IMPROVED ENTROPY OF RGB IMAGE ENCRYPTION USING NOVEL DNA EXCLUSIVE OR ENCODING IN COMPARISON WITH DNA ADDITIVE ENCODING

C. Reddy Manjunath[1], Radhika Baskar[2*]

Article History: Received: 12.12.2022 **Revised:** 29.01.2023 **Accepted:** 15.03.2023

Abstract

Aim: The aim of the research work is to improve the entropy of Red Green Blue (RGB) image encryption using novel Deoxy Nucleic Acid (DNA) Exclusive OR encoding in comparison with DNA additive encoding using MATLAB software.
Materials and Methods: The image encryption is performed using novel DNA Exclusive OR encoding with number of samples (N=10) and additive encoding with number of samples (N=10) having pre-test power of 80% using MATLAB software.
Results: The entropy of Novel DNA Exclusive OR encoding is 1.62056 whereas the entropy of DNA additive encoding is 1.53383. There is a significant difference in the results obtained for entropy and were considered to be error-free since it has the significance value $p = 0.0329$ ($p<0.5$) in SPSS statistical analysis.
Conclusion: Novel DNA Exclusive OR encoding performs significantly better in increasing entropy in RGB image encryption when compared to DNA additive encoding.

Keywords: Novel DNA Exclusive OR Encoding, DNA Additive Encoding, Image Encryption, Entropy, RGB Image, Diffusion

[1]Research Scholar, Department of Electronics and Communication Engineering, Saveetha School of Engineering,
Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India. Pincode:602105.
[2*]Department of Electronics and Communication Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India. Pincode:602105.

1. Introduction

With the increased usage of media in communication, picture encryption is required to protect against assaults. The authors offered a new picture security technique based on elliptic curve cryptography and DNA encoding (Chen, Xie, and Zhang 2022). Information security has become an increasingly essential concern in modern civilization, with digital picture protection being one among them. A safe picture encryption approach is given in this research, Which is based on logistics and spatiotemporal chaotic sysytems (Craik 2021). The preponderance of chaos-based encryption algorithms work at the bit level, making them useless in high-resolution digital files. The expand-shrink operation for confusion and the diffusion operation in the chaos algorithm are used in this research study as a novel color to present novel color picture encryption techniques (Rashmi, Supriya, and Kiran 2020). Image encryption algorithms have been a study priority as an essential subject in information security. At the same time, among the different encryption techniques, there are few works on fractal sets as the encryption key for diffusion process (Sun et al. 2010).

The total number of articles published in this topic over the past five years is more than 40 papers in IEEE Xplore, 33 papers in the google scholar, 67 papers in sci hub and 55 papers in springer. With the surge in pace, volume, and velocity of collected multi-modal data, security and privacy of photographs recorded through electronic devices are of crucial concern (Jithin and Sankar 2020). A plain image related chaotic image encryption algorithm based on DNA sequence operation and discrete (Feng et al. 2019). Research on new types of chaotic image encryption algorithms combining DNA operation and S-box (C. Li et al. 2021). Novel permutation diffusion images encryption algorithm with chaotic dynamic S-box and DNA sequence operation (Tian and Lu 2017). Quantum logistics images encryption algorithm based on SHA-3 and RSA this paper states that the image encryption in the quantum logistics (Ye, Jiao, and Huang 2021). From the previous findings it can be concluded that the best cited article is (Feng et al. 2019) many contemporary chaotic picture encryption techniques, according to research efforts in the literature on chaotic cryptanalysis, are vulnerable to chosen plaintext attacks.

Our institution is keen on working on latest research trends and has extensive knowledge and research experience which resulted in quality publications (Rinesh et al. 2022; Sundararaman et al. 2022; Mohanavel et al. 2022; Ram et al. 2022; Dinesh Kumar et al. 2022; Vijayalakshmi et al. 2022; Sudhan et al. 2022; J. A. Kumar et al. 2022; Sathish et al. 2022; Mahesh et al. 2022; Yaashikaa et al. 2022).From the previous findings it is observed that the drawbacks of existing image encryption schemes was the increased complexity which in turn results in lesser entropy values and increased computation time. To overcome these limitations the RGB image encryption using novel DNA exclusive-OR encoding is performed and it is compared with DNA additive encoding.

2. 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, India. The customized data set contains 20 sample images, each image is resized into a standard size of 512x512. The sample size was calculated using previous study results and it is found to be 10 for each group thus the total sample size was 20. Present analysis was carried out by using clinical.com by keeping the G-power at 80 % threshold at 0.86 % confidence interval at 70 % (N. S. Kumar et al. 2017). The tool used to execute the process was MATLAB software version 21a (Michael Fitzpatrick and Lédeczi 2015).

Image is taken as an input in matrix form and every pixel of an image is converted into binary form. The binary number of every pixel is divided into four equal parts and the values are compared with the DNA nucleic acid bases and each divided binary part is assigned to its respective DNA variable. This is clearly explained in Table 1. There are four nucleic acid bases in DNA sequence: namely A(Adenine), G(Guanine), C(Cytosine), T(Thymine). Double-stranded DNA satisfies the principle of Watson-Crick complementary base pairing: A and T are complementary; G and C are complementary in binary, 0 and 1 are complementary, so are 00 and 11, 01 and 10 . By using four bases A, G, C and T to encode 00, 01, 10 and 11, there are certain encoding rules.
A novel DNA exclusive OR encoding is also one type of image encryption algorithm which exhibits some type of behavior where confusion and diffusion of pixels takes place. The novel exclusive OR encoding algorithm is explained in table 2 and it shows how the pixels are changed (Huo et al. 2019).

DNA additive encoding is also one type of image encryption algorithm which exhibits some type of behavior where confusion and diffusion of pixels takes place. The additive encoding algorithm is explained in table 3 and it shows how the pixels are changed after diffusion (Yadav and Chaware 2021).

The entropy of both methods were evaluated to identify the good image encryption scheme. The formula used to calculate the entropy is given by equation (1).

$$\text{Entropy} = -P_i \log(P_i) \qquad (1)$$

Where P_i is the pixel value at i position.

Statistical Analysis

SPSS version 21 was used for statistical analysis of collected data for parameter entropy (Aldrich 2018). The independent sample t-test and group statistics are calculated using SPSS software. Entropy is the dependent variable and the size of the image is an independent variable.

3. 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 novel Exclusive OR encoding technique. Fig. 1 (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 Fig. 2 (b), (e), (g) shows the encrypted images using the additive encoding. Fig. 3 (c), (f), (g) are the decrypted images of encrypted images.

Table 4 shows the values of entropy of original images and encrypted images using novel DNA Exclusive OR encoding and DNA additive encoding.

Table 5 shows the statistical analysis of independent samples t-test between novel exclusive OR encoding and additive encoding. The significance for correlation coefficient is 0.0329. The confidence interval is 95%. This analysis test consists of significance, significance (2-tailed), mean difference, standard error difference, lower and upper interval difference.

4. Discussion

Two different methods were employed to the entropy of the pixels in the encrypted image. The novel Exclusive OR image encryption performs significantly better in increasing the entropy of encrypted images with 1.62056 mean entropy value when compared to additive encoding which has only 1.53383 entropy value. The results obtained have the significance value p=0.0329 ($p < 0.5$) in SPSS statistical analysis.

The proposed algorithm introduces the DNA exclusive OR operation with high parallelism to further improve the encryption efficiency with an entropy of 1.8904 (Feng et al. 2019). The RGB image encryption algorithm based on a memristor-based neuron model achieved an entropy value of 2.9890 for DNA exclusive OR operation (Yildirim 2022). Information entropy is a mathematical property that reflects the randomness of information sources, and it indicates the uncertainty of the image in the image information.The entropy obtained by using DNA exclusive OR operation is nearly 1.7804 (X. Li and Li 2019). Hyperchaotic sequence matrix is generated through a HCCNN system and is conducted as a XORed operation with an entropy of 2.5677 (Elmanfaloty, Alnajim, and Abou-Bakr 2021). Based on chaotic encryption technology and DNA cryptography, the entropy between pixels after DNA exclusive OR encoding was found to be 1.9560. There were no opposite findings found regarding this research.

The limitation of this additive encoding technique was that it takes more time for random shuffling of pixels. The future work is to produce an efficient encryption algorithm that can produce a higher entropy encrypted image in a lesser encryption time period.

5. Conclusion

Two different methods to determine entropy were evaluated using performance parameters and it is found that novel Exclusive OR encoding has a mean entropy of 1.62056 which is higher compared with the additive encoding mean entropy of 1.53383. So the novel Exclusive OR encoding is significantly better in increasing the entropy of an image.

DECLARATIONS

Conflicts of Interest

No conflict of interest in this manuscript.

Author Contribution

Author RM was involved in the data collection, data analysis and manuscript writing.
Author RB 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 enabled 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.

6. References

Aldrich, James O. 2018. *Using IBM SPSS Statistics: An Interactive Hands-On Approach*. SAGE Publications.

Chen, Yong, Shucui Xie, and Jianzhong Zhang. 2022. "A Hybrid Domain Image Encryption Algorithm Based on Improved Henon Map." *Entropy* 24 (2). https://doi.org/10.3390/e24020287.

Craik, Fergus I. M. 2021. "Encoding and Encoding–Retrieval Interactions." *Remembering*. https://doi.org/10.1093/oso/9780192895226.003.0004.

Dinesh Kumar, M., V. Godvin Sharmila, Gopalakrishnan Kumar, Jeong-Hoon Park, Siham Yousuf Al-Qaradawi, and J. Rajesh Banu. 2022. "Surfactant Induced Microwave Disintegration for Enhanced Biohydrogen Production from Macroalgae Biomass: Thermodynamics and Energetics." *Bioresource Technology* 350 (April): 126904.

Elmanfaloty, Rania A., Abdullah M. Alnajim, and Ehab Abou-Bakr. 2021. "A Finite Precision Implementation of an Image Encryption Scheme Based on DNA Encoding and Binarized Chaotic Cores." *IEEE Access*. https://doi.org/10.1109/access.2021.3118050.

Feng, Wei, Yigang He, Hongmin Li, and Chunlai Li. 2019. "A Plain-Image-Related Chaotic Image Encryption Algorithm Based on DNA Sequence Operation and Discrete Logarithm." *IEEE Access*. https://doi.org/10.1109/access.2019.2959137.

Huo, Dongming, Ding-Fu Zhou, Sheng Yuan, Shaoliang Yi, Luozhi Zhang, and Xin Zhou. 2019. "Image Encryption Using Exclusive-OR with DNA Complementary Rules and Double Random Phase Encoding." *Physics Letters A*. https://doi.org/10.1016/j.physleta.2018.12.011.

Jithin, K. C., and Syam Sankar. 2020. "Colour Image Encryption Algorithm Combining Arnold Map, DNA Sequence Operation, and a Mandelbrot Set." *Journal of Information Security and Applications*. https://doi.org/10.1016/j.jisa.2019.102428.

Kumar, J. Aravind, J. Aravind Kumar, S. Sathish, T. Krithiga, T. R. Praveenkumar, S. Lokesh, D. Prabu, A. Annam Renita, P. Prakash, and M. Rajasimman. 2022. "A Comprehensive Review on Bio-Hydrogen Production from Brewery Industrial Wastewater and Its Treatment Methodologies." *Fuel*. https://doi.org/10.1016/j.fuel.2022.123594.

Kumar, N. Suresh, Arun Kumar Sangaiah, M. Arun, and S. Anand. 2017. *Advanced Image Processing Techniques and Applications*. IGI Global.

Li, Changping, Lidan Wang, Dengwei Yan, and Hang Shi. 2021. "Research on a New Type of Chaotic Image Encryption Algorithm Combining DNA Operation and S-Box." *2021 International Conference on Neuromorphic Computing (ICNC)*. https://doi.org/10.1109/icnc52316.2021.9608202.

Li, Xue, and Xiaohui Li. 2019. "A Novel Block Image Encryption Algorithm Based on DNA Dynamic Encoding and Chaotic System." *2019 IEEE 4th International Conference on Signal and Image Processing (ICSIP)*. https://doi.org/10.1109/siprocess.2019.8868638.

Mahesh, Narayanan, Srinivasan Balakumar, Uthaman Danya, Shanmugasundaram Shyamalagowri, Palanisamy Suresh Babu, Jeyaseelan Aravind, Murugesan Kamaraj, and Muthusamy Govarthanan. 2022. "A Review on Mitigation of Emerging Contaminants in an Aqueous Environment Using Microbial Bio-Machines as Sustainable Tools: Progress and Limitations." *Journal of Water Process Engineering*. https://doi.org/10.1016/j.jwpe.2022.102712.

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

Mohanavel, Vinayagam, K. Ravi Kumar, T. Sathish, Palanivel Velmurugan, Alagar Karthick, M. Ravichandran, Saleh Alfarraj, Hesham S. Almoallim, Shanmugam Sureshkumar, and J. Isaac JoshuaRamesh Lalvani. 2022. "Investigation on Inorganic Salts K2TiF6 and KBF4 to Develop Nanoparticles Based TiB2 Reinforcement Aluminium Composites." *Bioinorganic Chemistry and Applications* 2022 (January): 8559402.

Ram, G. Dinesh, G. Dinesh Ram, S. Praveen Kumar, T. Yuvaraj, Thanikanti Sudhakar Babu, and Karthik Balasubramanian. 2022.

"Simulation and Investigation of MEMS Bilayer Solar Energy Harvester for Smart Wireless Sensor Applications." *Sustainable Energy Technologies and Assessments*. https://doi.org/10.1016/j.seta.2022.102102.

Rashmi, P., M. C. Supriya, and Kiran. 2020. "Colour Image Encryption Using Expand-Shrink Operation in Chaos Encryption Algorithm." *IOP Conference Series: Materials Science and Engineering*. https://doi.org/10.1088/1757-899x/925/1/012027.

Rinesh, S., K. Maheswari, B. Arthi, P. Sherubha, A. Vijay, S. Sridhar, T. Rajendran, and Yosef Asrat Waji. 2022. "Investigations on Brain Tumor Classification Using Hybrid Machine Learning Algorithms." *Journal of Healthcare Engineering* 2022 (February): 2761847.

Sathish, T., V. Mohanavel, M. Arunkumar, K. Rajan, Manzoore Elahi M. Soudagar, M. A. Mujtaba, Saleh H. Salmen, Sami Al Obaid, H. Fayaz, and S. Sivakumar. 2022. "Utilization of Azadirachta Indica Biodiesel, Ethanol and Diesel Blends for Diesel Engine Applications with Engine Emission Profile." *Fuel*. https://doi.org/10.1016/j.fuel.2022.123798.

Sudhan, M. B., M. Sinthuja, S. Pravinth Raja, J. Amutharaj, G. Charlyn Pushpa Latha, S. Sheeba Rachel, T. Anitha, T. Rajendran, and Yosef Asrat Waji. 2022. "Segmentation and Classification of Glaucoma Using U-Net with Deep Learning Model." *Journal of Healthcare Engineering* 2022 (February): 1601354.

Sundararaman, Sathish, J. Aravind Kumar, Prabu Deivasigamani, and Yuvarajan Devarajan. 2022. "Emerging Pharma Residue Contaminants: Occurrence, Monitoring, Risk and Fate Assessment – A Challenge to Water Resource Management." *Science of The Total Environment*. https://doi.org/10.1016/j.scitotenv.2022.153897.

Sun, Yuan-Yuan, Rui-Qing Kong, Xing-Yuan Wang, and Lian-Cheng Bi. 2010. "An Image Encryption Algorithm Utilizing Mandelbrot Set." *2010 International Workshop on Chaos-Fractal Theories and Applications*. https://doi.org/10.1109/iwcfta.2010.70.

Tian, Ye, and Zhimao Lu. 2017. "Novel Permutation-Diffusion Image Encryption Algorithm with Chaotic Dynamic S-Box and DNA Sequence Operation." *AIP Advances*. https://doi.org/10.1063/1.4994860.

Vijayalakshmi, V. J., Prakash Arumugam, A. Ananthi Christy, and R. Brindha. 2022. "Simultaneous Allocation of EV Charging Stations and Renewable Energy Sources: An Elite RERNN-m2MPA Approach." *International Journal of Energy Research*. https://doi.org/10.1002/er.7780.

Yaashikaa, P. R., P. Senthil Kumar, S. Jeevanantham, and R. Saravanan. 2022. "A Review on Bioremediation Approach for Heavy Metal Detoxification and Accumulation in Plants." *Environmental Pollution* 301 (May): 119035.

Yadav, Kanchan, and Trushita Chaware. 2021. "Review of Joint Encoding and Encryption for Image Transmission Using Chaotic Map, LDPC and AES Encryption." *2021 6th International Conference on Signal Processing, Computing and Control (ISPCC)*. https://doi.org/10.1109/ispcc53510.2021.9609351.

Ye, Guodong, Kaixin Jiao, and Xiaoling Huang. 2021. "Quantum Logistic Image Encryption Algorithm Based on SHA-3 and RSA." *Nonlinear Dynamics* 104 (3): 2807–27.

Yildirim, Melih. 2022. "Optical Color Image Encryption Scheme with a Novel DNA Encoding Algorithm Based on a Chaotic Circuit." *Chaos, Solitons & Fractals*. https://doi.org/10.1016/j.chaos.2021.111631

Narayanasamy, S., Sundaram, V., Sundaram, T., & Vo, D. V. N. (2022). Biosorptive ascendency of plant based biosorbents in removing hexavalent chromium from aqueous solutions–Insights into isotherm and kinetic studies. Environmental Research, 210, 112902.

Tables and Figures

Table 1. Representation of Nucleic Acid Bases in Binary values.The Nucleic acid bases are assigned in such a way that A=00, G=01, C=10, T=11.

NUCLEIC ACID BASE	BINARY VALUE
A	00
G	01
C	10
T	11

Table 2. Encryption rule using novel DNA Exclusive OR encoding. The Exclusive OR operation is done between Nucleic acid bases which results in anyone of the binary sequence identified as the A, G, C, T based on the assignment given in the initial stage. For example, the results obtained on additive operation of A (00) and A(00) will be A(00).

-	A	G	C	T
A	A	G	C	T
G	G	A	T	C
C	C	G	A	G
T	T	C	G	C

Table 3. Encryption rule for DNA Additive Encoding. The addition operation is done between Nucleic acid bases which results in anyone of the binary sequence identified as the A, G, C, T based on the assignment given in the initial stage. For example, the results obtained on additive operation of A (00) and A(00) will be A(00).

+	A	G	C	T
A	A	G	C	T
G	G	C	T	A
C	C	T	A	G
T	T	A	G	C

Table 4. Comparison of entropy of novel DNA subtractive encoding and DNA additive encoding encrypted images.

Images	Entropy of novel exclusive OR encoding	Entropy of additive encoding
anime	1.5526	1.5317
jinmiran	1.5967	1.6045
ronaldo	1.5991	1.5621
man.united	1.2143	1.1981
football	1.5648	1.5287
forest	1.541	1.5234
mandril	1.6542	1.6245
lenna	1.6146	1.5908
rice	1.5919	1.5592
vegetable	1.685	1.6153

Table 5. Independent samples t-test Analysis. The significance for correlation coefficient is 0.0329. The confidence interval is 95%.

<table>
<tr><th colspan="2" rowspan="2">GROUP</th><th colspan="2">Leven's Test for Equality of Variance</th><th colspan="7">T-test for Equality of Means</th></tr>
<tr><th>F</th><th>Sig</th><th>t</th><th>df</th><th>sig(2-tailed)</th><th>Mean Difference</th><th>Std. Error Difference</th><th>Lower</th><th>Upper</th></tr>
<tr><td>Entropy</td><td>Equal variance assume</td><td>1.007</td><td>0.0329</td><td>-1.046</td><td>18</td><td>0.309</td><td>-0.08673</td><td>0.082921626</td><td>-0.260941872</td><td>0.087481872</td></tr>
</table>

	d									
	Equal variance not assumed			-1.046	13.750	0.314	-0.08673	0.082921626	-0..264883027	0.091423027

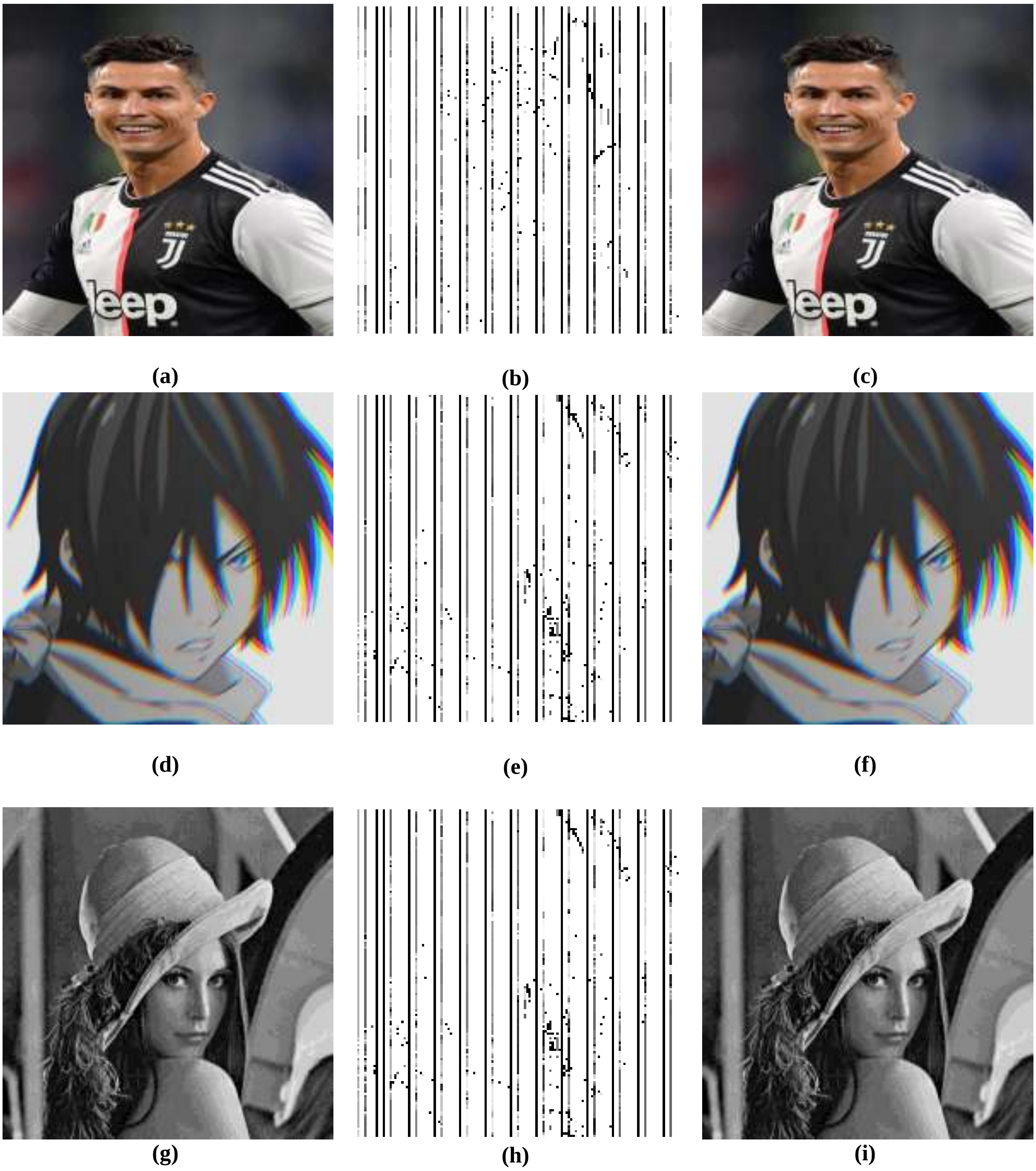

Fig. 1**. Novel DNA exclusive OR encoding Technique** (a) sample image 1 ronaldo (b) encrypted ronaldo image (c) decrypted ronaldo image (d) sample image 2 anime (e) encrypted anime image (f) decrypted anime image (g) sample image 3 lenna (h) encrypted lenna image (i) decrypted lenna image.

Fig. 2. DNA additive encoding Technique (a) sample image 1 ronaldo (b) encrypted ronaldo image using additive encoding (c) decrypted ronaldo image (d) sample image 2 anime (e) encrypted anime image using additive encoding (f) decrypted anime image (g) sample image 3 lenna (h) encrypted lenna image using additive encoding (i) decrypted lenna image.

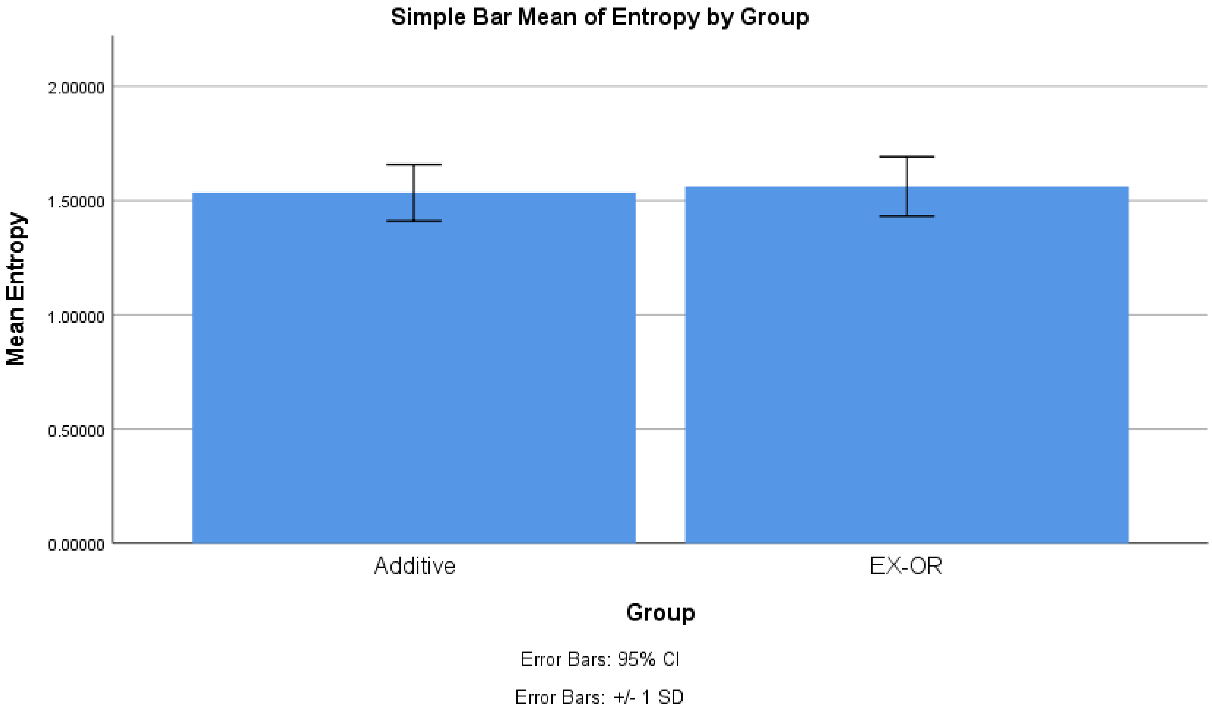

Fig. 3. Simple Bar mean of entropy. X-Axis: Additive DNA encoding vs EX-OR DNA encoding. Y-Axis: Entropy. The graph compares groups on the x-axis and y-axis using the mean of additive and EX-OR with +/- 1 standard deviation (SD). The novel EX-OR encoding provides better entropy 1.62056 when compared to additive encoding entropy is 1.53383.