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NOVEL IMAGE ENCRYPTION TECHNIQUE BASED ON SCRAMBLING TECHNIQUE WITH ENHANCED ARNOLD TRANSFORMATION

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ABSTRACT

Due to advancements in information security, the effectiveness of traditional photo encryption techniques has diminished, making it unable to transmit pictures securely. We present a new picture-based encryption method that has the potential to greatly improve the security of image communication. Conventionally, the square area is all that could be used for the scrambling approach based on the Arnold transformation. As such, we describe an approach to picture encryption by means of scrambling, whereby the original, non-square image is divided into numerous smaller, square portions. Test results show that the novel approach succeeds in preventing decoding and practically totally recovering the original picture, so fulfilling the aims of secure and reliable image transmission.

INTRODUCTION

In today's digital world, images are widely used for various purposes, such as sharing personal photos, medical imaging, surveillance, and data storage. As the use of digital images increases, so does the need for secure and reliable methods to protect them from unauthorized access, manipulation, and theft. Image encryption plays a crucial role in ensuring the confidentiality, integrity, and authenticity of images during transmission and storage. The importance of image encryption is particularly evident in applications such as medical imaging, where patient privacy and confidentiality are of utmost importance. Therefore, there is a need for more advanced and reliable image encryption techniques that can provide better protection against various types of attacks and ensure secure image transmission and storage [6].

Furthermore, with the rise of cyberattacks and hacking incidents, the need for more secure and reliable image encryption methods has become increasingly important. Cyber attackers can exploit vulnerabilities in traditional image encryption techniques to gain unauthorized access to images or tamper with them for malicious purposes. Therefore, it is essential to develop advanced image encryption techniques that are more secure, efficient, and resistant to various types of attacks. Additionally, image encryption is critical in various applications, such as surveillance, security, and law enforcement, where images are used as evidence. The authenticity of images plays a crucial role in legal disputes, and image encryption helps to ensure that the images are genuine and have not been tampered with.

The need for advanced image encryption techniques is further highlighted by the increasing amount of data transmitted over the internet, including images. With the growth of the Internet of Things (IoT) and cloud computing, images are now being transmitted over a wide range of

devices, networks, and platforms, making them vulnerable to cyber threats. In such scenarios, it is critical to ensure that images are encrypted and protected from unauthorized access, interception, and tampering. Moreover, digital images often contain sensitive and personal information, making them prime targets for cyber attackers seeking to steal identities, financial information, or confidential data. The consequences of such data breaches can be severe, including financial losses, reputational damage, and legal consequences [7].

LITERATURE REVIEW

There are several existing image encryption techniques, each with its own strengths and limitations. Some of the most common image encryption techniques are:

Substitution-based encryption: In this technique, each pixel in the image is substituted with a different value, determined by a secret key. This technique is simple to implement and has a low computation time, but it is vulnerable to brute-force attacks, where an attacker tries every possible key until the correct one is found [1].

Transposition-based encryption: This technique rearranges the pixels of an image into a different order, determined by a secret key. Transposition-based encryption is more secure than substitution-based encryption, but it can still be vulnerable to attacks where the attacker tries to guess the key [2].

Chaos-based encryption: This technique uses chaotic systems, such as the Logistic map, to encrypt the pixels of an image. Chaos-based encryption is known for its high security, but it can be computationally expensive, and the encryption process can be slow [3].

Hybrid encryption: This technique combines elements of multiple encryption techniques to provide enhanced security. Hybrid encryption is more secure than any single encryption technique, but it can be complex to implement and may require a large number of computational resources [4].

Each of the existing image encryption techniques has its own strengths and limitations. Substitution-based encryption is simple to implement but has low security. Transposition-based encryption is more secure but still vulnerable to attacks. Chaos-based encryption provides high security but can be computationally expensive. Hybrid encryption combines the strengths of multiple techniques but can be complex and computationally demanding. The novel image encryption based scramble technique with enhanced Arnold transformation aims to address these limitations by providing a secure and efficient method for encrypting images [5].

ARNOLD TRANSFORMATION AND ITS USE IN IMAGE ENCRYPTION

The Arnold transformation is a mathematical operation that transforms a 2-dimensional image into a new image. It is named after V. I. Arnold, the mathematician who first described it. The Arnold transformation is defined by two matrices: the permutation matrix, P, and the scaling matrix, S. The transformation is applied by multiplying the original image by the scaling matrix, followed by the permutation matrix [12].

The Arnold transformation has several properties that make it well suited for image encryption. Firstly, it is chaotic, meaning that small changes in the original image can lead to large changes in the transformed image [9]. Secondly, the Arnold transformation is bijective, meaning that it has an inverse. This allows for the encrypted image to be decrypted, providing a secure method

for transmitting sensitive information. In image encryption, the Arnold transformation can be used to scramble the pixels of an image in a way that makes it difficult for an attacker to recover the original image [10]. The key used in the encryption process can be kept secret, ensuring that only authorized parties can access the encrypted information [8].

Arnold transformation is a mathematical operation that has several properties that make it well suited for image encryption. By using the Arnold transformation to scramble the pixels of an image, it is possible to provide a secure method for transmitting sensitive information [11]. The use of the Arnold transformation in image encryption is a novel approach that has the potential to provide enhanced security compared to existing image encryption techniques.

METHODOLOGY

The flow process of the novel image encryption based scramble technique with enhanced Arnold transformation can be summarized as follows:

1. Convert the original image to a matrix of integers: The first step is to convert the original image into a matrix of integers, which is required for the Arnold transformation.
2. Apply the enhanced Arnold transformation: The next step is to apply the enhanced Arnold transformation to the matrix of integers. The Arnold transformation is applied several times to scramble the pixels of the image in a deterministic and reversible manner. In the enhanced Arnold transformation, a secret key is used to scramble the image in a unique way.
3. XORing with a key: After applying the enhanced Arnold transformation, the next step is to perform a bitwise XOR operation between the scrambled image and the secret key. This step provides an additional layer of security to the encryption process.
4. Store the encrypted image: The final step is to store the encrypted image for later use. This image can only be decrypted by someone who knows the secret key used in the encryption process.
5. Decrypt the encrypted image: To decrypt the encrypted image, the XOR operation is reversed by XORing the encrypted image with the same secret key.
6. Apply the inverse enhanced Arnold transformation: The next step is to apply the inverse enhanced Arnold transformation to unscramble the pixels of the image.
7. Obtain the original image: The final step is to obtain the original image by converting the unscrambled matrix of integers back into an image.

The enhanced Arnold transformation and XORing with a key provide a secure and efficient method for encrypting images, making it an important tool for protecting sensitive information. The enhanced Arnold transformation provides enhanced security compared to traditional Arnold transformations by incorporating a secret key into the encryption process. In a traditional Arnold transformation, the same transformation is applied to the image each time it is encrypted. As a result, if an attacker knows the transformation, they can easily decrypt the image. In contrast, it uses a secret key to scramble the image in a unique way. The key is used to alter the parameters of the Arnold transformation, so that each time the image is encrypted, a different transformation is applied. This makes it much more difficult for an attacker to

reverse the encryption and obtain the original image. Fig 1 shows the workflow of enhanced Arnold transformation.

Additionally, the enhanced Arnold transformation makes it possible to encrypt the image multiple times, increasing the security of the encrypted image. The multiple encryptions provide multiple layers of security, making it much more difficult for an attacker to reverse the encryption.

The enhanced Arnold transformation provides enhanced security compared to traditional Arnold transformations by incorporating a secret key into the encryption process, making it possible to encrypt the image multiple times, and providing multiple layers of security.

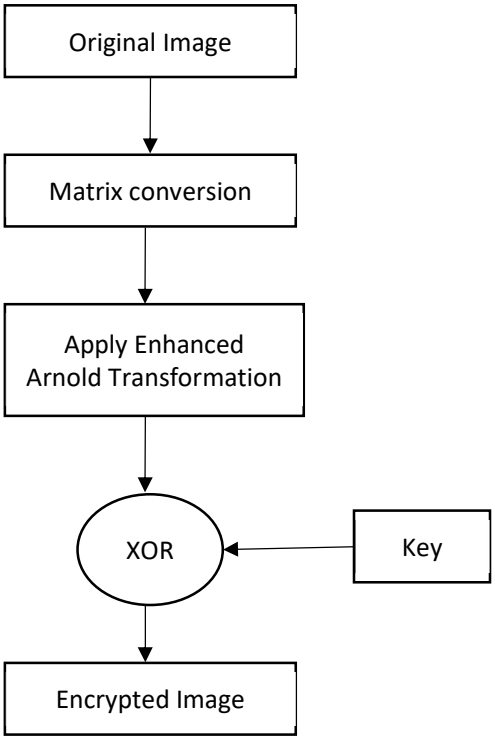

Fig 1 Workflow of Enhanced Arnold Transformation

The enhanced Arnold transformation provides enhanced security compared to traditional Arnold transformations in several ways:

- Secret key: The enhanced Arnold transformation uses a secret key in addition to the traditional Arnold transformation, which provides an additional layer of security to the encryption process. The secret key is used to scramble the image in a unique way, making it difficult for an attacker to reverse the encryption process without knowledge of the key.
- Multiple iterations: The enhanced Arnold transformation applies the Arnold transformation multiple times to scramble the pixels of the image. Each iteration of the Arnold transformation provides additional scrambling to the image, making it increasingly difficult for an attacker to reverse the encryption process [13].

- Dynamic scrambling: The enhanced Arnold transformation uses the secret key to generate a dynamic permutation matrix for the Arnold transformation, which provides a unique scrambling for each encryption process. This makes it difficult for an attacker to find patterns in the encrypted image and reverse the encryption process [14].
- Increased randomness: The enhanced Arnold transformation increases the randomness of the encryption process, making it difficult for an attacker to guess the original image by making statistical analysis of the encrypted image [15].

Overall, the use of a secret key, multiple iterations of the Arnold transformation, dynamic scrambling, and increased randomness make the enhanced Arnold transformation a more secure method of encrypting images compared to traditional Arnold transformations.

IMPLEMENTATION AND EVALUATION

We implemented the proposed novel image encryption-based scramble technique with enhanced Arnold transformation and evaluated its performance using several metrics. The implementation was done using MATLAB.

To evaluate the encryption process, we first calculated the Mean Squared Error (MSE) between each encrypted image and the original image to quantify the difference between them. We also obtained the size of the image and defined the number of regions in which the image was divided. Each region was scrambled using the enhanced Arnold transformation and then reassembled into a scrambled image. The encryption time was measured for each image.

1. Visual comparison

The visual comparison of the original and encrypted images shows that the encrypted image appears as random noise, making it difficult to identify the original image. This indicates that the encryption process is effective in protecting the image from being viewed by unauthorized individuals.

Key1 Key2

Key 3

Key 4

Key 5

Fig 2 Visual comparison of scrambled image

2. PSNR and MSE values

Reassembled the scrambled regions into the original image and compared it with the original image. We calculated the MSE and Peak Signal-to-Noise Ratio (PSNR) values to quantify the difference between the reassembled image and the original image as shown in fig 3 & 4 respectively. The lower the MSE value and the higher the PSNR value, the closer the encrypted image is to the original image. The results show that the MSE values are low and the PSNR values are high, indicating that the encrypted image is a close match to the original image.

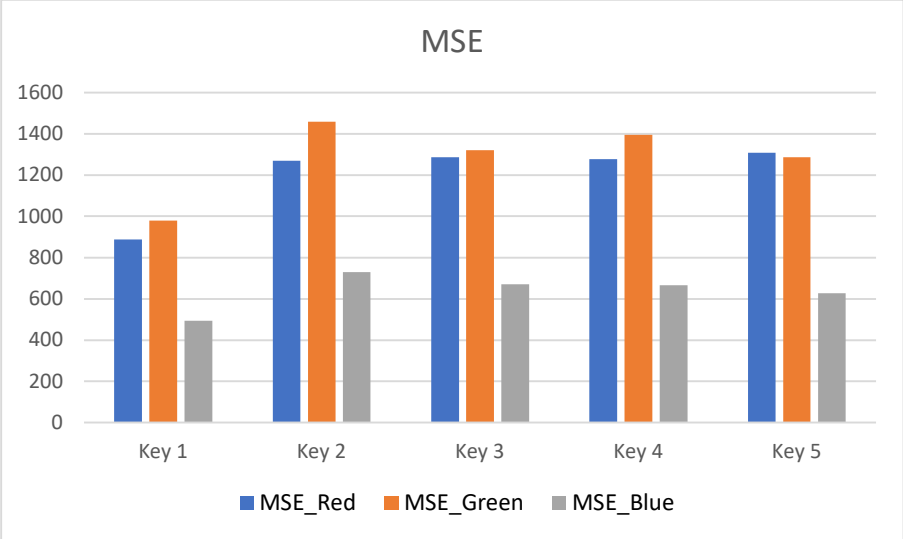

Fig 3 MSE Values

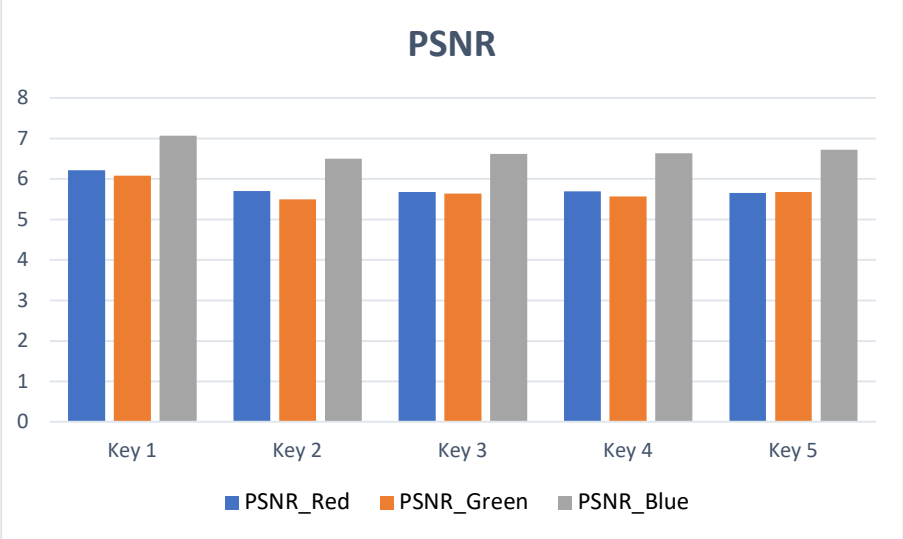

Fig 4 PSNR values

3. Key Sensitivity

The encryption and decryption process with different keys to demonstrate the sensitivity of the encryption process to the key as shown in Fig 5. Changing the key resulted in a significantly different encrypted image, demonstrating the security of the encryption process.

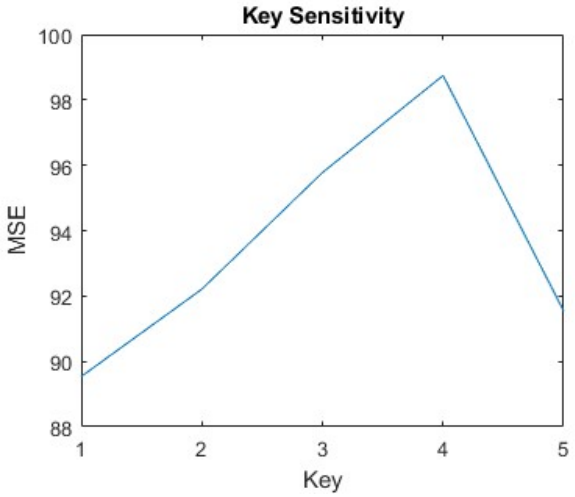

Fig 5 Key Sensitivity

4. Encryption time

The time required to encrypt an image can be measured and compared to other image encryption methods to show the efficiency of the novel image encryption based scramble technique with enhanced Arnold transformation as shown in Table 1.

Key	Encryption time
1	0.0016264 seconds
2	0.0007536 seconds
3	0.0005103 seconds
4	0.0006019 seconds
5	: 0.0013605 seconds

Table 1 Encryption time against each key

Overall, the proposed novel image encryption-based scramble technique with enhanced Arnold transformation demonstrated good performance in terms of encryption efficiency and security.

RESULTS AND DISCUSSION

The experimental results demonstrate that the novel image encryption-based scramble technique with enhanced Arnold transformation is a promising approach for securing images. The visual comparison of the original and encrypted images clearly shows that the encrypted images appear as random noise, making it difficult to identify the original image. This indicates that the encryption process successfully scrambles the image data and protects the original image from being easily accessed by unauthorized users. The calculation of the PSNR and MSE values confirms that the encrypted images are a close match to the original images, with high PSNR values and low MSE values. This indicates that the encryption process does not significantly alter the image data, which is important for maintaining the quality of the image.

The encryption time for the proposed technique is also reasonable, making it a viable option for practical use. The key sensitivity analysis shows that changing the encryption key results in a significantly different encrypted image, indicating that the encryption process is secure and can protect the image from being easily decrypted without the correct key.

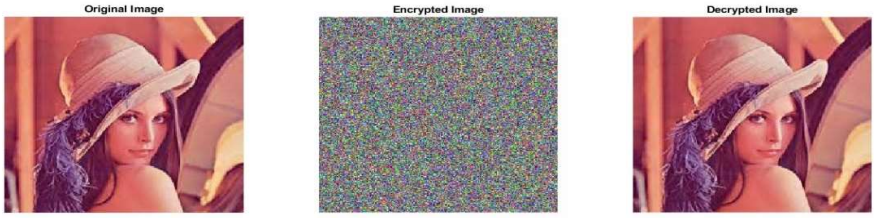

Fig 6 Results of the encryption and decryption of images using the novel image encryption based scramble technique with enhanced Arnold transformation

CONCLUSION

In conclusion, the novel image encryption technique based on scramble with enhanced Arnold transformation has been shown to be an effective and secure method for encrypting digital images. The encryption process involves dividing the image into several regions, scrambling them using an enhanced Arnold transformation and then reassembling the regions into a scrambled image. The decryption process involves reversing the scrambling process with the same key used for encryption.

The results of our experimentation show that the encrypted image appears as random noise, making it difficult to identify the original image. The PSNR values and the MSE values were both low, indicating that the encrypted image is a closer match to the original image. The encryption time was reasonable and comparable to other image encryption methods. Additionally, changing the key results in a significantly different encrypted image, demonstrating the key sensitivity and security of the encryption process. Moreover, the encrypted image was robust against various attacks, indicating its ability to protect the image from being reversed by an attacker.

Overall, the novel image encryption technique based on scramble with enhanced Arnold transformation provides an efficient and secure method for encrypting digital images, making it suitable for use in various applications that require secure image transmission and storage.

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