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Editorial
Message from Managing Editor

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We thank all those authors who contributed papers to the April 2010 issue and the reviewers, all of whom responded to a short and challenging timetable. We are committed to placing this journal at the forefront for the dissemination of novel and exciting research. We should like to remind all prospective authors that IJCSIS does not have a page restriction. We look forward to receiving your submissions and to receiving feedback.

IJCSIS April 2010 Issue (Vol. 8, No. 1) has an acceptance rate of 35%.

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TABLE OF CONTENTS

Dr. A. Ebenezer Jeyakumar, Director/Academics, SREC, Coimbatore, Tamilnadu, India

Priyanka Vij (Author) Student, Computer Science Engg. Lingaya"s Institute of Mgt. & Tech, Faridabad, Haryana, India
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Siti Fazilah Shamsudin, Faculty of ICT, LIMKOKWING University of Creative Technology, CYBERJAYA, Selangor, Malaysia
Jawad Tayyub, Software Engineering With Multimedia, LIMKOKWING University of Creative Technology, CYBERJAYA, Selangor, Malaysia

Gowri. R, Kailas. A, Jeyaprakash.R, Carani Anirudh
Department of Information Technology, Sri Manakula Vinayagar Engineering College, Puducherry – 605 107.

V. Prasannamoorthy and N.Devarajan
Department of Electrical Engineering, Government College of Technology, Coimbatore, India

Dr Muid-ur-Rahman Mufti, Department of Computer Engg, UET Taxila, Taxila, Pakistan

38. Paper 31031089: Approach towards analyzing motion of mobile nodes- A survey and graphical representation (pp. 250-253)

A. Kumar, Sir Padampat Singhania University, Udaipur , Rajasthan , India
P.Chakrabarti, Sir Padampat Singhania University, Udaipur , Rajasthan , India
P. Saini, Sir Padampat Singhania University, Udaipur , Rajasthan , India

39. Paper 31031092: Recognition of Printed Bangla Document from Textual Image Using Multi-Layer Perceptron (MLP) Neural Network (pp. 254-259)

Md. Musfique Anwar, Nasrin Sultana Shume, P. K. M. Moniruzzaman and Md. Al-Amin Bhuiyan
Dept. of Computer Science & Engineering, Jahangirnagar University, Bangladesh

40. Paper 31031081: Application Of Fuzzy System In Segmentation Of MRI Brain Tumor (pp. 261-270)

Mrigank Rajya, Sonal Rewri, Swati Sheoran
CSE, Lingaya's University, Limat, Faridabad India, New Delhi, India

41. Paper 30031059: E-Speed Governors For Public Transport Vehicles (pp. 270-274)

C. S. Sridhar, Dr. R. ShashiKumar, Dr. S. Madhava Kumar, Manjula Sridhar, Varun. D
ECE dept, SJCIT, Chikkaballapur.

42. Paper 31031087: Inaccuracy Minimization by Partioning Fuzzy Data Sets - Validation of Analystical Methodology (pp. 275-280)

Arutchelvan. G, Department of Computer Science and Applications Adhiparasakthi College of Arts and Science G. B. Nagar, Kalavai , India
Dr. Srivatsa S. K., Dept. of Electronics Engineering, Madras Institute of Technology, Anna University, Chennai, India
Dr. Jagannathan. R, Vinayaka Mission University, Chennai, India

43. Paper 30031065: Selection of Architecture Styles using Analytic Network Process for the Optimization of Software Architecture (pp. 281-288)

K. Delhi Babu, S.V. University, Tirupati
Dr. P. Govinda Rajulu, S.V. University, Tirupati
Dr. A. Ramamohana Reddy, S.V. University, Tirupati
Ms. A.N. Aruna Kumari, Sree Vidyanikethan Engg. College, Tirupati

44. Paper 27031041: Clustering Time Series Data Stream – A Literature Survey (pp. 289-294)

V.Kavitha, Computer Science Department, Sri Ramakrishna College of Arts and Science for Women, Coimbatore, Tamilnadu, India.
M. Punithavalli, Sri Ramakrishna College of Arts & Science for Women, Coimbatore ,Tamil Nadu, India.

45. Paper 31031086: An Adaptive Power Efficient Packet Scheduling Algorithm for Wimax Networks (pp. 295-300)

R Murali Prasad, Department of Electronics and Communications, MLR Institute of technology, Hyderabad
P. Satish Kumar, professor, Department of Electronics and Communications, CVR college of engineering, Hyderabad

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A new joint lossless compression and encryption scheme combining a binary arithmetic coding with a pseudo random bit generator

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Abstract—**In this paper, we propose a new scheme which performs both lossless compression and encryption of data. The lossless compression is based on the arithmetic coding (AC) and the encryption is based on a pseudo random bit generator (PRBG). Thus, the plaintext is compressed with a binary arithmetic coding (BAC) whose two mapping intervals are swapped randomly by using a PRBG. In this paper, we propose a PRBG based on the standard chaotic map and the Engel Continued Fraction (ECF) map to generate a keystream with both good chaotic and statistical properties. To be used in cryptography, a PRBG may need to meet stronger requirements than for other applications. In particular, various statistical tests can be applied to the outputs of such generators to conclude whether the generator produces a truly random sequence or not. The numerical simulation analysis indicates that the proposed compression and encryption scheme satisfies highly security with no loss of the BAC compression efficiency.**

I. Introduction

In recent years, a variety of lossless data compression methods have been proposed [4], [3], [23], [31]. All of these methods can not perform both lossless compression and encryption of data. This paper presents a new scheme which combines arithmetic coding (AC) with a pseudo random bit generator (PRBG) to perform both compression and encryption of data.

AC has been widely used as an efficient compression algorithm in the new standards such JBIG2, JPEG2000 and H.264/AVC. For some specific applications, AC is also considered as an encryption algorithm. In [5], Cleary *et al.* considered the AC as an encryption scheme and they demonstrated that it is vulnerable against chosen plaintext attack and known plaintext attack. In [8], Bergen *et al.* studied the data security provided by an adaptive arithmetic coding (AAC). The improved algorithm based on regular re-initialisation and adjustment of one of the model parameters provides significant data security, but is vulnerable to a chosen plaintext attack. In [27], Wen *et al.* designed the binary arithmetic coding (BAC) with key-based interval splitting. They proposed to use a key for splitting the interval associated with the symbol to be encoded. Thus, the traditional assumption in AC that a single contignous interval is used for each symbol is not preserved. The repeated splitting at each encoding/decoding step allowing both encryption and compression. In [12], Kim *et al.* demonstrated the insecurity of the interval splitting AC against a known plain-text attack and a chosen plain-text attack. They also provided an improved version called the secure AC by applying a series of permutations at the input symbol sequence and output codeword. It should be noticed that due to the permutations process, the scheme has a high complexity and it is difficult to extend the secure AC to the context-based AC that exploits the input symbol redundancy to encode messages. In [34], Zhou *et al.* demonstrated that the secure AC is vulnerable against a chosen cipher-text attack. The basic idea is to progressively design codewords input to the decoder, and establish the correspondance of the bit location before and after the codeword permutation step. In [35], Zhou *et al.* presented a new scheme for joint security and performance enhancement of secure AC. They proposed to incorporate the interval splitting AC scheme with the bit-wise XOR operation. This scheme can be extended to any adaptive and context-based AC due to the elimination of the input symbol permutation step. In addition, the implementation is lower complexity than the original secure AC. Zhou *et al.* also presented a selective encryption scheme with even lower complexity. In [6], Grangetto *et al.* proposed a novel multimedia security framework by means of AC. The scheme is based on a random organization of the encoding intervals using a secret key. This technique can be applied to any multimedia coder employing AC as entropy coding stage, including static, adaptive and context-based AC. They proposed an implementation for their scheme tailored to the JPEG2000 standard. Mi *et al.* [17] proposed a new chaotic encryption scheme based on randomized AC using the logistic map for pseudo random bit generator. However, the logistic map is weak in security because it does not satisfy uniform distribution property and it has a small key space with only one control parameter [1], [2].

In addition, chaotic systems have been used for several applications [14], [32], [29], [30], [33] and some of these novel chaotic systems have designed pseudo random bit generators (PRBG) for stream cipher applications [10], [20]. The chaotic systems used in cryptography generate a keystream with good properties such as ergodicity, sensitivity to initial values and sensitivity to control parameters. However, some of them are not very suitable to be used in cryptography due to their density function which is not uniform distributed or due to their small key space. To be used in cryptography, a PRBG may need to meet stronger requirements than for other applications. In particular, various statistical tests [21], [16] can be applied to the outputs of such generators to conclude whether the generator produces a truly random sequence or not. The use of ECF-map increases the complexity of a cryptosystem based on only one chaotic system and thus makes difficult to extract information about it [20]. In addition, ECF-map conserves the cryptography properties of the chaotic system; like sensitivity to initial conditions and control parameters; non periodicity and randomness; and add interesting statistical properties such uniform distribution density function and zero co-correlation.

In this paper, we propose a new joint compression and encryption scheme based on AC and PRBG. The proposed PRBG is based on the use of the standard chaotic map coupled with the Engle Continued Fractions (ECF) map. The outputs of the standard map are used as the inputs of ECF-map. The standard map with good chaotic properties and the ECF-map which possesses good statistical properties motivate us to design a new PRBG for secure AC.

The rest of this paper is organized as follows. In Section 2, we briefly discuss the AC. Section 3 details the proposed PRBG which is based on the standard chaotic map and the engel continued fraction map. In Section 4, we describe the proposed algorithm for secure AC. In Section 5, we analyze the security of the proposed scheme and we discuss experiment results. Finally, conclusions of this paper will be discussed in Section 6.

II. Overview of arithmetic coding

AC [13], [28], [9], [18] is a statistical coder and is very efficient for data compression. In addition, AC has been widely used in many standards including JPEG2000, JBIG2 and H.264/AVC. The principe of AC is that it assigns one codeword to the entire input data symbols and this codeword is a real number in the interval $[0, 1)$. To calculate the appropriate codeword for input data symbols, the AC works with a modeler that estimates the probability of each symbol at the encoding/decoding process. The model used by AC can be either static or adaptive. Let $S = \{s_1, ..., s_n\}$ be an independent and identically distributed binary sequence of n random symbols. During the encoding process, we firstly estimate the probability of each symbol and we calculate the cumulative distribution vector (CDV) by assigning, for each symbol s_i, a subinterval with a size proportional to its probability in the interval $[0, 1)$. Next, for any new symbol s_i from the input sequence, we select the subinterval for s_i and we define it as the new current interval. We iterate this step until all input sequence has been processed and we finally generate the codeword that uniquely identifies the final interval. There are many types of AC. Thus, the binary arithmetic coding (BAC) is an important type of encoder due to its ability to reduce the complexity created with the dynamic update of the CDV when we use an adaptive models. In addition, BAC has universal applications because data symbols which are putted out from any alphabet can be coded as a sequence of binary symbols. When we work with a binary source alphabet, the CDV is $[0, p_0, 1]$, with p_0 the probability of the symbol "0". The interval $[0, 1)$ is partitionned in two parts. In this case, the symbol "0" is represented by the range $[0, p_0)$ and the symbol "1" is represented by the range $[p_0, 1)$. The Algorithms 1 and 2 illustrate the encoding and decoding procedures for the BAC.

Algorithm 1 Binary encoder

```
Initialize base ← 0, length ← 2^N − 1
for i ← 1 to n do
  x ← length × p(0)
  if b_i = 0 then
    length ← x
  else
    init_base ← base
    base ← base + x
    length ← length − x
    if init_base > base then
      propagate_carry()
    end if
  end if
  if length < length_min then
    renorm_enc_interval()
  end if
end for
```

Algorithm 2 Binary Decoder

```
Initialize base ← 0, length ← 2^N − 1, code = input 4
bytes from compressed file
while Not end of compressed file do
  x ← length × p(0)
  if code ≥ x then
    b_i ← 1
  else
    b_i ← 0
  end if
  if b_i = 0 then
    length ← x
  else
    code ← code − x
    length ← length − x
  end if
  if length < length_min then
    renorm_dec_interval()
  end if
  output b_i
end while
```

III. Pseudo random bits generated from the standard chaotic map and the ECF-map

In this section, we describe the process of the proposed PRBG. In this PRBG, we suggest to use the standard chaotic map which is defined by:

$$\begin{cases} x_j = x_{j-1} + p_0 \times sin(y_{j-1}) \\ y_j = y_{j-1} + x_j \end{cases}, \quad (1)$$

where x_j and y_j are taken modulo 2π. The secret key in the proposed PRBG is a set of three floating point numbers and one integer (x_0, y_0, p_0, N_0), where $\{x_0, y_0\} \in [0, 2\pi)$ is the initial values set, p_0 is the control parameter which can have any real value greater than 18.0 and N_0 is the number of initial iterations of the standard chaotic map [19]. The standard map has good chaotic properties and a large key space of the order 157 bits [19] with an accuracy of 10^{-14}. This key space is sufficient enough to resist the brute-force attack. However, the standard chaotic map generates a sequence with non uniform density function. The experimental results presented in Table I, show that sequences generated from standard chaotic map failed some tests of the NIST statistical test suite [21] and these sequences are not good enough to be used in cryptographic applications. It seems a good idea to transform the chaotic sequence generated from the standard chaotic map to a new sequence which satisfies uniform distribution property and have many important characteristics of cryptography such as zero co-correlation, randomness and ideal nonlinearity. In [7], a new nonlinear dynamical system has been proposed which called Engel Continued Fraction map.

The Engel continued fraction (ECF) map $T_E : [0, 1] \to [0, 1)$ is given by:

$$T_E(x) = \begin{cases} \frac{1}{\lfloor \frac{1}{x} \rfloor}\left(\frac{1}{x} - \lfloor \frac{1}{x} \rfloor\right) & if \quad x \neq 0 \\ 0 & if \quad x = 0. \end{cases} \quad (2)$$

For any $x \in [0, 1)$, the ECF-map generates a new and unique continued fraction expansion [15], [22], [25], [24], [11] of x of the form:

$$x = \cfrac{1}{b_1 + \cfrac{b_1}{b_2 + \cfrac{b_2}{b_3 + \ddots + \cfrac{b_{n-1}}{b_n + \ddots}}}}, \quad b_n \in \mathbb{N}, \quad b_n \leq b_{n+1} \quad (3)$$

Let $x \in [0, 1)$, and define:

$$\begin{aligned} b_1 &= b_1(x) = \lfloor \tfrac{1}{x} \rfloor \\ b_n &= b_n(x) = b_1(T_E^{n-1}(x)), \quad n \geq 2, \quad T_E^{n-1}(x) \neq 0, \end{aligned} \quad (4)$$

where $T_E^0(x) = x$ and $T_E^n(x) = T_E(T_E^{n-1}(x))$ for $n \geq 1$. From definition of T_E it follows that:

$$\begin{aligned} x &= \frac{1}{b_1 + b_1 T_E(x)} \\ &= \cfrac{1}{b_1 + \cfrac{b_1}{b_2 + \cfrac{b_2}{b_3 + \ddots + \cfrac{b_{n-1}}{b_n + b_n T_E^n(x)}}}}. \end{aligned} \quad (5)$$

The method used for generating the ECF-continued fraction expansion of x is described in Algorithm 3.

From the theorem presented in [7], if we let $x \in [0, 1)$, then x has a finite ECF-expansion (i.e., $T_E^n(x) = 0$ for some $n \geq 1$) if and only if $x \in \mathbb{Q}$. Thus, all floating number has a unique and finite ECF-expansion. Note that, we paid most attention to the following sequence:

Algorithm 3 ECF expansion

Initialize $x_0 \leftarrow x, i \leftarrow 0$
while $x_i \neq 0$ **do**
  $i \leftarrow i + 1$
  $b_i \leftarrow \lfloor \frac{1}{x_{i-1}} \rfloor$
  $x_i \leftarrow \frac{1}{\lfloor \frac{1}{x_{i-1}} \rfloor}\left(\frac{1}{x_{i-1}} - \lfloor \frac{1}{x_{i-1}} \rfloor\right)$
end while

$$Z_n(x) = b_n(x) T_E^n(x), \; n \geq 1. \quad (6)$$

The sequence $\{Z_i(x)\}_{i=1}^n$ is in $[0, 1)$ and uniformly distributed for almost all points x (for a proof see [7]). So, the ECF-map generates a random and unpredictable sequence $\{Z_i(x)\}_{i=1}^n$ with a uniform distribution. These properties, which are very useful in cryptography, motivate us to use ECF-map in our PRBG.

The use of the standard chaotic map make the output very sensitive to the input and in our PRGB, the outputs of this chaotic map are used as the input to the ECF-map for generating sequences with desirable chaotic and statistical properties.

In the following paragraph, we give the detailed procedure to generate pseudo random binary sequences using the standard and ECF maps.

We define a function $G : [0, 1) \to [0, 1)$ such that:

$$G(x_i) = \sum_j Z_j(x_i) - \lfloor \sum_j Z_j(x_i) \rfloor, \quad (7)$$

where $\{Z_j\}$ is the set calculated according to (6) using ECF-map. In addition, assume that we have defined a function $F : [0, 1] \to \{0, 1\}$ that converts the real number x_i to a discrete bit symbol as follows:

$$F(x_i) = \begin{cases} 0 & if \quad x_i < 0.5 \\ 1 & otherwise \end{cases}. \quad (8)$$

We propose to use the 2-D standard map, with $\{x_0, y_0\}$ the initial values and p_0 the control parameter of the chaotic map. The majority of cryptosystems with keystreams independent of plaintexts are vulnerable under known plaintext attacks [26]. Thus, to enhance the security of our encryption method, we propose to use the plaintext when producing keystreams. In our scheme, we firstly iterate the chaotic map N_0 times and the operation procedures of the proposed PRBG are described as follows:

- **Step 1:** The standard map is iterated continuously. For the jth iteration, the output of the standard map is a new set $\{x_j, y_j\}$.
- **Step 2:** Assuming that the plaintext is a binary sequence $B = b_1...b_n$. For the jth bit of the plaintext we calculate S_j the decimal representation of $b_{j-8}...b_{j-1}$. Note that for the first 8 bits of the plaintext, S_j equals to a secret value S_0. In addition, the standard map generates a set $\{x_j, y_j\} \in [0, 2\pi)$. So we propose to calculate the set $\{a_j\}_{j=1}^n$ using the relation:

$$a_j = (x_j + y_j + \frac{S_j}{256}) - \lfloor (x_j + y_j + \frac{S_j}{256}) \rfloor. \quad (9)$$

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- **Step 3:** Finally, the sequence $K^n = \{k_j\}_{j=1}^n$ represents the random binary sequence and it is generated by:

$$k_j = F(G(a_j)). \quad (10)$$

The standard and ECF maps are iterated until the generation of a keystream with length n. In order to generate the random binary sequence $\{k_j\}_{j=1}^n$, an initial sequence $\{a_j\}_{j=1}^n$ has to be created using the standard map. To test the randomness of the sequence generated by using the standard map, we propose to calculate the sequence $\{M_j\}_{j=1}^n$ as follows: $M_j = F(a_j)$ for $1 \leq j \leq n$. From a cryptographic point of view, the sequence $\{M_j\}_{j=1}^n$ is not good enough for designing a PRBG because it does not pass all statistical tests designed by the NIST [21]. Therefore, we propose to use the ECF-map to convert the generated sequence $\{a_j\}_{j=1}^n$ to a binary sequence $\{k_j\}_{j=1}^n$ of the same length by applying (10). Table I shows the passing rate of the sequences without and with using ECF-map. A noticeable improvement is observed after mixing standard map with the ECF-map and all the tests are passed. Figures 1 and 2 present respectively the chaotic trajectory and the distribution function of the proposed PRBG for a keystream of length $10,000$ bits generated with a random encryption key. In these two figures, we have supposed that the keystream acts as byte, so the range of the keystream is $0 - 255$.

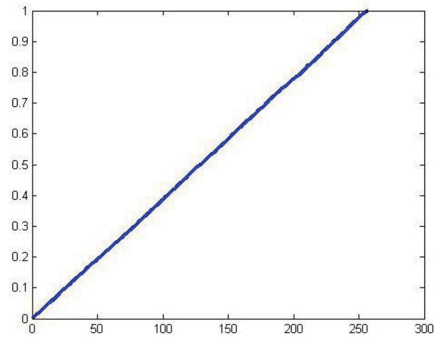

Fig. 1. Distribution function of the generated keystream by using our PRBG.

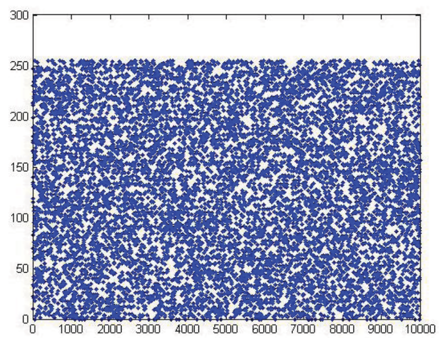

Fig. 2. The uniform property of the generated keystream by using our PRBG

IV. The Proposed Compression and Encryption Scheme

We assume that the plaintext is a binary sequence $B = b_1...b_n$. Let p_0 the probability of symbol "0" and p_1 the probability of symbol "1". We propose to use the keystream $K^n = \{k_j\}_{j=1}^n$ generated from our PRBG to randomly exchange the two intervals of the CDV used in BAC encoding/decoding process. Thus, before encoding the bit b_j of the plaintext B, we propose to generate the jth key k_j using our PRBG. In the encryption and decryption algorithms, we suggest to use two variables called $lower$ and $upper$ which initially equal to 0 and 1 respectively, and the CDV is $[0, p_0, 1]$. If the generated key k_j equals to 1, then these two variables are permuted and the CDV becomes $[0, p_1, 1]$. So, we only suggest to permute the probabilities p_0 and p_1 in the CDV according to the generated key k_j. The encryption and decryption procedures are illustrated in Algorithms 4 and 5 respectively. The proposed scheme leads to make BAC performing both lossless compression and encryption simultaneously. In addition, AC is very sensitive to errors in the compressed data, and this undesired property ameliorates the security of the proposed method. The cryptographic properties of the proposed PRBG lead to perform maximum randomization in the swapping intervals process. The decryption process is similar to the encryption one. It should be noted that the proposed scheme conserves the compression efficiency of the BAC because we use the same probabilities when encoding the binary symbols without and with the permutation process. The most advantage of the work presented in this paper is the use of the chaos theory with the use of the ECF-map into arithmetic coding to provide a new scheme which performs both compression and encryption of data.

Algorithm 4 Encryption algorithm

```
Initialize base ← 0, length ← 2^N − 1 , lower ← 0 ,
upper ← 1 ,
for i ← 1 to n do
  generate k_i using the PRBG
  if K_i = 1 then
    permute(lower, upper)
  end if
  x ← length × p(lower)
  if b_i = lower then
    length ← x
  else
    init_base ← base
    base ← base + x
    length ← length − x
    if init_base > base then
      propagate_carry()
    end if
  end if
  if length < length_min then
    renorm_enc_interval()
  end if
end for
```

V. Experiment Results and Security Analysis

The BAC implementation used during the experiment analysis was downloaded from the website (http://www.cipr.rpi.edu/~said/fastac.html) and it was implemented using C++. In this paper, we propose to analyze

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Test No.	Test Name	$x_0 = 3.59587469543$ $y_0 = 0.8512974635$ $p_0 = 120.9625487136$ $N_0 = 250$		$x_0 = 5.02548745491$ $y_0 = 2.9654128766$ $p_0 = 100.6$ $N_0 = 250$	
		$\{k_j\}_{j=1}^N$	$\{a_j\}_{j=1}^N$	$\{k_j\}_{j=1}^N$	$\{a_j\}_{j=1}^N$
1	FT	0.950563	0.000000	0.571394	0.000000
2	BFT (m = 128)	0.487702	0.004997	0.606546	0.025579
3	RT	0.852448	0.000000	0.588039	0.000000
4	LROT	0.909896	0.217013	0.676629	0.419327
5	MRT	0.931527	0.406179	0.104819	0.760720
6	SPT	0.760384	0.417304	0.067271	0.019833
7	NOTMT (m = 9, B = 000000001)	0.976154	0.004070	0.285350	0.000407
8	OTMT (m = 9, B = 111111111)	0.528047	0.000343	0.509185	0.198951
9	MUST (L=7, Q= 1280)	0.189804	0.026644	0.087637	0.296153
10	LZT	0.537151	0.234318	0.061457	0.002342
11	LCT (M = 500)	0.482937	0.275970	0.685647	0.829220
12	ST (m = 16)	0.442602	0.115116	0.252451	0.952714
13	AET	0.182287	0.000000	0.784454	0.000000
14	CST (Forward)	0.837613	0.000000	0.606517	0.000000
	CST(Reverse)	0.801266	0.000000	0.223216	0.000000
15	RET (x = +1)	0.938621	0.000000	0.403319	0.000000
16	REVT (x = -1)	0.241429	0.000000	0.764309	0.000000

TABLE I
STATISTICAL TESTS ON THE SEQUENCES $\{k_j\}_{j=1}^n$ AND $\{M_j\}_{j=1}^n$ WITH DIFFERENT KEYS.

Lena bit plane 512×512	Static model		Adaptive model	
	Traditional AC	Our method	Traditional AC	Our method
Bit plane 8	32780	32780	27622	27622
Bit plane 7	32182	32182	30085	30085
Bit plane 6	32786	32786	31151	31151
Bit plane 5	32790	32790	32295	32295

TABLE II
THE COMPRESSION EFFICIENCY (IN BYTE) OF BIT PLANE WITH DIFFERENT INFORMATION ENTROPY.

Algorithm 5 Decryption algorithm

Initialize $base \leftarrow 0$, $length \leftarrow 2^N - 1$, code = input 4 bytes from compressed file
while Not end of compressed file **do**
  generate k_i using the PRBG
  if $K_i = 1$ **then**
    $permute(lower, upper)$
  end if
  $x \leftarrow length \times p(lower)$
  if code $\geq x$ **then**
    $b_i \leftarrow upper$
    $code \leftarrow code - x$
    $length \leftarrow length - x$
  else
    $b_i \leftarrow lower$
    $length \leftarrow x$
  end if
  if length $<$ length_min **then**
    renorm_dec_interval()
  end if
  output b_i
end while

our method in multimedia application and especially to each binary bit plane of the gray-scale images of different size with 8-bits per pixel. Table II shows the compression results of the Lena binary bit plane images for both traditional BAC and our approach in static model and adaptive model. From Table II, the obtained bytes using both static and adaptive model are the same with and without using the encryption process. Thus, our proposed scheme conserves the compression efficiency.

Image size in pixels	Total elapsed time(s) using our method	
	in static model	in adaptive model
256×256	2.30	3.00
512×512	9.23	12.00
1024×1024	34.30	45.50

TABLE III
THE COMPRESSION AND ENCRYPTION SPEEDS OF OUR METHOD IN BOTH STATIC AND ADAPTIVE MODEL.

There is an other important issue on a compression and encryption scheme which is the running speed. The analysis has been done using a machine with Intel core 2 Duo 2.93 GHZ CPU and 2 GB RAM running on Windows XP Professional Edition. The execution times of our method for images with different size are shown in Table III.

The proposed compression and encryption scheme is based on a BAC whose two mapping intervals are exchanged randomly by using a PRBG. This scheme is sensitive to both plaintext and key. As shown in Figure 3, the ciphertext has uniform distribution for both on static model and adaptive model. Therefore, the proposed scheme does not provide any clue to employ any statistical attack on the ciphertext.

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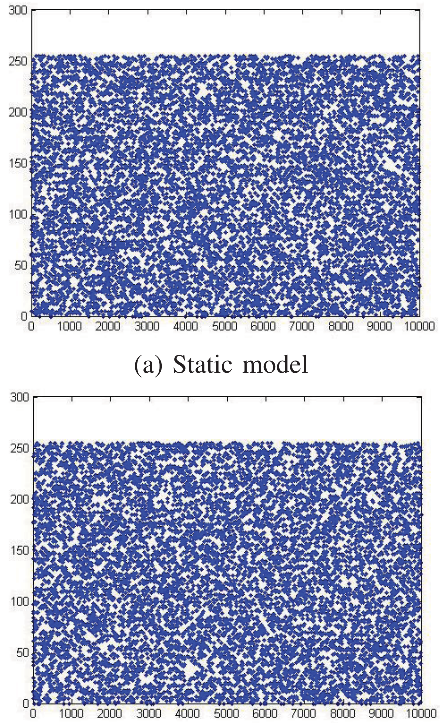

(a) Static model

(b) Adaptive model

Fig. 3. The uniform property of the ciphertext for the first $10,000$ bits of the encrypted Lena in (a) Static model and (b) Adaptive model.

VI. Conclusions

In this paper, we proposed a new scheme which combines BAC with a PRBG to perform both lossless compression and encryption of data. In our scheme, we exploit both the efficiency of the BAC in lossless data compression and the advantages of chaos theory in data encryption to provide a scheme which can be very useful in many applications such as multimedia applications and medical imaging.

References

[1] G. Alvarez, F. Montoya, M. Romera, and G. Pastor. Cryptanalysis of a Discrete Chaotic Cryptosystem Using External Key. *Physics Letters*, 9:319–334, 2003.

[2] G. A. Alvarez and L. B. Shujun. Cryptanalyzing a Nonlinear Chaotic Algorithm (NCA) for Image Encryption. *Communications in Nonlinear Science and Numerical Simulation*, 14(11):3743–3749, 2009.

[3] B. Carpentieri, M. J. Weinberger, and G. Seroussi. Lossless Compression of Continuous-Tone Images. *Proceedings of the IEEE*, 88(11):1797–1809, November 2000.

[4] T. J. Chuang and J. C. Lin. A New Algorithm for Lossless Still Image Compression. *Pattern Recognition*, 31(9):1343–1352, September 1998.

[5] J. Cleary, S. Irvine, and I. Rinsma-Melchert. On the Insecurity of Arithmetic Coding. *Computers and Security*, 14:167–180, 1995.

[6] M. Grangetto, E. Magli, and G. Olmo. Multimedia Selective Encryption by Means of Randomized Arithmetic Coding. *IEEE Transactions on Multimedia*, 8(5):905–917, October 2006.

[7] Y. Hartono, C. Kraaikamp, and F. Schweiger. Algebraic and Ergodic Properties of a New Continued Fraction Algorithm with Non-Decreasing Partial Quotients. *Journal de théorie des nombres de Bordeaux*, 14(2):497–516, 2002.

[8] A. B. Helen and M. H. James. A chosen plaintext attack on an adaptive arithmetic coding compression algorithm. *Computers and Security*, 12:157–167, 1993.

[9] P. G. Howard and J. S. Vitter. Arithmetic Coding for Data Compression. *Proceedings of the IEEE*, 82(6):857–865, Jun. 1994.

[10] A. Kanso and N. Smaoui. Logistic Chaotic Maps for Binary Numbers Generations. *Chaos, Solitons and Fractals*, 40:2557–2568, 2009.

[11] A. Y. Khintchin. Continued Fractions. *Noordhoff, Groningen*, 1963.

[12] H. Kim, J. Wen, and J. Villasenor. Secure Arithmetic Coding. *IEEE Trans Signal Processing*, 55(5):2263–2272, 2007.

[13] G. G. Langdon. An Introduction to Arithmetic Coding. *IBM Journal of Research and Development*, 28(2), Mar. 1984.

[14] S. Li and X. Mou. Improving Security of a Chaotic Encryption Approach. *Physics Letters A*, 290(3-4):127–133, 2001.

[15] L. Lorentzen and H. Waadeland. Continued Fractions with Applications. *North Holland*, 1992.

[16] G. Marsaglia. DIEHARD: A Battery of Tests of Randomness. *http://stat.fsu.edu/geo/diehard.html*, 1997.

[17] B. Mi, X. Liao, and Y. Chen. A Novel Chaotic Encryption Scheme Based on Arithmetic Coding. *Chaos, Solitons and Fractals*, 38:1523–1531, 2008.

[18] A. Moffat, R. M. Neal, and I. H. Witten. Arithmetic Coding Revisited. *ACM Transactions on Information Systems*, 16(3):256–294, Jul. 1998.

[19] V. Patidar, N. K. Parekk, and K. K. Sud. A New Substitution-Diffusion Based Image Cipher Using Chaotic Standard and Logistic Maps. *Communications in Nonlinear Science and Numerical Simulation*, 14:3056–3075, 2009.

[20] V. Patidar and K. K. Sud. A Novel Pseudo Random Bit Generator Based on Chaotic Standard Map and its Testing. *Electronic Journal of Theoretical Physics*, 6(20):327–344, 2009.

[21] A. Rukhin, J. Soto, J. Nechvatal, M. Smid, E. Barker, S. Leigh, M. Levenson, M. Vangel, D. Banks, A. Heckert, J. Dray, and S. Vo. Statistical Test Suite for Random and Pseudo Random Number Generators for Cryptographic Applications. *NIST special publication 800-22 Revision 1*, 2008.

[22] R. B. Seidensticker. Continued Fractions for High-Speed and High-Accuracy Computer Arithmetic. *in Proc. 6th IEEE Symp. Comput. Arithmetic*, 1983.

[23] S. Sudharsanan and P. Sriram. Block-based Adaptive Lossless Image Coder. In *Proc. IEEE Int. Conf. on Image Processing, Vancouver, BC, Canada*, pages 120–123, 2000.

[24] J. Vuillemin. Exact Real Computer Arithmetic with Continued Fractions. *INRIA Report 760. Le Chesnay, France: INRIA*, NOV. 1987.

[25] H. S. Wall. Analytic Theory of Continued Fractions. *Chelsea*, 1973.

[26] J. Wei, X. F. Liao, K. W. Wong, and T. Zhout. Cryptoanalysis of Cryptosystem Using Multiple one-Dimensional Chaotic Maps. *Communications in Nonlinear Science and Numerical Simulation*, 12:814–22, 2007.

[27] J.G. Wen, H. Kim, and J.D. Vilasenor. Binary Arithmetic Coding Using Key-Based Interval Splitting. *IEEE Signal Process Lett*, 13(2):69–72, 2006.

[28] I. H. Witten, R. M. Neal, and J. G. Cleary. Arithmetic Coding for Data Compression. *Communications of the ACM*, 30(6):520–540, Jun. 1987.

[29] K. W. Wong, B. S. H. Kwoka, and C. H. Yuena. An Afficient Diffusion Approach for Chaos-Based Image Encryption. *Chaos, Solitons and Fractals*, 41(5):2652–2663, 2008.

[30] X. G. Wu, H. P. Hu B. L., and Zhang. Analyzing and Improving a Chaotic Encryption Method. *Chaos, Solitons and Fractals*, 22(2):367–373, 2004.

[31] W. Xiaolin. An Algorithmic Study on Lossless Image Compression. In *Data Compression Conference*, pages 150–159. IEEE Computer Society Press, 1996.

[32] T. Yang. A Survey of Chaotic Secure Communication Systems. *Journal of Computational Cognition*, 2(2):81–130, 2004.

[33] L. Zhang, X. Liao, and X. Wang. An Image Encryption Approach Based on Chaotic Maps. *Chaos, Solitons and Fractals*, 24(3):759–765, 2005.

[34] J. Zhou, O. C. Au, X. Fan, and P. H. W. Wong. Joint security and performance enhancement for secure arithmetic coding. *ICIP*, pages 3120–3123, 2008.

[35] J. Zhou, O. C. Au, and P. H. Wong. Adaptive Chosen-Ciphertext Attack on Secure Arithmetic Coding. *IEEE Trans Signal Processing*, Feb. 2008.

http://sites.google.com/site/ijcsis/
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