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Enhancing Information Security and Cryptography Efficiency with the Kushare Transform

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الملخص:

ينصب التركيز في الوقت الحالي على ضمان أمن وسرية المعلومات، خاصة في ظل التهديد الذي يشكله المتسللون الذين يمكنهم الوصول غير المصرح به إلى البيانات الخاصة المتعلقة بالأفراد والمؤسسات. ولذلك، فمن الضروري أن يتم تشفير المعلومات بطريقة تؤدي إلى إخفائها بشكل فعال.

ولمعالجة هذه المشكلة، يظهر علم التشفير كحل قابل للتطبيق لحماية الرسائل والمعلومات المشتركة عبر الإنترنت. يقترح هذا البحث استخدام تقنيات التشفير وفك التشفير بناءً على نموذج رياضي يعتمد على طريقتين هما استخدام تحويل تكاملي أحادي كوشيرا وتحويل ثنائي لابلاس – كوشيرا لتشفير النص الأصلي، إلى جانب التحويلات العكسية المقابلة لفك التشفير. يعمل هذا النهج كوسيلة لتحصين المعلومات ضد الاختراق، مع تطبيقات عملية في الاستفادة من النماذج الرياضية المذكورة أعلاه لعمليات التشفير وفك التشفير.

الكلمات المفتاحية: تحويل كوشيرا؛ تحويل لابلاس؛ أمن المعلومات؛ تشفير؛ فك التشفير.

Abstract:
The focus lies on ensuring the security and confidentiality of information, particularly in light of the threat posed by hackers who can gain unauthorized access to private data belonging to individuals and institutions. Therefore, it is imperative that information be encoded in a manner that conceals it effectively.
To address this issue, encryption emerges as a viable solution for safeguarding messages and shared online information. This research proposes the utilization of encryption and decryption techniques based on a mathematical model.
Specifically, the unary Kushare integral transform and the binary Laplace-Kushare transform are employed for encrypting plaintext, along with their corresponding inverse transforms for decryption. This approach serves as a means of fortifying information against intrusion, with practical applications in utilizing the aforementioned mathematical models for encryption and decryption processes.
Keywords: Kushare transform; Laplace transform; Information Security; encrypt; decrypt.

1.Introduction

An encryption technique that converts information in some way into secret codes so that it is protected from unauthorized access. Encryption can be defined as a technique that converts readable graphical data (called plain text) into unambiguous data and text (called cipher text). An encryption encoder is the conversion of cipher text into plaintext (Koshy, 2007). Modern cryptography uses mathematical algorithms and secret keys to encrypt and decrypt data, shares significant overlap in applied mathematics, and has been used as a powerful tool in the field of building cryptosystems. The encryption value of encrypted information is neither broken nor delayed by the decryption time.
In this research, we use the symmetric encryption method (P. L. Chitraand K. Sathya, 2018), where there is a key at both ends and the encryption algorithm is similar to the decryption algorithm.
There is a shift towards using the Internet to transfer data, emphasizing the importance of information security and confidentiality. Steganography has emerged as a solution,

ensuring that only the intended recipient understands the message.
Many previous studies related to information security have addressed:
(G. Naga Lakshmi et al., 2011) proposed using the Laplace transform for encryption and its inverse for decryption, demonstrating its superiority over traditional methods.
Mahgoub (Kumar P. Senthil, Vasuki S., 2018), Aboodh (Abdelilah K. Hassan Sedeeg and others, 2016), and El-Zaki (Uttam Dattu Kharde, 2017) discovered cryptography using integral transformations.
(MampiSaha, 2017) developed an encoding model based on binary linear integral transformations, using the Laplace-Milne transform to encrypt the data, which concluded its effectiveness in protecting the data.
Unlike previous research, our study compares the unary Kushare transform and the efficiency of the dual Laplace- Kushare transform in enhancing information security and confidentiality. This evaluation includes definitions, properties, and theorems of encryption, the Laplace transform, and the Kushare transform.

2.Research problem

The research problem was defined in the following main question:
Are there mathematical models that guarantee the Enhancing Information Security and Cryptography Efficiency with the Kushare Transform to a high degree?
The sub-question is derived from it: Is the Kushare transform a good model to ensure security and confidentiality the information?

3. Research aims

The primary goal served by integral transformations is to provide a new method For the process of data encryption and decryption to maintain information security.
The article is divided into sections: definitions and basic concepts, encryption and decryption using the Kushare transform, using Kushare-Laplace encryption and decryption, then presenting the results and references.

4. Preliminaries

Definition 4.1. (Koshy, 2007)

Let a and b be integers and m a positive integer. Then $a \equiv b \ (mod\ m)$ if $m|(a-b)$.

Theorem 4.1. (Koshy, 2007)

Let $a \equiv b \ (mod\ m)$ if and only if $a = b + qm$ for some integer q.

Definition 4.2. (Kushare & Patil, 2021)

The Ku-transform denoted by the the conversion is represented by the symbol κ , defined by integral equations.

$$\kappa\{f(t)\} = S(v) = v\int_0^{\infty} f(t)e^{-tv^{\alpha}}dt, t \geq 0, \tau_1 \leq v \leq \tau_2$$

Where α is any non-zero real number.

and Inverse Kushare transform $f(t) = \kappa^{-1}\{S(v)\}$

Kushare and Inverse Kushare transform for some popular functions

1) $\kappa\{1\} \quad = \frac{1}{v^{\alpha-1}} = S(v)$
2) $\kappa\{t^n\} \quad = \frac{\Gamma(n+1)}{v^{\alpha(n+1)-1}} = S(v)$
3) $\kappa\{sin\, at\} = \frac{av}{v^{2\alpha}+a^2} = S(v)$
4) $\kappa^{-1}\left\{\frac{1}{v^{\alpha(n+1)-1}}\right\} = \frac{t^n}{\Gamma(n+1)} = f(t)$
5) $\kappa^{-1}\left\{\frac{av}{v^{2\alpha}+a^2}\right\} = sin\, at = f(t)$

Diagram (1) shows the relationship between κ and κ^{-1}

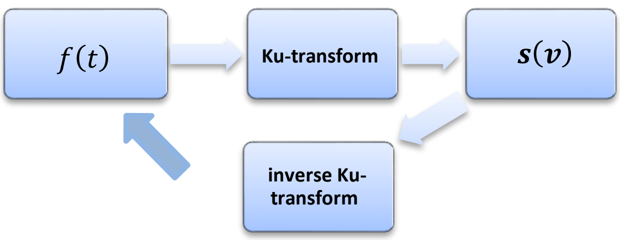


Diagram: (1) Element Models of Kushare transform

Definition 4.3. (Schiff, J.L, 1999)

The Laplace Transform denoted by the the conversion is represented by the symbol $\mathcal{L}$, defined by integral equations.

$$\mathcal{L}\{f(t)\} = \int_0^{\infty} e^{-st} f(t)dt = F(s) \qquad ; s \geq 0 \quad , \tau_1 \leq s \leq \tau_2$$

and Inverse Laplace transform $f(t) = \mathcal{L}^{-1}\{F(s)\}$

Laplace and Inverse Laplace transform for some popular functions

1) $\mathcal{L}\{1\} = \frac{1}{s}$
2) $\mathcal{L}\{t^n\} = \frac{n!}{s^{n+1}}$
3) $\mathcal{L}^{-1}\left\{\frac{n!}{s^{n+1}}\right\} = t^n$

4) $\mathcal{L}^{-1}\left\{\frac{1}{s}\right\} = 1$

If $f_1(t)$ and $f_2(t)$ are two functions and a,b are constant then Kushare transform (Patil, Tile & Mahajan, 2023) is Linear Property of $\kappa\{af_1(t) + bf_2(t)\} = a\kappa\{f_1(t)\} + b\kappa\{f_2(t)\}$ and inverse Kushare transform is Linear Property.

Laplace transform (Schiff, J.L, 1999) is Linear Property of $\mathcal{L}\{af_1(t) + bf_2(t)\} = a\mathcal{L}\{f_1(t)\} + b\mathcal{L}\{f_2(t)\}$ and inverse Laplace transform is Linear Property.

5. Application of Enhancing Information Security and Cryptography Efficiency

5.1. Cryptographic method on Ku- Transform

5.1.1.Encyption Algorithm

Step 1: The sender and receiver agree on the encryption key, before starting the encryption process.

Step 2: Ku-transform is used in the proposed encryption algorithm. For the Maclaurin series of $sin\, at$ in Eq. (1). Likewise for the function $t\, sin\, at$ the plaintext is determined using Eq. (2).

$$sin\, at = at - \frac{a^3t^3}{3!} + \frac{a^5t^5}{5!} - \frac{a^7t^7}{7!} + \frac{a^9t^9}{9!} - \cdots = \sum_{n=0}^{\infty} \frac{(-1)^n (at)^{2n+1}}{(2n+1)!} \qquad (1)$$

where $a \in \mathbb{N}$ is a constant, and so

$$t\, sin\, at = at^2 - \frac{a^3t^4}{3!} + \frac{a^5t^6}{5!} - \frac{a^7t^8}{7!} + \frac{a^9t^{10}}{9!} - \cdots = \sum_{n=0}^{\infty} \frac{(-1)^n (a)^{2n+1} (t)^{2n+2}}{(2n+1)!} \qquad (2)$$

The number 0 represents the letter *A*, the number 1 represents the letter *B*, and so on to *Z*, which is represented by the number 25.

Step 3: The plain text of the word "DISCOVERY" was equivalent to

3 , 8 , 18, 2, 14 ,21 ,4 ,17, 24.

Recognizing coefficients that

$$C_0 = 3, C_1 = 8, C_2 = 18, C_3 = 2, C_4 = 14, C_5 = 21, C_6 = 4, C_7 = 17,$$
$$C_8 = 24, C_n = 0 \ \forall\, n \geq 9.$$

Writing these numbers as a coefficients of t sin t, and assuming $f(t) = C\, t\, sin\, t$, we get

$$f(t) = C_0t^2 - C_1\frac{t^4}{3!} + C_2\frac{t^6}{5!} - C_3\frac{t^8}{7!} + C_4\frac{t^{10}}{9!} - C_5\frac{t^{12}}{11!} + C_6\frac{t^{14}}{13!} - C_7\frac{t^{16}}{15!} + C_8\frac{t^{18}}{17!}$$
$$= \sum_{n=0}^{n=8} \frac{(-1)^n (t)^{2n+2}}{(2n+1)!}\, C_n$$

Step 4: Take Ku-transform on both sides the have

$$\kappa[f(t)] = \kappa[t\ \sin t] = 3\frac{2!}{1!}.\frac{1}{v^{3\alpha-1}} - 8\frac{4!}{3!}.\frac{1}{v^{5\alpha-1}} + 18\frac{6!}{5!}.\frac{1}{v^{7\alpha-1}} - 2\frac{8!}{7!}.\frac{1}{v^{9\alpha-1}} + 14\frac{10!}{9!}.\frac{1}{v^{11\alpha-1}} - 21\frac{12!}{11!}.\frac{1}{v^{13\alpha-1}} + 4\frac{14!}{13!}.\frac{1}{v^{15\alpha-1}} - 17\frac{16!}{15!}.\frac{1}{v^{17\alpha-1}} + 24\frac{18!}{17!}.\frac{1}{v^{19\alpha-1}}$$

$$= 6.\frac{1}{v^{3\alpha-1}} - 32.\frac{1}{v^{5\alpha-1}} + 108.\frac{1}{v^{7\alpha-1}} - 16.\frac{1}{v^{9\alpha-1}} + 140.\frac{1}{v^{11\alpha-1}} - 252.\frac{1}{v^{13\alpha-1}} + 56.\frac{1}{v^{15\alpha-1}} - 272.\frac{1}{v^{17\alpha-1}} + 432.\frac{1}{v^{19\alpha-1}}$$

Now let assume that

$$P_0 = 6, P_1 = -32, P_2 = 108, P_3 = -16, P_4 = 140, P_5 = -252\ ,$$
$$P_6 = 56,\ P_7 = -272\ ,\ P_8 = 432, P_n = 0\ \forall\, n \geq 9.$$

And we will obtain P′ such that

$$P_n \equiv P_n'\ mod\ 26$$

Table 1. Values P'_n included in the coding proposal

n	P'_n
0	6
1	20
2	4
3	10
4	10
5	8
6	4
7	14
8	16

Step 5: Sender sends the values,

$$6, -32, 108, -16, 140, -252, 56, -272, 432$$

assuming

$$P_0' = 6, P_1' = 20, P_2' = 4, P_3' = 10, P_4' = 10, P_5' = 8, P_6' = 4, P_7' = 14, P_8' = 16$$

The givenplain text was converted ti cipher text

$$6, 20, 4, 10, 10, 8, 4, 14, 16$$

The messge “DISCOVERY” was converted to “GUEKKIEOQ”

Step 6: Find the key k_n such that $k_n = \frac{P_n - P_n'}{26}$ for all $n = 0,1,2, \ldots$

$$K_0 = 0, K_1 = -2, K_2 = 4, K_3 = -1, K_4 = 5, K_5 = -10, K_6 = 2,$$

$K_7 = -11, K_8 = 16.$

5.1.2.Decyption Algorithm

Step 1: Take the ciphertext and key received from the sender. In the example above, ciphertext is "GUEKKIEOQ" and the key

0 , -2 , 4 , -1 , 5 , -10 , 2 , -11 , 16

Step 2: Convert the ciphertext corresponding to the finite sequence of numbers

$$P'_0, P'_1, P'_2, P'_3, P'_4, P'_5, P'_6, P'_7, P'_8$$

6 , 20 , 4 , 10, 10 , 8 , 4 ,14 , 16

Step 3: *Let* $P_n \equiv 26K_n + P'_n , \forall n = 0,1,2,. ....$

Table 2. Values P_n included in the coding proposal

n	P_n
0	6
1	-32
2	108
3	-16
4	140
5	-252
6	56
7	-272
8	432

Step 4: Let $S(v) = \sum_{n=0}^{\infty} C_n \frac{(-1)^n (at)^{2n+1}}{(2n+1)!}$

$$= 6.\frac{1}{v^{3\alpha-1}} - 32.\frac{1}{v^{5\alpha-1}} + 108.\frac{1}{v^{7\alpha-1}} - 16.\frac{1}{v^{9\alpha-1}} + 140.\frac{1}{v^{11\alpha-1}}$$
$$- 252.\frac{1}{v^{13\alpha-1}} + 56.\frac{1}{v^{15\alpha-1}} - 272.\frac{1}{v^{17\alpha-1}} + 432\,.\frac{1}{v^{19\alpha-1}}$$
$$= 3\frac{2!}{1!}.\frac{1}{v^{3\alpha-1}} - 8\frac{4!}{3!}.\frac{1}{v^{5\alpha-1}} + 18\frac{6!}{5!}.\frac{1}{v^{7\alpha-1}} - 2\frac{8!}{7!}.\frac{1}{v^{9\alpha-1}} + 14\frac{10!}{9!}.\frac{1}{v^{11\alpha-1}}$$
$$- 21\frac{12!}{11!}.\frac{1}{v^{13\alpha-1}} + 4\frac{14!}{13!}.\frac{1}{v^{15\alpha-1}} - 17\frac{16!}{15!}.\frac{1}{v^{17\alpha-1}}$$
$$+24\frac{18!}{17!}\,.\frac{1}{v^{19\alpha-1}}$$

Step 5: Now take the inverse Ku-transform of $S(v)$ in Step 4 we get

$$\kappa^{-1}(S(v)) = f(t)$$
$$= 3t^2 - 8\frac{t^4}{3!} + 18\frac{t^6}{5!} - 2\frac{t^8}{7!} + 14\frac{t^{10}}{9!} - 21\frac{t^{12}}{11!} + 4\frac{t^{14}}{13!} - 17\frac{t^{16}}{15!} + 24\frac{t^{18}}{17!}.$$

Step 6: Considering the coefficients of the series $f(t)$ is finite

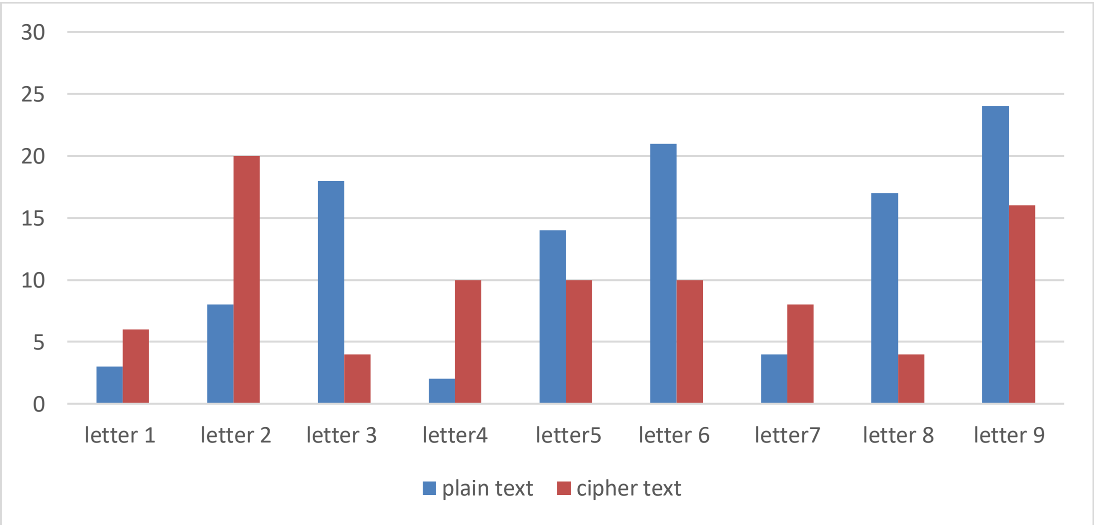
3 ,8 , 18 , 2 ,14 , 21 , 4 , 17 , 24

Step 7: Now we have translated the above limited number of sequences into alphabets. We get the original plaintext "DISCOVERY".

The previous steps can be abbreviated as in the diagram(2)

***Diagram:* (2)** *Block diagram symmetric Key of data encryption and decryption us Ku-transform*

Figure:(1) Relative frequency of letters in the original text and the cipher text



5.2. Cryptographic method on based Laplace- Ku- Transform

5.2.1.Encyption Algorithm

We follow **Step1** to **Step 4** as in the previous paragraph 5.1.1

Take Ku-transform on both sides the have

$$\kappa[f(t)] = \kappa[t\ \sin t] = 3\frac{2!}{1!}.\frac{1}{v^{3\alpha-1}} - 8\frac{4!}{3!}.\frac{1}{v^{5\alpha-1}} + 18\frac{6!}{5!}.\frac{1}{v^{7\alpha-1}} - 2\frac{8!}{7!}.\frac{1}{v^{9\alpha-1}} +$$

$$14\frac{10!}{9!}.\frac{1}{v^{11\alpha-1}} - 21\frac{12!}{11!}.\frac{1}{v^{13\alpha-1}} + 4\frac{14!}{13!}.\frac{1}{v^{15\alpha-1}} - 17\frac{16!}{15!}.\frac{1}{v^{17\alpha-1}} + 24\frac{18!}{17!}.\frac{1}{v^{19\alpha-1}}$$
$$= 6.\frac{1}{v^{3\alpha-1}} - 32.\frac{1}{v^{5\alpha-1}} + 108.\frac{1}{v^{7\alpha-1}} - 16.\frac{1}{v^{9\alpha-1}} + 140.\frac{1}{v^{11\alpha-1}} - 252.\frac{1}{v^{13\alpha-1}} + 56.\frac{1}{v^{15\alpha-1}} - 272.\frac{1}{v^{17\alpha-1}} + 432.\frac{1}{v^{19\alpha-1}}$$

Put $\alpha = -1$

$$\kappa\{f(t)\} = \kappa\{t \ \sin t\}$$
$$= 6.v^4 - 32.v^6 + 108.v^8 - 16.v^{10} + 140.v^{12} - 252.v^{14} + 56.v^{16} - 272.v^{18} + 432.v^{20}$$

Step 5: applying Laplace transform on $\kappa\{f(t)\}$

$$\mathcal{L}\{K\{f(t)\}\} = \mathcal{L}\{K\{t \ \sin t\}\}$$
$$= \mathcal{L}\{6.v^4 - 32.v^6 + 108.v^8 - 16.v^{10} + 140.v^{12} - 252.v^{14} + 56.v^{16} - 272.v^{18} + 432.v^{20}\}$$
$$= 6.\frac{4!}{s^5} - 32.\frac{6!}{s^7} + 108.\frac{8!}{s^9} - 16.\frac{10!}{s^{11}} + 140.\frac{12!}{s^{13}} - 252.\frac{14!}{s^{15}} + 56.\frac{16!}{s^{17}} - 272.\frac{18!}{s^{19}} + 432.\frac{20!}{s^{21}}$$

Now let assume that

$$P_0 = 6(4!), P_1 = -32(6!), P_2 = 108(8!), P_3 = -16(10!), P_4 = 140(12!),$$
$$P_5 = -252(14!), \quad P_6 = 56(16!), \quad P_7 = -272(18!), P_8 = 432(20!),$$
$$P_n = 0 \ \ \forall\, n \geq 9.$$

And we will obtain P' such that

$$P_n \equiv P_n' \ mod\ 26$$

Table 3. Values P'_n included in the coding proposal

n	P'_n
0	14
1	2
2	2
3	8
4	16
5	0
6	0
7	0

8	0

Step 6: Sender sends the values,
$6(4!), -32(6!), 108(8!), -16(10!), 140(12!), -252(14!),\ 56(16!),$
$-272(18!), 432(20!)$
assuming

$$P_0' = 14, P_1' = 2, P_2' = 2, P_3' = 8, P_4' = 16, P_5' = 0, P_6' = 0, P_7' = 0, P_8' = 0$$

The givenplain text was converted ti cipher text

14 ,2,2,8,16,0,0,0,0

The messge "DISCOVERY" was converted to "OCCIQAAAA"

Step 6: Find the key k_n such that $k_n = \frac{P_n - P_n'}{26}$ for all $n = 0,1,2, \ldots$

$$K_0 = 5, K_1 = -637, K_2 = 167483,$$

Likewise, values can be found K_3, K_4, K_5, K_6, K_7 to $K_8 = \frac{432(20!)}{26}$.

5.2.2.Decyption Algorithm

Step 1: Take the ciphertext and key received from the sender. In the example above, the ciphertext is "OCCIQAAAA" and the key

$$5, -637, \quad \ldots \quad , \frac{432(20!)}{26}.$$

Step 2: Convert the ciphertext corresponding to the finite sequence of numbers

$$P_0' = 14, P_1' = 2, P_2' = 2, P_3' = 8, P_4' = 16, P_5' = 0, P_6' = 0, P_7' = 0, P_8' = 0$$

Step 3: Let $P_n = 26K_n + P_n'$, $\forall n = 0,1,2, \ldots..$

Table 4. Values P_n included in the coding proposal

n	P_n
0	6(4!)
1	23(6!)
2	12(9!)
3	- 16 (10!)
4	14(12!)
5	-252(14!))
6	56(16!)

7	$-272(18!)$
8	$432(20!)$

Step 4: Let $\mathcal{L}\{\kappa\{f(t)\}\} = \sum_{n=0}^{\infty}\frac{P_n}{s^{2n+5}}$

$$= \frac{P_0}{s^5}+\frac{P_1}{s^7}+\frac{P_2}{s^9}+\frac{P_3}{s^{11}}+\frac{P_4}{s^{13}}+\frac{P_5}{s^{15}}+\frac{P_6}{s^{17}}+\frac{P_7}{s^{19}}+\frac{P_8}{s^{21}}$$

Step 5: Now take the inverse Laplace transform and inverse Ku-transform of $S(v)$ in Step 4 we get

$$\kappa\{f(t)\} = \mathcal{L}^{-1}\{\frac{P_0}{s^5}+\frac{P_1}{s^7}+\frac{P_2}{s^9}+\frac{P_3}{s^{11}}+\frac{P_4}{s^{13}}+\frac{P_5}{s^{15}}+\frac{P_6}{s^{17}}+\frac{P_7}{s^{19}}+\frac{P_8}{s^{21}}\}$$

$$= P_0\frac{v^4}{4!}+P_1\frac{v^6}{6!}+P_2\frac{v^8}{8!}+P_3\frac{v^{10}}{10!}+P_4\frac{v^{12}}{12!}+P_5\frac{v^{14}}{14!}+P_6\frac{v^{16}}{16!}$$

$$+P_7\frac{v^{18}}{18!}+P_8\frac{v^{20}}{20!}.$$

$$f(t) = \kappa^{-1}\{\frac{P_0}{4!\,v^{3\alpha-1}}+\frac{P_1}{6!\,v^{5\alpha-1}}+\frac{P_2}{8!\,v^{7\alpha-1}}+\frac{P_3}{10!\,v^{9\alpha-1}}+\frac{P_4}{12!\,v^{11\alpha-1}}+\frac{P_5}{14!\,v^{13\alpha-1}}$$

$$+\frac{P_6}{16!\,v^{15\alpha-1}}+\frac{P_7}{18!\,v^{17\alpha-1}}+\frac{P_8}{20!\,v^{19\alpha-1}}\}$$

$$= P_0\frac{t^2}{4!\,2!}+P_1\frac{t^4}{6!\,4!}+P_2\frac{t^6}{8!\,6!}+P_3\frac{t^8}{10!\,8!}+P_4\frac{t^{10}}{12!\,10!}+P_5\frac{t^{12}}{14!\,12!}+P_6\frac{t^{14}}{16!\,14!}$$

$$+P_7\frac{t^{16}}{18!\,16!}+P_8\frac{t^{18}}{20!\,18!}.$$

Then

$$f(t) = 3\frac{t^2}{1!}-8\frac{t^4}{3!}+18\frac{t^6}{5!}-2\frac{t^8}{7!}+14\frac{t^{10}}{9!}-21\frac{t^{12}}{11!}+4\frac{t^{14}}{13!}-17\frac{t^{16}}{15!}+24\frac{t^{18}}{17!}.$$

Step 6: Considering the coefficients of the series $f(t)$ is finite

3 , 8 , 18 ,2 , 14 ,21,4,17,24

Step 7: Now we have translated the above limited number of sequences into alphabets. We get the original plaintext "DISCOVERY".

in above technique we use $\{\mathcal{L}\kappa\}^{-1} = \mathcal{L}^{-1}\kappa^{-1}$

CONCLUSION

- This article explained that the Ku- transform is a good mathematical model that guarantees the confidentiality, protection and security of data from any attack.
- Ku- transform is more easy in the application than others.
- Ku -transformation has been applied to enhance information security they

obtained result is compared with the results of the Laplace, Zakie and Mahgoub transformations, Similar results.

- Since confidentiality lies in the encryption key, there is the possibility of generating and changing the key to ensure enhanced data security.
- The encryption keys used are random and difficult to detect.
- The second method used in this research is considered more secure and guarantees the confidentiality of information.

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