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Reduction of Correlation in 2D Image Encryption using Novel Gingerbreadman Chaotic Map in Comparison with Tinkerbell Map

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ABSTRACT

Aim: The objective of the work is to develop 2D Image Encryption using Novel Gingerbreadman chaotic encryption method for reducing the correlation and it is compared with Tinkerbell chaotic encryption method. **Materials and Methods:** Comparative analysis of correlation is performed by Novel Gingerbreadman Map where number of samples (N=10) and Tinkerbell map where number of samples (N=10) techniques with pre-test power of 80% using MATLAB software. **Results:** The correlation coefficient of novel gingerbreadman chaotic map is 0.00055 in vertical, 0.00189 in horizontal, 0.00080in diagonal direction and whereas the correlation coefficient of tinkerbell chaotic map is -0.00162 in vertical, 0.00277 in horizontal, -0.00140 in diagonal direction. There is a significant difference in the results obtained and considered to be error-free since it has the significance value of p=0.0375 (p < 0.05) in SPSS analysis. **Conclusion**: The Novel Gingerbreadman chaotic map performs significantly better in reducing the correlation in 2D image encryption compared to Tinkerbell Chaotic map method.

Keywords

Novel Gingerbreadman Chaotic Map, Tinkerbell Chaotic Map, Image Encryption, Correlation, Shuffling, Diffusion.

INTRODUCTION

In this new generation of digital technology the worldwide interchange of information is taking place. Several new technologies have been developed in information technology. Special attention is being paid to network policies as well as security in order to make it easier and adaptable (A. Kumar and Raghava 2021). Because digital images contain a substantial quantity of data, an encryption module should be quick and simple to use in a shared network environment(Tyagi 2018). Correlation is a numerical measure of how closely two random variables fluctuate in response to one another. When one variable rises, the other tends to fall, which is positive, when the one variable rises, the other rises with it, forming a negative correlation. (Périé and Passieux 2020). Image encryption is

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used in a wide range of applications in healthcare, there has been a huge need for image multimedia security. Many strategies have been developed but they are not adaptive and withstand(Sarosh, Parah, and Bhat 2022).

The Gingerbreadman chaotic map and Tinkerbell chaotic map have recently been used in various researches using different methods. While 25 publications were identified in IEEE Xplore and 37 research papers were published in google scholar. Data is constantly vulnerable to many forms of assaults owing to the public nature of the internet so (F. A. Khan et al. 2017) introduced a new image encryption technique using many properties like gingerbreadman chaotic map. To increase the security. During the diffusion process based on Lorenz chaotic maps are used in the existing approach. To reduce high connection between simple text picture pixels. A chaotic substitution-based picture encryption technique based on Gingerbreadman is proposed by (Prajwalasimha et al. 2020) encryption is done by transformation and substitution two steps. Images have intrinsic qualities such as higher inter-pixel redundancy and bulk data capacity. Pseudo hadamard transformation lowers correlation between neighbouring components in the host picture, whereas modified Gingerbreadman chaotic substitution increases entropy. In (Hao and Ma 2019) by extracting a part of sequence of Gingerbreadman discrete systems randomly. Calculate Lyapunov exponents and compare them to the Lyapunov exponents derived from the original system. (M. Khan and Asghar 2018) suggested a nonlinear component using the Gingerbreadman chaotic map and S8 permutations to convert an understandable message into an enciphered format through diffusion. The results show that using the proposed box to image encryption system to real-time communications is both efficient and safe. Tinkerbell's chaotic map with a fractional caputo-difference form has been proposed by (Ouannas et al. 2018). The dynamics of the proposed map are quantitatively explored from multiple viewpoints using phase plots, bifurcation diagrams, and Lyapunov exponents. In (Krishna et al. 2018) presented a persuasive chaos based encryption approach that is particularly good for photos. In this tinkerbell map starting conditions were created using a secret hexadecimal key. The proposed method has the advantage of unique starting seed for each cycle, which increases encryption security. In (Iyengar and Balakrishnan 2018) looked at the q- deformed tinkerbell map and showed how some of the properties might be beneficial. When the deformation parameter q fluctuates, the map undergoes Neimark-Sacker(NS) bifurcation, resulting in limit cycles. In some regimes, several limit cycles from separate basins of attraction can coexist.

Previously our team has a rich experience in working on various research projects across multiple disciplines (Venu and Appavu 2021; Gudipaneni et al. 2020; Sivasamy, Venugopal, and Espinoza-González 2020; Sathish et al. 2020; Reddy et al. 2020; Sathish and Karthick 2020; Benin et al. 2020; Nalini, Selvaraj, and Kumar 2020).The correlation coefficient is high in current techniques due to improper pixel shuffling, confusion as well as insufficient pixel diffusion. The main purpose of this study is to provide an effective technique using the Novel Gingerbreadman chaotic map and Tinkerbell chaotic map for reducing correlation in vertical, horizontal and diagonal directions.

MATERIALS AND METHODS

This study was conducted at the digital image processing laboratory of the department of electronics and communication engineering at saveetha school of engineering, SIMATS, Tamilnadu, India. Each of the 20 original images in the custom data set has been resized to 512x512 pixels. The sample size was calculated based on previous research findings and it is found to be 10 for each group. To simulate the software, you will need a system with following parameters: CPU 8th gen, I5, 8GB RAM, 1TB HDD and a MATLAB application with the relevant library and tool functions. The calculations are completed with G-power at 80%, threshold at 0.86% confidence interval at a 70% confidence level.

The Novel Gingerbreadman Chaotic map is one form of chaotic map that shows some type of chaotic behavior. The Gingerbreadman function is given below as eq (1) and eq (2) (F. A. Khan et al. 2017).where x_n, y_n denote as state variables. Since the system is chaotic two chaotic sequences x_n and y_n can be generated. The gingerbreadman function is used to generate two random arrays of key values. These key values are used to encrypt the image.

$$x_{(n+1)}=1 - y_n + |x_n| \quad (1)$$
$$y_{(n+1)}=x_n \quad (2)$$

Tinkerbell chaotic map is one form of chaotic map that shows some type of chaotic behavior. The tinkerbell function is given below as eq (3) and eq (4) where a, b, c and d denote system parameters considered a 0.9, b as -0.6, c as 1.8, d as 0.50 and x_n, y_n denote as state variables. Since the system is chaotic two chaotic sequences x_n and y_n can be generated (A. Kumar and Raghava 2021). The tinkerbell function is used to generate two random arrays of key values Now these key values are used to encrypt the image.

$$x_{(n+1)}=x_n^2-y_n^2+ax_n+by_n \quad (3)$$
$$y_{(n+1)}=2x_ny_n+cx_n+dy_n \quad (4)$$

The software receives an image that has been customized, with each pixel represented in decimal form. Each pixel must be first converted to binary before the XOR operation can be performed. A method to generate two keys in the 256 and 512 range has now been created. The first key in the range 256 will be used to XORed the image pixel, and the second key in range of 512 will be used to shuffle the row and column of another key matrix. The encrypted picture pixels are shifted to get a lower correlation coefficient. Random shuffling of pixels determines less correlation coefficient. A new variable will be created to store the encrypted image. The binary image is converted to decimal once again, resulting in a series of pixels that are blended to produce a digital image.

These procedures are carried out with the help of the MATLAB programme version 21a (Ciaburro 2017). The random key approach, in which a series of digits is used to confuse pixels that are not related to one another. The encryption image has a poor correlation coefficient as a result of less diffusion of pixels.

STATISTICAL ANALYSIS

SPSS version 21 was used for statistical analysis of collected data for parameters vertical correlation coefficient, horizontal correlation coefficient and diagonal correlation coefficient (McCormick and Salcedo 2017). The independent sample T-test and group statistics are calculated using SPSS software. Correlation is a dependent variable and size of the image is an independent variable.

RESULTS

Figure 1 The original, encrypted and decrypted images are shown. The original images are shown in figures (a), (d) and (g). The encrypted images utilizing the Gingerbreadman chaotic map are shown in figures (b), (e) and (h). The decrypted images of encrypted images are shown in figures (c), (f) and (i).

Figure 2 The original, encrypted and decrypted images are shown. The original images are shown in figures (a), (d) and (g). The encrypted images utilizing the Tinkerbell chaotic map are shown in figures (b), (e) and (h). The decrypted images of encrypted images are shown in figures (c), (f) and (i).

Figure 3 illustrates the Gingerbreadman chaotic map’s correlation analysis of the cameraman image. Figure (a), (c) and (e) shows the original image correlation in vertical, horizontal and diagonal directions. Whereas figures (b), (d) and (f) show the encrypted image correlation in vertical, horizontal and diagonal directions respectively.

Figure 4 illustrates the Tinkerbell chaotic map's correlation analysis of the cameraman image. Figure (a), (c) and (e) shows the original image correlation in vertical, horizontal and diagonal directions. Whereas figures (b), (d) and (f) show the encrypted image correlation in vertical, horizontal and diagonal directions respectively.

Figure 5 shows the graph created with spss that compares the mean of diagonal correlation coefficients of gingebreadman chaotic map and tinkerbell chaotic map. It represents the gingerbreadman chaotic map having lesser correlation coefficient in comparison with the tinkerbell chaotic map. For gingerbreadman chaotic maps the correlation is -0.00065 but the tinkerbell chaotic map has correlation 0.00115.

Table 1 shows the values of the correlation coefficient of the original image and the encrypted images using the Gingerbreadman chaotic map in vertical, horizontal and diagonal directions.

Table 2 shows the values of the correlation coefficient of original and encrypted images using the Tinkerbell chaotic map in vertical, horizontal and diagonal directions.

Table 3 shows that from spss statistical analysis, mean, standard deviation and standard error rate for gingerbreadman encryption method and the tinkerbell encryption method were obtained. There is a statistical significance difference between correlation coefficients of two methods. The gingerbreadman encryption method obtained a maximum standard deviation of 0.00108 and minimum standard error mean of 0.0003 while the tinkerbell encryption method obtained a maximum standard deviation of 0.00186 and minimum standard error of 0.00032. The mean correlation using the gingerbreadman encryption method of 0.00055 was better than the tinkerbell encryption method of -0.00140 and the standard deviation of the gingerbreadman encryption method is 0.00108 which is slightly higher than 0.00186 of the tinkerbell encryption method.

Table 4 displays the statistical calculations for independent samples tested between gingerbreadman chaotic map and tinkerbell chaotic map. The significance for correlation coefficient is 0.049. Independent samples T-test is applied for comparison of gingerbreadman chaotic map and tinkerbell chaotic map with the confidence interval as 95% and level of significance as 0.6959. The independent sample test consists of significance as 0.000, significance (2-tailed), mean difference, standard error difference, lower and upper interval difference.

DISCUSSION

Two different strategies were employed to reduce the correlation of the pixels in the encrypted image by proper random shuffling and diffusion. The new gingerbreadman chaotic map reduces correlation by 0.00055 in vertical direction, 0.00189 in horizontal, and 0.0008 in the diagonal direction. When compared to the Tinkerbell chaotic map -0.00162 in vertical, 0.00277 in horizontal and -0.00140 in diagonal direction. In spss analysis, the findings were obtained with a significance value $p<0.005$.

From the study of previous research analysis (F. A. Khan et al. 2017), used the gingerbreadman chaotic map and S8 permutation and obtained a minimum correlation coefficient of 0.0299 by the proper diffusion of pixels. (M. Khan and Asghar 2018) used the non-linear component and by the proposed S-box the best correlation coefficient obtained was -0.00135, used in the real time image encryption techniques. On the other hand by using Tinkerbell chaotic map (M. Khan and Asghar 2018; Krishna et al. 2018) obtained a correlation coefficient of -0.0112 by proposing the chaos-based encryption algorithm particularly for digital images and also altering the random shuffling pattern of the encryption method, (J. Kumar, Singh, and Yadav 2020) used the tinkerbell chaotic map in image encryption and obtained an overall minimum correlation of 0.0023 by splitting the image into red, blue and green components. From the above findings we can conclude that gingerbreadman chaotic map achieve a good correlation coefficient when compared with tinkerbell chaotic map. There were no opposite findings related to this study.

The limitation of this chaotic encryption method was the random shuffling and confusion took longer time. The purpose of this future work is to create an efficient encryption algorithm that creates the least amount of correlation in minimum time possible.

CONCLUSION

Two techniques for measuring correlation coefficient were evaluated using performance parameters, and it was found that tinkerbell chaotic map had a mean correlation of -0.00162 in vertical, 0.00277 in horizontal and -0.00140 in diagonal. This is greater than the gingerbreadman chaotic map's mean correlation coefficient, which is 0.00055 in vertical, 0.00189 in horizontal and 0.00080 in diagonal. As a result the Novel Gingerbreadman chaotic map performs significantly better in reducing the correlation coefficient of the image compared to the Tinkerbell Chaotic map.

DECLARATIONS

Conflicts of Interest
No conflict of interest in this manuscript.

Author Contribution
Author PVS was involved in the data collection, data analysis and manuscript writing. Author RN was involved in conceptualization, guidance and critical review of manuscript.

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TABLES AND FIGURES

Table 1. Comparison of correlation coefficients of original images and the novel Gingerbreadman chaotic map encrypted images. The encrypted Cameraman image achieved the lesser vertical correlation of 0.00080, horizontal correlation of 0.00097 and the diagonal correlation of 0.00154 for the novel Gingerbreadman Chaotic Encryption.

Standard images	Standard image			Encrypted image		
	Vertical	Horizontal	Diagonal	Vertical	Horizontal	Diagonal
cameraman	0.9334	0.9723	0.9647	0.00080	0.00097	0.00154
coins	0.9872	0.9654	0.9576	0.00176	0.00324	-0.00021
fabric	0.9845	0.9934	0.9845	-0.00079	0.00244	0.00191
football	0.9345	0.9746	0.9933	0.00213	0.00218	-0.00072
forest	0.9849	0.9847	0.9847	-0.00080	0.00183	0.00037
lenna	0.9843	0.9473	0.9476	0.00098	0.00083	0.00185
mandril	0.9873	0.9883	0.9877	-0.00010	0.00333	0.00061
pears	0.9766	0.9643	0.9465	0.00076	0.00292	0.00093
rice	0.9822	0.9887	0.9753	-0.00028	0.00067	0.00177

Table 2. Comparison of correlation coefficients of original images and the Tinkerbell chaotic map encrypted images.The encrypted Cameraman image achieved the vertical correlation of 0.00241, horizontal correlation of 0.00281 and the diagonal correlation of -0.00082 for the Tinkerbell Chaotic Encryption.

Standard images	Standard image			Encrypted image		
	Vertical	Horizontal	Diagonal	Vertical	Horizontal	Diagonal
cameraman	0.9334	0.9723	0.9647	0.00241	0.00281	-0.00082
coins	0.9872	0.9654	0.9576	-0.00256	0.00460	-0.00110
fabric	0.9845	0.9934	0.9845	-0.00108	0.00154	-0.00181

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football	0.9345	0.9746	0.9933	-0.00238	0.00104	-0.00021
forest	0.9849	0.9847	0.9847	0.00093	0.00176	-0.00153
lenna	0.9843	0.9473	0.9476	-0.00280	0.00207	-0.00071
mandril	0.9873	0.9883	0.9877	-0.00224	0.00410	-0.00057
pears	0.9766	0.9643	0.9465	-0.00239	0.00247	-0.00186
rice	0.9822	0.9887	0.9753	-0.00306	0.00220	-0.00388
cameraman	0.9334	0.9723	0.9647	0.00241	0.00281	-0.00082

Table 3. Group statistics of image encryption can be done for analysis of Vertical, Horizontal, Diagonal comparison between the novel gingerbreadman chaotic map encryption and the tinkerbell chaotic map encryption.

	Groups	**N**	**Mean**	**Std.Deviation**	**Std.Error Mean**
Vertical Correlation coefficient	Gingerbreadman	10	0.00055	0.00101	0.00032
	Tinkerbell	10	-0.00162	0.00186	0.00058
Horizontal Correlation coefficient	Gingerbreadman	10	0.00189	0.00108	0.00034
	Tinkerbell	10	0.00277	0.00136	0.00043
Diagonal Correlation coefficient	Gingerbreadman	10	0.00080	0.00095	0.0003
	Tinkerbell	10	-0.00140	0.00103	0.00032

Table 4. The independent samples test between novel gingerbreadman chaotic map and tinkerbell map was done using statistical technique. The correlation coefficient has a significance of 0.0375.

Group		**Leven's Test for Equality of Variance**		**T-test for Equality of Means**						
		F	**Sig**	**t**	**df**	**sig(2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval (Lower)**	**95% Confidence Interval (Upper)**
Correlation	**Equal variance**	0.242	0.0375	3.247	18	0.004	0.00217	0.00067	0.00769	0.00358

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	assumed									
	Equal variance not assumed			3.247	13.925	0.006	0.00217	0.00067	0.00769	0.00358

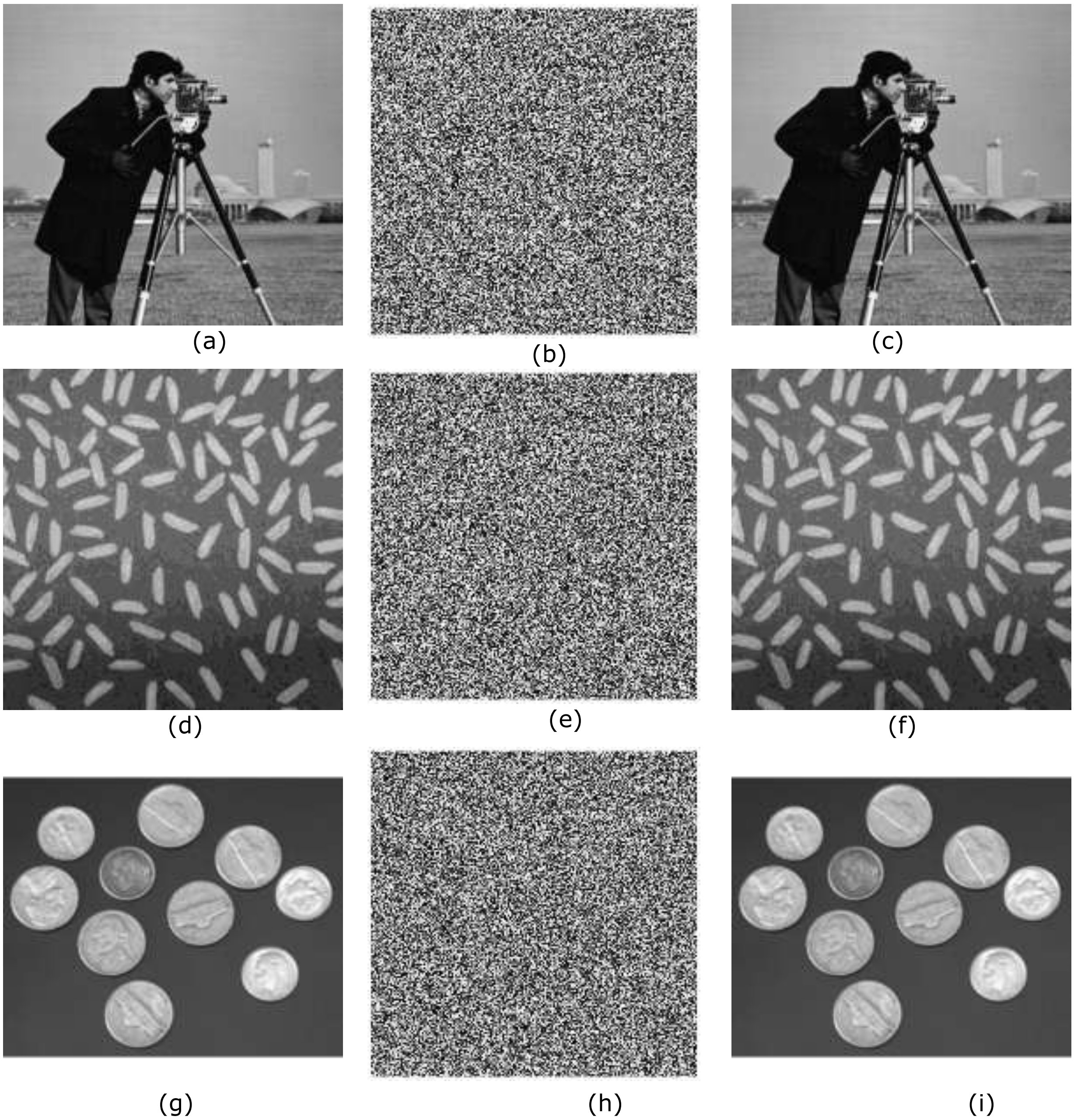


Fig. 1. Novel Gingerbreadman chaotic map encryption technique (a) sample image cameraman (b) encrypted cameraman using gingerbreadman chaotic map (c) decrypted cameraman image (d) sample image rice of size (512x512) (e) encrypted rice using gingerbreadman chaotic map (f) decrypted rice image (g) sample image coins of size (512x512) (h) encrypted coins using gingerbreadman chaotic map (i) decrypted coins image.

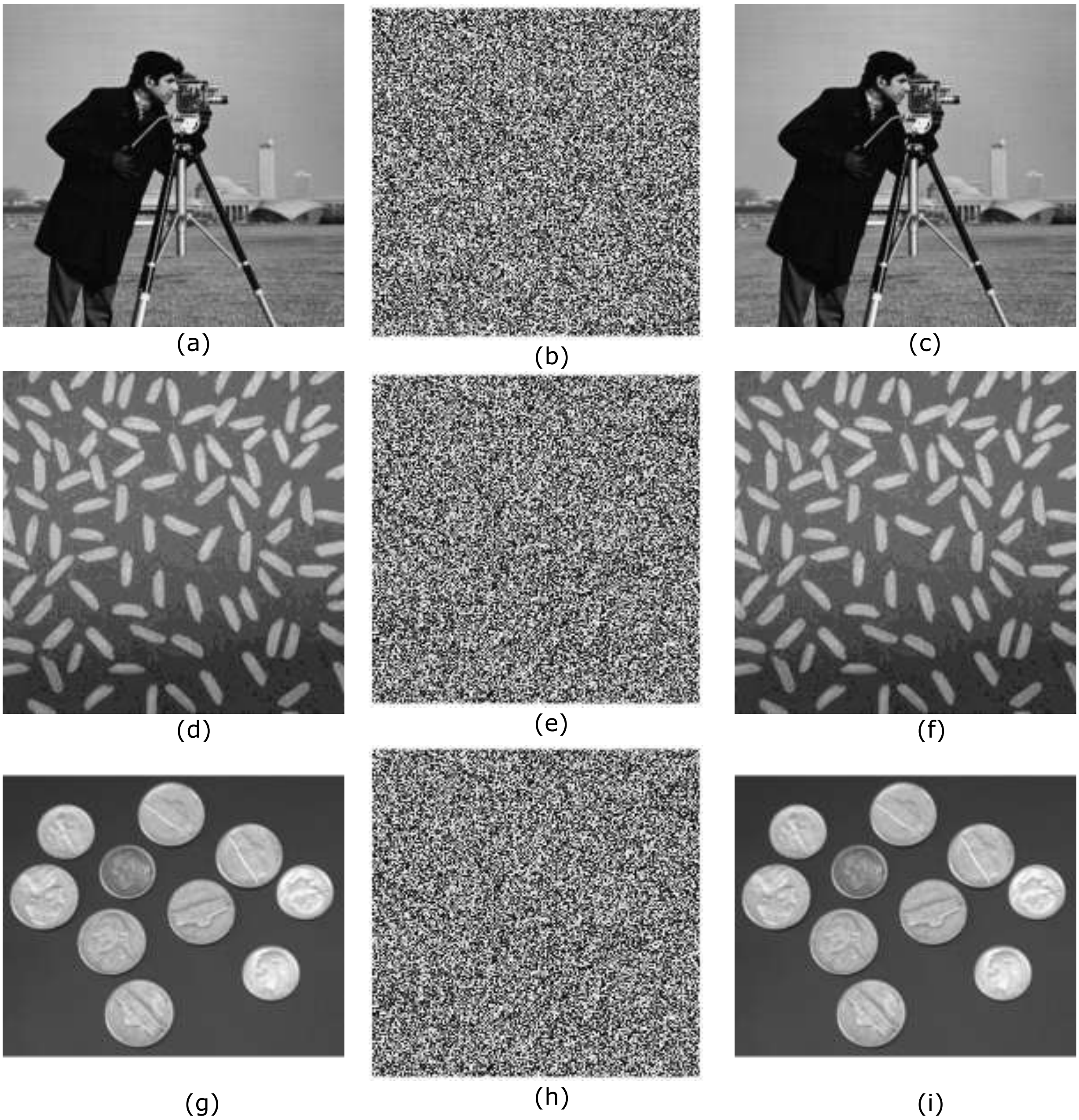


Fig. 2. Tinkerbell chaotic map encryption technique (a) sample image cameraman of size (512x512) (b) encrypted cameraman using tinkerbell chaotic map (c) decrypted cameraman image (d) sample image rice of size (512x512) (e) encrypted rice using tinkerbell chaotic map (f) decrypted rice image (g) sample image coins of size (512x512) (h) encrypted coins using tinkerbell chaotic map (i) decrypted coins image.

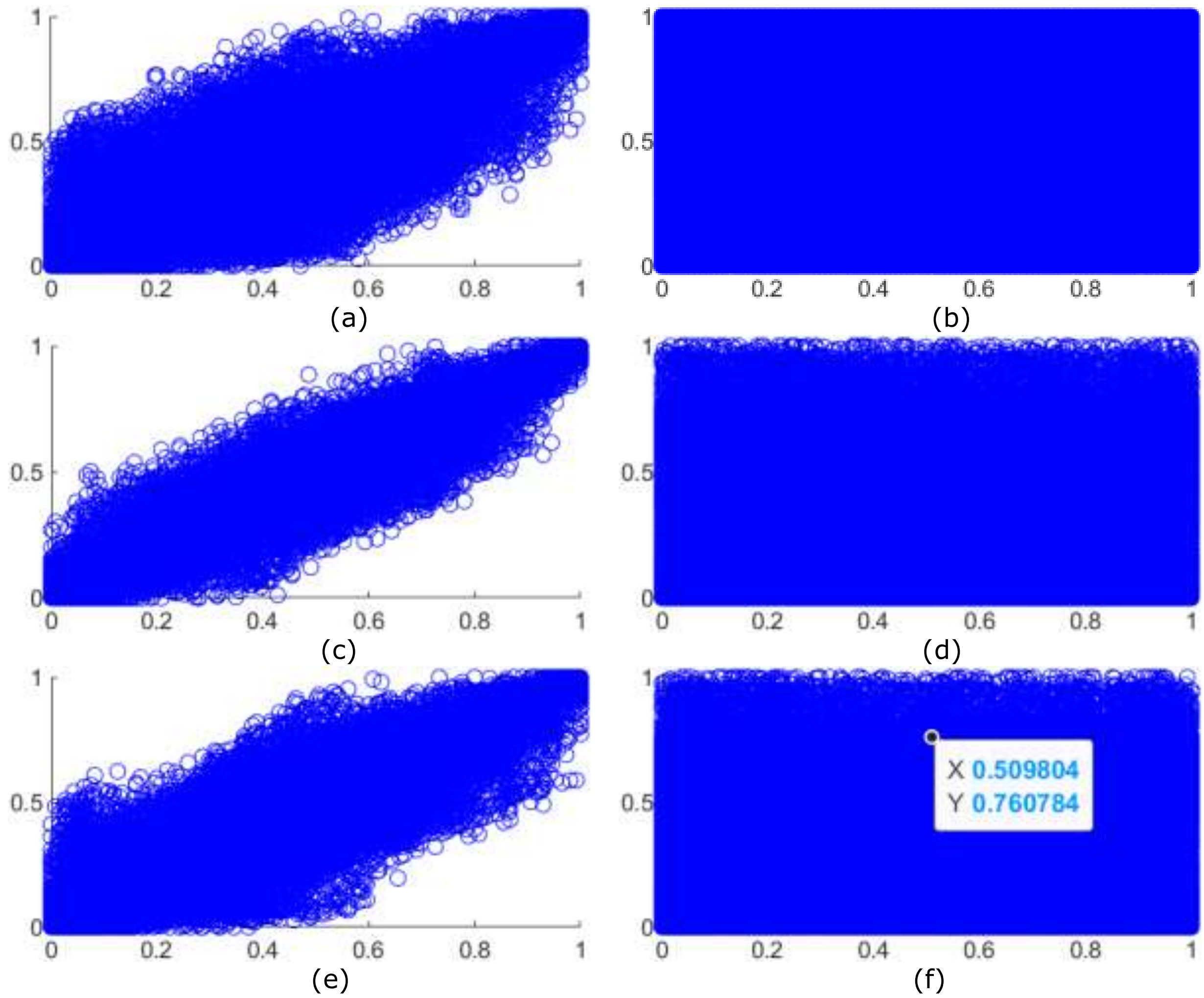
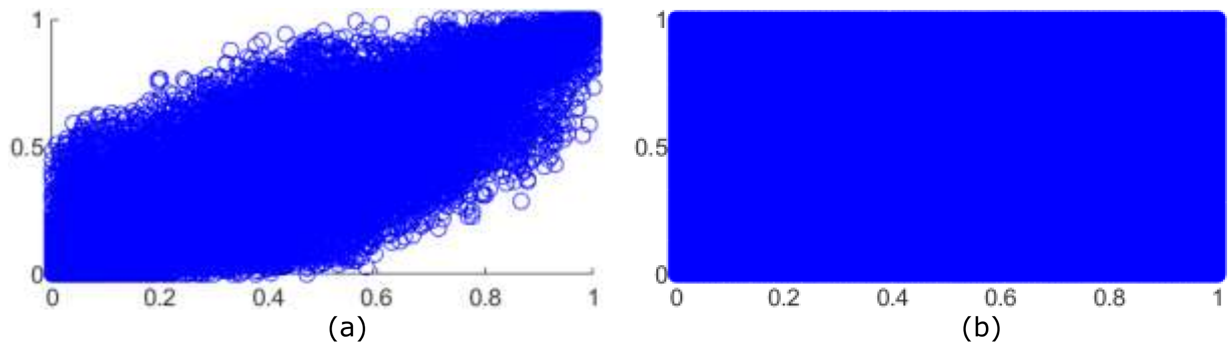


Fig. 3. Correlation analysis of Novel Gingerbreadman chaotic method of cameraman standard image (a)vertical correlation of standard image (b) vertical correlation of encrypted image (c) horizontal correlation of standard image (d) horizontal correlation of encrypted image (e) diagonal Correlation of standard image (f) diagonal correlation of encrypted image



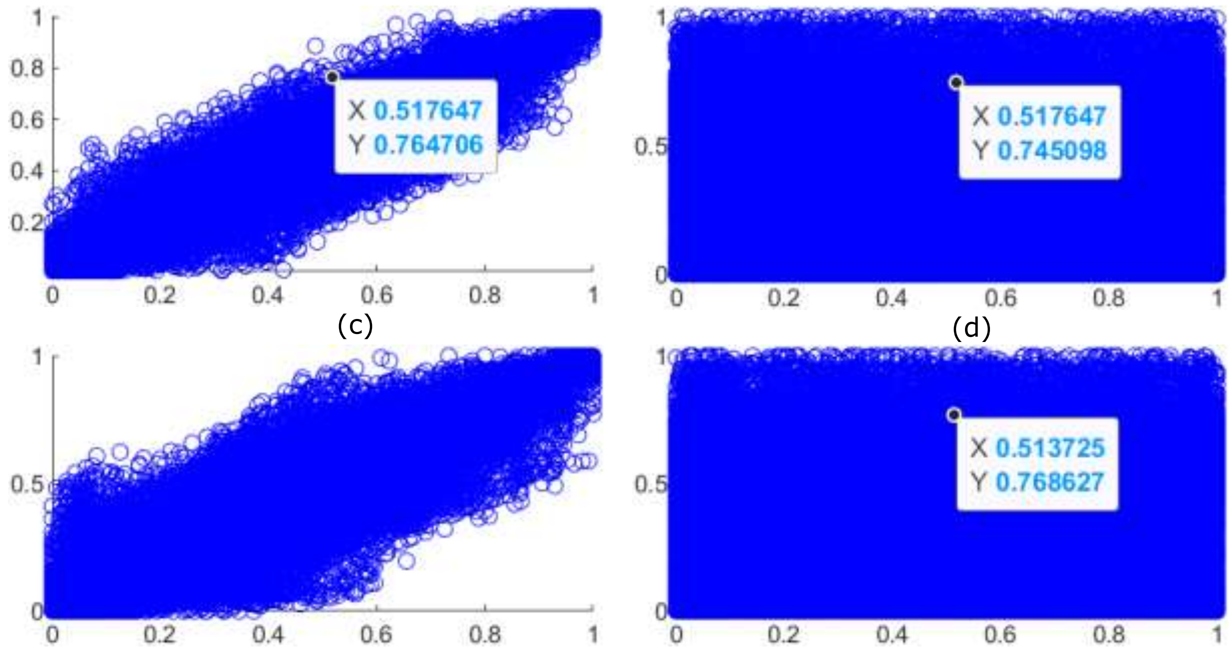


Fig. 4. Correlation analysis of Tinkerbell Chaotic method of cameraman standard image (a) vertical correlation of standard image (b) vertical correlation of encrypted image (c) horizontal correlation of standard image (d) horizontal correlation of encrypted image (e) diagonal Correlation of standard image (f) diagonal correlation of encrypted image

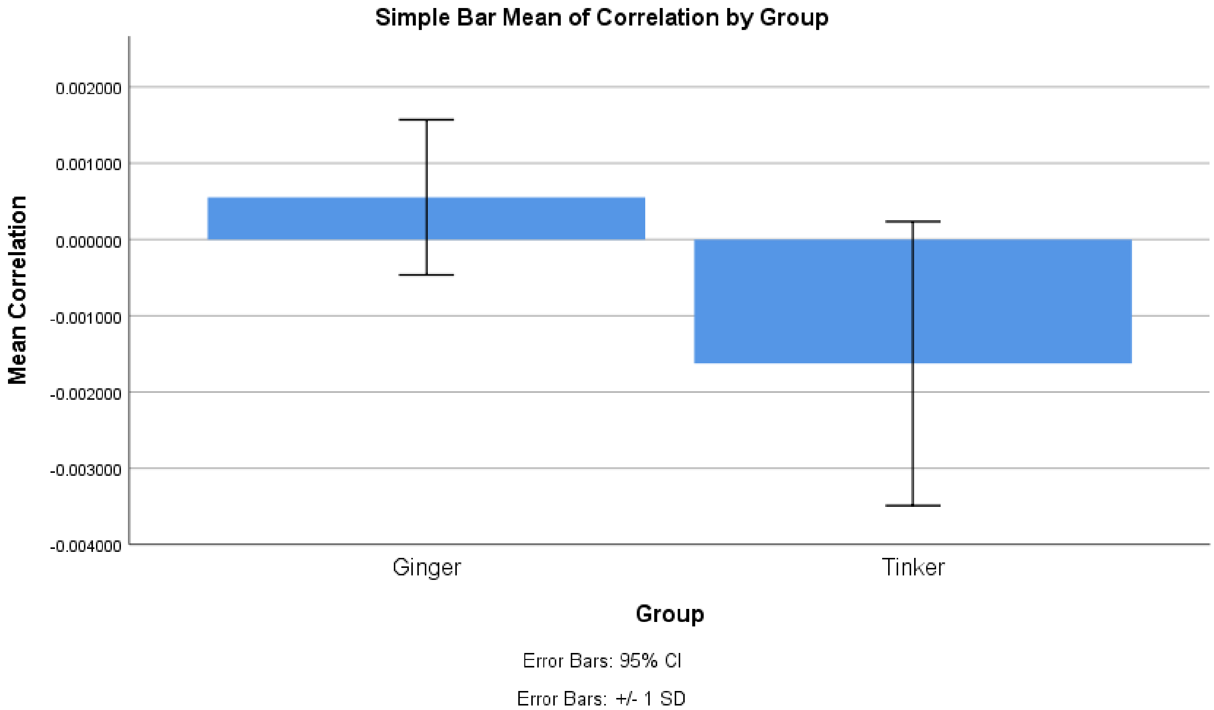


Fig. 5. Simple Bar mean of Correlation. X-Axis: Gingerbreadman chaotic encryption Vs Tinkerbell chaotic encryption. Y-Axis: Correlation. The graph compares groups on the x-axis and y-axis using the mean of Novel Gingerbreadman and Tinkerbell with +/- 1 standard deviation (SD).