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Applying deep learning to known-plaintext attack on chaotic image encryption schemes

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Outline

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1. Introduction

The known plaintext attack, as one cryptanalysis method, is crucial to evaluate the security of image encryption.

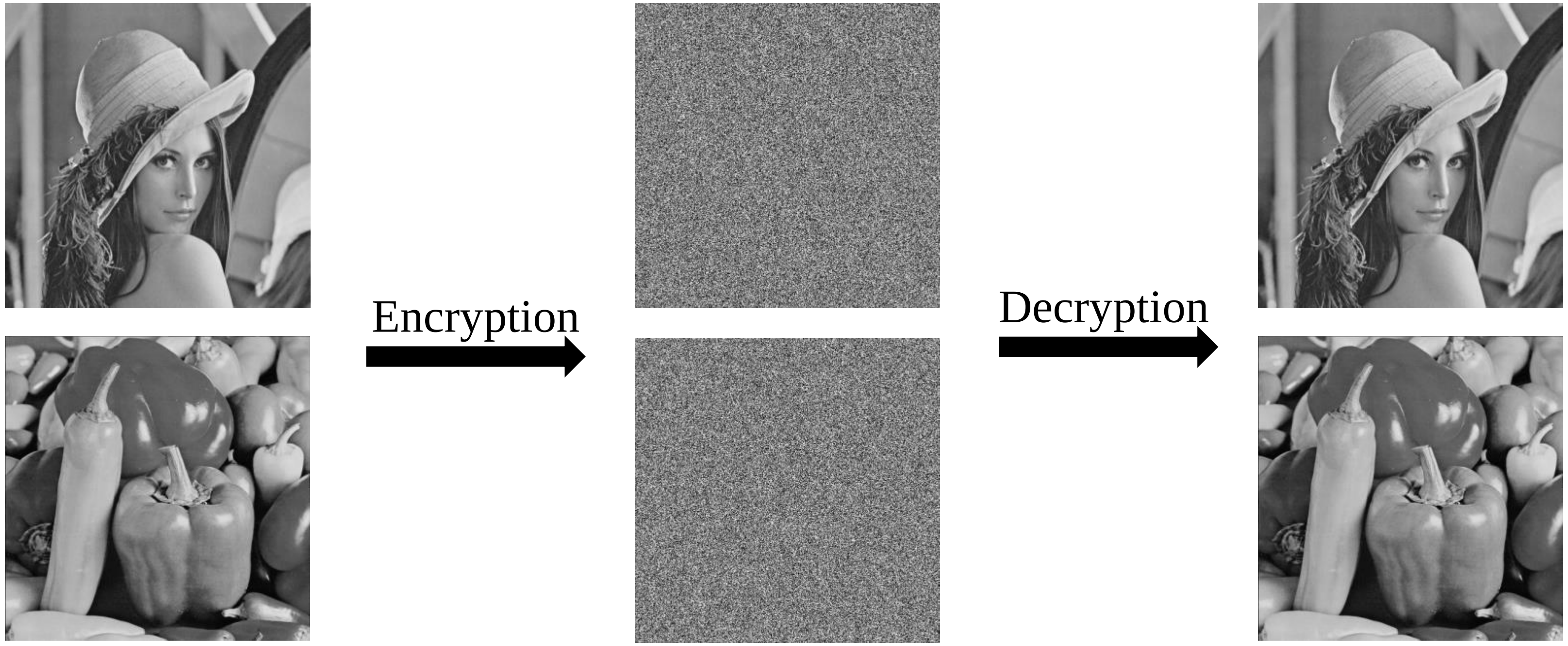

Fig. 1 Some “plaintext-ciphertext” image pairs.

2. Traditional Known plaintext attack

The traditional known plaintext attack works are usually based on some mathematical means, such as differential attack. It has some shortcomings:

- It is complicated to design an attack scheme.
- Usually, one attack method is only designed for a specific chaotic encryption system, which is hard to be applied to other chaotic encryption systems.

3. Proposed Approach

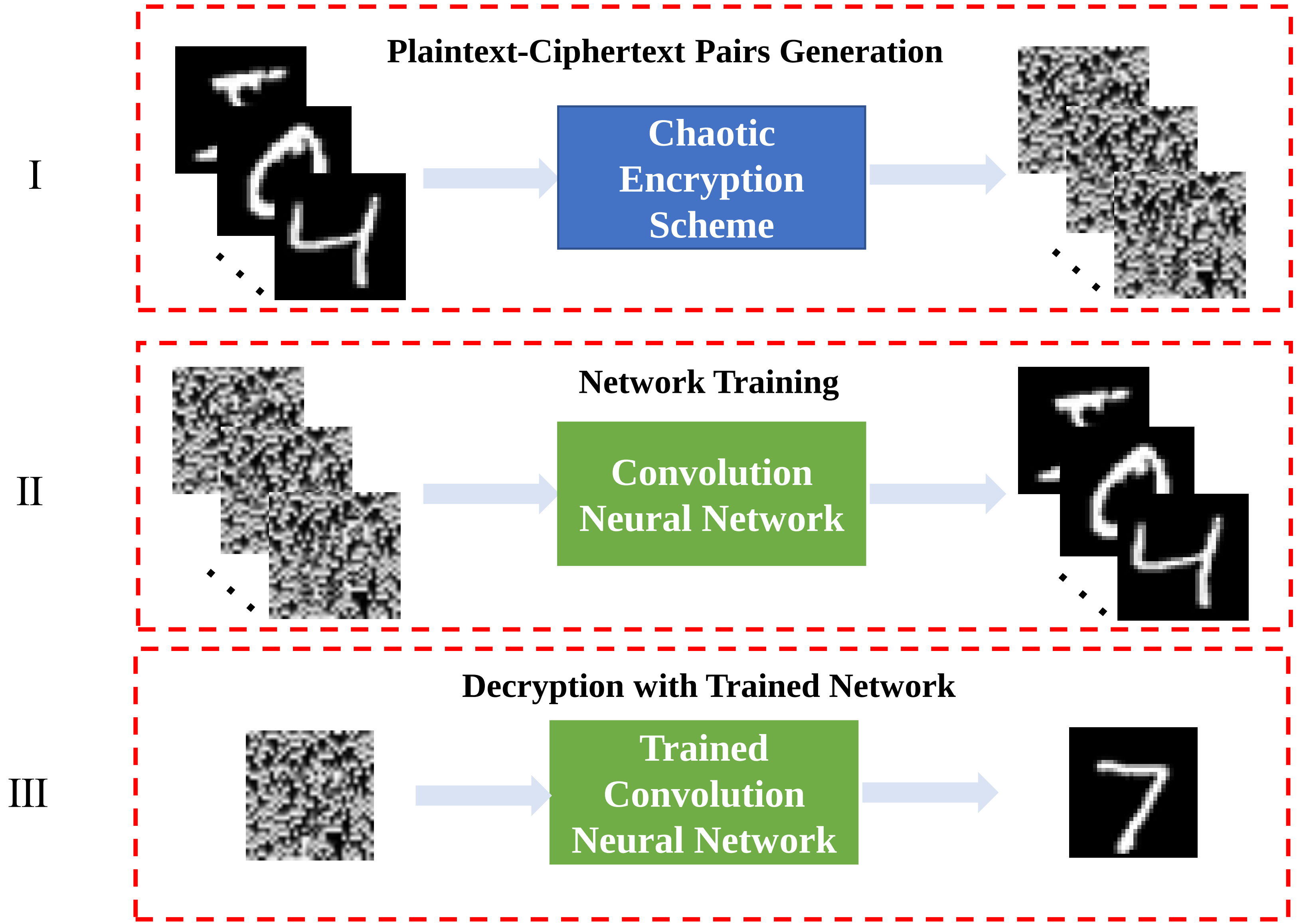

Fig. 2 The overall framework of deep learning-based known-plaintext attack on chaotic cryptosystem.

Advantages

The advantages of the proposed deep learning-based known-plaintext attack method:

- It is easy to design a convolution neural network for the known plaintext attack.
- Different from the traditional known-plaintext attack methods for chaotic cryptosystems, a convolutional neural network can be employed to decrypt different chaotic cryptosystems.

Network architecture

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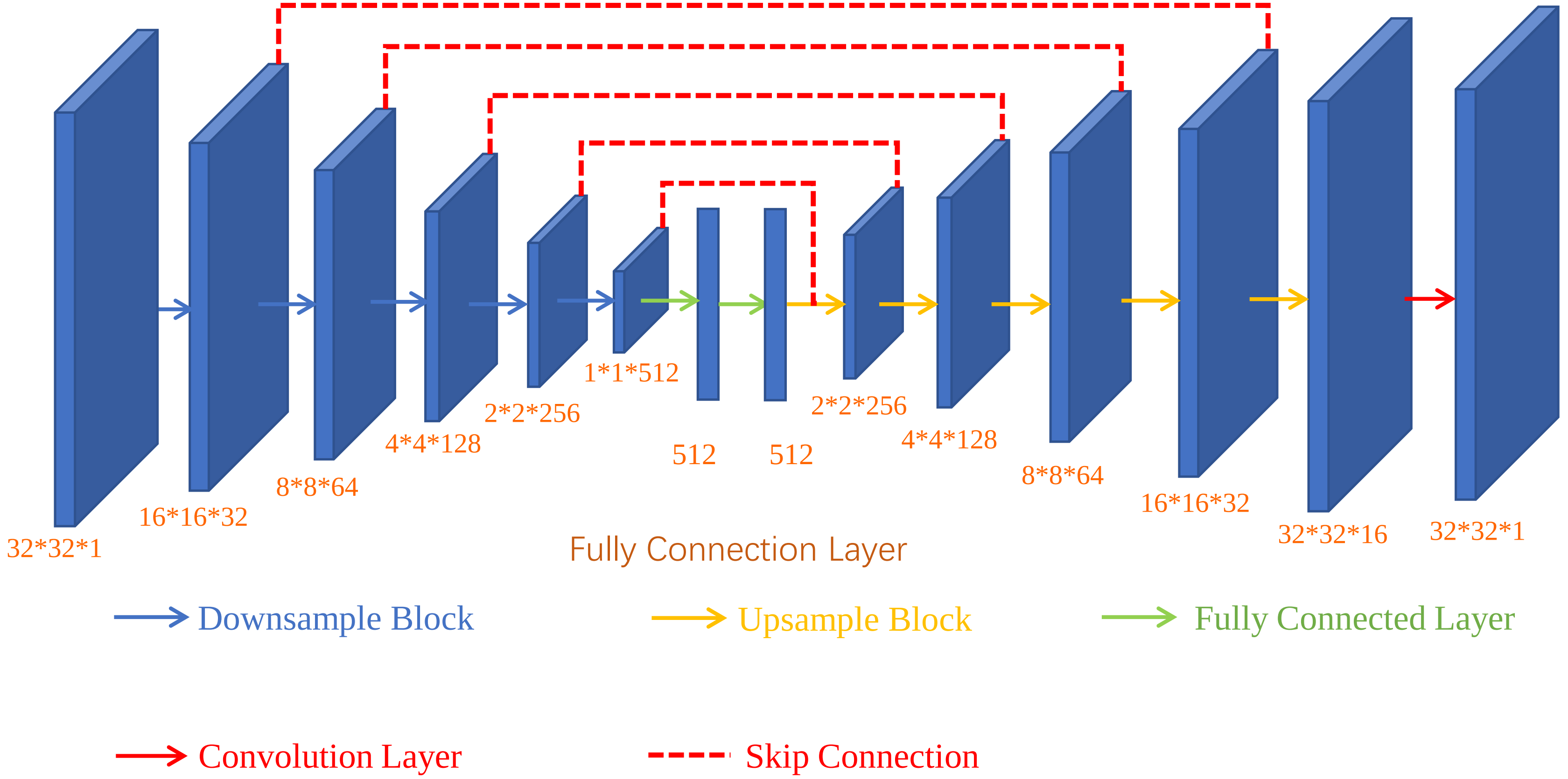


Fig. 3 The architecture of the proposed image decryption encoder-decoder network IDEDNet.

4. Implementation Details

- Loss Function (L1 Loss).

$$\mathcal{L}_1 = \frac{1}{N}\sum_{i=1}^{N} |O(C_i;\theta) - P(C_i)|$$

- Attacked chaotic encryption schemes.

  (1) Song et al. [5]; (2) Pak et al. [10]; (3) H. N. Abdullah et al. [4].

- Evaluation metric (Pearson correlation coefficient).

$$Corr = \frac{(O-\overline{O})(P-\overline{P})}{\sigma(O)\sigma(P)}$$

[5] Y. Song, J. Song, and J. Qu, “A secure image encryption algorithm based on multiple one-dimensional chaotic systems,” in ICCC, 2016.

[10] C. Pak and L. Huang, “A new color image encryption using combination of the 1d chaotic map,” Signal Process, vol. 138, pp. 129–137, 2017.

[4] H. N. Abdullah and H. A. Abdullah, “Image encryption using hybrid chaotic map,” in ICCIT, 2017.

5. Experiment

Table. 1 The ciphertext reconstruction result of known-plaintext attack method based on deep learning on MNIST and MNIST-Fashion datasets.

Network	Encryption Scheme	dataset	Training correlation coefficient	Testing correlation coefficient	Epoch	Time/ Epoch
IDEDNet	Song et al. [5]	MNIST and Fashion	97.6%	94.2%	300	5.8s
	Pak et al. [8]		97.7%	94.5%		5.7s
	H. N. Abdullah et al. [4]		98.6%	96.7%		5.8s

Visualization

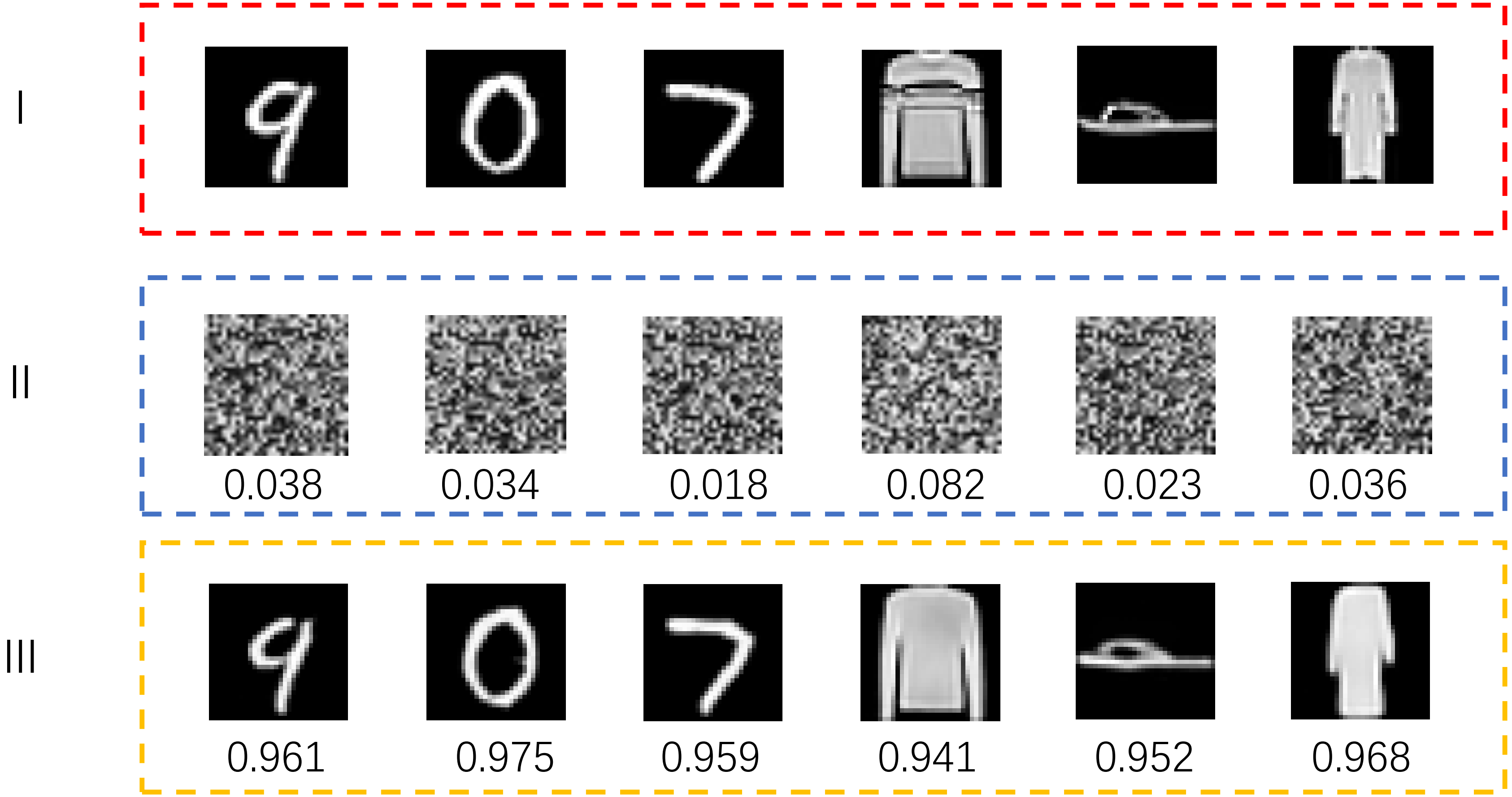
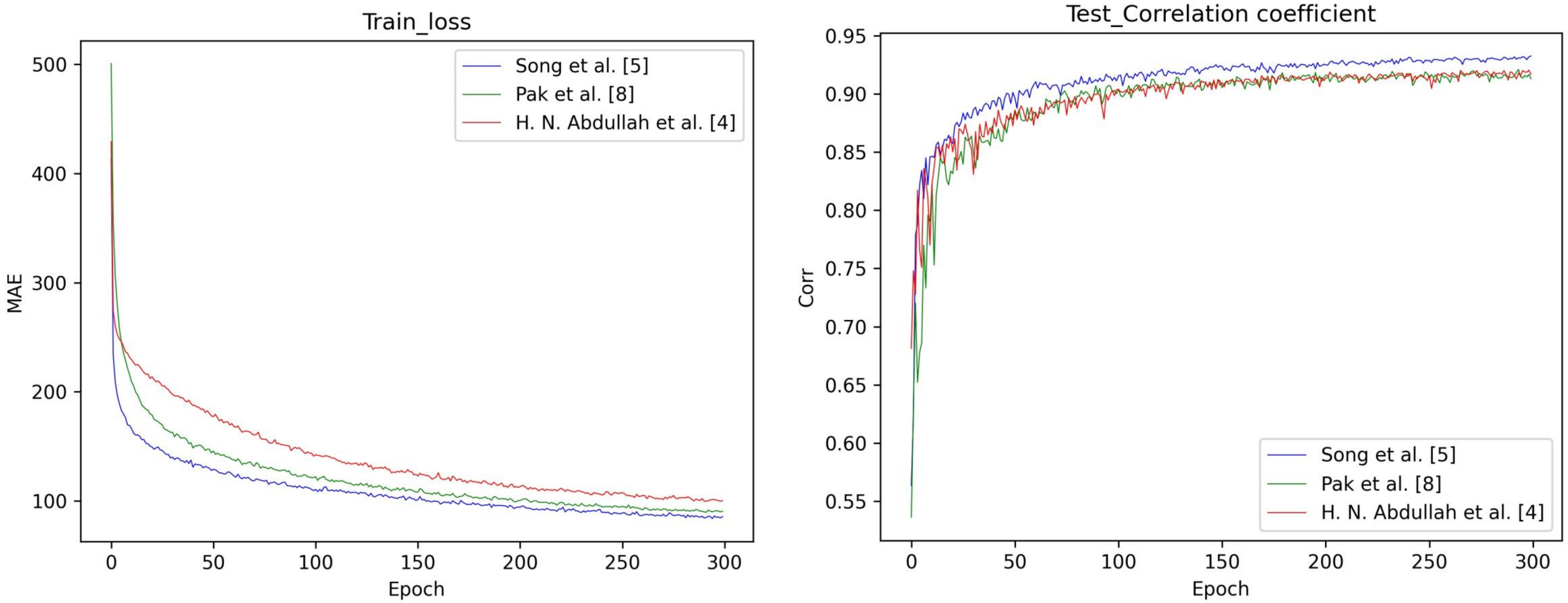


Fig. 4 visualization results on Song et al. [5]. (I) Plaintext image; (II) Ciphertext image; (III) Decrypted image; The number under the image represents the correlation coefficient between the image and the plaintext.

Visualization



(a) (b)

Fig. 5 The change curve of training and testing process on the mixed dataset of MNIST and MNIST-Fashion: (a) Training L1Loss, (b) Testing Correlation Coefficient. The blue, green and red lines represent the chaotic encryption schemes of Song et al. [5], Pak et al. [10], H. N. Abdullah et al. [4].

6. Conclusion

- Compared with the traditional known-plaintext attack methods specific to a certain chaotic cryptosystem, our method is more cost-effective, flexible;
- The chaotic cryptanalysis method based on deep learning can be introduced to multiple chaotic cryptosystems and even to the field of non-chaotic cryptosystems;
- It also proposes a new research direction in the field of multimedia security, i.e., how to prevent cryptography attack methods based on deep learning.

Q&A