BALTIC JOURNAL OF LAW & POLITICS
A Journal of Vytautas Magnus University
VOLUME 15, NUMBER 4 (2022)
ISSN 2029-0454

sciendo

Cite: *Baltic Journal of Law & Politics* 15:4 (2022): 119-130
DOI: 10.2478/bjlp-2022-004012

Reduction of Correlation in 2D Image Encryption using Novel Baker Chaotic Map in Comparison with Ikeda Map

Palagiri Venkata Saiganesh Reddy
Research Scholar, Department of Electronics and Communication Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India. Pincode:602105.

Nithya.R
Project Guide, Corresponding Author, Department of Electronics and Communication Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India. Pincode:602105.

Received: August 8, 2022; reviews: 2; accepted: November 29, 2022.

Abstract

Aim: The objective of the work is to develop 2D Image Encryption using Novel Baker chaotic encryption method for reducing the correlation and it is compared with Ikeda chaotic encryption method. **Materials and Methods:** Comparative analysis of Correlation is performed by Novel Baker Map where number of samples (N = 10) and Ikeda map where number of samples (N = 10) techniques with pre-test power of 80% using MATLAB software. **Results:** The correlation coefficient of Novel baker chaotic map is 0.00019 in vertical, 0.00196 in horizontal, 0.00115 in diagonal directions and whereas the correlation coefficient of ikeda chaotic map is 0.00126 in vertical, -0.00062 in horizontal, -0.00093 in diagonal. There is a significant difference in the results obtained for correlation and were considered to be error-free since it has the significance value p = 0.048 (p < 0.05) in SPSS statistical analysis. **Conclusion**: The Novel Baker Chaotic map was found not to be significantly better in reducing correlation in 2D image encryption when compared to Ikeda chaotic map.

Keywords

Novel Baker chaotic Map, Ikeda chaotic Map, Image Encryption, Correlation, Random Shuffling, Diffusion.

INTRODUCTION

The fundamental concept of chaotic encryption is primarily based on the few dynamic structures to supply a series of numbers which can be random in nature. This series of numbers is used to encrypt images or messages. For decryption, the series of random numbers is exceedingly dependent on the preliminary situation used for producing this series (Zhou et al. 2021). Correlation is a numerical measure of how closely two random variables vary in a response to one another. A positive correlation indicates that as one variable rises, the other tends to decrease as well. A negative correlation suggests that as one variable rises the other also increases as well. There is no predictable link between the variables if there is no correlation(Benlashram et al. 2020). Image encryption is important inorder to provide users with such protection and privacy. Image encryption is critical to fight against unauthorized user access. Chaotic maps provide some confusion or disorder of pixels through random shuffling. (National Academies of Sciences, Engineering, and Medicine et al. 2018). The chaotic image encryption has a wide range of applications (Liu et al. 2018) in internet communication, medical imaging and military applications.

Recently a lot of research has been done on chaotic maps based in 2D image encryption using the baker chaotic map and ikeda chaotic map. IEEE Xplore published 47 research papers, and google scholar found 63 articles. In (Ozturk and Kilic 2019) implemented new methods on digital platforms such as integer domain chaotic systems(IDCS) realized in all dimensions. LSB- extension also proposed. In (Musanna and Kumar 2020) constructed a secure quantum image algorithm using the selected intra bit-XOR-ing and XOR-ing with the pseudorandom sequence. In (Luo et al. 2019) a novel image encryption algorithm based on the double chaotic systems was proposed. This improved map has been proven to be random and unpredictable by the complexity analysis. It is showing comparatively better results. In (Ray et al. 2019) found that the probability density function of massive spiking events has a long tail distribution, which is consistent with unusual event features. In (Tayel, Dawood, and Shawky 2018) implemented an efficient S-box. Because implementing an efficient S-box becomes a new challenge . An S-box is generated using Fisher-Yates shuffle to enforce nonlinearity in a block cipher. In (Stoyanov 2021) aim is to achieve a novel pseudo random number output algorithm. A new ikeda attractor based pseudorandom byte output scheme was proposed.

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 main drawback of the existing methods is that the correlation coefficient is high because of improper shuffling or confusion of pixels and also diffusion of pixels is poor. The main aim of this research work is to propose an efficient technique for the reduction of correlation coefficient in vertical, horizontal and diagonal directions using Baker chaotic map in comparison with ikeda chaotic map.

MATERIALS AND METHODS

This study was conducted in the Digital image processing laboratory, Department of Electronics and Communication Engineering in Saveetha School of Engineering, SIMATS, Tamilnadu, and India. The customized data set contains 20 sample images, each image is resized into a standard size of 512x512. The sample size was calculated by using previous study results and it is found to be 10 for each group. To simulate this software we require a system of size (CPU 8th gen, i5,8GB RAM, 1TB HDD), and MATLAB software with the required library functions and tool functions. The calculation is performed utilizing G-power at 80% threshold at 0.86% confidence interval at 70%.

Baker chaotic map is one type of chaotic map which exhibits some type of chaotic behavior where confusion and diffusion of pixels takes place. The Baker map diffuses the image in an unpredictable fashion in these schemes, going horizontally to the end of the block and then to the row above the current row. The baker function is given below as eq(1) and eq(2), where a and b denote the system parameters considered a = 1.4 and b = 0.3 and x_n and y_n denote as state variables (Saravanan and Sivabalakrishnan 2020). Since the system is chaotic two chaotic sequences x_n and y_n can be generated. The baker function is used to generate two random arrays of key values. Now these key values are used to encrypt the image.

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

Ikeda chaotic map is also another chaotic map which makes the random shuffling and diffusion of pixels in the image. The ikeda chaotic function is given below as eq(3), eq(4) and the time function as eq(5), where μ denotes the system parameters and x_n and y_n as static variables (Ray et al. 2019). t_n also denotes a static variable. Where μ>0.6 or μ = 0.6 this function also generates two chaotic sequences.

$$x_{n+1} = 1 + \mu(x_n \cos t_n - y_n \sin t_n) \quad (3)$$

$$y_{n+1} = \mu(x_n \sin t_n - y_n \cos t_n) \quad (4)$$

$$t_n = 0.4 - 6 /(1+x^2_n+y^2_n) \quad (5)$$

Each and every pixel of an image is in decimal form. So first each pixel is converted into binary form in order to perform xor operation. Now a function is written to generate two keys which are in a range of 256 and 512. The key within range 256 will be xored with the image pixel and the other key which is in the range of 512 is used to shuffle the row or column sequence of the other key. This makes the encrypted image pixels shuffled inorder to achieve a lesser correlation coefficient through random shuffling. Diffusion plays a vital role in reducing the correlation coefficient of the images. Now the encrypted image is stored in a new variable. Again the encrypted image binary value is converted into the decimal to form a sequence of pixels which are combined to form a digital image. The diffusion makes the pixels scatter from the original position and proper random shuffling is also required to reduce the correlation coefficient. Now the encrypted image is used to find the correlation coefficient using the correlation algorithms.

The tool used to execute the process was MATLAB software version 21a (Michael Fitzpatrick and Lédeczi 2015). The pixels are confused using the random process of getting the key from a sequence of values. This process provides a set of pixels which are not related to each other. This makes the encrypted image to achieve very low correlation coefficients.

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 shows the original, encrypted and decrypted images. Fig 1(a), (d), (g) are the original images Whereas fig 1(b),(e),(g) shows the encrypted images using the baker chaotic map. Fig (c), (f), (g) are the decrypted images of encrypted images.

Figure 2 shows the original, encrypted and decrypted images. Fig 2(a), (d), (g) are the original images Whereas fig2 (b),(e),(g) shows the encrypted images using the ikeda chaotic map. Fig2 (c), (f), (g) are the decrypted images of encrypted images.

Figure 3 shows the correlation analysis of the cameraman image using the baker chaotic map fig 3(a),(c),(e) shows the original image correlation in vertical, horizontal, and diagonal whereas fig 3(b), (d), (f) shows the encrypted image correlation in vertical, horizontal and diagonal direction

Figure 4 shows the correlation analysis of the cameraman image using the ikeda chaotic map fig 4(a),(c),(e) shows the original image correlation in vertical, horizontal, and diagonal direction whereas 4(b),(d),(f) shows the encrypted image correlation in vertical, horizontal and diagonal direction

Figure 5 shows the graph created with spss that compares the mean of horizontal correlation coefficient of baker chaotic map and ikeda chaotic map. It represents the Ikeda chaotic map having lesser value in terms of correlation coefficient comparison with the Baker chaotic map. The variable results with a correlation of -0.00062 for ikeda chaotic map whereas results of baker chaotic map correlation is 0.00196.

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

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

Table 3 shows the statistical analysis, mean, standard deviation and standard error rate for novel baker chaotic map encryption method and the ikeda chaotic encryption method were obtained. There is a statistical significance difference between correlation coefficients of two methods. The baker chaotic map obtained a maximum standard deviation of 0.0013 and minimum standard error of 0.00041 while the ikeda encryption method obtained a maximum standard deviation of 0.00432 and minimum standard error of 0.00045. The mean correlation using the ikeda chaotic map is -0.00093 which is better than the baker chaotic map is 0.00098 and the standard deviation of the ikeda chaotic map is 0.00432 was slightly higher than the baker chaotic map 0.00131.

Table 4 displays the statistical calculations for independent samples tested between Baker chaotic map and ikeda chaotic map. The significance for correlation coefficient is 0.049. Independent samples T-test is applied for comparison of Baker chaotic map and ikeda 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 methods were employed to reduce the correlation of the pixels in the encrypted image. The Ikeda chaotic map encryption performs significantly better in reducing the correlation 0.00126 in vertical, -0.00062 in horizontal and -0.00093 in diagonal direction. when compared to the novel baker chaotic map encryption with the correlation 0.00019 in vertical, 0.00196 in horizontal and 0.00115 in diagonal direction. The results obtained have the significance value $p = 0.048$ ($p < 0.05$) in SPSS statistical analysis.

By comparing with the previous research (Luo et al. 2019) proposed encryption based on the baker and logistic map was described and the baker map shows significantly better results with correlation of -0.00030 in horizontal. Random shuffling was proper and the achieved best correlation coefficient. The results obtained in the research shows that an ikeda map shows a minimum correlation coefficient of -0.00004 horizontally. So the results were obtained in favor of the ikeda map. (Musanna and Kumar 2020) described a 3D baker chaotic map and the results obtained with the minimum correlation of −0.0050 horizontally hence the results shows that ikeda map is better when compared to baker map. By using the RGB image encryption (Jain and Sharma 2016) with Baker chaotic map by shuffling and masking technique obtained a minimum correlation of 0.0001 red component here the results are in favor of baker chaotic map due to the RGB image encryption. In (Tayel, Dawood, and Shawky 2018) the ikeda based image encryption was described and the minimum correlation coefficient obtained was 0.021 in horizontal whereas in this research the results obtained were similar with the finding hence the study is in favor of our research. There is only one opposite finding found regarding this research and remaining are in favor of this research.

The limitation of the novel baker chaotic method of encryption was that it takes more time for random shuffling and confusion and it is not suitable for the images which have uniform distribution of pixels. The future work is to produce an efficient encryption method that can produce a minimum correlation in a lesser encryption time period.

CONCLUSION

Two different methods to determine correlation coefficient were evaluated using performance parameters such as horizontal, vertical and diagonal correlation coefficients. The Novel Baker Chaotic map achieved the correlation of about 20% and the Ikeda map achieved the correlation of about 10%. It is found that the Novel Baker chaotic map is not found to be significantly better compared to Ikeda 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.

Acknowledgement

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences(formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Fundings

We thank the following organizations for providing financial support and enabling us to complete the study.

1.Kacho Pvt.Ltd,Chennai
2.Saveetha University.
3.Saveetha School of Medical and Technical Sciences.
4.Saveetha School of Engineering.

REFERENCES

Benin, S. R., S. Kannan, Renjin J. Bright, and A. Jacob Moses. 2020. "A Review on Mechanical Characterization of Polymer Matrix Composites & Its Effects Reinforced with Various Natural Fibres." *Materials Today: Proceedings* 33 (January): 798–805.

Benlashram, Arwa, Maryam Al-Ghamdi, Rawan AlTalhi, and Pr Kaouther Laabidi. 2020. "A Novel Approach of Image Encryption Using Pixel Shuffling and 3D Chaotic Map." *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742-6596/1447/1/012009.

Gudipaneni, Ravi Kumar, Mohammad Khursheed Alam, Santosh R. Patil, and Mohmed Isaqali Karobari. 2020. "Measurement of the Maximum Occlusal Bite Force and Its Relation to the Caries Spectrum of First Permanent Molars in Early Permanent Dentition." *The Journal of Clinical Pediatric Dentistry* 44 (6): 423–28.

Jain, Rachit, and J. B. Sharma. 2016. "Symmetric Color Image Encryption Algorithm Using Fractional DRPM and Chaotic Baker Map." *2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*. https://doi.org/10.1109/rteict.2016.7808152.

Liu, Jizhao, Yide Ma, Shouliang Li, Jing Lian, and Xinguo Zhang. 2018. "A New Simple Chaotic System and Its Application in Medical Image Encryption." *Multimedia Tools and Applications*. https://doi.org/10.1007/s11042-017-5534-8.

Luo, Yuqin, Jin Yu, Wenrui Lai, and Lingfeng Liu. 2019. "A Novel Chaotic Image Encryption Algorithm Based on Improved Baker Map and Logistic Map." *Multimedia Tools and Applications*. https://doi.org/10.1007/s11042-019-7453-3.

McCormick, Keith, and Jesus Salcedo. 2017. *SPSS Statistics for Data Analysis and Visualization*. John Wiley & Sons.

Michael Fitzpatrick, J., and Ákos Lédeczi. 2015. *Computer Programming with MATLAB*.

Musanna, Farhan, and Sanjeev Kumar. 2020. "Image Encryption Using Quantum 3-D

Baker Map and Generalized Gray Code Coupled with Fractional Chen's Chaotic System." *Quantum Information Processing*. https://doi.org/10.1007/s11128-020-02724-3.

Nalini, Devarajan, Jayaraman Selvaraj, and Ganesan Senthil Kumar. 2020. "Herbal Nutraceuticals: Safe and Potent Therapeutics to Battle Tumor Hypoxia." *Journal of Cancer Research and Clinical Oncology* 146 (1): 1–18.

National Academies of Sciences, Engineering, and Medicine, Division on Engineering and Physical Sciences, Computer Science and Telecommunications Board, and Committee on Law Enforcement and Intelligence Access to Plaintext Information. 2018. *Decrypting the Encryption Debate: A Framework for Decision Makers*. National Academies Press.

Ozturk, Ismail, and Recai Kilic. 2019. "Higher Dimensional Baker Map and Its Digital Implementation With LSB-Extension Method." *IEEE Transactions on Circuits and Systems I: Regular Papers*. https://doi.org/10.1109/tcsi.2019.2934714.

Ray, Arnob, Sarbendu Rakshit, Dibakar Ghosh, and Syamal K. Dana. 2019. "Intermittent Large Deviation of Chaotic Trajectory in Ikeda Map: Signature of Extreme Events." *Chaos* 29 (4): 043131.

Reddy, Poornima, Jogikalmat Krithikadatta, Valarmathi Srinivasan, Sandhya Raghu, and Natanasabapathy Velumurugan. 2020. "Dental Caries Profile and Associated Risk Factors Among Adolescent School Children in an Urban South-Indian City." *Oral Health & Preventive Dentistry* 18 (1): 379–86.

Saravanan, S., and M. Sivabalakrishnan. 2020. "An Image Encryption Scheme Using Chaotic Baker Map." *Journal of Computational and Theoretical Nanoscience*. https://doi.org/10.1166/jctn.2020.8859.

Sathish, T., and S. Karthick. 2020. "Gravity Die Casting Based Analysis of Aluminum Alloy with AC4B Nano-Composite." *Materials Today: Proceedings* 33 (January): 2555–58.

Sathish, T., D. Bala Subramanian, R. Saravanan, and V. Dhinakaran. 2020. "Experimental Investigation of Temperature Variation on Flat Plate Collector by Using Silicon Carbide as a Nanofluid." In *PROCEEDINGS OF INTERNATIONAL CONFERENCE ON RECENT TRENDS IN MECHANICAL AND MATERIALS ENGINEERING: ICRTMME 2019*. AIP Publishing. https://doi.org/10.1063/5.0024965.

Sivasamy, Ramesh, Potu Venugopal, and Rodrigo Espinoza-González. 2020. "Structure, Electronic Structure, Optical and Magnetic Studies of Double Perovskite Gd2MnFeO6 Nanoparticles: First Principle and Experimental Studies." *Materials Today Communications* 25 (December): 101603.

Stoyanov, Borislav. 2021. "Double Ikeda Map as a Source of Pseudorandom Numbers." *THERMOPHYSICAL BASIS OF ENERGY TECHNOLOGIES (TBET 2020)*. https://doi.org/10.1063/5.0041614.

Tayel, Mazhar, George Dawood, and Hamed Shawky. 2018. "Block Cipher S-Box Modification Based on Fisher-Yates Shuffle and Ikeda Map." *2018 IEEE 18th International Conference on Communication Technology (ICCT)*. https://doi.org/10.1109/icct.2018.8600161.

Venu, Harish, and Prabhu Appavu. 2021. "Experimental Studies on the Influence of Zirconium Nanoparticle on Biodiesel–diesel Fuel Blend in CI Engine." *International Journal of Ambient Energy* 42 (14): 1588–94.

Zhou, Shuang, Xingyuan Wang, Yingqian Zhang, Bin Ge, Mingxu Wang, and Suo Gao. 2021. "A Novel Image Encryption Cryptosystem Based on True Random Numbers and Chaotic Systems." *Multimedia Systems*. https://doi.org/10.1007/s00530-021-00803-8.

TABLES AND FIGURES

Table 1. Comparison of correlation coefficients of original images and the novel baker chaotic map encrypted images.

Standard	**Standard image**	**Encrypted image**

images	Vertical	Horizontal	Diagonal	Vertical	Horizontal	Diagonal
cameraman	0.9334	0.9723	0.9647	-1.27E-07	0.00221	-0.00144
coins	0.9872	0.9654	0.9576	-0.00036	0.00132	0.00038
fabric	0.9845	0.9934	0.9845	0.002585	0.00196	0.00210
football	0.9345	0.9746	0.9933	-0.00055	0.00304	0.00214
forest	0.9849	0.9847	0.9847	-0.00063	0.00152	-0.00026
lenna	0.9843	0.9473	0.9476	0.00014	0.00162	0.002451
mandril	0.9873	0.9883	0.9877	0.00029	0.00192	-0.00002
pears	0.9766	0.9643	0.9465	-0.00057	0.00139	0.00244
rice	0.9822	0.9887	0.9753	0.00103	0.00204	0.00110

Table 2. Comparison of Correlation coefficient of an original image and ikeda chaotic map encrypted images.

Standard images	**Standard image**			**Encrypted image**		
	Vertical	**Horizontal**	**Diagonal**	**Vertical**	**Horizontal**	**Diagonal**
cameraman	0.9334	0.9723	0.9647	0.00199	-0.00052	-0.00018
coins	0.9872	0.9654	0.9576	0.00483	-0.00397	-0.01198
fabric	0.9845	0.9934	0.9845	-0.00041	0.00022	-0.00183
football	0.9345	0.9746	0.9933	0.00062	-0.00125	0.00431
forest	0.9849	0.9847	0.9847	0.00131	0.00023	0.00091
lenna	0.9843	0.9473	0.9476	0.00150	0.00085	-0.00200
mandril	0.9873	0.9883	0.9877	0.00028	0.00040	-0.00065
pears	0.9766	0.9643	0.9465	0.00035	0.000380	0.00081
rice	0.9822	0.9887	0.9753	0.00086	-0.00069	0.00218
cameraman	0.9334	0.9723	0.9647	0.00132	-0.00185	-0.00090

 ISSN 2029-0454
2022

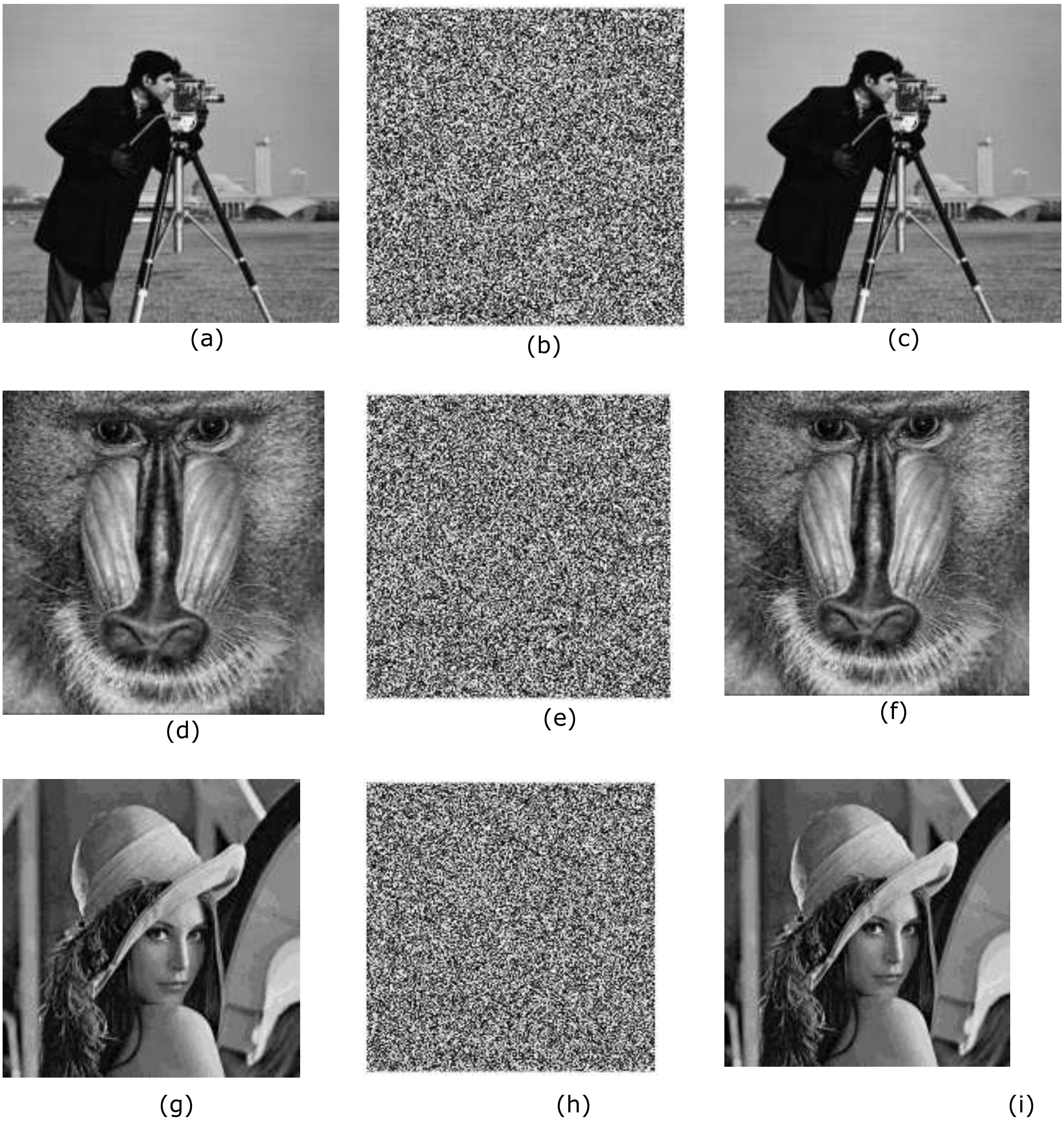
Table 3. Group statistics of image encryption can be done for analysis of vertical, horizontal, diagonal comparison between the novel Baker chaotic map encryption and the Ikeda chaotic map encryption.

	Groups	N	Mean	Std.Deviation	Std.Error Mean
Vertical Correlation coefficient	Baker	10	0.00199	0.00098	0.00030
	Ikeda	10	0.00126	0.00143	0.00045
Horizontal Correlation coefficient	Baker	10	0.00196	0.00054	0.00017
	Ikeda	10	-0.00062	0.00144	0.00045
Diagonal Correlation coefficient	Baker	10	0.00115	0.00131	0.00041
	Ikeda	10	-0.00093	0.00432	0.00136

Table 4. The independent samples test between novel baker chaotic map and ikeda map was done using statistical technique. The correlation coefficient has a significance of 0.048. The baker chaotic map and ikeda chaotic map are compared using an independent sample T-test with a confidence interval of 95 percent and a level of significance of 0.69595. The significance level is 0.000, the significance level is two-tailed, the mean difference, the standard error difference, and the lower and upper interval difference are all included in this independent sample test.

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 assumed**	4.491	0.048	5.284	18	0.000	0.00258	0.00048	0.00155	0.00361

	Equal variance not assumed			5.284	11.467	0.000	0.00258	0.00048	0.00151	0.00365



(a) (b) (c) (d) (e) (f) (g) (h) (i)

Fig. 1. Novel Baker chaotic map encryption technique (a) sample image cameraman of size (512x512) (b) encrypted cameraman using baker chaotic map (c) decrypted cameraman image (d) sample image mandril of size (512x512) (e) encrypted mandril using baker chaotic map (f) decrypted mandril image (g) sample image lenna of size (512x512) (h) encrypted lenna using baker chaotic map (i) decrypted lenna image.

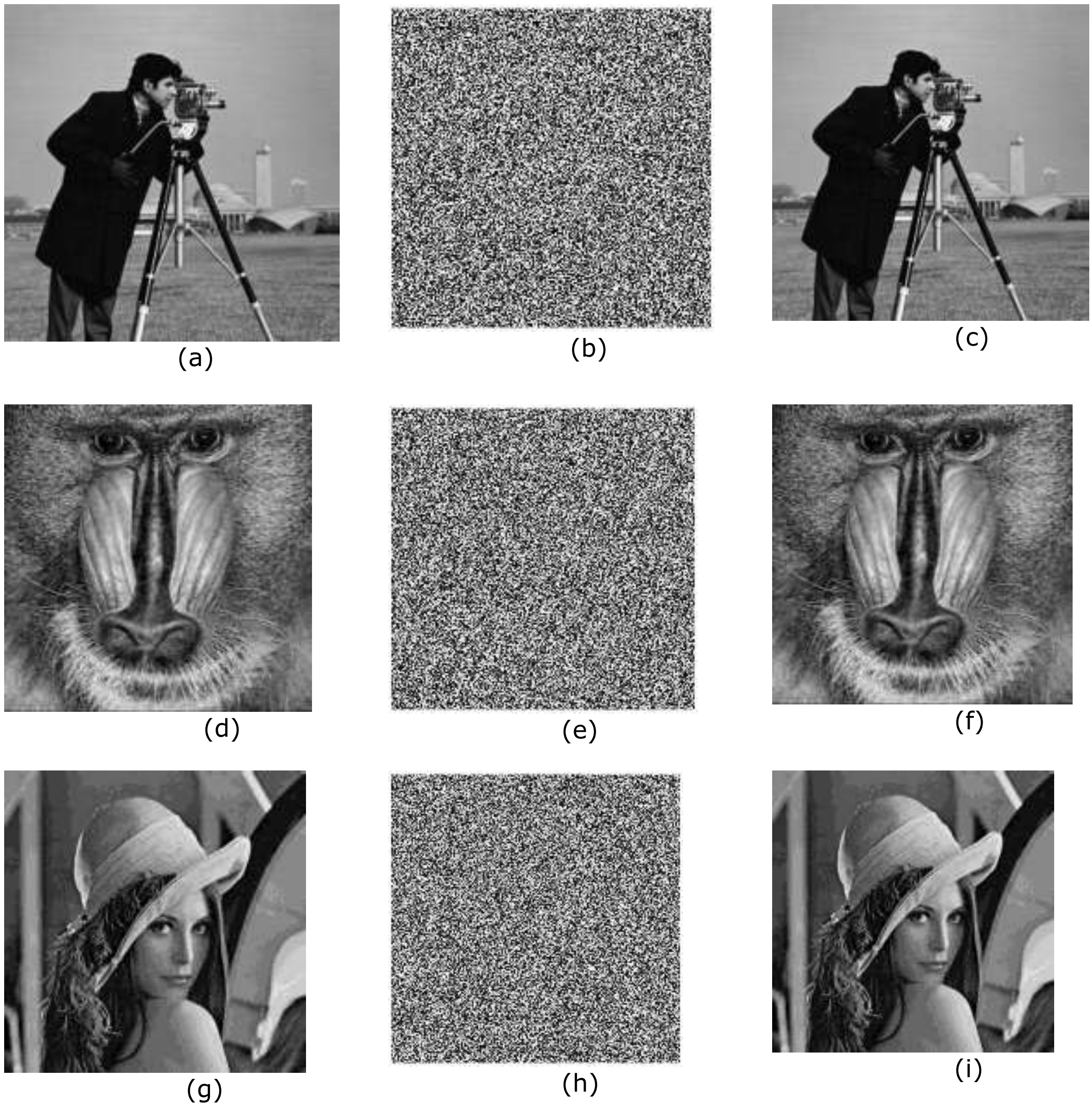
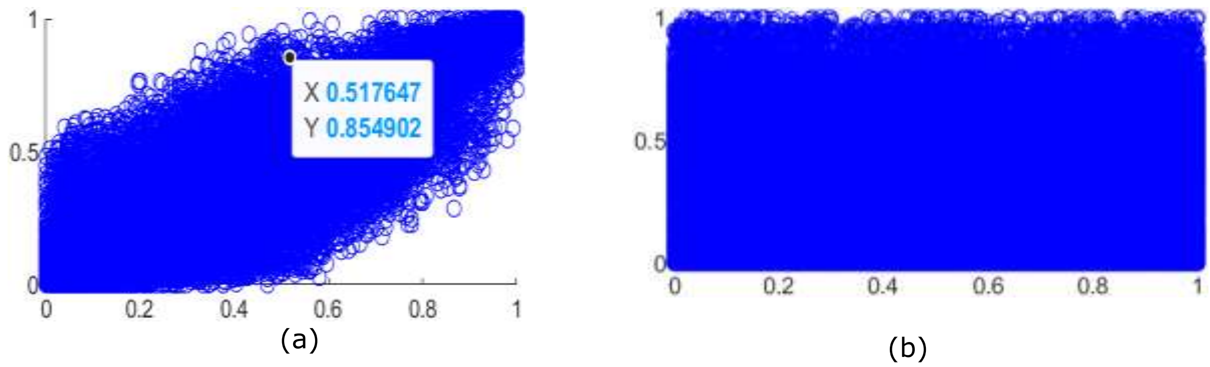


Fig. 2. Ikeda chaotic map encryption technique (a) sample image cameraman of size (512x512) (b) encrypted cameraman using ikeda chaotic map (c) decrypted cameraman image (d) sample image mandril of size (512x512) (e) encrypted mandril using ikeda chaotic map (f) decrypted mandril image (g)sample image lenna of size (512x512) (h) encrypted lenna using ikeda chaotic map (i) decrypted lenna image.



ISSN 2029-0454
2022

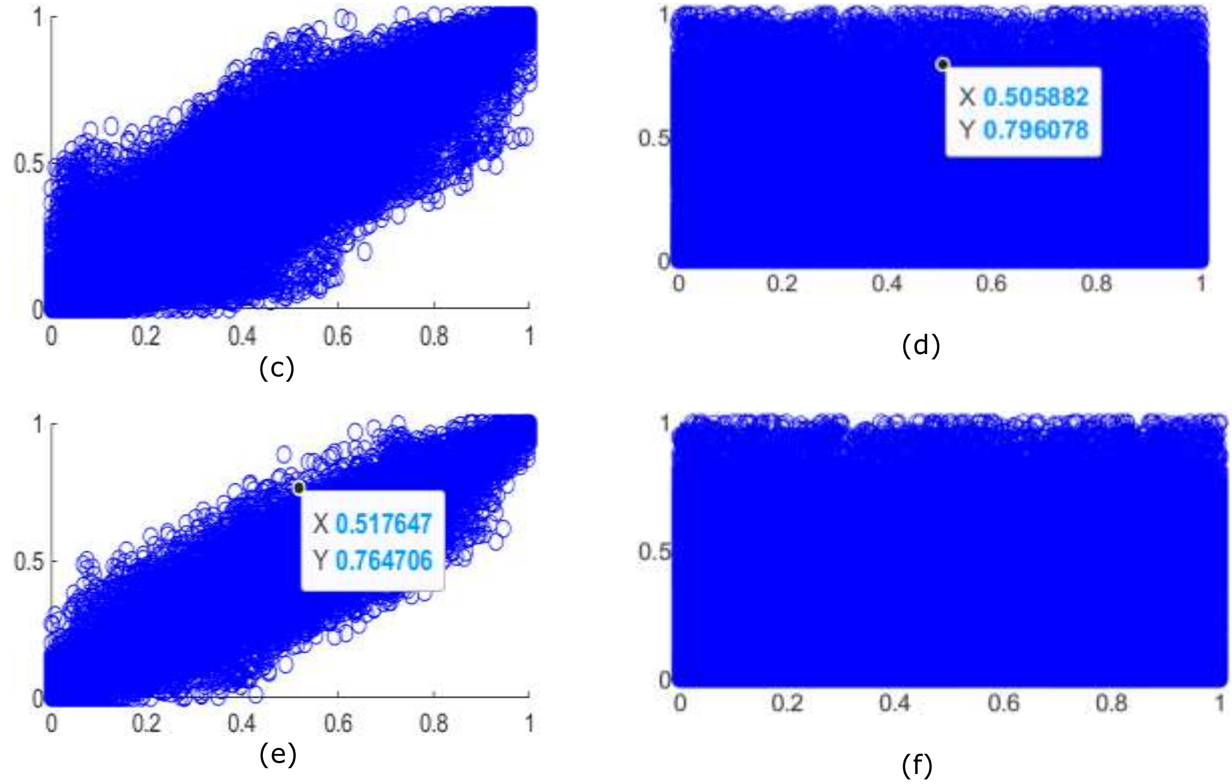
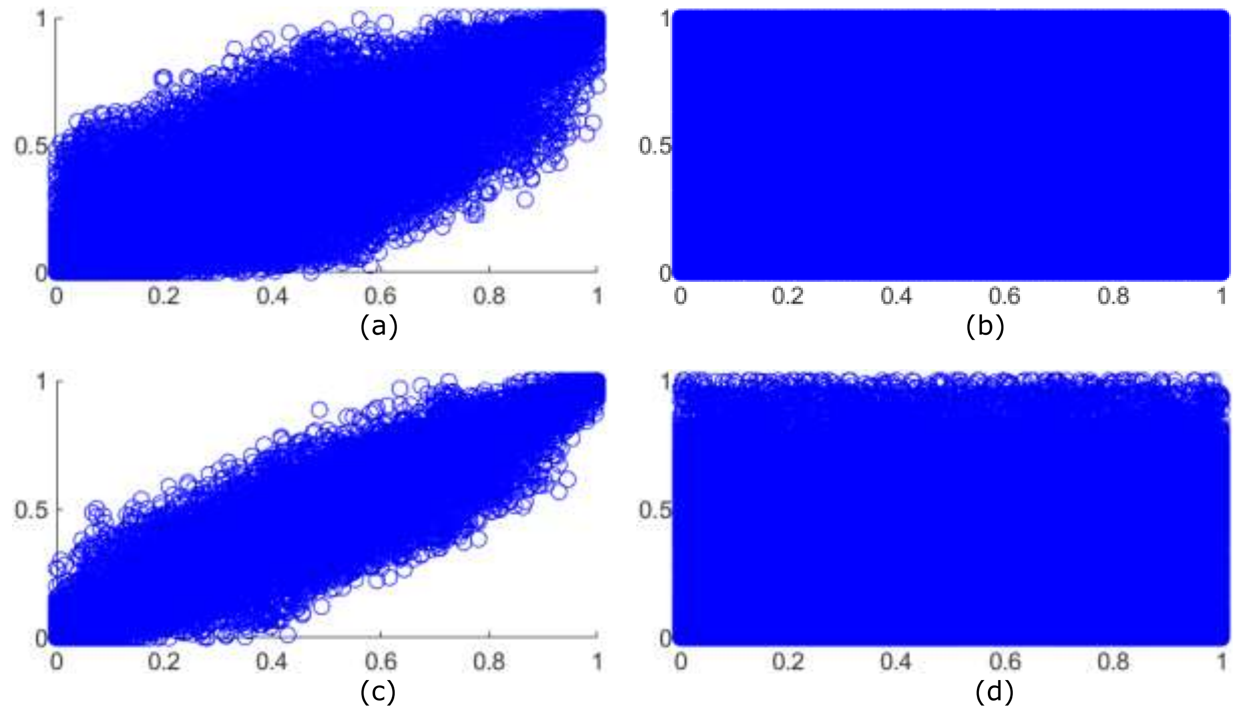
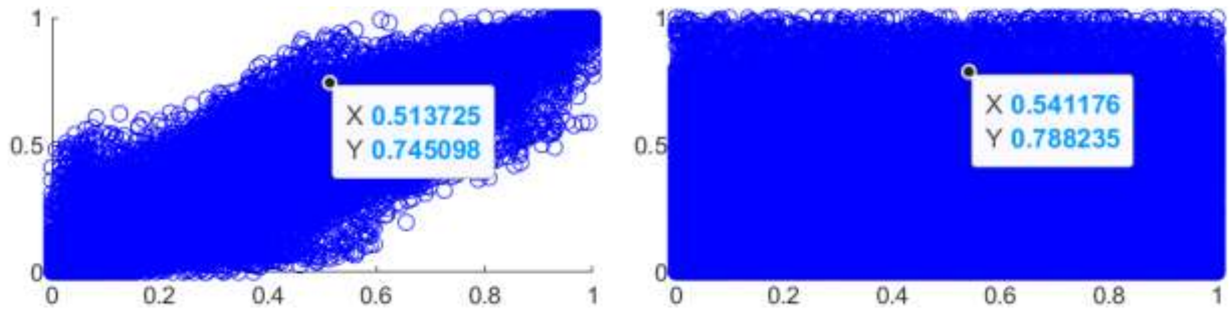


Fig. 3. Correlation analysis of Novel Baker chaotic method of cameraman standard image (a) vertical correlation of original image (b) vertical correlation of encrypted image (c) horizontal correlation of original image (d) horizontal correlation of encrypted image (e) diagonal Correlation of original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



ISSN 2029-0454
2022



(e) (f)

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

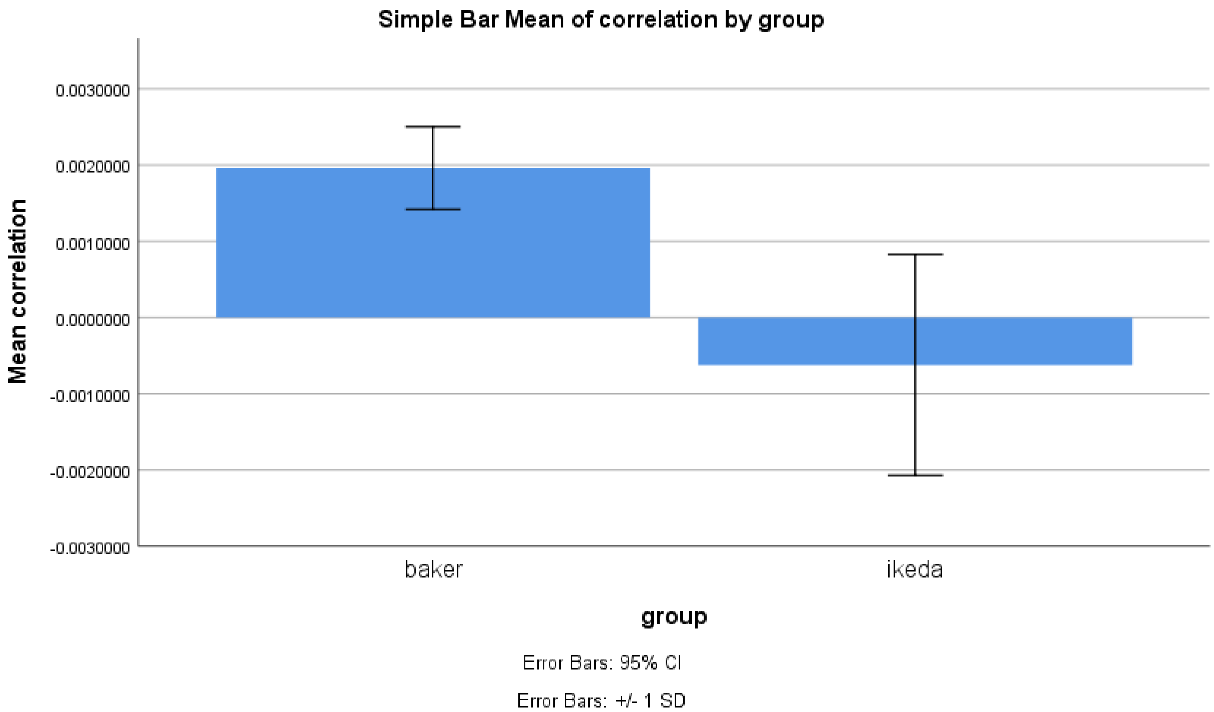


Fig. 5. Simple Bar mean of Correlation. X-Axis: Baker chaotic encryption vs Ikeda chaotic encryption. Y-Axis: Correlation. The graph compares groups on the x-axis and y-axis using the mean of baker and ikeda with +/- 1 standard deviation (SD). The Ikeda chaotic encryption provides better correlation -0.00062 when compared to Baker chaotic encryption correlation is 0.00196.