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A joint image compression and encryption scheme based on a novel coupled map lattice system and DNA operations

Key words: Compressive sensing; Coupled map lattice (CML); DNA operations; Semi-tensor product

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Motivation

1. How to design a secure and efficient image encryption scheme has always been a challenging issue. Image encryption based on compressive sensing (CS) faces the following challenges:

(1) An extremely large measurement matrix is needed when encrypting large-size images, and it will cost a lot of storage resources;

(2) CS cannot resist known-plaintext attacks (NPAs) or chosen-plaintext attacks (CPAs);

(3) The CS decryption process generally takes a long time.

Motivation (Cont’d)

2. Although the spatiotemporal chaotic system has been studied, the range of logistic map parameters is still not large enough and the randomness is unstable. Therefore, it is necessary to optimize the existing spatiotemporal chaotic system.

The proposed spatiotemporal chaotic system in this paper can not only applied in our encryption scheme, but also adapt to general encryption algorithms based on chaotic sequence.

Main idea

1. The central thought in this paper is that the scheme of using the spatiotemporal chaotic system with good performance to generate a CS measurement matrix, combined with semi-tensor product compressive sensing (STP-CS) and DNA encryption, can improve the encryption security and reduce the encryption speed of CS.

Method

1. Introducing a random parameter of linear and nonlinear neighbors can greatly improve the randomness of mixed linear–nonlinear coupled map lattice (MLNCML) system.

2. Plaintext-related scrambling and DNA encryption can resist NPAs and CPAs. Therefore, the security can be improved.

3. Using semi-tensor product (STP) of matrices in compressive sensing can reduce the decryption time.

Major results

1. The proposed chaotic system

A novel mixed linear–nonlinear coupled map lattice (NMLNCML) system with L lattices is defined as

$$x_{n+1}(i) = \mathrm{mod}(f[x_n(i)] + (1-\eta)\cdot\{f[x_n(i+1)] + f[x_n(i-1)]\} + \eta\cdot\{f[x_n(j)] + f[x_n(k)]\}, 1),$$

where i, j, k are different lattices ($2 \le i \le L-1$, $1 \le j, k \le L$), η is the coupling parameter ($0 \le \eta \le 1$), n is the time sequence ($n=1, 2, \ldots$), and $x_{n+1}(i)$ is the state of lattice i at time $n+1$. Logistic map $f(x)=\mu x(1-x)$, and $\mu \in [3.56, 4]$. The neighbor relationship among j, k, and i obeys the Arnold transform.

Major results (Cont’d)

Simulation results show that, compared with the MLNCML system,

(1) the Kolmogorov–Sinai entropy of our NMLNCML system is larger;

(2) the range of optional parameter μ in NMLNCML has been enlarged from [3.56, 4] to [2.28, 4];

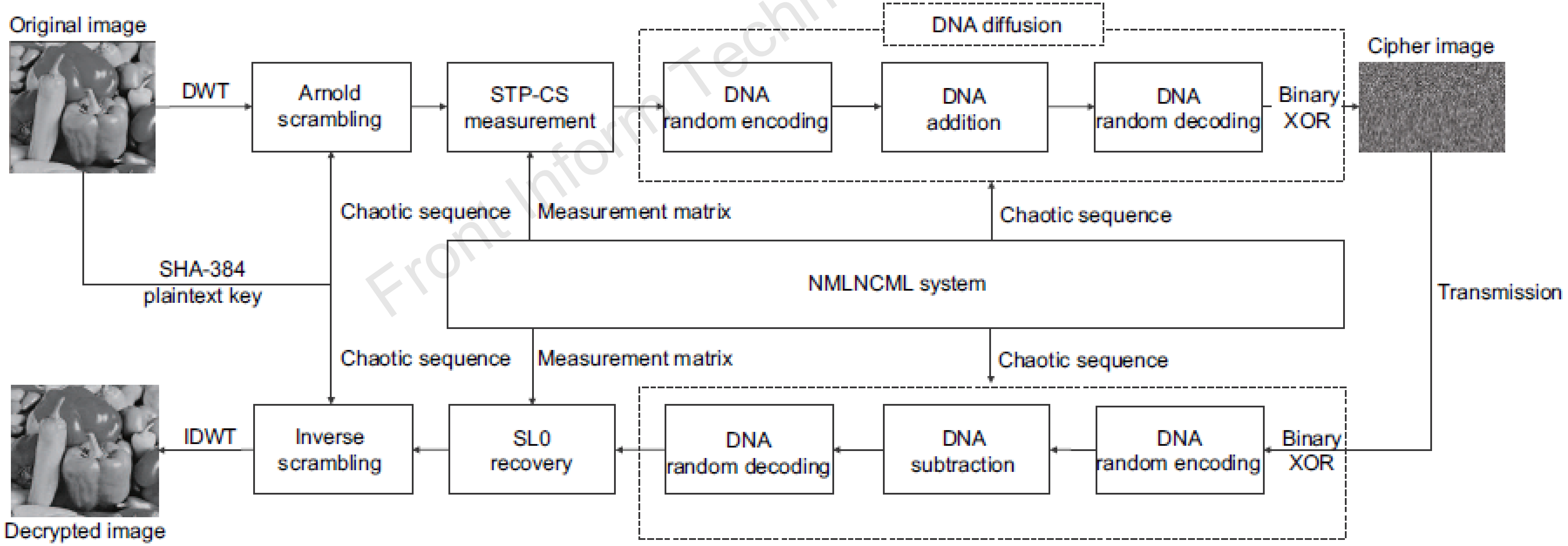
(3) the number of periodic windows in bifurcation diagrams has decreased.

Thus, the chaotic property is stronger and ergodicity of the system has been significantly improved.

Major results (Cont’d)

2. Image encryption scheme

The encryption algorithm consists of scrambling, STP-CS measurement, and DNA diffusion. The process is shown as follows:



Major results (Cont’d)

Simulation results and security analysis indicated that our cryptosystem has significant key space, high sensitivity to secret keys, great resistance to chosen-plaintext, statistical, and differential attacks, and good robustness to noise and data loss.

In addition, the outstanding compression and encryption performance can promote secure image compression and transmission on public channels and networks.

Conclusions

In this paper, we presented a scheme for image encryption that takes advantages of a spatiotemporal chaotic system and DNA operations in CS.

A new chaotic system was proposed and applied to generate the CS measurement matrix. STP-CS and DNA encryption were used to reduce the decryption speed and enhance security.

Simulation results show the effectiveness and superiority of the proposed image encryption scheme.

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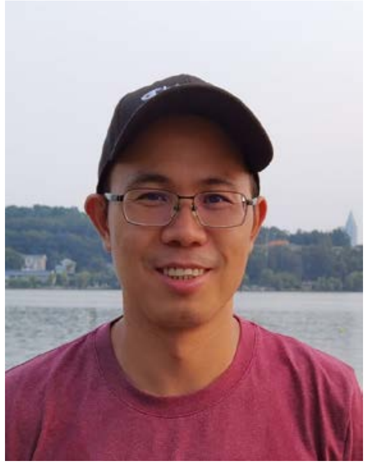

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