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A combination chaotic system and application in color image encryption

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ABSTRACT

In this paper, by using Logistic, Sine and Tent systems we define a combination chaotic system. Some properties of the chaotic system are studied by using figures and numerical results. A color image encryption algorithm is introduced based on new chaotic system. Also this encryption algorithm can be used for gray scale or binary images. The experimental results of the encryption algorithm show that the encryption algorithm is secure and practical.

1. Introduction

Image plays an important role in the data transfer. With rapid development network communication, image security has become increasingly important. The first step in chaotic encryption was introduced by Matters [1]. In recent years, much attention has been given in the literature to the development, analysis and implementation of chaotic system for the image and the data encryption; see, for example [2–6]. Chaos maps as Logistic map, Sine map and Tent map are used in image encryption algorithm because chaotic maps have high sensitivity to their initial values and control parameters [7,8]. Logistic, Sine and Tent maps have some disadvantages. These maps for some values of r have chaotic behavior. Also these maps have non-uniform distribution over output. Many methods have been proposed to solve these problems, for example see [9]. To overcome these problems, in this paper by using different functions as $\sin(x), \cos(x), \ldots$, we combine Logistic (or Sine) map and Tent map then by using this combination the different chaotic systems can be found. In the next step by using combination map, XOR operation and circ shift the color image encryption algorithm is introduced. In this encryption algorithm in the first step, color image is divided into twelve parts and then by using combination map the encryption process for each of the parts is done, in the last step, we combine parts and then the encryption process combination image is repeated.

The organization of this paper is as follows: In Section 2, Logistic-Tent combination map is explained. In Section 3, we present the color image encryption algorithm. Simulation results and security analysis are given in Section 4. A summary is given at the end of the paper in Section 5.

2. A combination chaotic system

In this section, we describe our combination of chaotic systems. Logistic, Sine and Tent maps are defined as follows

$$x_{n+1} = L(r, x_n) := rx_n(1 - x_n), \quad (2.1)$$
$$x_{n+1} = S(r, x_n) := r\sin(\pi x_n)/4, \quad (2.2)$$

$$x_{n+1} = T(r, x_n) := \begin{cases} rx_n/2, & \text{when } x_n < 0.5, \\ r(1 - x_n)/2, & \text{when } x_n \geqslant 0.5. \end{cases} \quad (2.3)$$

where parameter $r \in (0, 4]$. It is known that Logistic system (Sine or Tent system) for some values of $r \in (0, 4]$ has chaotic behavior. Figs. 2(a) and 4(a) show that Logistic system for $r = 2$ has not chaotic behavior. To overcome the above problem, the combination of chaotic system as Logistic Tent system (LTS) introduced in [9]. Histogram of Logistic Tent system is showed in Fig. 3(a). Chaotic range is not limited for Logistic Tent system but from Fig. 3(a) we can see that the histogram of Logistic Tent system is not flat enough. Non-uniform distribution over output series leads to weakness in the statistical attack. For solving this problem we add weights and functions in Logistic Tent system or Sine Tent system as follows (see Fig. 1)

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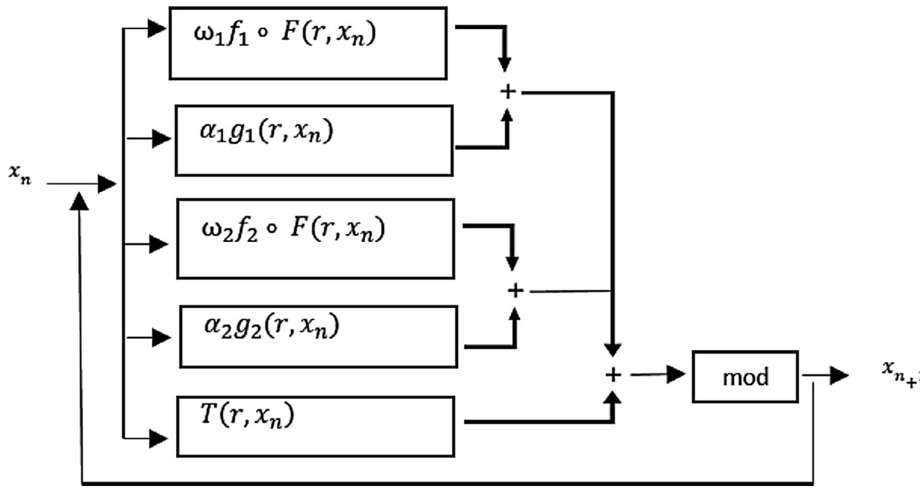

Fig. 1. The combination chaotic system.

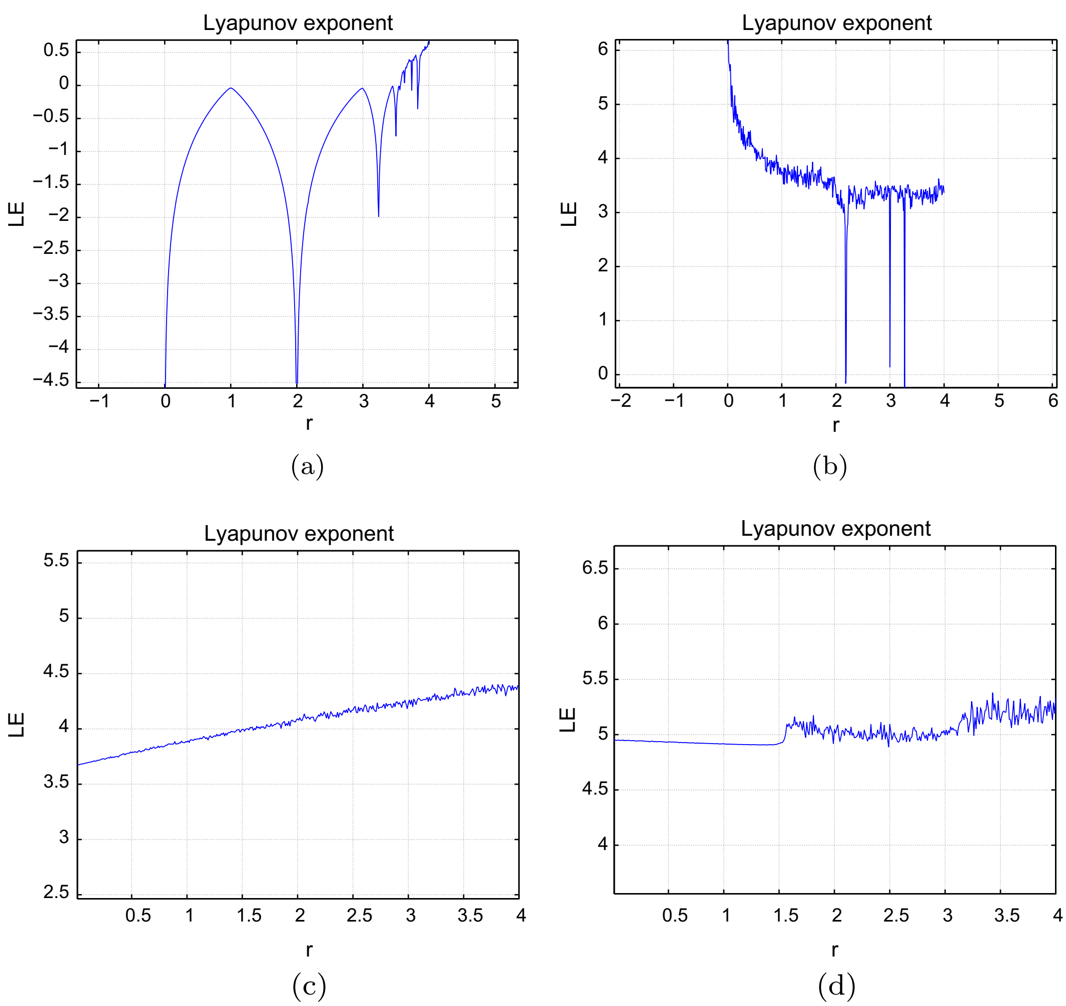

Fig. 2. Lyapunov exponent plot for (a) Logistic map, (b) Case (i), (c) Case (ii), (d) Case (iii).