + \mathrm{Q}y_i^4 f_i + \mathrm{P}x_i^5 + \mathrm{T}k_i^6 f_i \tag{6}$$

$$k_{i+1} = \mathrm{a}k_i(1 - k_i) + \mathrm{B}f_i^2 k_i + \mathrm{Y}h_i^3 + \mathrm{Q}z_i^4 k_i + \mathrm{P}y_i^5 + \mathrm{T}x_i^6 k_i \tag{7}$$

The chaotic behavior in the preceding equations may be seen here in 3.57<a<4, 0<B<0. 14*10^{-11}, 0<Y<0.045*10^{-11}, 0<Q<0.061*10^{-11}, 0<P<0.012*10^{-11}, 0<T<0.0021*10^{-11}, and the starting value of x, y, z, h, f, and k between 0 and 1. The presence of hexagonal quadratic coupling and six constant terms complicates and secures the 6D logistic map. Figure 2 shown the performance of the proposed chaotic sequences, while Figures 2 (a) to (f) shown the chaotic sequences formed using the (3) to (8) and a starting value of x(1)=0.01+1/D; y(1)=0.02+5/D; z(1)=0.03+10/D; h(1)=0.04+15/D; f(1)=0.05+20/D; k(1)=0.06+25/D; a=4; B=1/D+0.135*10^{-11}; Y=0.1262*10^{-11}; Q=0.1573*10^{-11}; P=0.1384*10^{-11}; T=5/D+0.1695*10^{-11}, and the number of iterations is 100.

Step 3: Reverse Image Bits and Rotate Left

Firstly, an algorithm used to invert the image bits and rotate it to the left in one-bit increments to improve the method's security, which make it have a good anti-noise attack. This step is shown as example: we have the value 216 as it is converted to binary value 11011000, the bits are inverted to get 00011011, after doing a left rotation, the value becomes 00110110 and returns to the integer 54. Figures 3(a) to 3(f) display the results of the first step, Figures 3(a) and 3(d) represent the original tested image, Figures 3(b) and 3(e) represent the inverting and rotating process, while Figures 3(c) and 3(f) represent the histogram of inverting and rotating process.

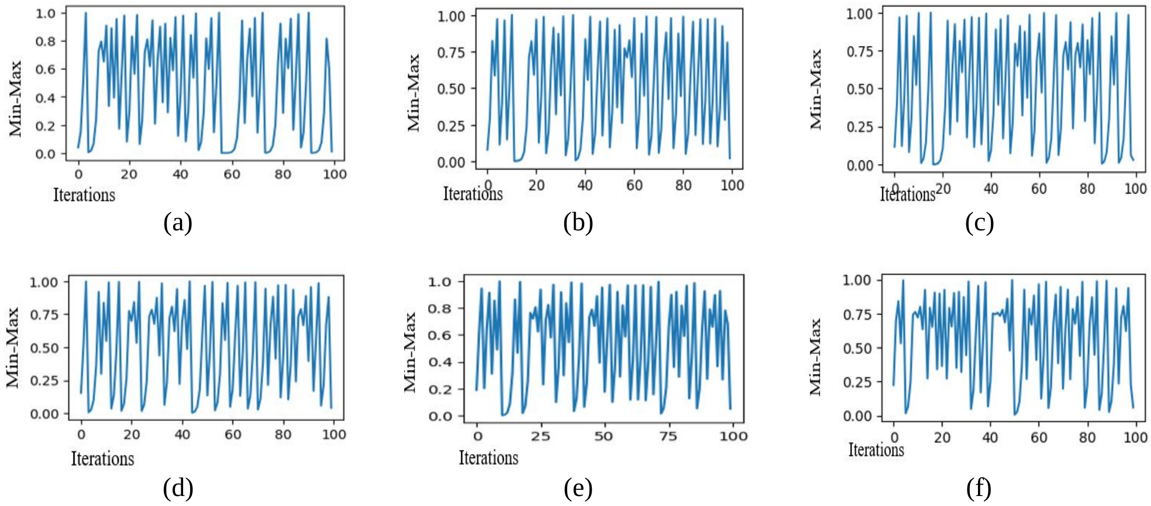


Figure 2. Performance of the 6D chaotic, (a) to (f) show the chaotic sequences

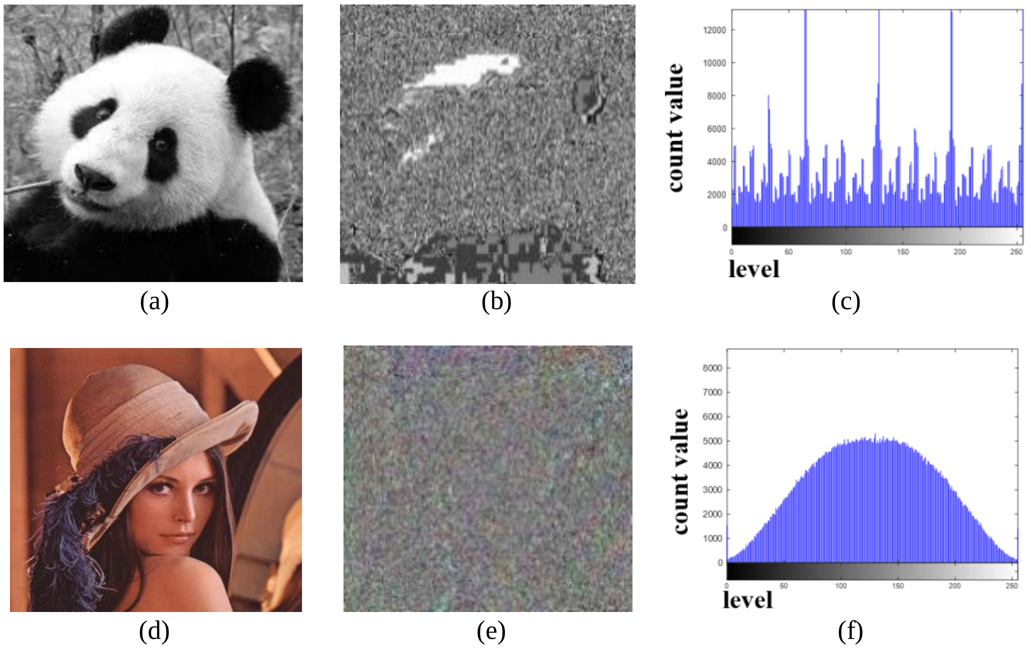


Figure 3. Result of panda gray: (a) original, (b) inverting and rotating, (c) histogram; and result of Lena: (d) original, (e) inverting and rotating, and (f) histogram

Step 4: Column rotation and row rotation

The image pixel values are rotated depending on the chaos, according to the chaos x value of (3) to enhance security by switching the image pixel values. We introduce a new way to rotate values based on the sequence of images and clutter X columns. We go left when clutter is even and right if clutter is odd. Row rotation is the same as column rotation, the image pixel values are rotated depending on the chaos, according to the chaos y value of (4), and further enhance security by switching the image pixel values. And to rotate the values based on the sequence of rows of images and the chaos y.

Step 5: XOR operation

The XOR technique is the final step in the encryption process. The XOR operation changes the value of a pixel to a new value and cannot be reversed without knowing the chaos key [21]. In the beginning, four of the chaos values Z, H, F, and K are generated, and the image was divided into three matrices: R, G, and B. The XOR operation was performed between the chaos value Z and the R matrix with the master key after performing the XOR operation with the chaos value K. And perform an XOR operation between the value of the chaos H with the G matrix and make an XOR for the resulting value with the value of the R matrix. Finally, perform an XOR operation between the chaos value of F with the B matrix, and XOR the resulting value with the G matrix value. By repeating these operations on all the pixels of the image, we get encrypted images. Algorithm 1 explains the steps of the proposed system.

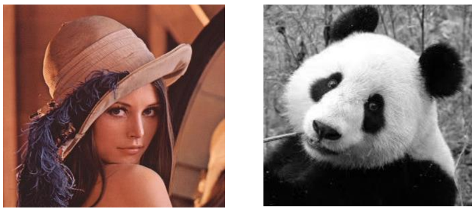
Algorithm 1. The proposed image encryption system

```
              Encryption Algorithm
Input: image, Initial (a, B, Y, Q, P, T,
x, y, z, h, f, k), key
Output: image encryption
Step1: Density Calculation
      Density = 0; i = 0
For all x, y Do {where 0≤ x≤ M, 0≤ y≤ N}
         Density = Density + image [x][y]
       End For// N, M
      Density = (Density/M*N)
      key = Key ⊕ Density
Step2: Generate Logistics Chaos Keys
       Logis6D = Generate
     (a,B,Y,Q,P,T,x,y,z,h,f,k,Density)
Step3: Reverse Image Bits and Rotate Left
      revImg = Reverse(image)
      rotLImg = RotateLeft(revImg)
Step4: Column and Row Rotation
      rotCImg = ColumnRotation (rotLImg,
      Logis6D.x)
      rotRImg = RowRotation (rotCImg,
      Logis6D.y)
Step5: XOR Operation
For all x, y Do {where 0≤ x≤ M, 0≤ y≤ N}
key = key ⊕Logis6D.k[i]
     R = rotRImg [x][y][0] ⊕ Mod
     (Logis6D.z[i] ⊕ key,256)
        G = rotRImg [x][y][1] ⊕ Mod
      (Logis6D.h[i] ⊕ R, 256)
        B = rotRImg [x][y][2] ⊕ Mod
      (Logis6D.f[i] ⊕ G, 256)
        Image_encryptio [x][y] = newRGB
      (R, G, B);   i = i + 1
      End For// N, M
```

```
              Decryption Algorithm
Input: image, Initial (a,B,Y, Q, P, T, x, y,
z, h, f, k), key,
            Density
Output: image decryption.
Step1: Key Calculation
            key = Key ⊕ Density
Step2: Generate Logistics Chaos Keys
      Logis6D =
     Generate(a,B,Y,Q,P,T,x,y,z,h,f,k,Density)
Step3: XOR Operation
             i = 0
      For all x, y Do {where 0≤ x≤ M, 0≤ y≤ N}
        key = key ⊕ Logis6D.k[i]
        OR = image[x][y][0]
         R = OR ⊕ Mod (Logis6D.z[i] ⊕ key,
     256)
        OG = image [x][y][1]
        G = OG ⊕ Mod (Logis6D.h[i] ⊕ OR, 256)
        OB = image [x][y][2]
        B = OB ⊕ Mod (Logis6D.f[i] ⊕ OG, 256)
        nImage [x][y]= newRGB (R, G, B); i=i+1
             End For// N, M
Step4: Reverse Row and Column Rotation
      rotRImg = RowRotation (nImage, Logis6D.y)
      rotCImg = ColumnRotation (rotRImg,
      Logis6D.x)
Step5: Reverse Image Bits and Rotate Left
      rotLImg = RotateLeft(rotCImg)
      image_decryption = Reverse(rotLImg)
```

4. RESULTS AND DISCUSSION

Experiments with the suggested approach were carried out on a machine with a 3.30 GHz CPU and 16 GB of RAM, which was running GO language at Windows 11 Home, 64-bit. Figure 3 displays the tested images utilized in experiments [22]. All of these images have a 512×512-pixel resolution. Color depths of up to 24 bits per pixel are used in the Lena image; color depths of up to 8 bits per pixel are used in the panda gray image. The proposed system is tested for ten images from the dataset (i.e., all dataset images), but this work only shows the results of two images as described in Figure 4 displays the test images for Lena and gray panda.



Lena panda gray

Figure 4. A set of experimental images

The following criteria are utilized to measure the performance of the presented cryptosystem.

– Histogram

One criteria used in the proposed system is histogram. The image histogram displays the number of pixels (along the y axis) at each intensity level (along the x-axis) to demonstrate how the pixels are distributed in the image [12], [23]. A successful image coding system should provide all encoded images with a uniform image outline, regardless of the original planar image structure [23], [24].

– Mean square error (MSE) and peak signal to noise ratio (PSNR)

The difference between the input and output images in terms of pixel intensity levels is measured using MSE. The MSE value is higher [15] for an ideal fully encrypted cipher image. The MSE is computed using (9).

$$MSE = \frac{1}{M\ x\ N} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} [C_1(i,j) - C_2\ (i,j)]^2 \tag{9}$$

where *M, N* is the width and height of images and *C1* is the original image and *C2* is the cipher image. PSNR analysis The PSNR reflects the encryption quality. The lower value of PSNR is the better encryption quality [15], [25],[26].

$$PSNR = 20 \text{ x } \log_{10}\left(\frac{255}{Sqrt\ (MSE)}\right) \tag{10}$$

– NPCR and UACI

NPCR value tells the rate of change of a number of pixels in an encrypted image when a pixel of the original image is changed [11], [16]. The highest value is the better in the encryption [25], [27], NPCR of an image can be defined as (11).

$$D(i,j) = \begin{cases} 1, & C_1\ (i,j) \neq\ C_2(i,j) \\ 0, & C_1\ (i,j) =\ C_2(i,j) \end{cases} NPCR = \frac{\sum_{i,j} D(i,j)}{M*N} * 100\%. \tag{11}$$

UACI value calculates the average intensity of differences between the original image and the encrypted image [11], [25]. The highest value is the better in the encryption [25], UACI of an image can be defined as (12).

$$UACI = \frac{1}{M*N}\left[\sum_{i,j} \frac{|C_1(i,j) - C_2(i,j)|}{15}\right] * 100\ \%. \tag{12}$$

– Entropy analysis

The entropy (H) of a symbol source (S) can be calculated by (13) [4].

$$H(s) = -\sum_{i=0}^{M-1} P(s_i) \log_2 \frac{1}{P(s_i)}. \tag{13}$$

where (Si) is the chance that a pixel will appear in an image, and N is the length of a pixel's binary number (typically N=8 for a gray image). The cryptosystem's ability to withstand entropy assaults is one of its most essential features; the optimal entropy value of encrypted pictures is 8 bits/pixel [2].

– Correlation coefficient analysis

The correlation coefficient of a visible image with correct brightness is one, but it is much lower for a ciphered image (almost equal to zero). An encryption technique produces ciphered images with randomly dispersed pixels of various brightness and a low correlation coefficient between neighboring pixels [3], [15], [28]. The correlation coefficient of any two-pixel color values at the same place in the original and cipher pictures is calculated using (14) [2].

$$Corr(x,y) = \frac{E[(x-\mu_x)(y-\mu_y)]}{\sigma_x\,\sigma_y}. \tag{14}$$

where μx and μy represent mean values of x and y, σx and σy are the standard deviations of x and y, and E [·] is the expectation function [2].

4.1. Results of image encryption and decryption using 6D logistic map

A picture encryption solution should be resistant to all known forms of attacks and should not be dependent on the plaintext or encryption key. If the encryption key is to be utilized consistently, a suitable picture encryption algorithm should be able to encrypt any plain text image into a randomly generated ciphertext [12]. The suggested picture encryption approach is put to the test in this part utilizing a six-dimensional logistics map and security analysis. Figures 5(a) to (f) show the results of encryption after applying the inverting and rotating of the bits, encryption and decryption for the tested images (i.e., panda and Lena), respectively, while Figures 5(g) to (l) show histogram analysis of applying the inverting and rotating of the bits, encryption and decryption for the tested images (i.e., panda and Lena), respectively.

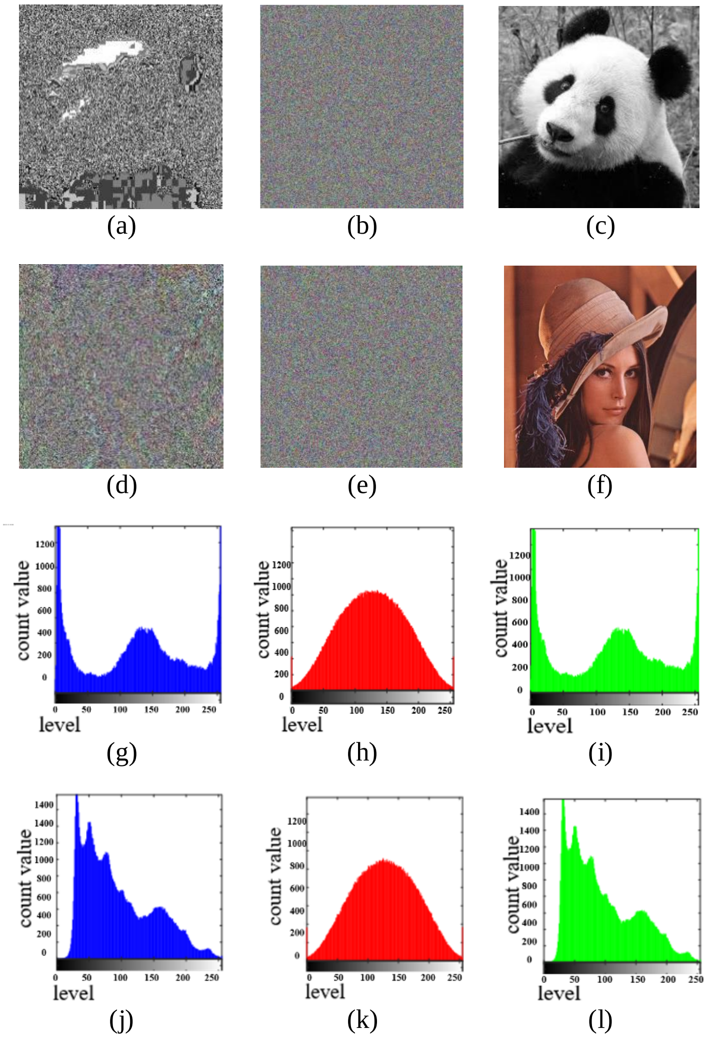


Figure 5. Results of encryption stage of panda gray: (a) inverting, (b) encryption, and (c) decryption; Results of encryption stage of Lena: (d) inverting, (e) encryption, and (f) decryption; Histogram of the tested images (panda gray): (g) inverting, (h) encryption, and (i) decryption; Histogram of the tested images (Lena): (j) inverting, (k) encryption, and (l) decryption

4.2. MSE and PSNR analysis

Table 1 shows the MSE and PSNR values of the original and encoded images of panda and Lena. The highest value of MSE indicates a better result of encryption, while the lower value of the PSNR indicates better encryption quality. While the value of MSE and PSNR of the decrypted stage equal to 0 and ∞ respectively.

Table 1. MSE and PSNR values for plain and cipher images of panda, Lena

Image Name	Encrypt		Decrypt	
	MSE	PSNR	MSE	PSNR
Panda	10731.8118	7.8241	0	∞
Lena	10974.8954	7.7268	0	∞

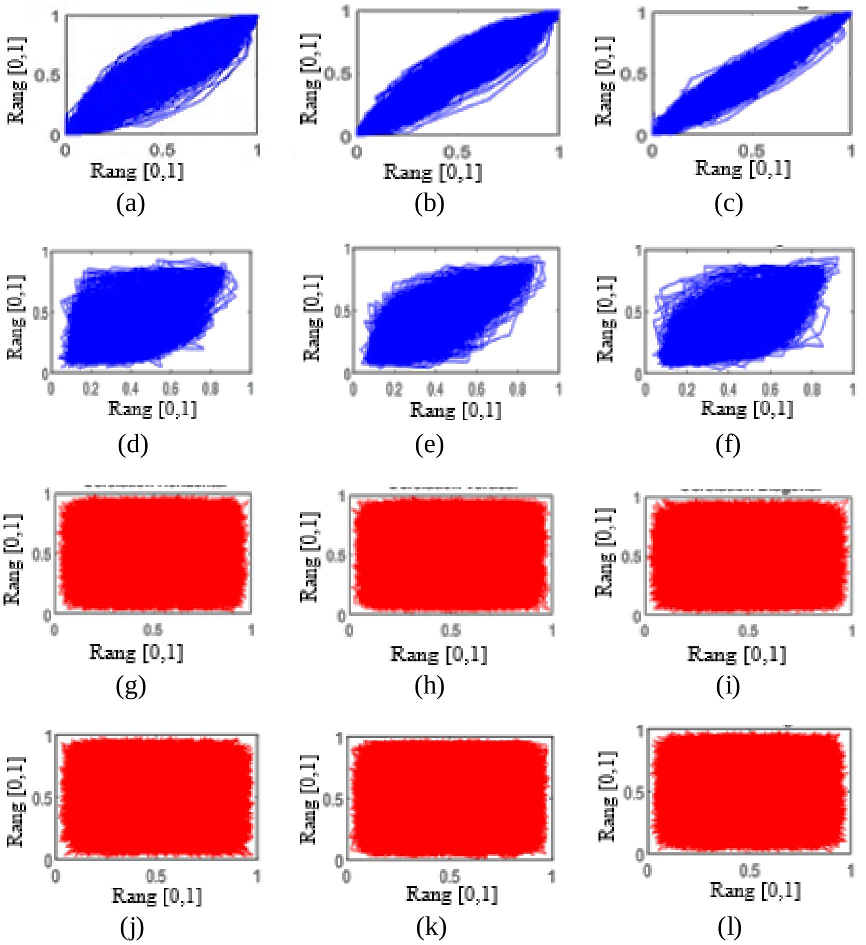
4.3. Correlation analysis and entropy analysis

The proposed algorithm is analyzed on the two test images. The encrypted images are obtained by applying five levels of encryption process on the input image which include: reverse bits, rotate left, 6D chaos generation, pixel permutation, column rotation, row rotation, and, XOR logical operation. Table 2 shows the results of the entropy and correlation of the two test images encrypted in the proposed system.

Figures 6(a) to (f) illustrate the scatter plots of correlation for plain images for all of the tested images (i.e., panda and Lena) in the horizontal, vertical, and diagonal directions respectively. While Figures 6(g) to (l) illustrate the scatter plots of correlation for encrypted images for all of the tested images (i.e., panda and Lena) in the horizontal, vertical, and diagonal directions respectively.

Table 2. shows the results of the entropy and correlation test of the encrypted images

Image Name	Entropy			Correlation		
	Plain	Encrypt	Decrypt	Horizontal	Vertical	Diagonal
Panda	7.5729	7.7048	7.5729	-0.00116	0.00070	-0.00117
Lena	7.4929	7.7043	7.4929	0.00311	0.00266	-0.00188



(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

(j) (k) (l)

Figure 6. The correlation scatter plots (a) horizontal, (b) vertical, and (c) diagonal for the plain panda image; The correlation scatter plots (d) horizontal, (e) vertical, and (f) diagonal for Lena images; The encrypted (g) horizontal, (h) vertical, and (i) diagonal for the plain panda image; The encrypted (j) horizontal, (k) vertical, and (l) diagonal for the Lena image

4.4. Differential attacks analysis

The results from the proposed system are two encrypted images: one by directly encrypting it and the other by altering the one pixel of the original image and then encrypting it. These images are needed to compute the value of NPCR and UACI values to evaluate the performance of the proposed system. NPCR and UACI values are listed in Table 3 for all tested images. All of the NPCR values are 100 percent, which means that changing one pixel of the original image changes 100 percent of the encrypted image. All UACI values are greater than 50.2011 percent, indicating that each pixel has been altered by a factor of more than 50.2011 percent. Because the experimental values match the theoretical values, the suggested method is resistant to differential assaults. The reason the values of NPCR and UACI are equal to 100% and 50.2011%, respectively is due to the change in the initial values of the logistic map variables that depend on the image density value. Thus, we get completely different encryption keys when changing only one pixel in the image.

Table 3. NPCR and UACI values of panda, Lena

Image Name	NPCR	UACI
Panda	100	50.1374
Lena	100	50.2011

4.5. Analysis of speed

The encryption time for a cryptosystem should be as short as feasible. The time taken to implement the suggested method for all test images is shown in Table 4. Given the proposed scheme's high level of security, these running speeds are acceptable.

Table 4. Encryption and decryption speed test

Image Name	Encryption Speed (second)	Decryption Speed (second)
Panda	0.7341407	0.6250961
Lena	0.6319286	0.5305631

4.6. Comparison

Table 5 shows the performance evaluation metrics attained by our proposed method with those given in previous studies. Also, shows the proposed method given better results than methods in the previous studies. Thus, improved the efficiency of the proposed system.

Table 5. Comparison of the proposed method for encryption images with the previous studies

Measurements	Proposed	[3]	[14]	[15]	[16]	[17]
MSE	10974.8954	-	-	10.984×10^3	-	-
PSNR	7.7268	-	-	7.7230	-	-
NPCR	100	99.6994	99.620	99.5994	99.6143	99.6166
UACI	50.2011	31.5592	33.470	33.5088	33.4857	33.4971
Entropy	7.7048	7.9996	7.9979	7.9020	7.9992	7.9994
Horizontal Correlation	-0.0011	− 0.0083	0.0010	− 0.0611	−0.0019	0.0051
Vertical Correlation	0.0007	0.0003	0.0042	− 0.0083	0.0020	−0.0212
Diagonal Correlation	-0.0011	− 0.0002	0.0063	0.0573	−0.0012	−0.0006
Encryption speed (second)	0.6319	-	-	1.4598	-	-
Decryption speed (second)	0.5305	-	-	-	-	-

5. NIST RANDOMNESS TEST

In the randomness tests, the NIST test is the most popular of all sequence randomness testing [15]. We run NIST tests in the random sequence of logistic map keys used for encryption to get the results. Table 6 shows the results of the NIST test and shows that all the generated encryption keys are random for the 16 items.

Table 6. NIST Testing for bit sequences that have a length 1000000 bits

Type of Test	P-Value	Status	Type of Test	P-Value	Status
Frequency test (Monobit)	0.1109360349	Random	Maurer's Universal Statistical	0.9474038661	Random
Frequency test within a Block	0.6844520627	Random	Linear Complexity	0.0835948312	Random
Runs test	0.8882324080	Random	Serial	0.0562166344	Random
Longest Run of Ones in a Block	0.2286732551	Random	Approximate Entropy	0.1026101879	Random
Binary Matrix Rank	0.9257659124	Random	Cumulative Sums (Forward)	0.1954422847	Random
Discrete Fourier Transform (Spectral)	0.7067371399	Random	Cumulative Sums (Reverse)	0.1369098792	Random
Non-Overlapping Template Matching	0.6902486144	Random	Random Excursions (+1)	0.1208959044	Random
Overlapping Template Matching	0.1856326458	Random	Random Excursions Variant (+1)	0.1686775974	Random

6. CONCLUSION

In previous studies, on chaotic logistic 3D, this topic has been widely researched and handled. But this paper presents an efficient and robust method for encrypted images based on chaotic logistic 6D with image density to generate key and encrypted images using XOR operation. The proposed system has been tested on all types of images and of different sizes. The experimental results show that the highest value is obtained when PSNR is 7.7268, UACI and NPCR are 50.2011 and 100 respectively. according to the testing data. We can infer that our algorithm has a good level of security and can effectively withstand a variety of assaults based on the results of the testing. All of these data show that our method is competitive with previously developed chaos-based image encryption techniques.

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