Hyperchaotic Agentic AI Framework for Image Encryption

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Abstract: This paper presents Agentic Hyperchaos which is an intelligent image encryption model that combines autonomous AI-controlled decision regulation with a 5-dimensional Ikeda hyperchaotic map. Otherwise, in contrast to the traditional chaos-based schemes where the parameterization of the scheme is determined by the fixed parameter settings, the framework proposed introduces an agentic orchestration layer where the parameters of the Ikeda-map and the encryption intensity are dynamically controlled based on the chosen security policy and runtime considerations. High entropy, close to zero-pixel correlation, high NPCR and UACI, as well as good key sensitivity are experimentally verified. The resulting modular architecture offers a scaled foundation of next-generation adaptive visual cryptosystems.

Keywords: Image Encryption; High dimensional; Agentic model; Ikeda Map; Evaluation Metrics

Introduction

In the cloud platforms, medical imaging, intelligent surveillance, satellite communication, and industrial IoT, the exponential increase of digital visual data has aggravated the necessity of efficient and safe process of image encryption [1]. Conventional encryption algorithms such as the AES are not optimally able to utilize image-specific statistical structure due to intrinsic characteristics such as: high pixel redundancy, high inter-pixel correlation, and large volume of data, are cryptographically strong. This drawback has led to massive research on chaos-based image encryption which exploits features of ergodicity, sensitivity to initial conditions and pseudo-randomness [2]. Although low-dimensional chaotic maps (e.g., Logistic, Tent, Henon) were used in early schemes, such maps have poor key space, and finite precision acceleration cannot be run in practice [3][4][5]. To achieve greater robustness, researchers have turned to higher-dimensional and hyperchaotic systems, with complicated nonlinear dynamics, multiple positive Lyapunov exponents, and greater resistance to statistical and differential attacks [6].

The proposed Agentic Hyperchaos architecture, based on this development, combines a 5 -dimensional Ikeda hyperchaotic map with an agent-based orchestration layer to address the hyperchaos of a static encryption arch. The hyperchaotic core produces high-entropy pseudo-random sequences with increased key space and diffusion strength, and the agentic layer dynamically manages encryption parameters, operational intensity, and round selection in accordance with predefined policies and runtime constraints. Such clever division of dynamical engine/ decision layer improves adaptability, scalability and structural unpredictability. The framework integrates nonlinear dynamics of high dimensionality with adaptive control, thereby going beyond traditional chaos-based techniques, and is statistically highly accurate, critically sensitive, and computationally stable, making it an excellent candidate to next-generation adaptive visual cryptosystems.

Methodology

The proposed framework is the Agentic Hyperchaos, which integrates a 5-dimensional Ikeda hyper chaotic with the autonomous decision control layer that achieves adaptive and scalable image encryption. The architecture comprises of four key parts: (i) a Agentic Control Layer, (ii), a 5D Ikeda Hyperchaotic Generator, (iii) a Confusion (Permutation) module and (iv) a Diffusion module. The 5D Ikeda map is a nonlinear coupled system with five state variables that is an extension of the classical model to produce complex attractor dynamics with many positive Lyapunov exponents and expanded key space. A projection operator is a guarantee of finite-precision computation. Once transient iterations have been discarded, the system generates pseudo-random sequences, and then transforms them into 8-bit keystream values and optionally with a skip factor to reduce serial correlation.

In encryption, the confusion phase randomizes the pixel locations of a pixel by sorting by a chaotic index based on a combination of state variables, effectively destroying strong inter-pixel correlations. Diffusion phase is subsequently used to spread pixel level pixel change throughout the cipher image with recursive XOR based operation of pixel change with generated keystream, which is good at avalanche. The agentic layer oversees the key parameters, which include encryption rounds, skip factor, choice of parameter set and diffusion mode, which allows to dynamically control the intensity of security without changing the dynamical core. This hardware-software separation based on modularity between hyperchaotic engine and intelligent control makes it more adaptable, structurally flexible and cryptographically resilient in varying computational environments. Figure 1 depicted the process of the suggested approach.

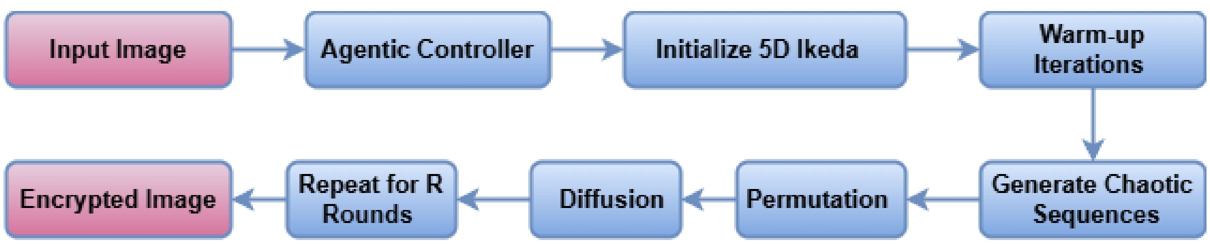

Figure 1. Flow chart of the Proposed Method.

Results & Analysis

The security of the suggested Agentic Hyperchaos framework in terms of the 5D Ikeda hyperchaotic map is measured in terms of traditional statistical and differential attack measures, such as information entropy, correlation coefficient, NPCR, UACI, and key sensitivity analysis. All these measures are an evaluation of the quality of randomness, diffusion and resistance to both differential and key-based attacks.

Analysis of entropy of information confirms that the image being encrypted is random [7]. The optimal entropy of an 8-bit grayscale image is 8, which means an equal distribution of the histogram. The correlation coefficient analysis quantifies the correlation between neighboring pixels and although natural images have high correlation, a secure encryption scheme ought to bring the horizontal, vertical and diagonal correlation into close to zero. The NPCR and UACI measures are used to evaluate the resistance to differential attack. Secure 8-bit encryption has the ideal values of about 99.6 for the NPCR and about 33% for UACI, which exhibit strong avalanche and diffusion properties in case of bit change in the plaintext.

Lastly, hyper chaoticity of 5D Ikeda system is established through the key sensitivity analysis. Even a small perturbation in important parameters (e.g., 10^{-4}) gives completely distinct outputs of the ciphertext, which shows a highly sensitive nature to initial conditions and inability to survive brute-force and key-related attacks. Collectively, these findings demonstrate that the suggested structure attains a high level of statistical randomness, high diffusion, and good key sensitivity. Table 1 shows the evaluation metrics like, entropy, correlation coefficient, NPCR, and UACI results of encrypted image.

Table 1. Evaluation Metrics values of the encrypted image.

Metric	Encrypted Image (Proposed)
Entropy	7.9992
Correlation (Horizontal)	0.0012
Correlation (Vertical)	-0.0023
Correlation (Diagonal)	0.0007
NPCR (%)	99.63%
UACI (%)	33.41%

The encryption was done based on the 5D Ikeda hyperchaotic map whose hyperchaotic parameters were verified. Figure 2 and 3 illustrated the simulation visual results and their histogram.

Figure 2. Visual Results.

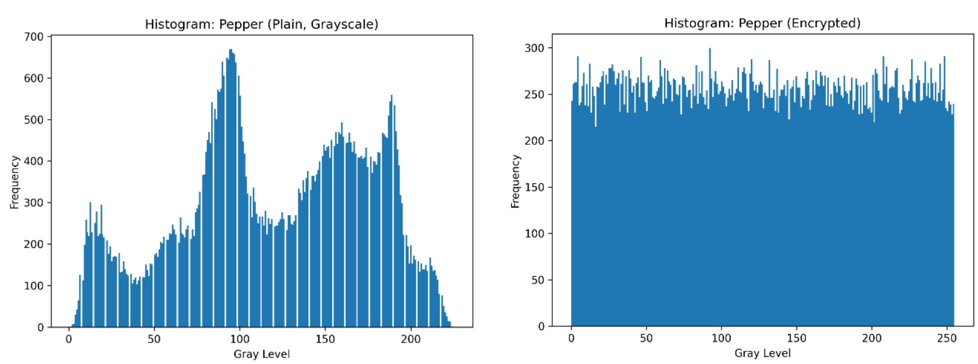

Figure 3. Histogram Analysis.

Conclusion

The paper suggests the Agentic Hyperchaos, a framework of adaptive image encryption applying a high-dimensional image encryption framework (Ikeda hyperchaos) within an autonomous decision-control interface to increase security and scalability. The proposed architecture adapts dynamically to encryption round tuning and working environment settings and uses agent-based organization instead of fixed parameters to ensure deterministic reproducibility unlike the conventional chaos-based schemes. Its 5D Ikeda hyperchaotic map is the fundamental pseudo-random generator that is highly sensitive to the initial conditions and that it has a multi-dimensional nonlinear dynamic which enhance essential sensitivity and resistance to prediction and reconstruction attacks. In general, the architecture is successful at integrating high dimensional hyperchaotic dynamics and intelligent architectural control, to provide increased unpredictability and key space as well as scalable performance to secure visual communication systems.

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