Secure Satellite Images Transmission Scheme Based on Chaos and Discrete Wavelet Transform

Musheer Ahmad\(^1\) and Omar Farooq\(^2\)

\(^1\)Department of Computer Engineering,
Faculty of Engineering and Technology,
Jamia Millia Islamia, New Delhi 110025, India
\(^2\)Department of Electronics Engineering,
ZH College of Engineering and Technology,
AMU, Aligarh 202002, India

Abstract. Many applications based on satellite communication like national defence and security rely on the satellite images as an important source of information. It is therefore, mandatory to secure satellite imagery while transmitting them over communication channels to protect from unauthorized access and usage. In this paper, chaotic logistic map based satellite image encryption scheme is proposed to meet the requirement of secure satellite-based communication. The algorithm is based on the concept of permuting the pixels of satellite image, then improving the pixels gray value distribution from cryptographic viewpoint. The permutation of image pixels is carried out in discrete wavelet domain and the relationship between the encrypted and the original satellite image is confused using chaotic-state modulation technique, thereby significantly increasing the resistance to statistical attacks. Experimental results demonstrate that the scheme has the advantage of high sensitivity to secret key and large key space. Moreover, the encrypted satellite images have uniform gray level distributions, high entropies and low correlation coefficients. Hence, the theoretical and experimental analyses confirm that the proposed scheme has high security and can be applied for practical satellite image protection.

Keywords: Satellite communication, satellite images, chaotic logistic map, security, image encryption, discrete wavelet transform.

1 Introduction

Recent advancement of satellite and network communication technologies have made the satellite communication crucial in application areas of defence and security, multimedia broadcasting, tele-medicine, tele-education and training, weather forecasting, disaster management and support, managing and monitoring the land and ocean resources [1]. Satellite images are the most preferred source for satellite-based communications [2]. For example, the national defence and military extensively relies on the satellite imagery as an important source of information. These application areas require reliable and secure mechanism to store and transmit satellite images. It is unsafe to directly transmit sensitive satellite images over various communication channels.
To fulfill the requirement of privacy and secrecy of satellite images, cryptographic techniques need to be applied. Therefore, a lot of encryption algorithms based on different techniques have been proposed to protect images [3-14]. Among them, chaos-based cryptographic techniques have suggested some new and efficient ways to develop secure image encryption schemes to meet the demand for reliable and secure image transmission. Chaotic signals have cryptographically desirable properties such as high sensitivity to initial conditions/parameters, long periods, high randomness and mixing. These properties make chaos-based image cryptosystems excellent and robust against statistical attacks.

In this paper, the cryptographic characteristics of chaos system are utilized to develop a reliable and secure encryption scheme to protect satellite images. The proposed encryption scheme performs two level of encryption. At first level, the original image is permuted in discrete wavelet domain using multi-resolution analysis to have visual effect of disorder so that image becomes meaningless or noise-like for a casual observer. The permutation matrix is generated using sequence generated from two chaotic logistic maps with different secret initial seeds and parameters. At second level, the gray value distribution of the permuted image is enforced by chaotically modulating the states of the logistic map. The modulated states are then used to extract keys to encrypt the permuted image by simple XOR operation. Rest of the paper is organized as follows: The multi-resolution wavelet transform and Chaos are briefly discussed in Section 2. Section 3 discusses the proposed satellite image encryption scheme in detail. The experimental results are discussed in section 4 followed by conclusion.

2 The DWT and Chaos

The discrete wavelet transform (DWT) is becoming popular in image/video applications due to its multi-resolution representation feature. The idea of multi-resolution DWT for an image is to decompose it at level $R=1$ into four sub-band images with different space and frequency: vertical and horizontal direction of low frequency sub-band $LL_1$, $LH_1$, $HL_1$ and $HH_1$ sub-bands. In the low frequency sub-band signal $LL_1$, the main energy is concentrated. The remaining three sub-bands signals are known as the details of signal. The low frequency sub-band signal $LL_1$ can be decomposed again at level $R=2$ into four sub-bands of $LL_2$, $LH_2$, $HL_2$ and $HH_2$. Similarly, the low frequency sub-band can be further decomposed on and on at multiple resolutions as desired for the application.

The 1D chaotic logistic map is one of the simplest discrete nonlinear dynamical systems that exhibit chaotic behavior and is defined by the following equation:

$$x(n+1) = \lambda x(n)(1 - x(n)). \quad (1)$$

Where $x(0)$ is initial condition, $\lambda$ is the system parameter, $n \geq 0$ is the number of iterations and $0 < x(n) < 1$ for all $n$. The research shows that the logistic map has good chaotic properties if $3.9 < \lambda < 4$. 