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Hyperchaotic technology-based efficient image encryption algorithm an overview.

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ABSTRACT

Multimedia data encryption is so crucial because the multimedia encryption algorithm needs more time and memory, and it is difficult to implement. Because of this, the hyperchaotic image encryption technique is becoming more and more popular, which uses little memory, time, or energy and offers the highest level of security for low-powered devices. This study offers a comprehensive overview of modern hyperchaotic systems. By focusing on these complex systems' uniqueness and fundamental features, a study of their dynamic behavior is offered. Such systems are now being used more and more in a variety of industries, including finance, secure communication, and encryption, for example. In reality, every field calls for particular performances of unusual complexity. This research then suggests a specific classification based on the crucial hyperchaotic characteristic, Lyapunov exponent, the equilibrium points, dynamical behavior, NPCR, and UACI..

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Introduction:

Nowadays, the high growth of digital multimedia technology leads to more challenges in security fields, more multimedia data are transmitted through computer networks [1] .the security of computerized images is turning into a major issue. Numerous image encryption methods are used to advance the security of images as their criticalness spread over the security,security and transfer of advanced information, images, and features are required in numerous genuine applications, for example, pay television, medical image frameworks, military image databases, remote sensing, remote learning, video conference, and so on [2][3]Modern cryptography depends on computer science practice and mathematical theory and it is hard to break and understand by any adversary in practice.Chaos in cryptology applications became a popular research area and proposed the massive chaos encryption algorithm [4] because of their parameters, high sensibility to initial values, unpredictability, and good pseudo-randomness of orbits, hyperchaotic systems are very suitable for image encryption [5].

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2.(Visual cryptography)

Now most of the networks are popular for the processing of the information of digital images, which is transferred in the system region, related to confidential secrets and private information Some scrambled calculations might be crucial to increase a satisfactory level of security to defeat the above confinements. The difficulties begin from the preparatory step, for example, how to make the content secure while minimizing computational overhead because of the vast size of information, The fact that data encryption is a key measure for information security in a computer network; however, most encryption and authentication systems designed to deal with passwords are text messages[8][9].

Visual cryptography is a cryptographic technique that allows visual information (pictures, text, etc.) to be encrypted in such a way that decryption can be done just by vision reading. Visual cryptography, a degree associated with rising cryptography technology, uses the characteristics of human vision to rewrite encrypted images. Visual cryptography provides secured digital transmission that is used just for merely once.[10][11].

There are many applications of Visual Cryptography some of them are following:

2. Copyright Protection 1. Secret Communication

3. Document Authentication 4. Secret data

.3.Chaos Theory

Chaos has praised its technological advancement since its debut in 1963. Their unexpected dynamic behaviors and great sensitivity to the initial state of the condition, justify this [12]. It has been demonstrated that a minute change in the starting circumstances multiplies exponentially over time and produces unforeseen outcomes security for multimedia data assets, including movies and images, has grown to be a significant issue [1]. Several image encryption techniques have been developed to safeguard this kind of data [13]. Because an image's adjacent pixels have a high degree of connection and require a lot of data, AES, DES, IDEA, and RSA are examples of preliminary approaches that are not capable of providing accurate encryption[14]. To address this issue, researchers have concentrated on approaches that address both confusion and criteria for diffusion, numerous hyper chaos-based algorithms have been presented recently and have gained a lot of support from academics[1]. The image encryption which is based on chaos systems suits high-security encryption due to the properties of chaos systems that are inherent to them, such as sensitivity to beginning value and randomness Nonlinear deterministic dynamical systems that produce pseudorandom sequences are known as chaotic systems [6] [15]. Because of their distinctive characteristics, chaos theories are viewed as being advantageous to multimedia encryption and enhancing the cryptosystem resistance to statistical attacks and the attributes are [5].

Important characteristics of chaos theory:

1- Mixing
2- Non-periodicity.
3- Highly sensitive to system parameters.
4- Pseudo-random.
5- Highly sensitive to initial conditions.

4.Methodologies of image encryption using hyperchaotic

One-dimensional logistical maps. [11] Henon's two-dimensional maps [12] and three-dimensional chaotic Lorenz systems [13] are an example of chaotic order. Low-dimensional chaos also has the disadvantages of small keyspace and low security, despite the fact that both one-dimensional and two-dimensional chaotic maps of chaotic systems have the advantages of simple mapping and high efficiency. [14].

Important characteristics of chaos theory include nonlinear dynamics and sensitivity to beginning conditions. Chaos in systems is characterized by sensitivity to beginning conditions. [15]. Edward Lorenz reported the findings of his differential system calculations of atmospheric thermal displacement and noted that, under some conditions, the system response exhibits irregular variations without the involvement of random elements or external disturbance. He came to the conclusion that even a little modification in the initial conditions of the equations used to predict atmospheric conditions would cause significant variations in the results. Numerous scientific fields, including secure communication, have been interested in chaos. [16], unreliable circuits While being difficult, the mapping of high-dimensional chaos provides better randomness and unpredictability as a result of which the key space is bigger and more secure. It can resist decryption of the phase space reconstruction and plaintext attacks, and better security is guaranteed Hyper chaotic systems are widely applied in the cryptography domain on account of their more complex dynamical behavior[17].

5.Related work

Zhouyi Hu and Chun-Kit Chan 2018 [22] suggested a 7-dimensional (7-D) hyperchaotic system with five positive Lyapunov exponents is created to satisfy the requirements of this encryption scheme and further increase security. Walsh-Hadamard transform (WHT) is utilized along with the discrete cosine transform (DCT) in this system to simultaneously expand key space and decrease computation complexity.Using four positive Lyapunov exponents, a hyperchaotic four dimensional fractional discrete Convolutional neural network system(4DFDHNN) is developed in [18] by **Liu, Zefei 2021** [21] Use four positive Lyapunov exponents, a hyperchaotic four dimensional fractional discrete Convolutional neural network system (4DFDHNN) and developed by comparing and analyzing,so chaotic dynamics Characteristics are confirmed, To increase the encryption technique effectiveness, they suggested a

Hilbert dynamic random diffusion method for the advanced diffusion phase simultaneously changing the pixel value size and location. **Xiaohong Gao et al 2021** [31] They suggested two 1D chaotic maps were used to introduce 2D hyperchaotic maps. The 2D hyperchaotic map's dynamic properties show that it possesses a universal attractor, good randomness and ergodicity, and a higher value complexity. Results indicate that the encryption method has greater key sensitivity and can fend off attacks including noise, differential, and aggressive ones. As a result, the newly developed technique provides more security for digital image encryption. **Fawad Masood** 2021 [24] highlighted the need for a secure encryption technique to protect confidential information in medical images. Proposed,that combines chaos theory with Brownian motion (BM) and Chen's chaotic system (CCS) the proposed system requires less computational resources and, at the same time, offer fast processing making it suitable for application in real-time encryption

Sadiq Abdul Aziz et al 2020[23] They describe a novel five-dimensional hyper-chaotic system with twelve positive parameters. They used equilibrium points, dissipative features, symmetry, Lyapunov proponents, waveform analyses, and sensitivity to initial conditions for examining the chaotic system's fundamental features and dynamic behaviors. Results confirm that the a hyperactivity system, random, and shows great complexity, because of its high sensitivity to primary conditions and is thus unpredictable for long periods. **Tsafack Nestor2022** [25] proposed the two positive Lyapunov exponents of a new 4D hyper chaotic nonlinear dynamical systems provided, It consists of a bit-wise diffusion phase and a pixel-based permutation round, input image SHA-256 value had utilized to calculate the 4D map's secret key. It serves as the input image's signature. Because of the extreme secret key sensitivity to single-bit image modifications, the cryptosystem is resistant to selected/known-plaintext attacks **.** **Alireza Arab et al 2021** [27] They designed an approach to decreasing the algorithm's time complexity and adding the diffusion capability to the new algorithm. Its space of key was big enough for resisting brute-force attacks images of input so small modifications can mad significant shifts in the encrypted images. The keys are created in the color image encryption algorithm, through SHA-512 of the hash function, and according to simulation results the plain color image information. It has good chaotic performance. **T. Gopalakrishnan'S et al. 2021** [26] They offered the hyper-chaotic mapping used to permute and diffuse in image encryption. In the actual permutation stage, an image has been scramble using a 2D hyper-chaotic map that generates permutation orders. Lorenz's and Chen's multiple hyper-chaotic maps further disperse it method substantially diluting the permuted image to produce randomization features. The cross 2D hyperchaotic map is constructed using one nonlinear function and two chaotic maps with cross structure proposed by **Lin Teng et al**[29]. Chaotic behaviors are illustrated using bifurcation diagrams, Lyapunov exponent spectra and phase portraits, etc. In the color image encryption algorithm, the keys are generated using hash function SHA-512 and the information of a plain color image. It has good chaotic performance, according to simulation results. **Jannatul Ferdush et al**[30] They have researched the lightweight chaotic-based image encryption technique. They initially introduced a common framework and technique for light image encryption based on two chaotic maps, such as Arnold and logistic, and ran some tests. The encrypted image does not provide any information to the attacker. The proposed solution also takes less time to implement than the current methods and is resistant to brute force attacks. **Basil H. Jasim1et al**[31]This study introduces a straightforward 4-dimensional hyperchaotic system. Since the suggested system lacks equilibrium points, it allows for hidden attractor, an intriguing characteristic of chaotic systems. One other intriguing aspect of the The coexistence of attractors in the proposed system demonstrates periodic and coexisting chaotic attractors. The system is first introduced, then it is Using computational and theoretical methods, dynamics are examined. Bifurcation diagrams, Lyapunov exponents, and analysis have all examined the ranges of system parameters, chaotic and hyperchaotic character. for various actions, the path to chaos, and the drivers of coexistence regions. develop a synchronization control mechanism for There are two identical systems planned, The design procedure uses a combination of simple synergetic control with adaptive updating laws to identify the unknown parameters derived based on

Lyapunov theorem. Microcontroller (MCU) based hardware implementation system is proposed and tested by using MATLAB as a display side. As an application, the designed synchronization system is used as a secure analog communication system. The designed MCU system with MATLAB Simulations used to validate the designed synchronization and secure communication systems and excellent results have been obtained. **Dumitru Baleanu et al 2021**[30] This study introduces a straightforward 4-dimensional hyperchaotic system. Since the suggested system lacks equilibrium points, it allows for hidden attractor, an intriguing characteristic of chaotic systems. One other intriguing aspect of the attractors in the new system demonstrates periodic and coexisting chaotic attractors.Two 1D chaotic maps were used to introduce a 2D hyperchaotic map suggested by **Xiaohong Gao et al 2021** [31] They suggested two 1D chaotic maps were used to introduce 2D hyperchaotic maps. The 2D hyperchaotic map's dynamic properties show that it possesses a universal attractor, good randomness and ergodicity, and a higher value complexity. Results indicate that the encryption method has greater key sensitivity and can fend off attacks including noise, differential, and aggressive ones. As a result, the newly developed technique provides more security for digital image encryption.

All of the above is an explanation and analysis of the algorithms and encryption methods that use sequential encryption. Let's explain the difference between them by applying encryption.Now we review the methods that use block encryption Block cryptosystems have been essential in the last few decades for providing data secrecy for storage and communication. To satisfy Shannon's condition of confusion, cryptographically powerful S-boxes are used in current block ciphers to accomplish this. Several substitution-permutation (S-P) networks or Feistel networks-based block cryptosystems, including the well-known data encryption standard (DES), Blowfish, advanced encryption standard (AES), Anubis, PRESENT, etc., rely on S-boxes as essential building blocks.as in [34][35] [36][37]

Eesa Al Solami 2018[34] They suggested a new hyperchaotic system with complex dynamics, describing a novel technique for building cryptographically robust bijective substitution boxes. Comparing the performance of the new S-box approach reveals its supremacy and efficacy for a strong S-box objectivity in construction. **Hala Saeed et al 2022** [35]Suggest a technique built on the hyperchaotic map foundation, numerous chaotic maps, and an S-box encoding color images. a two-level method for changing color image data was devised. The construction of the 3D Hénon map and 1D logistic map has successfully demonstrated its effectiveness against a variety of cryptographic attacks. **Adi alhudhaif 2021** [34] The suggested 5-D dynamical system contains Complex phase attractors,conservative, unstable equilibrium point, hyperchaotic phenomenon that makes it suitable for cryptography applications. The proposed 5-D dynamical system contains complex phase attractors, a conservative, unstable equilibrium point, and a hyperchaotic phenomenon that make it suitable for cryptography applications. In comparison to other recently examined S-boxes, the proposed S-box justifies its superior strength and characteristics. The hyperchaotic system-based S-box is created by **Nirmal Chaudhary et al 2022** [37] the Arnold cat and logistic maps are utilized, whilst the block cipher approach uses the advanced encryption standard (AES). the chaotic algorithm application to encrypt images and are evaluated for many performance metrics The findings demonstrate the superior UACI and NPCR values of hybrid chaotic maps which makes it more resistant to the chosen plain text assaults or differential attacks.

Titel	Author	Method	Dimension Equilibrium point	NPCR and UACI	Result
A New Hyperchaotic System-Based Design for Efficient Bijective Substitution-Boxes	Eesa Al Solami 2018 [34]	Using the complex dynamics of a new hyperchaotic system, bijective substitution-boxes	5		suitable for use in a powerful block cipher architecture as well as other security applications

DESIGN AND ANALYSIS OF A NOVEL FIVE- IMENSIONAL HYPER-CHAOTIC SYSTEM	**A new 4-D hyperchaotic hidden attractor system: Its dynamics, coexisting attractors, synchronization and microcontroller mplementation**	**Image Encryption Using Hyper- chaotic Map for Permutation and Diffusion by Multiple Hyper- chaotic Maps**	**An image encryption method based on chaos system and AES algorithm**	**A 7-D Hyperchaotic System-Based Encryption Scheme for Secure Fast-OFDM-PON**
Sadiq Abdul Aziz2020[25]	**Basil H. Jasim 1et a2020 l[31]**	**T. Gopalakrishnan 2019 [39]**	**Alireza Arab et a2019l[28]**	**Zhouyi Hu; Chun-Kit Chan2018[22]**
The novel system has twelve positive parameters and is tested through equilibrium points.	**The coexistence of attractors in the proposed system exhibits both periodic and chaotic attractors.**	**Lorenz's and Chen's system**	**Chaos and the modified AES algorithm.**	**I/Q encryption in two steps for fast-OFDM signals**
5D 2 unstable	**4D no equilibria points**	**2D**	**1D**	
		99.68 33.79	**77.8 0.93**	**7D**
suitable to be used in numerous applications and could be employed in information encryption,	**effectiveness of the designed synchronization**	**robust security and its validity**	**secure against the entropy attacks**	**improving physical layer security in fast orthogonal frequency division multiplexing passive optical network (fast-OFDM-PON).**

Block Cipher Nonlinear Confusion Components Based on New 5-D Hyperchaotic System	**A DNA image encryption based on a new hyperchaotic system**	**Chaotic Lightweight Cryptosystem for Image Encryption**	**Color Image Encryption Based on Cross 2d Hyperchaotic Map Using Combined Cycle Shift Scrambling and Selecting Diffusion**	**Synchronization of 6D hyper-chaotic system with unknown parameters in the presence of disturbance and parametric uncertainty with unknown bounds**
adi alhudaif et al 2021 [36]	**Yuanyuan Hui2021[40]**	**Jannatul Ferdush et a2021l[30]**	**Lin Teng et a 2021l[29]**	**Alireza Sabaghian 2020[16]**
creating block ciphers' (S-boxes). Based on a unique, the predicted S-box design scheme)	**Secure Hash Algorithm-512 (SHA-512) function**	**lightweight image encryption technique based on chaos.**	**created using two chaotic cross-structured maps and one nonlinear function**	**synchronization of two 6D hyper-chaotic systems**
5D unstability	**4D zero**		**2D**	**Two system 6D**
		99.53 26.51(lina)	**99.62 33.47**	
use in block ciphers lightweight block cipher based on proposed S-box	**resist exhaustive attacks, statistical attacks and plaintext attacks.**	**lowered security and memory requirements**	**a secure algorithm that can encrypt color images**	**Simulation results in MATLAB demonstrate the applicability of controllers in the presence of disturbance and uncertainty**

New Image Encryption Algorithm Using Hyperchaotic System and Fibonacci Q-Matrix	Efficient Hyperchaotic Image Encryption Algorithm Based on a Fast Key Generation Method and Simultaneous Permutation-Diffusion Structure	Hyperchaotic behaviors, optimal control, New 4D and synchronization of a no autonomous cardiac conduction system	A Lightweight Chaos- Based Medical Image Encryption Scheme Using Random Shuffling and XOR Operations	Image encryption algorithm based on 2D hyperchaotic map
Khalid M. [42]Hosny , et al2021	Bin Ge[41] 2021	Basil H. Jasim et al2021[26]	Fawad Masood2021 [24]	[33] Xiaohong Gao2021
noise and data cut attacks, histograms, keyspace, and sensitivity.	simultaneous permutation-diffusion and a quick key generation method	analysis, optimal control, and synchronization	security. Medical picture encryption using Chen's chaotic system and the Henon chaotic map with higher security .	Row and column shifting, followed by forward and backward diffusion, are employed to confuse the image.
	4	3 unstable	2	2
		4D		
fantastic level of protection and outperformed the presently used image encryption techniques.	greater security and more robustness to withstand popular assaults including differential, brute-force, and statistical	flexible behavior	provides improved security due to the high key space associated with it.	This algorithm is still not entirely secure and effective.

A New 4D Hyperchaotic System with Dynamics Analysis,Synchronization, and Application to Image Encryption	Secure Image Encryption Using Chaotic, Hybrid Chaotic and Block Cipher Approach	A Novel Chaos-Based Image Encryption Using Magic Square Scrambling and Octree Diffusing`	A New Hyperchaotic 4D-FDHN System with Four Positive Lyapunov Exponents and Its Application in Image Encryption	An effective multiple-image encryption algorithm based on 3D cube and hyperchaotic map
Tsafack Nestor2022[26]	Nirmal Chaudhar2022y[8]	Jie Wan2022g[43]	[18] Zefei Liu 2022	Xinyu 2022Gao[23]
Using two positive Lyapunov exponents, a new 4D hyperchaotic nonlinear dynamical system is described.	Arnold cat map in combination with a logistic map and block cipher	utilizing nonlinear feedback and parameter perturbation to enhance the initial Logistic map	new 4D-FINN	Columns are used to segment a number of images
4	3 and 4	2	4	3
	67and 33.4	99.6 33.4		99.6023% and 33.4955
best in terms of the trade-off between complexity and performance,	hybrid chaotic map has better NPCR and UACI values	encryption algorithm has a high-level of security,	large key space, excellent performance, and resistance to typical attacks	good multiple-image encryption algorithm

Hyperchaotic behaviors, optimal control, and synchronization of a nonautonomous cardiac conduction system	A Novel Image Encryption Algorithm by Delay Induced Hyper-chaotic Chen System	Evaluation of The Most Suitable Hyper chaotic Map In S-Box Design Used In Image Encryption
Dumitru Baleanu et al[32] 2021	Chaofeng Zhao[44] 2023	Hala Saeed et 2022al [35]
4-dimensional hyperchaotic system.	HCMACS-TD generating by linear time delay feedback	S-box-based method for modifying and encoding color images that uses many chaotic maps and the hyperchaotic map foundation
No equal point	infinite D	3 and 4
	99.60 33.46	99.619 33.441 Lina))
The novel nonlinear fractional model has a more adaptable behavior than its classical version, according to simulation data, which supports this assertion.	considerable advantages over some existing algorithms	efficiency against a variety of cryptographic attacks and has had positive outcomes.

6. Results and discussion

In many hyper chaotic systems, the characteristics of their dynamic behavior vary. However, their implementations for Technologies are difficult due to the particularity of each field. In this paper, we first analyzed the most famous hyper chaotic systems by indicating their originality namely the chaotic system with coexisting attractors , the hyper chaotic system with and without equilibrium. Then, we proposed a classification of these systems based on the number of equilibriums , the first Lyapunov exponent, dynamical beaver, NPCR and UACI. A high NPCR/UACI score is typically interpreted ciphers and algorithms in light of differential attacks[45]

With these two432` hypothesis tests, it is easy to accept or reject the null hypothesis that test cipher text images are random-like. Therefore, such tests provide qualitative results rather than quantitative results for image encryption. Experimental results show the estimated expectations and variance of NPCR and UACI are very close to the theoretical values, which justify the validity of theoretical values NCPR value should be higher than 99.5%, The ideal case of NPCR and UACI tests count on the images size and significance level a according to obtained results.

Analysis of entropy. Information entropy gauges how random or uncertain an encryption method is. That is an important need for a common encryption algorithm, Typically, a better encryption scheme results from a greater information entropy value , [35][29] **Table.2** show the values entropy of the encrypted image [30] [28]

Table .2 NPCR, UACI values ,Entropy

Algorithm	image	Dimensional Equilibrium point	NPCR	UACI	Entropy	
					Plain Image	Cipher image
	lina	1D	77.8 and	0.93	7.8693	7.9974
	lina	——	99.53	26.51	7.9642	7.9642
[2	lina	2D	99.62	33.47	——	R 7.2531 ,G 7.5940, B 6.9684
[3	lina	3 and 4 Equilibrium	99.619	33.441	7.75994	7.99918

In Table.3 this table, we made a comparison between the algorithms that used the same image, the lina image, in order to be able to measure the efficiency of each algorithm by comparing the statistical values of the image after encryption,

Table 3 Correlation coefficients between adjacent pixels for different algorithm on lina image

Image	Lina	[28]	[30]	[29]	[35]
Original image	Horizontal	0.2724	0.9028	0.9774	0.946001
	Vertical	0.2681	0.9563	0.962438	0.972003
	Diagonal	0.0765	0.8642	0.972488	0.921201
Encryption image	Horizontal	0.0027	0.011	0.000617	0.003301
	Vertical	0.0012	0.01	-0.000535	0.007001
	Diagonal	0.0003105	-0.0082	-0.000411	0.002701

7. Conclusion:

This paper is based on providing an integrated study of the uses of the hyperchaotic in the field of encrypting over the past five years in an integrated manner with other techniques that we have mentioned in our research according to the years and the techniques supporting hyper chaotic, number of equalburem if the research mentioned ,number of deamination, NPCR and UACI. We presented this study so that any researcher can develop this field by choosing the appropriate techniques used with the hyperchaotic.

Through our analysis of the studies that used hyperchaotic technique, we noted the ongoing effort of the researchers to apply it to the encryption methods used due to its advantages of ease of generation and difficulty of penetration compared to traditional methods of encryption such as the AES algorithm. Also increasing key space by using many parameters for the hyperchaotic sequence and for reshaping the plain image (as a secret key) makes a brute-force attack on the algorithm difficult. System implementation is easy and it requires a short time.

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خوارزمية تشفير الصور الفعالة المستندة إلى التكنولوجيا المفرطة: نظرة عامة

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الخلاصة:

يعد تشفير بيانات الوسائط المتعددة أمرًا بالغ الأهمية لأن خوارزمية تشفير الوسائط المتعددة تحتاج إلى مزيد من الوقت والذاكرة ، ومن الصعب تنفيذها. لهذا السبب، أصبحت تقنية تشفير الصور فائقة التشابه أكثر شيوعًا، والتي تستخدم القليل من الذاكرة أو الوقت أو الطاقة وتوفر أعلى مستوى من الأمان للأجهزة منخفضة الطاقة. تقدم هذه الدراسة نظرة عامة شاملة على أنظمة فرط التشتت الحديثة. من خلال التركيز على تفرد هذه الأنظمة المعقدة مميزاتها الأساسية، يتم تقديم دراسة لسلوكها الديناميكي. يتم الآن استخدام مثل هذه الأنظمة بشكل متزايد في مجموعة متنوعة من الصناعات، بما في ذلك التمويل والتواصل الأمن والتشفير، على سبيل المثال. في الواقع، يتطلب كل مجال أداءً معينًا من التعقيد غير العادي. يقترح هذا البحث بعد ذلك تصنيفًا محددًا يعتمد على الخاصية الفائقة الأهمية، أس ليابونوف ، ونقاط التوازن، والسلوك الديناميكي، و **NPCR** ، و**UACI.** .

الكلمات المفتاحية: التشفير المرئي، أنظمة التشابه المفرط، أس ليابونوف، التوازن، تشفير الصور، العراق.