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# A novel color image encryption algorithm based on a fractional-order discrete chaotic neural network and DNA sequence operations

**Key words:** Fractional-order discrete systems; Neural networks; Deoxyribonucleic acid (DNA) encryption; Color image encryption

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# Motivation

With the rapid development of computers and the Internet, the total amount and transmission speed of multimedia information have considerably increased. However, due to the openness of the network, it is difficult to guarantee the security of information generated during user communication. Because digital images are important parts of multimedia information, the security and integrity of digital image data in the transmission process has become a growing concern. Image encryption techniques are effective means of ensuring image transmission security. However, image information has special properties, such as bulk data capacity and strong correlation between pixels. Therefore, traditional encryption methods are not suitable for image data. It is necessary to propose a new image encryption algorithm.

# Main idea

1. A fractional-order discrete Hopfield neural network is used as a pseudo-random number sequence generator. It has a larger parameter selection space and stronger chaotic characteristics than other systems, which greatly improves the secret key space and ensures system security.

2. In the proposed algorithm, a pseudo-random sequence generated by the fractional-order discrete Hopfield neural network is used to select a unique encoding method for each pixel of the color image. This makes it difficult for hackers to obtain useful information from the DNA matrix, thus improving the security performance of encryption.

3. A novel 3D projection confusion algorithm is proposed. It can significantly confuse the pixels between different color channels, considerably reducing the correlation between pixels and improving the security of the encryption algorithm.

# Method

1. As can be seen from the system phase diagram below, the novel fractional-order discrete Hopfield neural network has more complex dynamic behaviors and a larger parameter selection space.

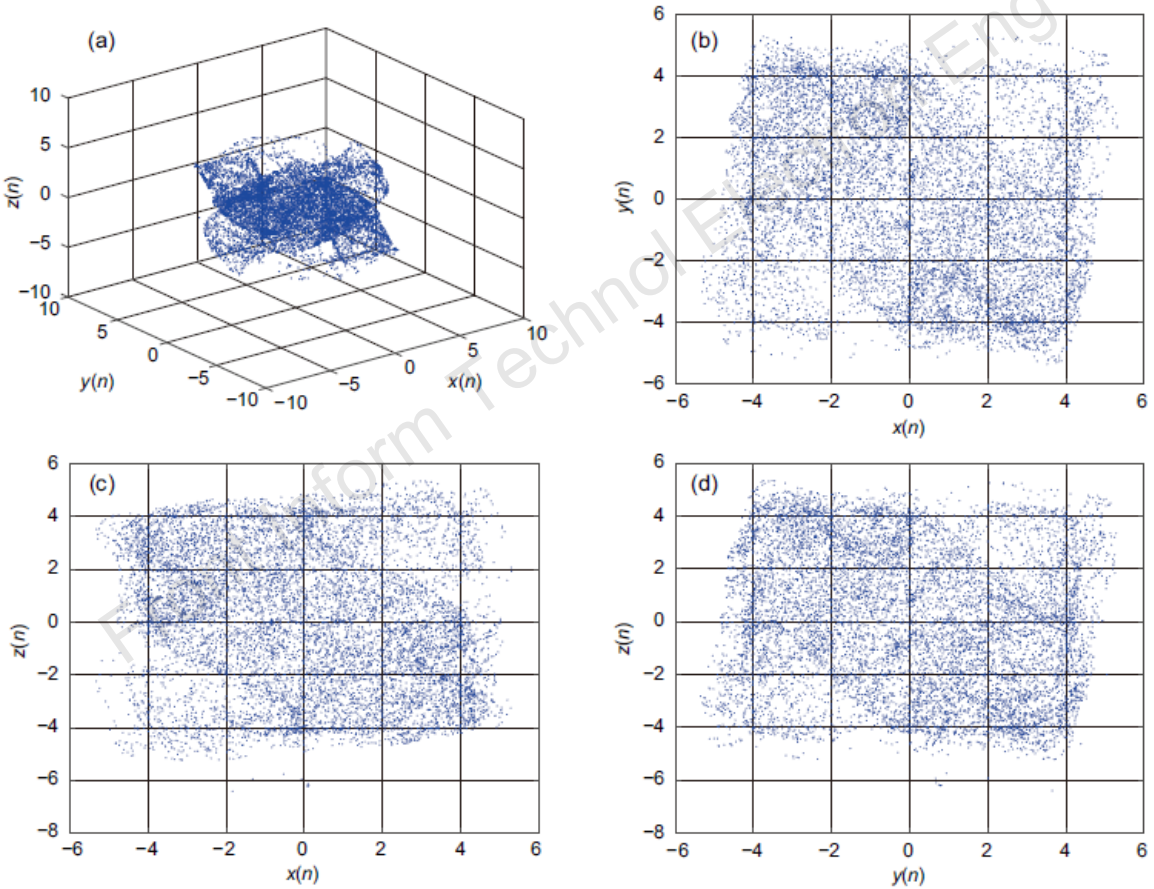


**Fig. 1** Phase diagrams of the FODHNN defined in system (5) for the initial value $(x(0), y(0), z(0)) = (0.08, 0.8, -6.2)$, fractional order ($\nu = 0.6$), and step size $h = 0.05$: (a) $x$-$y$-$z$ space; (b) $x$-$y$ plane; (c) $x$-$z$ plane; (d) $y$-$z$ plane

# Method (Cont'd)

2. The flowchart of the encryption algorithm is shown below, in which the DNA coding method is selected for different pixels through the pseudo-random sequence, which greatly improves the security performance of the algorithm. The decryption process is the reverse operation of the encryption process.

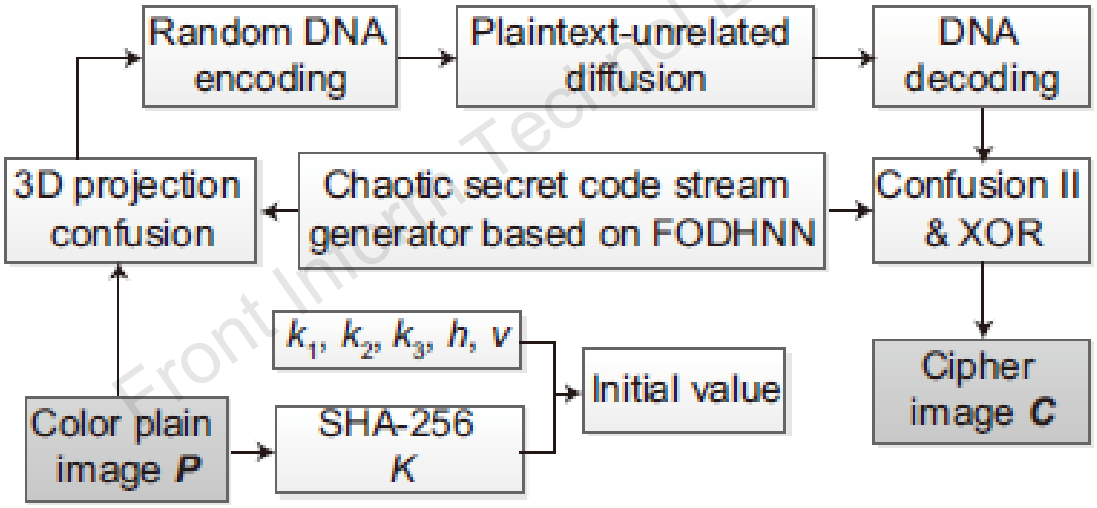


**Fig. 3 Schematic representation of the new encryption scheme**

# Method (Cont'd)

3. The novel 3D projection confusion algorithm (1) links the three color components of the image through the spatial stereo structure, (2) maps the pseudo-random number sequence generated by FODHNN into the space body, and (3) confuses the three projection points by random selection.

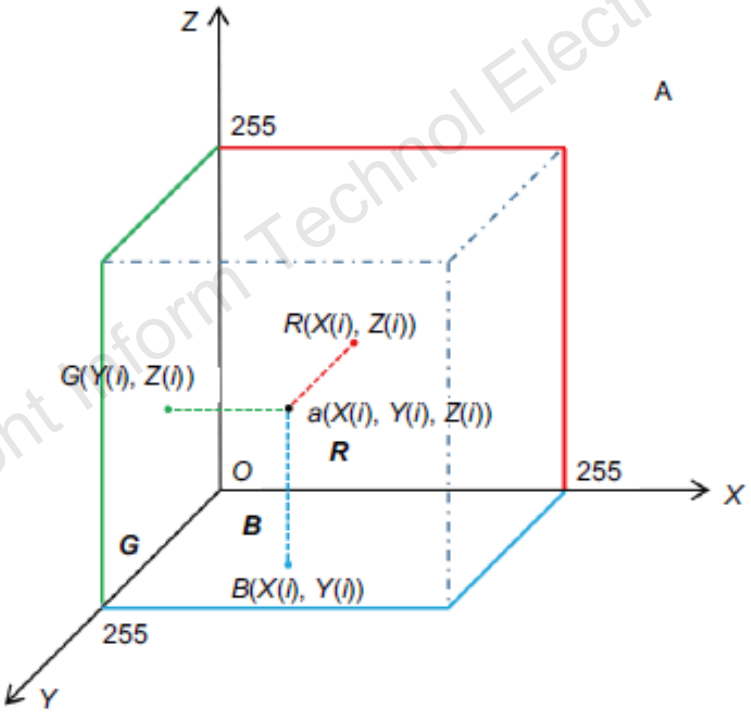




**Fig. 4 Cube "A"**

# Major results

Lena was selected as the experimental object, and the five-parameter user-supplied key is (0.07, 0.8, −6.2, 0.05, 0.6).

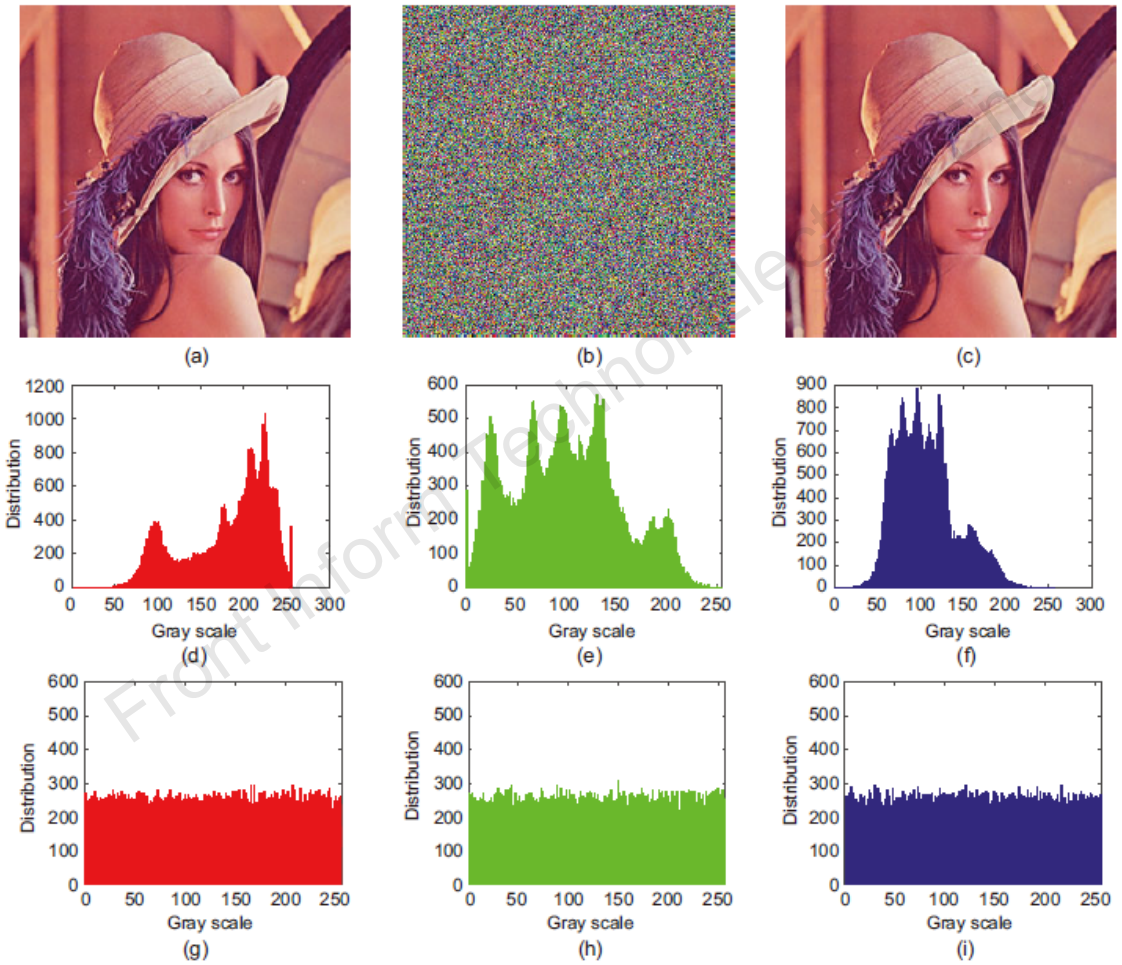


**Fig. 5** Lena: (a) plain image; (b) ciphered image; (c) deciphered image; (d) histogram of the plain image (red component); (e) histogram of the plain image (green component); (f) histogram of the plain image (blue component); (g) histogram of the ciphered image (red component); (h) histogram of the ciphered image (green component); (i) histogram of the ciphered image (blue component)

# Major results (Cont'd)

The distribution of pixel correlation under the same initial conditions:

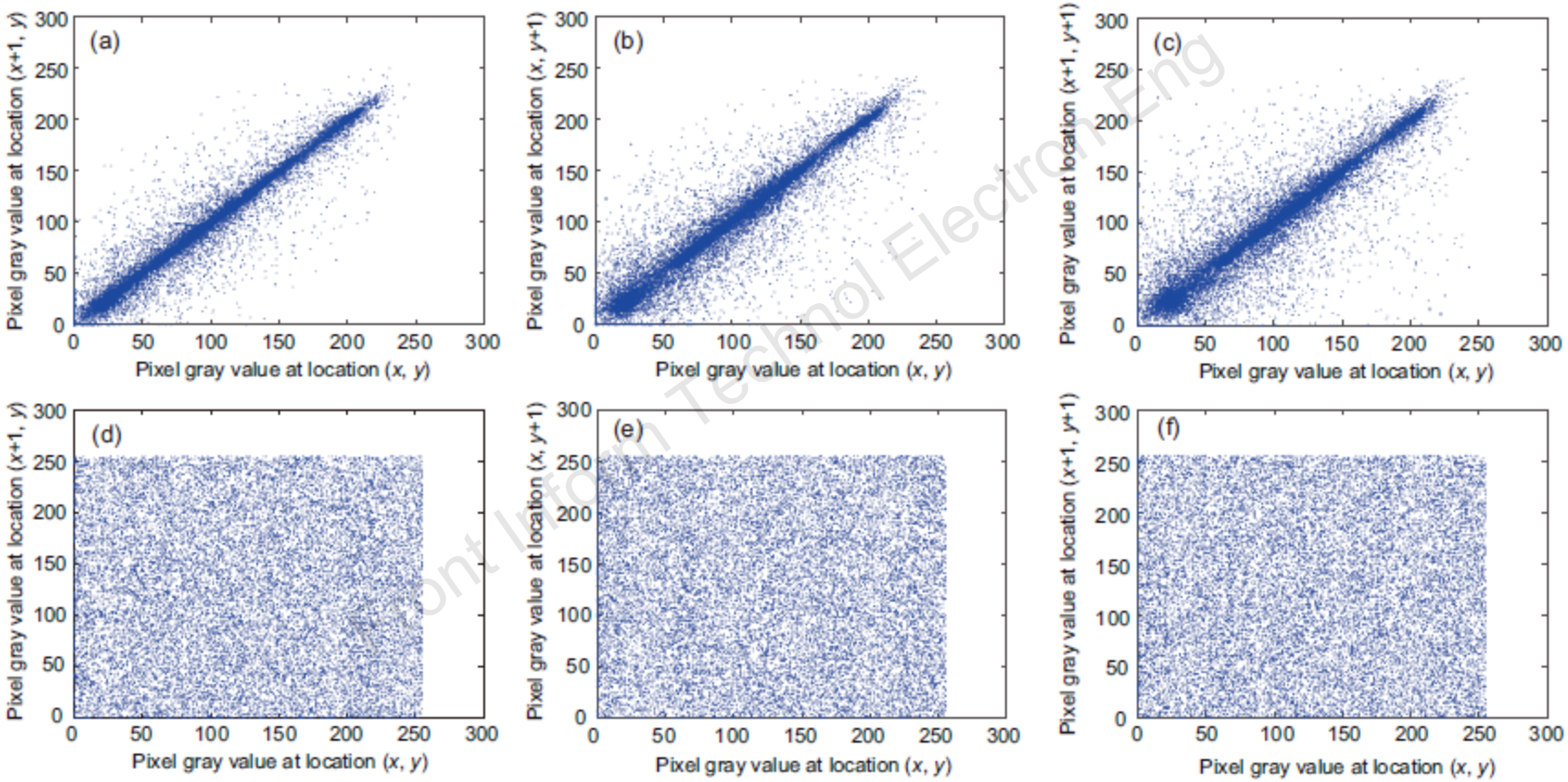


**Fig. 7** Correlation distribution of vertical, horizontal, and diagonal adjacent pixels of the original and ciphered images of Lena: (a) horizontal, plain image; (b) vertical, plain image; (c) diagonal, plain image; (d) horizontal, ciphered image; (e) vertical, ciphered image; (f) diagonal, ciphered image

# Major results (Cont'd)

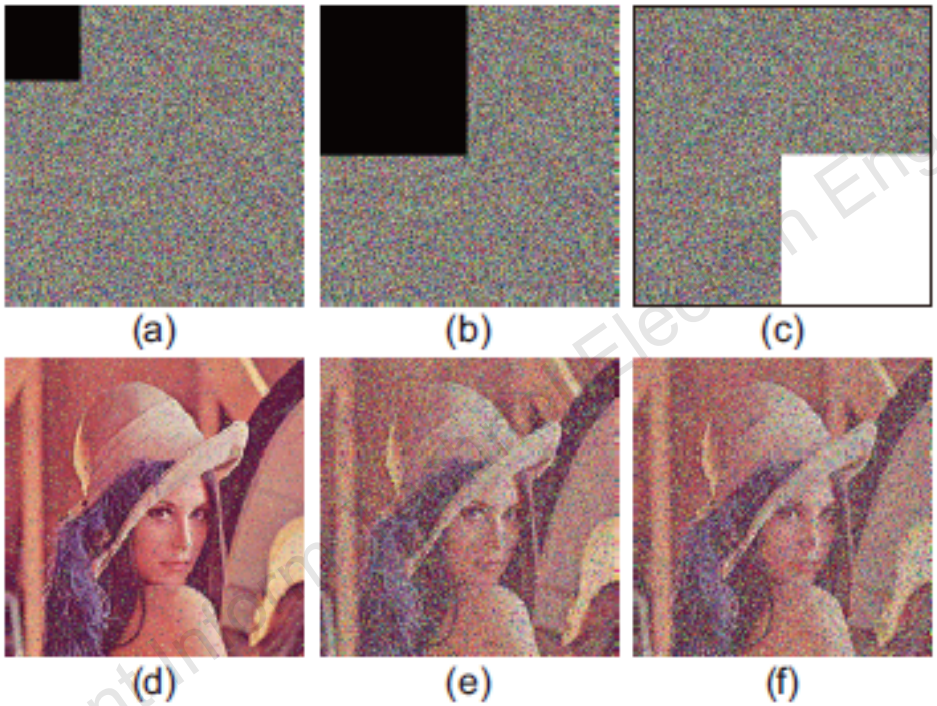


**Fig. 9** Occlusion attack on the image Lena. Ciphered images with different occlusion effects and their corresponding decrypted versions: (a) cutting 1/16 on the top left corner; (b) cutting 1/4 on the top left corner; (c) cutting 1/4 on the bottom right corner; (d) decrypted version of (a); (e) decrypted version of (b); (f) decrypted version of (c)

# Summary

- A new discrete chaotic encryption algorithm based on DNA encoding and SHA-256 has been presented.
- First, a new FODHNN model was obtained and adopted to generate pseudo-random sequences.
- Second, a 3D projection confusion method based on a pseudo-random sequence has been proposed to scramble the pixels between the R, G, and B components of the plain image.
- Third, a new random DNA encoding method and DNA encoding based diffusion have been proposed to further diffuse the information of the plain image.
- Finally, DNA sequence decoding, confusion II, and XOR have been implemented to improve the encryption method. The simulation results and security analysis showed that the proposed algorithm is suitable for color image encryption.