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REVIEW

Symmetric encryption algorithms using chaotic and non-chaotic generators: A review

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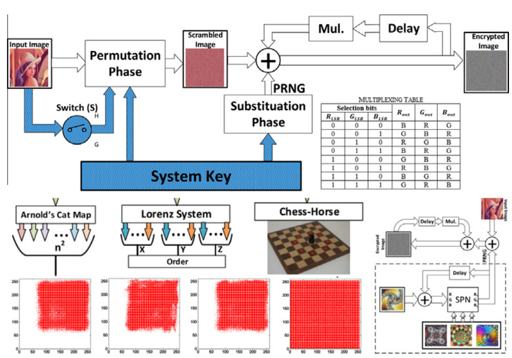
GRAPHICAL ABSTRACT



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ABSTRACT

This paper summarizes the symmetric image encryption results of 27 different algorithms, which include substitution-only, permutation-only or both phases. The cores of these algorithms are based on several discrete chaotic maps (Arnold's cat map and a combination of three generalized maps), one continuous chaotic system (Lorenz) and two non-chaotic generators (fractals and chess-based algorithms). Each algorithm has been analyzed by the correlation coefficients

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between pixels (horizontal, vertical and diagonal), differential attack measures, Mean Square Error (MSE), entropy, sensitivity analyses and the 15 standard tests of the National Institute of Standards and Technology (NIST) SP-800-22 statistical suite. The analyzed algorithms include a set of new image encryption algorithms based on non-chaotic generators, either using substitution only (using fractals) and permutation only (chess-based) or both. Moreover, two different permutation scenarios are presented where the permutation-phase has or does not have a relationship with the input image through an ON/OFF switch. Different encryption-key lengths and complexities are provided from short to long key to persist brute-force attacks. In addition, sensitivities of those different techniques to a one bit change in the input parameters of the substitution key as well as the permutation key are assessed. Finally, a comparative discussion of this work versus many recent research with respect to the used generators, type of encryption, and analyses is presented to highlight the strengths and added contribution of this paper.

Ahmed G. Radwan (M'96–SM'12) received the B.Sc. degree in Electronics, and the M.Sc. and Ph.D. degrees in Eng. Mathematics from Cairo University, Egypt, in 1997, 2002, and 2006, respectively. He is an Associate Professor, Faculty of Engineering, Cairo University, and also the Director of Nanoelectronics Integrated Systems Center, Nile University, Egypt. From 2008 to 2009, he was a Visiting Professor in the ECE Dept., McMaster University, Canada. From 2009 to 2012, he was with King Abdullah University of Science and Technology (KAUST), Saudi Arabia. His research interests include chaotic, fractional order, and memristor-based systems. He is the author of more than 140 international papers, six USA patents, three books, two chapters, and h-index = 17.

Dr. Radwan was awarded the Egyptian Government first-class medal for achievements in the field of Mathematical Sciences in 2012, the Cairo University achievements award for research in the Engineering Sciences in 2013, and the Physical Sciences award in the 2013 International Publishing Competition by Misr El-Khair Institution. He won the best paper awards in many international conferences as well as the best thesis award from the Faculty of Engineering, Cairo University. He was selected to be among the first scientific council of Egyptian Young Academy of Sciences (EYAS), and also in first scientific council of the Egyptian Center for the Advancement of Science, Technology and Innovation (ECASTI).

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Introduction

Symmetric encryption algorithms can be classified into stream ciphers and block ciphers where the image-pixels are encrypted one-by-one in stream ciphers and using blocks of bits in block ciphers. Although block ciphers require more hardware and memory, their performance is generally superior to stream ciphers since they have a permutation phase as well as a substitution phase. As suggested by Shannon, plaintext should be processed by two main substitution and permutation phases to accomplish the confusion and diffusion properties [1,2].

The target of the permutation process is to weaken the correlations of input plaintext by spreading the plaintext bits throughout the cipher text. On the other hand, the substitution