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Performance Analysis of Six Chaos Cryptographic Algorithms for Image Encryption

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ABSTRACT
The increase in cyber crimes such as theft and piracy adds to the vulnerability of storing and sending image data in cyberspace. To deal with the rampant crime in cyberspace, especially in image data, cryptography is implemented on images. Cryptography based on chaos theory was chosen because it has a random key generator value. Implementation of image cryptography based on chaos theory makes image cryptography more developed, chaos-based algorithms that have been implemented are the Algorithm Arnold Cat Map, Baker's Map, Ikeda Map, Tent Map, Logistic Map 3, Gauss Iterated Map, Henon Map, and Duffing Map Gingerbreadman Map. Of the many algorithms implemented previously in 2016 against the Logistic Map 3, Gauss Iterated Map, Henon Map, Duffing Map Gingerbreadman Map algorithms, comparisons and analysis of encryption time, decryption time, key sensitivity, histogram, lossy and lossless in the decrypted image have been carried out. In this study, the Tinkerbell Map algorithm was initiated to be implemented in image cryptography and compared to the Logistic Map 3 algorithm, Gauss Iterated Map, Henon Map, Duffing Map Gingerbreadman Map. Also added correlation coefficient analysis, MSE and PSNR analysis, to analyze the security of encrypted images. Based on testing of Logistic Map 3, Gauss Iterated Map, Henon Map, Duffing Map Gingerbreadman Map, Tinkerbell Map have different performance. The histogram analysis produces a very good spread of pixels, each algorithm has a different key sensitivity, the highest is the Tinkerbell Map. Henon Map is the best algorithm for correlation coefficient, MSE and PSNR. Time analysis found that the Tinkerbell Map algorithm has the longest process value, and the fastest is logistics map 3.

General Terms
The increase in cyber crimes such as theft and piracy adds to the vulnerability of storing and sending data in cyberspace. Unknowingly, data and information that should be used for personal consumption are vulnerable to being exploited by irresponsible parties. In addition, there are many applications that can be used to manipulate data and information, especially data in the form of images. This is a concern for users about data and information security. The more complicated the method used, the better the resulting level of security.

Keywords
Image Cryptographic, Encryption, Decryption, Chaos Cryptographic Algorithms

1. INTRODUCTION
Modern cryptographic algorithms have implemented the bit method in encoding messages. This makes the resulting message even more difficult to decipher. The chaos-based encryption algorithm has the right criteria because it is sensitive to initial conditions, has random behavior, and does not have a repeating period. The use of chaos in cryptography can produce confusion and diffusion effects [1].

Chaos-based image encryption algorithms have undergone many developments, such as Logistic Map 3 which has been developed from Logistic Map [2]. The Gauss Iteration Map is examined for its bifurcation diagram [3]. Duffing Map is implemented in the application and the key space is analyzed [4]. Gingerbreadman Map is implemented and analyzed key sensitivity of the algorithm [5]. Henon Map is implemented in the application and measures the time it takes to brute force [6]. Chaos-based algorithms are implemented to help secure data and information. Research that compared the five chaos-based algorithms was carried out, including the five chaos-based algorithms [7] thereare Logistic Map 3, Gauss Iterated Map, Duffing Map, Gingerbreadman Map and Henon Map with image analysis in PNG, BMP, JPEG/JPG formats. Analysis includes histogram, decryption time, lossy and lossless images when decrypted and key sensitivity. It was found that the images were in JPEG/JPG format when they were decrypted, the images did not return to the original image or were lossy. Furthermore, the longest decryption time in previous studies is the Gingerbreadman Map [7]. In this study an algorithm was added as a comparison, that is the Tinkerbell Map algorithm. Previously the Tinkerbell Map algorithm had been studied and the results obtained were that the bifurcation generated by the algorithm was very random [8].

In this study proposed analysis of the correlation coefficient, MSE (Mean Square Error) and PSNR (Peak Signal-to-Noise Ratio). The correlation coefficient is the relationship between two variables, if in the image is the relationship between two pixels. If the two neighboring pixels in an image, then there will be a close correlation between the two pixels [9]. PSNR is a calculation that determines the value of a resulting image. The PSNR value is determined by the size of the MSE value that occurs in the image. The greater the PSNR value, the better the results obtained in the resulting image display. Conversely, the smaller the PSNR value, the worse the results obtained in the resulting image display. The unit of value for PSNR is the same as MSE, is decibels (dB) [10] [11]. So the relationship between the PSNR value and the MSE value is that the greater the PSNR value, the smaller the MSE value.

PSNR is generally used to measure the quality of image rearrangement. This is easier to define with MSE. MSE is the mean squared error. The MSE value is obtained by comparing the value of the difference in the pixels of the original image with the resulting image at the same pixel position. The greater the MSE value, the worse the appearance of the resulting image will be. Conversely, the smaller the MSE value, the better the appearance of the resulting image [10] [11].

JPEG/JPG formatted images are not carried because these formatted images cannot be decrypted, or the images will be damaged when decrypted [7]. Based on the algorithms mentioned, this study analyzes the performance of the six algorithms, there are Logistic Map 3, Gauss Iterated Map, Duffing Map, Gingerbreadman Map, Henon Map and Tinkerbell Map. As a research tool, an image cryptography application was created with the help of the MATLAB program which encrypts and decrypts images using the six algorithms. Then the results of the image processing produce values that are useful for measuring the performance of the chaos-based algorithm.

Image encryption is an alternative to securing digital images, chaos-based algorithms have the right criteria for digital images such as Logistic Map 3, Duffing Map, Henon Map, Gauss Map, Gingerbreadman Map and Tinkerbell Map. Chaos-based algorithms have different formulas or equations, one way to be able to choose the best algorithm according to their needs is by analyzing the algorithm with the help of image cryptography applications. The analysis was performed by comparing the time, histogram, key sensitivity, MSE and PSNR values, and the correlation coefficient of the encrypted image to determine the performance of each of these algorithms.

In the world of mathematics, chaos theory describes the behavior of a dynamic system, whose state always changes with time and is very sensitive to its own initial conditions. This theory is often referred to as the butterfly effect. Chaos theory comes from system theory which shows the emergence of irregular data, even though this theory is actually used to explain the emergence of random data [12].

Chaos theory can be implemented in image cryptography to generate encryption keys. The encrypted image will produce a different image which is useful for maintaining security when storing or sending data. There are six chaos-based algorithms in this study:

1. Logistic Map is a polynomial map of degree 2, often cited as an example of an archetype of complexity. Random or chaotic behavior can arise from very simple nonlinier dynamical equations. Equation (1) Logistic Map 3 is development of the Logistic Map algorithm [2].

$$x_{n+1} = r \times x_n \times (1 - x_n) \times (1 - 1.2 \times x_n)^2 \quad (1)$$

In equation (1) the value of r will increase the random area and x_n is the initial value in the equation, and these two values are secret.

2. Gauss Iterated Map in mathematics commonly called Gaussian Map or Mouse Map is a nonlinear equation that maps real numbers to an interval of real numbers by using the Gauss function [3].

$$x_{n+1} = exp\ exp\ (-ax_n^2) + b \quad (8)$$

The variables a and b affect the width and height of the Gaussian curve representation, x_n is the initial$x$ value. Even though Gaussian is the same as Logistic Map, but the dynamics associated with this map is more complicated as it contains two parameters. Even though most of the features of the Logistic Map are also presented in the Gaussian Map, certain features of the Gaussian map such as the non-multiplying period and stability are not shown at all by the Logistic Map.

3. Duffing map is a dynamic system using discrete time that applies chaos properties. The duffing map takes a point at a coordinate and then maps it to a new point according to equation (2) and equation (3) [4]:

$$x_{n+1} = y_n \quad (2)$$

$$y_{n+1} = -bx_n + ay_n - y_n^3 \quad (3)$$

The generation of the encryption key is influenced by two values, variables a and b. In equations (2) and (3) there are variables a and b, the value of variable a is often used is 2.75 and the value often used b is 0.2. These two numbers are often used to generate random numbers. The x_n and y_n values are initial values and are secret.

4. The Gingerbreadman Map is a two-dimensional mapping which is defined by the formula in previous research on equation (4) and equation (5) [5]:

$$x_{n+1} = 1 - y_n + |x_n| \quad (4)$$

$$y_n = x_n \quad (5)$$

Equations (4) and (5) Gingerbreadman produce a random mapping of the six existing hexagonal areas. In this mapping, there are several areas that experience chaos and are stable in other areas. The x_n andy_n values are initial values and are secret. Gingerbreadman takes the point (x, y) in the equation and maps it to a new point. The dots form like the characters from the Gingerbreadman story, so it'scalled the Gingerbreadman Map.

5. Henon map is a dynamic system that implements a discrete system Henon's equation is one of the most frequently studied examples of chaos-based algorithms. The Henon equation can generate pseudo-random numbers. The Henon equation uses a point (x, y) in an equation and maps it to a new point with equation (6) and equation(7):

$$x_{n+1} = y_n + 1 - ax_n^2 \quad (6)$$

$$y_{n+1} = bx_n \quad (7)$$

Equations (6) and (7) Henon Map are affected by two values, that is variables a and b. Both variables can be randomized. For variable a, it is usually used with value a = 1,4 and b = 0,3.. Equation (6) x_n is the initial x value, and in equation (7) y_n is the initial y value and both variables are secret values.

6. The Tinkerbell map is a dynamic system using discrete time which has equations (9) and (10) [13]:

$$x_{n+1} = x_n^2 - y_n^2 + ax_n + by_n \quad (9)$$

(8)

$$y_{n+1} = 2x_ny_n + cx_n + dy_n \quad (10)$$

Equations (9) and (10) of the Tinkerbell Map have been studied repeatedly because they show a very rich dynamics including chaotic behavior and their range of period states. In this equation a, b, c, d are variables and n is a discrete loop. With the most frequently used variables a = 0,9; b = -0,6; c = 2; d = 0,5 [13]. In Equations (9) and (10) the x_n value is the initial x value, and the y_n is the initial y value, x_n dan y_n are secret values. The name Tinkerbell is taken from the character of the Cinderella story, because the trajectory generated by this mapping algorithm will be like when Tinkerbell is present in the Cinderella film story.

2. METHODOLOGY

The steps taken to analyze the performance of the Logistic Map 3 algorithm, Duffing Map, Gingerbreadman Map, Henon Map, Gauss Iterated Map, Tinkerbell Map consist of six stages as shown in Figure 1.

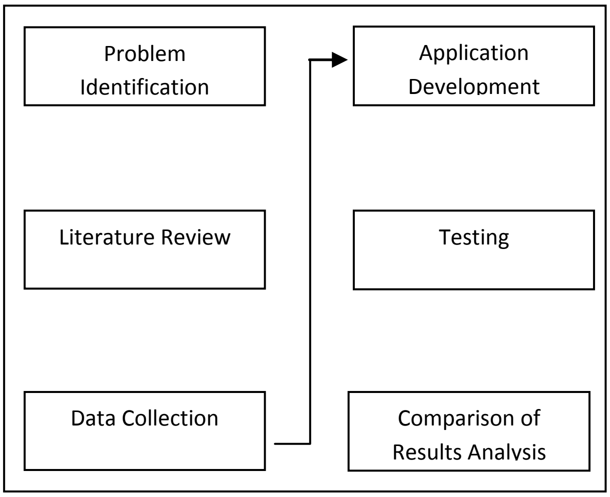


Fig1: Research stages

2.1 Problems Identification

The cryptographic algorithm has been widely applied to encoding messages for data security, especially image security. Make sending or storing data secure, because the resulting message is difficult to decode. Algorithm based on chaos theory is an algorithm that is currently often used for image cryptography. Algorithm Arnold Cat Map, Baker's Map, Ikeda Map, Tent Map, Logistic Map 3, Gauss Iterated Map, Henon Map, Duffing Map Gingerbreadman Map, Tinkerbell Map, is an algorithm based on chaos theory. These algorithms have different equations or formulas. This study aims to analyze six chaos-based algorithms, the Logistic Map 3 algorithm, Gauss Iterated Map, Henon Map, Duffing Map Gingerbreadman Map, Tinkerbell Map. The reason for choosing the six algorithms is because no one has compared the six algorithms to find the algorithm that has the best performance according to needs.

2.2 Literature Review

Therefore it is necessary to collect data by reading and studying books, literature, articles and journals related to chaos-based image encryption. The data collection was carried out on a chaos-based algorithm because a strong reference was needed for six algorithms, Logistic Map 3, Gauss Iterated Map, Henon Map, Duffing Map, Gingerbreadman Map, Tinkerbell Map.

2.3 DataCollection

This study collects the data and requirements needed for the implementation of chaos-based algorithms in image cryptography applications, as well as collects image data to be tested in this study.

2.4 Application Development

Making this application consists of making a mockup design for the image cryptography application display. After the design view is made, the next stage is implementing the GUI (Graphical User Interface) in MATLAB. Next is the coding stage, implementing six chaos-based algorithms for cryptographic applications.

2.5 Testing

Fig2: Testing Image

The trial phase was carried out on images, images measuring 324x484 pixels each in PNG and BMP formats as shown in Figure 2. The image was tested for encryption with the six algorithms with the Logistic Map 3 algorithm using keys A = 0,4 and B/r = 8,4. Gauss Iterated Map algorithm with keys A = 5,9 and B = -0,58. Duffing algorithm with keys A = 0,1 and B = 1, Gingerbreadman Map algorithm with keys A = 4,7 and B = 3,5. Henon Map uses keys A = 1 and B = 0,1.Finally the Tinkerbell Map algorithm uses keys A = -0,33 and B = -0,42. After all successfully encrypted images are saved and decrypted the encrypted images using the key and the algorithm that encrypts them, after that the decrypted images are stored.

2.6 Comparison of Results Analysis

Six algorithms will be analyzed, time analysis, key sensitivity analysis, histogram image comparison, calculating the correlation coefficient value of the original image with the encrypted image, calculating the MSE and PSNR values of the original image with the encrypted image.

3. RESEARCH RESULT

3.1 Application Development

The application was built using MATLAB 2013a, the equations obtained at the literature study stage were implemented in image cryptographic applications. The application is also built to be able to display histogram comparisons, processing time, calculate correlation coefficient values, calculate MSE and PSNR values.

3.1.1 Main Menu

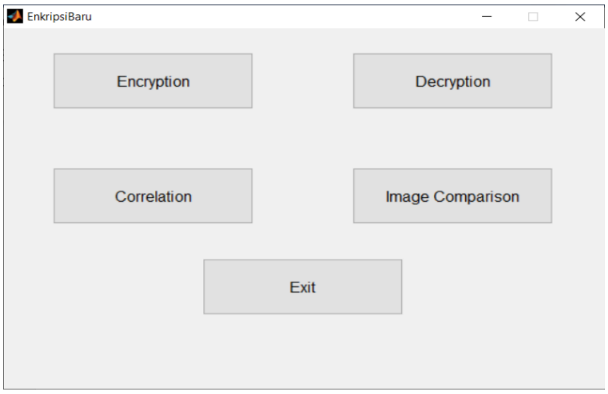


Fig3: Main Menu

Figure 3. is the Main Menu of the application, there are 4 buttons to go to the next menu, the Encryption, Decryption, Correlation, Image Comparison buttons, and one Exit button to exit the cryptographic application.

3.1.2 EncryptionMenu

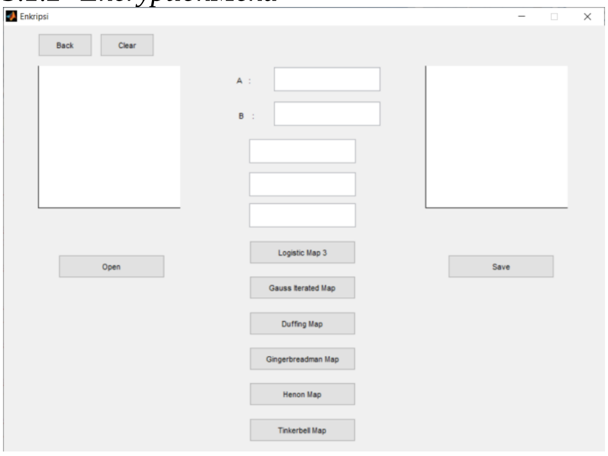


Fig4: Encryption Menu

In Figure 4, there is an Open button to open an encrypted image, a Save button to save the image, a Back button to return to the previous menu, Clear to clear the view. Two input parameters A and B to determine the encryption key parameters, under parameters A and B there are processing time, MSE and PSNR outputs. Then six buttons for image encryption according to cryptographic algorithms, Logistic Map 3, Gauss Iterated Map, Duffing Map, Gingerbreadman Map, Henon Map, Tinkerbell Map.

3.1.3 DecryptionMenu

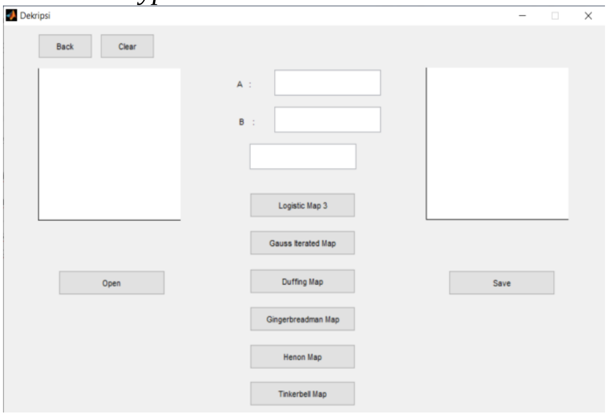


Fig5: Decryption Menu

Figure 5. There is an Open button to open an encrypted image, a Save button to save the image, a Back button to return to the previous menu, Clear to clear the view. Two input parameters A and B to determine the encryption key parameters, under parameters A and B there is a processing time output. Then six buttons for image decryption according to cryptographic algorithms, Logistic Map 3, Gauss Iterated Map, Duffing Map, Gingerbreadman Map, Henon Map, Tinkerbell Map.

3.1.4 Correlation Menu

Fig6: Correlation Menu

In Figure 6. there are two Open buttons useful for opening images that will be displayed in Image 1 and Image 2. The Horizon, Vertical, Diagonal buttons are used to process correlation values and mappings will be displayed in each respective window.

3.1.5 Image Comparison Menu

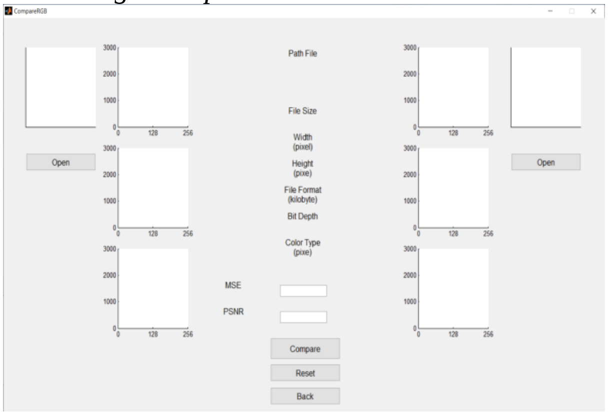


Fig7: Image Comparison Menu

In Figure 7. there are two Open buttons that will be displayed on the image in their respective windows. There are three windows lined up vertically to display RGB (Red, Green, Blue) graphics. Compare button to display detailed data and calculate MSE and PSNR values. Reset button to clear the display, and Back to return to the previous menu.

4. DISCUSSION

4.1 Application Testing

The test was carried out by encrypting 324x484 pixel images in PNG and BMP formats. The test was carried out on PNG images using the Logistic Map algorithm with generating keys A = 0.1 and B = 8.1 in Figure 8. Two values are needed as keys to generate random values for encrypt image.

Fig 8: Image Encryption

Fig 9: Image Decryption

After the image has been successfully encrypted, the image is decrypted using the encryption key and the encryption algorithm, the results of the decryption can be seen in Figure 9. It can be seen in Figure 8 that the image was successfully encrypted and difficult to recognize, in Figure 9 the image was successfully restored to its original state.

4.2 Analysis

After testing the application, the next step is the analysis of time, histogram, time sensitivity, correlation coefficient values, MSE and PSNR values.

4.2.1 Time Analysis

Time analysis aims to calculate the length of time for the encryption and decryption algorithms of Logistic Map 3, Gauss Iterated Map, Duffing Map, Gingerbreadman Map, Henon Map and Tinkerbell Map. In Table 1, image encryption and decryption is performed on images in BMP format and Table 2 in PNG format, after which the processing time is recorded, experiments are carried out 10 times for each algorithm and the average processing time is calculated. It was found that the encryption and decryption images for BMP and PNG Tinkerbell Map had the longest decryption time, and the highest encryption time was the Logistic Map 3 algorithm.

Table 1. Time for BMP Image Processing

Algorithm	Encryption (sec)	Decryption (sec)
Logistic Map 3	0,3628505	0,8350861
Gauss Iterated Map	0,3822889	0,854964
Duffing Map	0.4298157	1.0461364
Gingerbreadman Map	0,5149641	1,2458373
Henon Map	0,3709992	0,8652754
Tinkerbell Map	0,8628298	2,2551725

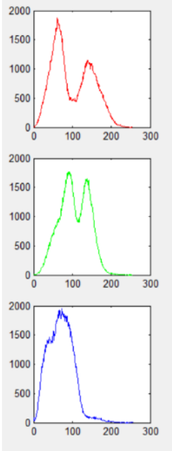
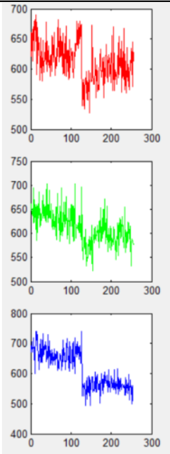
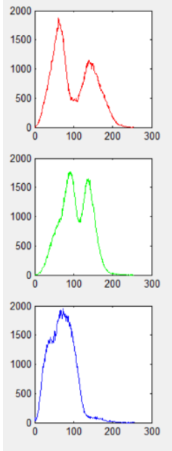
Table 2. Time for PNG Image Processing

Algorithm	Encryption (sec)	Decryption (sec)
Logistic Map 3	0,35361	0,8508705
Gauss Iterated Map	0,3701424	0.8556818
Duffing Map	0,4395064	1,0461364
Gingerbreadman Map	0,4983531	1,2619467
Henon Map	0,3695938	0,871644
Tinkerbell Map	0,8660619	2,3171139

4.2.2 Histogram

The histogram on the image is a graphical representation that shows the color distribution of the digital image or describes the pixel intensity values of the image [14] [15]. Histogram testing is done to see the intensity of the pixels in the encrypted image and decrypted image. The histogram also aims to see security in image encryption. Research was conducted on the original image, image encryption, and image decryption. The histogram test table can be seen in Table 3.

Table 3. Histogram of Logistic Map 3

Real Image	Encryption Image	Decryption Image
		

4.2.3 *Key Sensitivity Analysis*

In key sensitivity analysis, it is performed by decrypting the image using a very small key difference, so that the encrypted image can be decrypted into the original image.

Table 4. Key Sensitivity

Algorithm	Key A	Key B
Logistic Map 3	10^{-16}	10^{-14}
Gauss Iterated Map	10^{-15}	10^{-16}
Duffing Map	10^{-14}	10^{-15}
Gingerbreadman Map	10^{-15}	10^{-15}
Henon Map	10^{-15}	10^{-16}
Tinkerbell Map	10^{-16}	10^{-16}

The results of the key sensitivity experiment can be seen in Table 4, six algorithms have more sensitivity than 10^{-14} to 10^{-16}. The Logistic Map and Tinkerbell Map algorithms have the highest sensitivity to the A key 10^{-16}, and the lowest is the Duffing Map 10^{-14}, for the key B Gauss Iteration Map, Henon Map, Tinkerbell Map has the highest key sensitivity up to 10^{-16}, and the lowest Logistic Map with key sensitivity 10^{-14}.

4.2.4 *Correlation Coefficient Analysis*

Correlation is a term that states a linear relationship between two or more variables. Correlation describes the relationship between neighboring pixels in the original image and the encrypted image. Analysis was carried out to obtain horizontal, vertical and diagonal correlation coefficient values. In natural-image, neighboring pixels have a strong linear relationship. It is characterized by its high correlation coefficient (close to +1 or -1). In a random image, there is no correlation between neighboring pixels or a zero correlation coefficient. Image encryption aims to make the correlation of neighboring pixels in the cipher-image weak or in other words make the correlation coefficient close to zero. The equation for calculating the correlation coefficient can be seen in equations (11), (12), (13) and (14) [7].

$$cc = \frac{cov(x,y)}{\sigma x \times \sigma y} \quad (11)$$

$$\sigma x = \sqrt{var(x)} \quad (12)$$

$$\sigma y = \sqrt{var(y)} \quad (13)$$

$$var(x) = \frac{1}{N}\sum_{i=1}^{N} \left(x_i - E(x)\right)^2 E(x) = \frac{1}{N}\sum^{N} x_i \quad (13)$$

$$cov(x,y) = \frac{1}{N}\left(x_i - E(x)\right)\left(y_i - E(y)\right) \quad (14)$$

A low correlation coefficient will complicate image reconstruction because each neighboring pixel has no correlation. In Table 5 the analysis of the 324x484 image shows that the correlation coefficient on neighboring pixels in each direction in the original image is close to 1 or -1, indicating a strong correlation between pixels. Whereas in encrypted images the correlation value is close to 0, which indicates that neighboring pixels are no longer correlated.

Table 5. Correlation Coefficient

Algorithm	Horizontal	Vertical	Diagonal
Logistic Map 3	0,00476	-0,06165	0,006570
Gauss Iterated Map	-0,00055	-0,09131	0,001860
Duffing Map	0,00006	-0,01392	0,001960
Gingerbreadman Map	-0,00432	0,00879	0,009460
Henon Map	-0,00095	-0,01509	0,000580
Tinkerbell Map	0.00343	0.02600	0.002018

Then the horizontal correlation values that are close to 0 can be sorted, Duffing Map algorithm, Gauss Iterated Map, Henon Map, Tinkerbell Map, Gingerbreadman Map and lastly Logistic Map 3. For vertical values closest to 0 can be sorted Gingerbreadman Map, Duffing Map, Henon Map, Tinkerbell Map, Logistic Map and Gauss Iterated Map. Diagonal correlation values closest to 0 can be sorted, Henon Map, Gauss Iterated Map, Duffing Map, Tinkerbell Map, Logistic Map and Tinkerbell Map.

4.2.5 *MSE & PSNR*

Image quality in this study was measured using two methods, MSE (Mean Square Error) and PSNR (Peak Signal Noise to Ratio). To obtain the MSE and PSNR values, compare the original image with the encrypted image, and the original image with the decrypted image. In encryption, a good PSNR value has a low value close to 0 and a good MSE value is getting bigger, meaning that a lot of data or image information is lost. For decryption, the greater the PSNR value and the smaller the MSE value, the decrypted image will be closer to the original image, in other words, no data or information is lost. If the two images are identical, the MSE value will be 0 and the PSNR cannot be defined [14] [15]. The equations for calculating MSE and PSNR can be seen in equations (15) and (16):

$$MSE = \left(\frac{1}{MN}\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left(g'(x,y) - g(x,y)\right)^2\right) (15)$$

$$PSNR = 20\left(\frac{2^n}{MSE}\right) \quad (16)$$

Table 6. MSE and PSNR

Algorithm	MSE (dB)	PSNR (dB)
Logistic Map 3	8081,94 dB	9,06 dB
Gauss Iterated Map	8594,84 dB	8,79 dB
Duffing Map	8479,37 dB	8,85 dB

Gingerbreadman Map	8464,75 dB	8,85 dB
Henon Map	8629,77 dB	8,77 dB
Tinkerbell Map	8163,48 dB	9,01dB

In Table 6 the analysis of the 324x484 image was carried out on the encrypted image of the resulting image, the MSE value is sorted from the largest, the Henon Map algorithm has an MSE value of 8629,77 dB, then the Gauss Iterated map algorithm with a value of 8594,84 dB, Duffing Map with a value 8479,37 dB, Gingerbreadman Map with a value of 8464,75 dB, Tinkerbell Map with a value of 8163,48 dB and the Logistic Map 3 algorithm has the smallest MSE value of 8081,94 dB.

For the PSNR value, the sequence of values from smallest to largest is the Henon Map algorithm, which is 8,77 dB and the smallest, then Gauss Iterated Map with a value of 8,79 dB, Duffing Map and Gingerbreadman Map have the same value of 8,85 dB, Tinkerbell Map with a value of 9,01 dB, and the largest is Logistic Map 3 with a value of 9,06 dB. It can be concluded that the Henon Map algorithm is the best for MSE and PSRN values, and the lowest value is the Logistic Map 3 algorithm.

5. CONCLUSION

In this study, the analysis of the performance of six algorithms based on chaos found that the six algorithms have a high level of security and each algorithm has a different performance in each analysis. The histogram of six chaos-based algorithms is very good because the pixels that appear on the histogram are very different from the initial image.

Logistic Map 3 can be chosen when you want to get fast encryption time, but fast decryption time among other algorithms, has MSE value, but has the highest PSNR value, the highest sensitivity of A Logistic Map 3 key, and has the highest correlation coefficient value pretty good.

Gauss Iterated Map has almost the same encryption and decryption times as Logistic Map 3, good correlation coefficient, MSE and PSNR, and the highest sensitivity of key B.

The Duffing Map has a longer encryption and decryption time than the Gauss Iterated Map, has good MSE and PSNR correlation coefficients, but the time sensitivity for key A is the lowest among the five algorithms.

Gingerbreadman Map has good encryption and decryption times above Duffing Map, correlation coefficient, MSE and PSNR values are good. Time sensitivity is quite large, but not the greatest.

Henon Map has the best correlation coefficient value among the five algorithms, encryption and decryption time is almost the same as Logistic Map 3 and Gauss Iterated Map, has the highest key B sensitivity the same as Gauss Iterated Map and Tinkerbell Map, good MSE and PSNR values .

Tinkerbell Map has the longest processing time, because it has the longest equation among the five algorithms. Highest sensitivity of keys A and B 10-16, good value of correlation coefficient, MSE and PSNR.

6. AUTHOR'S PROFILE

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