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A New Technique for Secure Image Communication via Chaotic Circuit

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Abstract
Our research paper describes secure imaging system based on chaotic noise generating circuit. A chaotic system operates based on a synchronized Master–Slave Chaotic circuits. Indeed the analog circuit is used as a master generator having chaotic and random number. In that frame, chaotic behavior is so difficult to be predicted by analytical methods without knowledge of the initial condition. Moreover, the chaotic systems show unpredictable and complex behaviors. These characteristics, make the chaotic circuit's ideal tools for improving the level of security. Moreover, in this paper, new technique has been used, and the chaotic signal with the gray image signal are masked. The sender and receiver must be able to produce exactly the same chaotic noise in order to add and subtract same chaotic noise. This becomes possible with synchronization between Chaotic circuit. The results from the experiments with statistical tests prove that suggested gray encryption of the image and decryption on the basis of chaotic.

Keywords
Secure Image System, Image Encryption/Decryption, Synchronized Master–Slave Chaotic Circuits.

I. Introduction
Researchers showed interest in non-linear circuits because of their usefulness for non-linear mathematical and experimental studies. For understanding non-linear systems, non-linear circuits are economical to construct for experiments [1-3]. Mathematically, they can be determined through differential equations. Precisely, the simplest circuits include resistor R, inductor L and diode D, which lead to period-doubling chaos [2]. Chaos can occur in the second-order, which has three linear elements and a Chua's diode [4]. Non-autonomous Chua's diode (NCD)[5] indicates non-linear resistors' function, which increases complexity of Chua's diodes. When a resistor, diode and inductor are joined in series, chaos becomes possible. Furthermore, using the invariants characterizing attractors as parameters for inputs, make it possible to get single-step and multiple-step predictions of chaotic time-series, which controls RLD circuits [6].

Chaotic synchronization recently gained more concern as area of research in secure communication. Some chaotic synchronizing and relevant factors are discussed here Feki [7]. Secure communication using synchronization between chaotic systems was a newly found method of communication security. This "hardware key" secures communication that rapidly takes place. This type of synchronization was first observed and filed in 1990 [8]. Electrical engineers of that time felt that it could help creating communication security because of its unique parameters. Later this type of chaotic hardware key was acknowledged as useful by researchers, engineers and experts all over the world [9]. Significant potentials of "hardware key" led to vast and multiple researches in the field of communication security that further opened new avenues for progress in this field. Communication security using encryption works by converting the data to an incomprehensible (not understandable) format with the help of a transmitter. The transmitter makes the data invisible and quite unreadable during the communication&transmission processes. This encryption is transmitted using any insecure link. On the recipient side, encrypted data is reconverted into comprehensible format and thus the information is transmitted securely. There are various methods for data hiding such as the spatial domain, frequency domain and compressed data domain. Among them, direct methods have certain advantages in the sense that they use all the image-based data and provide very accurate registration[10]. It has a disadvantage as well and that is their memory requirement, and besides, close initialization and techniques may not be easy to implement. In order to prove robust chaos encryption system, there are many tests to check. Histogram results and correlation values have shown that encryption of images can be unpredictable [11]. The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. Chaotic Secure Communication Systems
There exist two main approaches to designing chaos-based cryptosystems: analog and digital. Analogue-based chaotic cryptosystems are secure communication links that are based on the unidirectional chaotic synchronization. Digital chaos-based cryptosystems are designed for digital computers, where one or more chaotic maps are implemented infinite computing precision to encrypt the plain-message in various ways. On the Other hand, digital chaotic cryptosystem does not depend on the chaotic synchronization but they have initial conditions and control parameters used as the secret key. Analogue-based chaotic cryptosystem can be implemented in a continuous time chaotic system or in discrete time chaotic maps.
Cuomo and Oppenheim have implemented masking secure communication scheme of Lorenz system in 1993 [8, 12]. The scheme of chaotic masking secure communication was improved and forward by Milanović and Zaghloul in 1996 [13]. According to work, the implementing of chaotic secure communication circuit have been done by electronic components based on Lorenz system [13]. From the perspective of Generalized Hamiltonian systems GHS, the work approached the problem of synchronization of chaotic systems with the fast development of chaotic secure communication [14]. The experimental application was presented by utilizing of the CCII plus. Where based on two Chua's oscillators, the chaotic secure communication system was amplitudes [15]. The fractional chaotic communication process by utilizing of an extended fractional Kalman has been proposed by Arman in 2009 [16]. The linear-state-observer was design in work [17] by used stabilization conditions, for the secure communization of a wide class of discrete-time hyper chaotic system via a scalar transmitted signal. To the transmission of binary-coded messages. In work [18] a new chaotic secure communication scheme was suggested, which based on chaotic doffing oscillators and frequency estimation. By a new method not requiring the same structure of master and slave circuits in work [19], the design and implementation of adaptive Generalized Projective Synchronization (GPS) are

studied between two chaotic circuits (master and slave) via a scalar transmitted signal.

It is well know that, in secure communication system, the chaotic attractor can be used. Because the chaotic systems offer more dynamical complexity, the chaotic systems composed of multi-scroll attractors are much preferred to the double-scroll attractors. Generally, the chaotic attractors should operate at high frequency in order to transmit high-speed data. When chaotic oscillator is designed with integrated circuit technology that made some difficulty to enhance the frequency response of analog realizations of chaotic oscillator. Latter, to observe attractors at high frequency the FPGA based realization emerged as a solution.

The paper [20] shows that by utilizing FPGAs can realize multi-scroll chaotic oscillators, which have better behaviour than by using active devices such as operational amplifiers. The work [21, 22] shown that synchronization can also be extended to complex topologies with multi-scroll attractors.

Works [23-26] showing that the study of chaotic secure communication is still in the phase of laboratory research in spite of has advantages of strong real-time performance and high security performance. Moreover, more researches are needed to be solved chaotic secure communication problems. As shown in [27-34], the contradiction between the confidential party and the broken party leads to a complex circuit implementation.

Small key space is one of features of low dimensional chaotic maps that make it vulnerable to attacks of cryptanalysis. The higher dimensional systems, in most of cases utilizing in image encryption. Where adopting of higher dimensional chaotic systems was suggested for image encryption, as well as the presence of more than one by producing high randomness and more complex dynamical behavior. In general, in this paper we dialed with the analog based chaotic cryptosystem [35].

III. Chaotic Synchronization

Pecora and Carroll [36] are shown that possible to have a synchronize two chaotic systems with starting from different initial conditions under certain condition. However, they showed that where two chaotic systems are connected by a common signal, therefore, it is possible to obtain chaotic synchronization in any case of the initial conditions. To realize chaotic synchronization, there had to be some order of coupling sitting between the two chaotic systems. in the case of unidirectional coupling, the signal from one chaotic circuit (master circuit) is being transmitted to a second chaotic circuit (slave circuit). Therefore, the chaotic signals can be used as the carrier signal as in analog communication systems.

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IV. Chaos Based Encryption Techniques

Many image encryption schemes based on chaos theory have been presented. The first chaotic encryption algorithm was suggested by Matthews in 1989. Afterwards, investigations on chaos-based encryption were done and one of these primarily studies was completed by Baptista [37]. Simple one-dimensional logistic map was utilized to encrypt each character of a text message as the integer number of iterations accomplished in the logistic equation. a new algorithm has been presented in 1992, by Maniccam and Bourbakis [11] which does two works: encryption of binary and gray-scale pictures and lossless compression. The encryption and compression schemes depend on SCAN patterns generated by the SCAN methodology. A wide range of scanning paths or space-filling curves can be generated by The SCAN which is formal language-based 2D spatial-accessing methodologies.

During last decade, researchers have studied many logistic map algorithms. As an example, an algorithm namely mirror-like image encryption based on 7 steps have been presented by Guo and Cheng Yen [38]. initially, 1-D chaotic system is determined and its initial point x (0) and sets k = 0. after that, the chaotic system generate the chaotic sequence. then, the chaotic system generates the binary sequence. Eventually, swap function is rearranging 4 stages image pixels according to the binary sequence. Shin, Seo, Chol, Lee, and Kim have used in [39] a Technique for Image Encryption using multi-level and image dividing technique. using binary phase, They proposed an algorithm which was a multi-level form of an image to encrypt it. Is done by exclusive OR (XOR) operation which following by image dividing technique. Binary pictures are regenerate to binary phase encoding and then these images are encrypted by binary phase XOR operation.

Belkhouche and Qidwai [40] used the technique for Image Encryption using 1D chaotic map. In this method can be used for binary images encryption with the chances of using several keys. as an example, initial state, the external parameters and iterations' number. A new algorithm done by Gu and Han have used in[41] which based on permutation and substitution methods. It had given a highly optimized for image encryption. It was done by enhancing the pseudorandom of chaotic sequences. Pisarchik and Zanin [42] dynamically shifted compound chaotic cipher sequence. They moved all the pixels through 2D chaotic map using substitution and permutation, which moved new pixels as a permutation of the original ones. In the substitution process, the pixel values are altered sequentially presented Fridrich [11], Gao, Zhang [43]. Of all the above techniques covers in the spatial domain or frequency domain based on chaotic schemes. To sum up, encryption and decryption techniques are vailed for real-time image encryption. Each technique has a unique way to encryption and decryption image, which might be suitable for different applications. in every day, a new encryption technique is evolving hence fast and secure conventional encryption techniques will always work out with a high rate of security.

V. Secure Communication System

Synchronization of chaotic circuits particularly encryption and decryption needs discussion. analog chaotic cryptosystem is summation of chaotic waveform and the real information signal, while the information can be recovered by using synchronization between the master and the salve circuits. At that point, if prefect synchronization does not take place, the information waveform cannot be obtained through the slave circuit. Finally, one requires an extracting circuit in order to get the chaotic signal out handle with pure information signal.

They are shown in fig. 1, The signal has a chaotic shape in the master circuit with initial parameters. The mask circuit S(t) gets the chaotic signal form master circuit and combines it with the information signal I(t) and later, the masked signal S(t) is

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transmitted to the recovery circuit and the chaotic part is eliminated through the slave circuit. Then, we obtain a clear information signal.

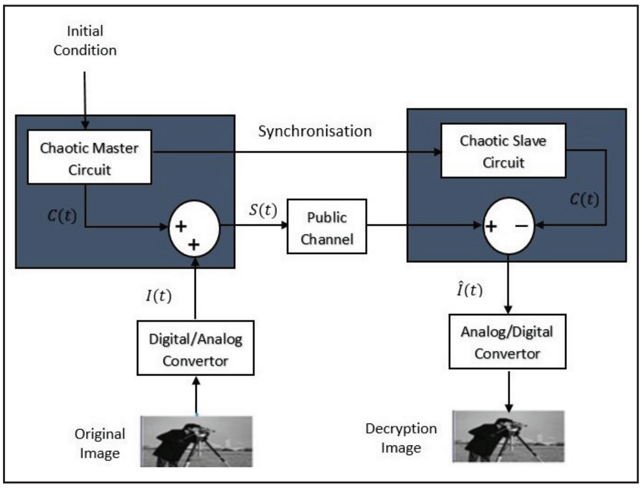


Fig. 1: The Secure Communication System

VI. New Image Encryption and Decryption Technique

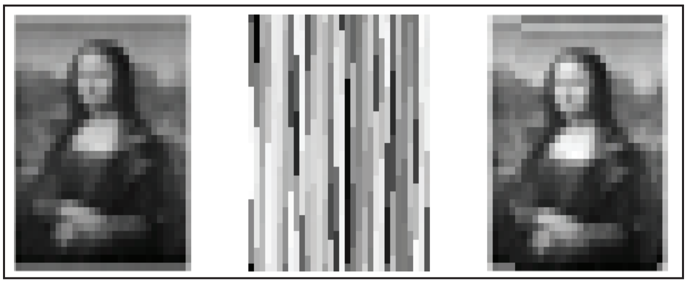
The algorithms for the image encryption use the digital random generation or chaotic maps with mathematical algorithm based on complex mathematical steps, which have drawbacks such as small key spaces, slow performance and weaker security. The new image encryption technique proposed in this paper depends on a chaotic circuit for secure image transfer without digital secure keys since it is a hardware-key based technique. The circuit parameters are enough to recover the data and no other parameter, image or secure key are not required for the receiving side

In Image Decryption: a receiver should know the initial condition for Chaos signal in master circuit. The decryption takes places through the following steps.

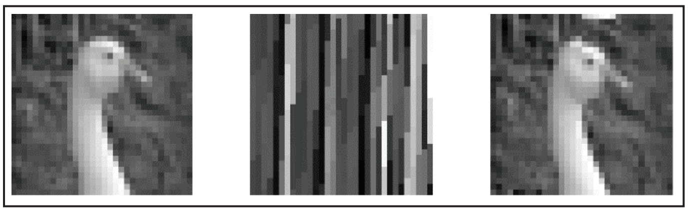
1. In receiver (slave circuit), chaos signal is subtracted from signal that comes from the modulation circuit, which results in gray image signal.
2. Takes convert $\hat{I}$ *(t)* signal to digital values and recovered to decryption image.

VIII. Experimental Results

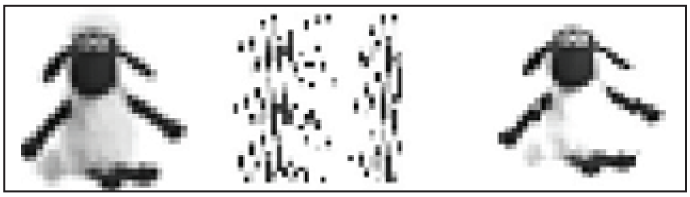
Fig. 2 (a,d,g) shows the original test image, the encrypted ones are shown in fig. 2 (b,e,h) and finally fig. 2 (c,f,i) shows the decrypted image



(a) (b) (c)



(d) (e) (f)



(g) (h) (i)

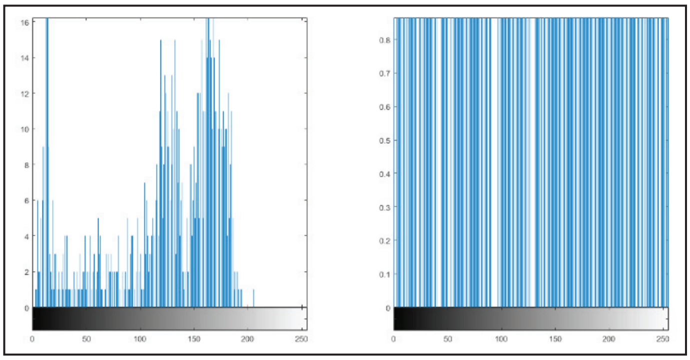
Fig. 2: The Original Transmitted Images (a,d,g), the Crypted Ones (b,e,h) and the Decrypted Forms (c,f,i).

Experimental Analysis

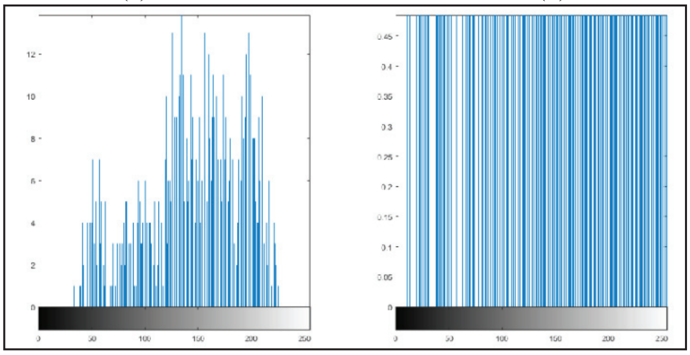
The tests on the encrypted images are important in order to make the communication in a safe way from the public channel. In that part, the histogram analyses and pixel correlation tests have been carried out.

Histograms Analysis

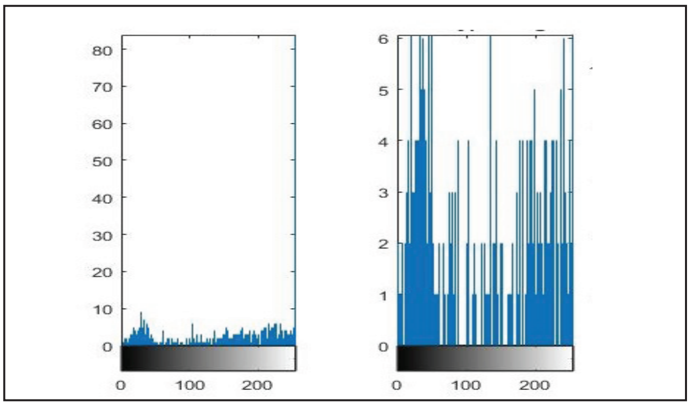
The factors, which measure image encryption, prevent information leakages to insecure sources or opponents because the encrypted images have no statistical resemblance with the originals. After having calculated and created histograms of the several encrypted and original images, we have



(a) (b)



(c) (d)



(e) (f)

Fig. 3: Histogram Test Results of the Decrypted Images

The histogram of genuine image is in the form of spikes, and these spikes show gray values of different dimensions of the photos. If we look at the histogram of any encrypted image, we will find it uniform and quite different as compared to the original image with no resemblance at all. Histograms of encrypted images do not give any kind of information regarding the specs of the original images; therefore, images are secure because no effort to decrypt those images by any unauthorized person can be successful.

B. Pixel Correlation

The correlation coefficients of the encrypted pixels for different sizes of images have been calculated for both the original and the encrypted images. Data correlation is defined as ρ or Crr, which is the coefficient of correlation, X and Y are datasets, and μ is the mean value in the standard deviation, so, when variables $X\&Y$ are highly correlated, the ρ value will be closer to one. (A positive correlation coefficient indicates that as one variable increases, the other also increases or vice versa). The opposite is true if their ρ value is closer to zero (zero indicates that the variables are not correlated). The coefficient correlation Equation is:

$$\rho_{x,y} = corr(X,Y) = \frac{cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E((X-\mu_X)(Y-\mu_Y))}{\sigma_X \sigma_Y}$$

In the above-mentioned formula, E is the expected value. Here cov stands for covariance while corr represents correlation. We found correlation between the original and the encrypted image. The values are shown in Table 1.

Table 1: Correlation Coefficient Images

Image name	Correlation coefficient images	
	Correlation $\rho_{x,y}$ Original-Encrypt	Correlation $\rho_{x,y}$ Original-Decrypt
Mona Liza	0.113	0.846
Duck	-0.094	0.899
Sheep	-0.0152	0.713

IX. Conclusion

In the present study, a new chaos based secure image communication technique has been designed and implemented. The new technique uses a new proposed chaotic synchronization circuit in master/ slave form and masks the plain image gray levels into the chaotic signal, transmit it with a public channel and recover it with a sufficient accuracy. Because synchronization between the sender andreceiver are ascertained for only the sending time period, thus one cannot recover the image without having the same chaotic signal.

In addition, the technique is useful because it does not need digital key while sending gray images to the receiver, because they are converted to the noisy signals in a synchronized way. Thus, that technique is better, reliable and fast compared to the other traditional techniques. In fact, a digital media is always unsecure due to software developments among the hackers, improvements in internet systems, etc. The only disadvantage whichhas was encountered in that technique was a little noise in the decrypted image, however if larger memory is used, that disadvantage can be annihilated.

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